Land-Use and Land-Cover Dynamics and Rural Livelihood Perspectives, in the Semi-Arid Areas of Central Rift Valley of Ethiopia

Efrem Garedew

Faculty of Forest Sciences
Department of Forest Resource Management
Umeå

Doctoral Thesis
Swedish University of Agricultural Sciences
Umeå 2010

Acta Universitatis agriculturae Sueciae
2010:7

ISSN 1652-6880
ISBN 978-978-91-576-7484-5

Print: Arkitektkopia, Umeå 2010

Land-Use and Land-Cover Dynamics and Rural Livelihood Perspectives, in the Semi-Arid Areas of Central Rift Valley of Ethiopia

Abstract

Global environmental changes in climate, land-use and bio-diversity are increasingly on top of scientific and political agenda. The impacts of climate change are manifested on all dimensions of food security: availability, accessibility, utilization and stability. This study presents land-use and land-cover (LULC) dynamics, rural livelihoods, and a dynamic simulation model of a socio-economical and environmental system in the Central Rift Valley of Ethiopia. Using different methods and approaches (remote sensing and participatory field point sampling, household survey, PRA and use of secondary data) the analyses revealed rapid LULC change over the past three decades. The area is characterized by high rate of conversion from woodland and wooded-grassland to farmland.

For decades, subsistence agriculture has been the most important livelihood strategy but low level of its income does not meet basic everyday household expenditure. The importance of livelihood diversification has grown in response to population pressure that led to a decline in farm size and agricultural shocks due to biophysical factor limitations. Food insecurity is persistent and widespread.

Using STELLA software, the dynamic model simulated an extensive land-use change, largely driven by the decisions of the people and population growth. It is characterized by rapid population growth, declining household farm size, declining household income, deterioration of the remnant forest and worsening land degradation if the situation remains unchanged. The simulated strategies, such as forest increase, and the projected micro-finance, better family planning and better education, are likely to improve forest cover and area, decrease land degradation, raising household income and help to slowing down population growth.

The following conclusions can be drawn from the study: 1) monitoring LULC dynamics using a combination of remote sensing and participatory field point sampling is a valuable approach for land-use inventory; 2) the dramatic trends in LULC were associated with rapid population growth, recurrent droughts, rainfall variability and declining agricultural productivity; 3) food security is vulnerable to climatic change; 4) Currently, opportunities for additional income generating activities are limited. External interventions are important to improve farmers' livelihoods and to heal the natural environment.

Keywords: Food insecurity, Global environmental change, Livelihood Diversification, Participatory field point sampling, Remote sensing, Simulation modeling

Author's address: Efrem Garedew, SLU, Department of Forest Resource Management, SE-901 83 Umeå, Sweden or Wondo Genet College of Forestry and N. Resources, P.O.Box 128, Shashemene, Ethiopia
E-mail: Efrem.Garedew@srh.slu.se or egnune@yahoo.com

Dedication to:

My precious wife Nune and our children Elshu and Kiduse. I was really missing you very much.
My late beloved sister Belaynesh Nigatu, who passed away during my PhD training, we had a pleasant time together and may Lord rest you in peace.

Contents

List of Publications

This thesis is based on the work contained in the following papers, referred to by Roman numerals in the text:

I. Garedew E., Sandewall M., Soderberg U., Campbell B.M. 2009. Land-use and land-cover dynamics in the Central Rift Valley of Ethiopia. *Environmental Management* 44(4), 683–694.

II. Garedew E., Sandewall M., Soderberg U., Campbell B.M. and Kassa H. Marginal environment and the food insecurity situation in the Central Rift Valley of Ethiopia. (manuscript).

III. Garedew E., Kassa H., Sandewall M. and Soderberg U. Evolving livelihood strategies and their contribution to household income in the Central Rift Valley of Ethiopia. (manuscript).

IV. Garedew E., Sandewall M. and Soderberg U. A Dynamic simulation model of land-use, population and rural livelihoods in the Central Rift Valley of Ethiopia. (manuscript).

Paper I is reproduced with the permission of the publisher.

1 Introduction

1.1 Background

Over the latest 50 years Africa has been characterized by remarkable changes, some related to progress, such as Pan-African political negotiations, advancements in health and education and in fact economic growth at least in urban areas. Africa has indeed become part of the global economy and society. It has become apparent that economic activities, energy use and trade relations in one country influence other countries, the environment and the economy. On the other hand there is political unrest, trade deficits, recurrent droughts, deforestation, HIV/AIDS and persistent poverty. As an example there have been a number of severe droughts with dramatic human consequences in dry-land Ethiopia over the last four decades (Dercon *et al.*, 2005; Webb *et al.*, 1992).

In the 21st century, global environmental changes are increasingly on top of the international scientific and political agenda. Global environmental changes are those that alter the Earth system of the atmosphere and oceans and hence are experienced globally, and those that occur in distinct sites but are so widespread as to constitute a global change (Steffen *et al.*, 2004; Vitousek, 1992). Examples of the first category includes: changes in the composition of the atmosphere and climate change. The second is exemplified by land use change, loss of biological diversity, and biological invasions. In the recent centuries, the impact of human activities on the land has grown enormously, altering landscapes and ultimately impacting the earth's biodiversity, nutrient and hydrological cycles as well as climate (Malhi *et al.*, 2008; Searchinger *et al.*, 2008; IPCC, 2007b; Templer *et al.*, 2005; Legesse *et al.*, 2003; Tilman & Lehman, 2001). The causes and consequences of human-induced environmental changes are not evenly distributed over the earth. They converge in certain regions where their impacts may threaten the long-term or the short-term sustainability of human-environmental relationships (Kasperson *et al.*, 1999). Understanding their dynamics, how they affect human society both today and tomorrow and how we could prepare ourselves for the future is important. Adger *et al* (2005) described two key developments in the analysis of interaction between global environmental change and human society over the past two decades. The first is an increasingly sophisticated understanding of Earth System processes and environmental change, allied to developments in the availability of data. The second development is a broadening of analytical perspectives on human–environment interactions and policy interventions.

Land is the major natural resource that economic, social, infrastructure and other human activities are undertaken on. Thus, changes in land-use have occurred at all times in the past, are presently ongoing, and are likely continue in the future (Lambin *et al.*, 2003; Moser, 1996). These changes have beneficial or detrimental impacts, the latter being the principal causes of global concern as they impact on human well-being and safety. For instance, deforestation and agricultural intensification are so pervasive when they aggregate globally and significantly affect key aspects of Earth Systems (Lewis, 2006; Zhao *et al.*, 2006). There were significant global historical changes in LULC occurred between 1700 and 1990, when the area of cropland expanded from about 3.5 million km^2 to some 16.5 million km^2 (Lambin & Geist, 2006). Much of this expansion occurred at the expense of forest, which has decreased from about 53 million km^2 to 43.5 million km^2. Even though the net loss of the global forest area have reduced significantly due to a large scale of afforestation reported in some countries, such as China and Vietnam, tropical deforestation has continued into the 21st century, the world is currently (2000-2005) experiencing about 0.073 million km^2 of net annual deforestation, largely due to agricultural expansion (FAO, 2005). It has essentially been a feature of the poorer countries and the average annual deforestation rate, between 1990 and 2005, in low-income countries was 0.5% while deforestation is lower (0.2%) in middle-income countries (World Bank, 2007). The human-induced causes of tropical deforestation and processes are illustrated in Figure 1. It identifies deforestation as a common phenomenon associated with multiple proximate causes and underlying multiple driving forces. The former comprises agricultural expansion, wood extraction, and infrastructure expansion while the later includes demographic, economic, technological, policy & institutional and cultural factors. Geist and Lambin (2002), reviewed 152 case studies of net losses of tropical forest cover to determine whether the proximate causes or underlying driving forces fall into any patterns. The results revealed that tropical deforestation is best explained by multiple factors and drivers acting synergistically rather than by single-factor causation. But the proximate cause of agricultural expansion is a dominant factor in land-use change and is associated with 96% of all deforestation cases. Another important area is economic factors which are associated with 81% of all cases.

Detrimental changes in land-use are associated with a large range of effects and issues. Suding *et al.* (2005) showed that nitrogen fertilization increased the risk of plant biodiversity loss that ranges from >60% for the rarest species to 10% for the most abundant species.

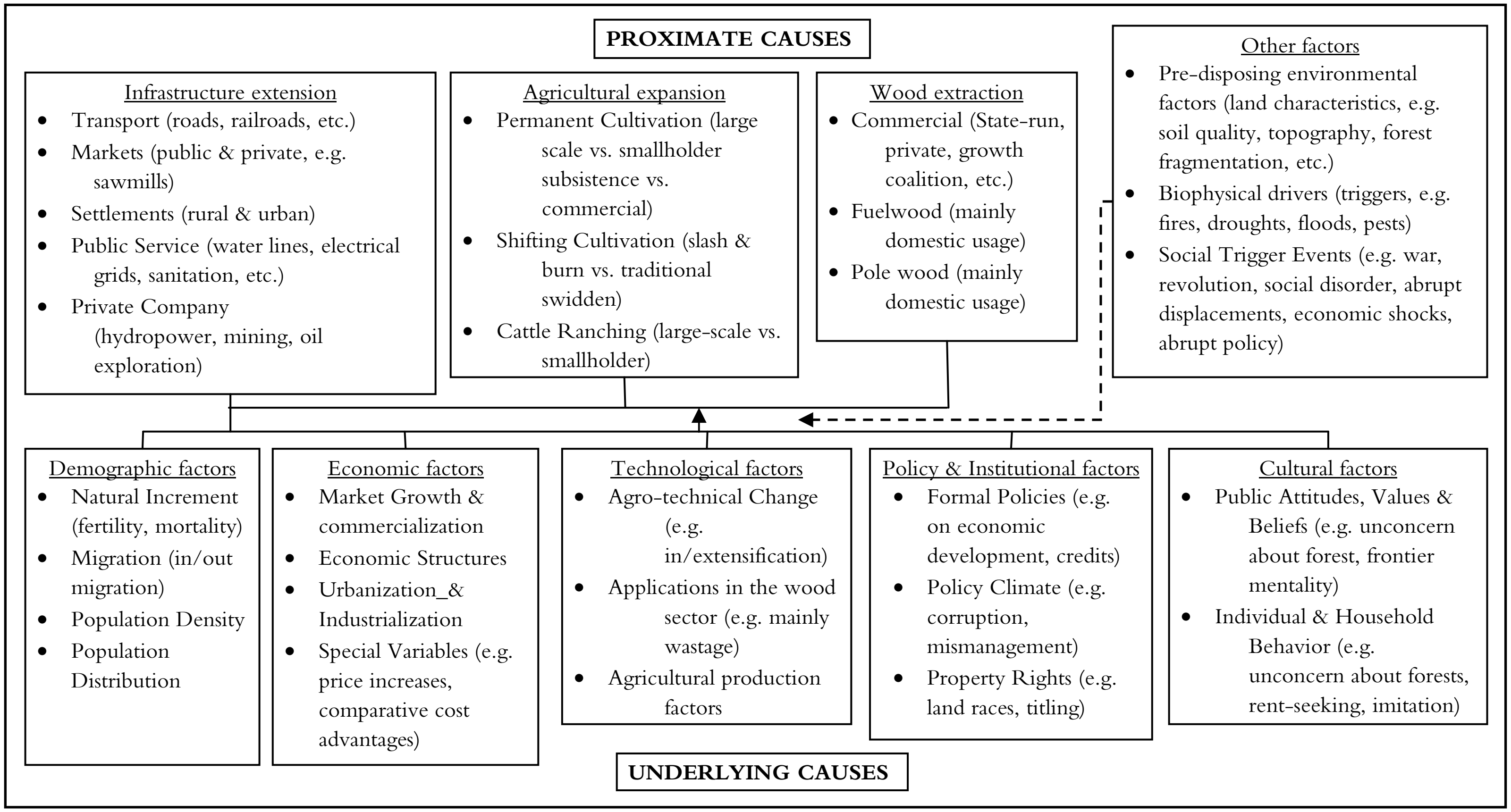

Figure 1. Five broad group of underlying driving forces (fundamental social processes) underpin the proximate causes (immediate human actions directly impacting forest cover) of tropical deforestation. Source: Geist and Lambin, 2002, figure 1, p. 144.).

Land-use change were also connected with the 5–20% of global species of birds, mammals, fish and plants threatened with extinction (Chapin *et al.*, 2000). In the dry-land Africa, harmful agricultural practices, such as over-cultivation, overgrazing, bush fires, cultivation of marginal and easily eroded land, mechanization and the widespread use of chemicals and pesticides, have intensified land degradation (Darkoh, 2003). Moreover, the wide use of biocides in agriculture also triggered severe negative human health consequences (Lambin & Geist, 2006). According to Tiwari (2008), in the recent past, Himalaya landscape has transformed considerably; cultivated land, forests, pastures and rangelands have been deteriorated and depleted steadily and converted into degraded and non-productive lands. The author also stated that the indiscriminate deforestation and degradation of land resources had an impact on the hydrological cycle which causes disruption and irreversible adverse impacts on the rural economy, and society. On the other hand, the forest biome of Amazonia (one of the major forest components) faces the threat of deforestation and stress from a drying climate and changes in precipitation (Malhi *et al.*, 2008). Human alteration of the environment also exacerbates mosquito-borne diseases by creating or expanding mosquito breeding habitats (Norris, 2004). Extensive land-use changes have left large areas exposed to erosion. For instance, in Ethiopia in the "Blue Nile Basin of Chemoga watershed", between 1957 and 1998, 70% of the total land area has been exposed to major erosion. In another development, land-use is considered the second largest source of greenhouse gas emissions (IPCC, 2007b), next to the burning of fossil fuels, and the drivers of global warming that lead to climate change. In turn, climate change globally may affect the sea levels through the melting polar ice caps and glaciers and an increase in temperature, along with increasing incidences of drought and flooding. Parry *et al.* (2005) reviewed a number of studies on the impacts of climate change to global agricultural yield potential, and the implications for changes in the number of hungry people. Some of the key conclusions from Parry et al. were: a) Climate change may lead to increases in yield potential at mid and high–mid-latitudes, and to decreases in the tropics and subtropics where many developing countries are located, of course with some exceptions. b) Risk of hunger appears to increase generally as a result of climate change, particularly in southern Asia and Africa. Similarly, Schmidhuber and Tubiello (2007) predicted that by 2080 between 5 and 170 million additional people in developing nations will be at risk of hunger because of climate change. A conceptual framework (Figure 2) of the interaction between climate change and food security highlights the key variables of food and climate systems (FAO, 2008). It suggests that climate change affects all dimensions of food security: food availability, food accessibility, food utilization and food system stability. The impacts are manifested on food production, distribution (purchasing power and market flows), livelihood assets and health.

Mitigation and adaptation, efforts to limit greenhouse gas emissions and minimize the effects of climate change, are the present key aspects of the global climate change issues. Forests have a potential to mitigate climate change through increased forest land, increased the cover of existing forests, substitution of carbon-intensive products through sustainable forest management, and reduced emissions from deforestation and forest degradation (Schlamadinger *et al.*, 2007). Since the United Nations Conference on Environment and Development (UNCED) in 1992, forests have been at the centre of the international debate related to the new paradigm of Sustainable Forest Management (SFM), which is based on the social, economic and environmental benefits of forests for both present and future generations.

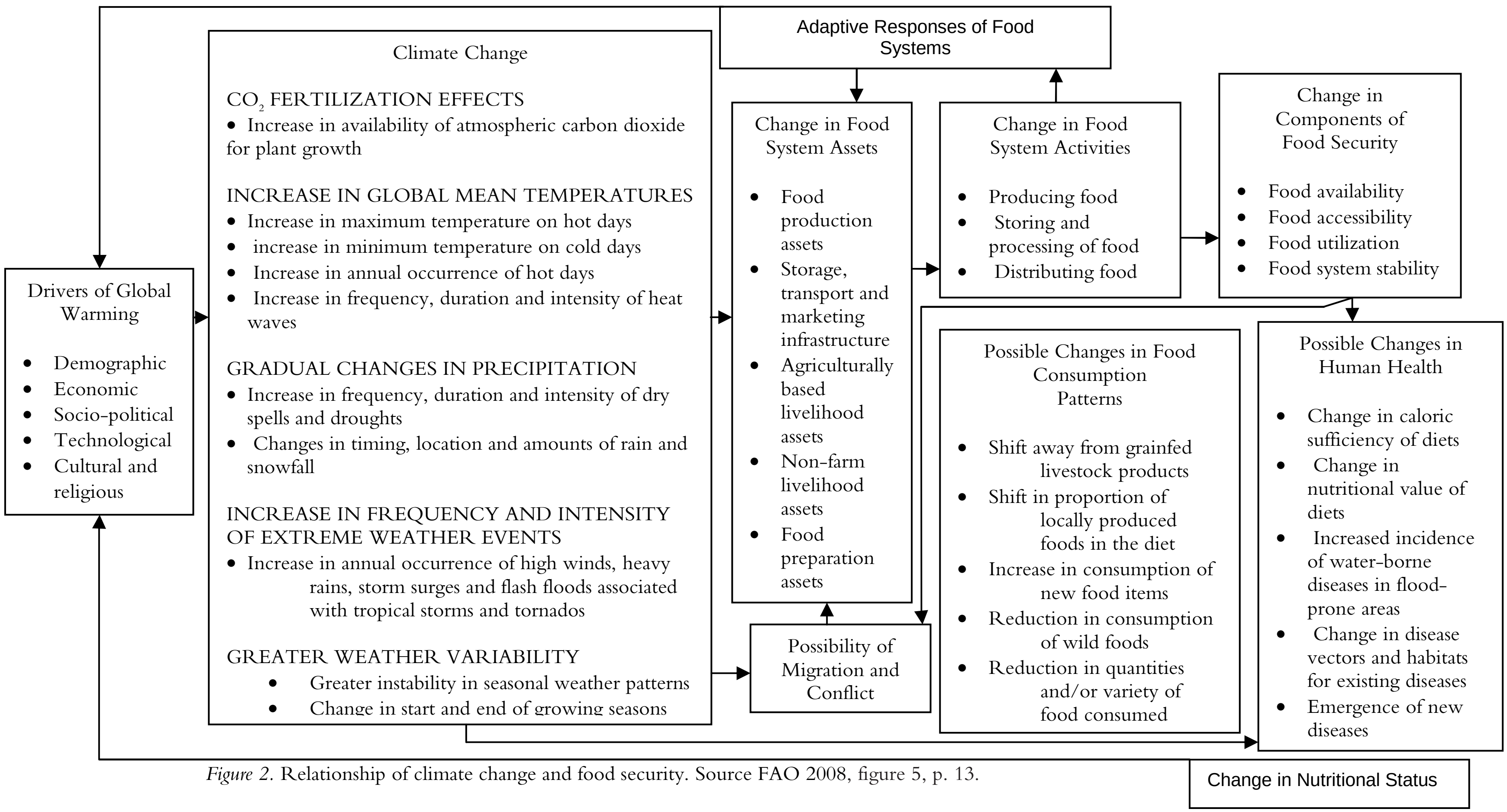

Figure 2. Relationship of climate change and food security. Source FAO 2008, figure 5, p. 13.

The three international conventions arising from UNCED- the United Nations Framework Convention on Climate Change (UNFCCC), the United Nations Convention to Combat Desertification (UNCCD) and the Convention on Biological Diversity (CBD) are also important initiatives in helping to heal the natural environment. At the United Nations Forum on Forests (UNFF) in 2006, it was agreed to reverse the loss of forest cover globally, increase the area of protected and sustainably managed forests, enhance forest-based benefits, and reverse the decline in official development assistance for SFM (United Nations, 2006). In relation to tropical forest contribution to reducing green house gas (GHG) emissions from deforestation and forest degradation (REDD), Angelsen (2008) suggested that REDD is commonly seen as a significant, cheap, quick and win-win way of reducing GHG emission than other mitigation categories. The Kyoto agreement also established a binding target for GHG reductions of lower than 7 percent below the 1990 levels for developed countries, to be met in the first commitment period from 2008 to 2012 (Karling, 2007). Developing countries contribute to climate change mitigation through participation in the Clean Development Mechanism (CDM) where carbon is sequestered from the atmosphere through reforestation and afforestation.

The next stage of the international effort must deal with adaptation-coping with those factors that cannot be avoided (Burton *et al.*, 2006). Studies in adaptation issues focus on reducing vulnerabilities of rural and urban people to risks associated with climate change, which is relevant at local, national and international levels (Smit & Wandel, 2006; Adger *et al.*, 2005; Parry *et al.*, 2005). However, substantial limits and barriers to adaptation are reported in developing countries especially Africa (Mertz *et al.*, 2009; IPCC, 2007a). For instance, the impacts of climate change will be more severe in poor developing countries since the national economy largely relies on agriculture which is directly affected by climate change.

Secondly, the economic and technological capacity to adapt to climatic change is often very limited in developing countries.

1.2 Ethiopian Forest Resources, the Challenge of Deforestation and the Need for Participatory Forest Governance

Owing to the extreme variations in climate and terrain, the forest vegetation of Ethiopia is very heterogeneous. However, in general the majority of areas suffer from severe disturbances (Soromessa *et al.*, 2004; Bekele & Berhanu, 2001 ; Worede *et al.*, 1991). The forest vegetation types consist mainly of the dry highland forest (north and south-eastern), the south-west broad-leaved forest and the lowland woodland zones (Bekele, 2003). The remnant natural high forests are located in southern and south-western parts of the country (Bishaw, 2001; Wood, 1993). For management purposes, these important high forests are grouped into 58 National Forest Priority Areas (FAO, 2003). However, protection of these areas from deforestation has not been effective (due to encroachment to search for new land for agriculture and for fuelwood) resulting from absence of good forest policy, lack of an appropriate institutional setup, and lack of legal status of these priority areas. Forests have enormous ecological and economic significance in terms of safeguarding the fragile ecosystem, contributing to the national economy and are of great importance to rural and urban people as a source of fuel wood and charcoal. They are also sources of many other products for the people and the country such as construction material, coffee, spices, fodder, fruits, honey, flora, medicinal plants, fiber, and income (Teketay, 2001). Meanwhile, the contribution of forestry to the national economy has not been assessed correctly and systematically (Bekele, 2001). Economic statistics indicate that forests contribute only by 5.5% of the national agricultural GDP (MNRCDEP, 1994). But this figure reflects only income derived from traditional industrial forestry activities involving only timber production. If we consider other direct and indirect utilization of forests the picture is different. For instance, in Ethiopia coffee is still produced mainly in its natural habitat, around 41% of coffee products come from forest or semi-forest areas (Lightbourne, 2006). Coffee is critical to the Ethiopian economy and contributes over 80% of the country's foreign exchange earnings, valued in 2006 to approximately US$350 million (von Braun & Olofinbiyi, 2007; Gebre-Selassie, 2004).

The estimates of forest cover in Ethiopia are varying noticeably according to different sources; which makes the available data unreliable. Historically, many reports and scientific papers show that at the turn of last century forest cover for the country was 35-40% of the total land mass (e.g., Bishaw, 2001; Cheng *et al.*, 1998; Hawando, 1997; Ethiopian Forestry Action Programme (EFAP), 1994). But a comprehensive literature study by Woien (1995) did not find the origin of this figure. Moreover, Bekele (2003) highlighted that wrong figures had repeatedly been reported over long time without establishing environmental history and empirical evidence. At present, FAO (2005) estimated 11.9% of Ethiopia's land area is forested (0.13 million Km^2) and this forest resource shows an alarming rate of deforestation at 1.1% annually. Deforestation is often thought of as a reduction of forests from natural forestland but it also takes place on individual farm plots in the form of removal of scattered trees. This reduces the conditions for soil improvement, conservation, wind protection and fodder for animals. Deforestation in Ethiopia is considered a result of many causes; some natural, but mainly due to human actions, including farmland expansion, unclear land tenure rights, poor economic conditions, population growth, market (wood extraction), and biophysical and socio-political factors (Garedew *et al.*, 2009; Dessie & Kleman, 2007; Bekele, 2003; Darbyshire *et al.*, 2003; Urgessa, 2003; Cheng *et al.*, 1998). Individual case studies in different parts of the country help underpin the alarming nature of the deforestation processes. Tekle and Hedlund (2000) compared two dates of land-use and land-cover using aerial photographs of an area in southern "Wollo" from 1958 and 1986 and demonstrated a decrease of shrubland from 27.6% to 13.5% and forest cover from 7.8% to 5.4%. Zeleke and Hurni (2001) revealed a disappearance of 27% natural forest cover from 1957-1997 in the North-western Ethiopian highlands. Dessie and Christiansson (2008) found a forest area decline in the South-central Rift Valley of Ethiopia to 2.8% in 2000 from 16% in 1972. They also estimated 0.9% deforestation rate of the area. In a study in the Central Rift Valley of Ethiopia, woodland deceased from 40% in 1973 to 5% in 2000 in one of the study sites while in the other site woodland lost 54% of its original extent (Garedew *et al.*, 2009).

With conventional forest management policies and strategies Ethiopian governments usually fail to manage and promote the sector for the socio-economic and environmental benefit of the people (Bekele, 2001). As mentioned, the drivers of deforestation are quite multifaceted and should be carefully addressed with other components of agro-ecological and socio-economical systems. Prohibiting people from felling trees, especially those who live in rural areas could actually hurt their daily life since it makes it difficult to meet their daily needs especially during lean agricultural periods. Today's concern must incorporate in the implementation of a system of forest management that will minimize further destruction of the natural forests, balancing protection objectives with production interests of the government and local communities. This could ensure the preservation and conservation of ecosystems, conservation of genetic resources and improve the local people legal access of forest to supplement food, energy and income (Medhin, 2002). In this respect, protected areas will contribute to the conservation of Ethiopia's remaining natural forests if they are able to meet the legitimate development aspirations of the people who live in and around the forests. There have been encouraging efforts since the mid 1990s by non-governmental groups, such as SOS-Sahel and Farm Africa, working together with the federal and local governments to create a better forest management and conservation system jointly with the local people (FARM-Africa / SOS Sahel Ethiopia, 2007). Such, participatory forest management (PFM) promotes the wide involvement of the local communities. To put this into practice there is a need to create a policy and legal framework which allows the participation of local communities in co-management of the resources and to avoid the participants' suspicions in the sustainability of PFM (Alemayehu, 2007). A study in Ethiopia, where PFM is operational, showed that forest cover and natural forest regeneration are gradually increasing under community forest management (see Gebre-Selassie, 2007; Amente *et al.*, 2006; Kubsa & Tadesse, 2002). In contrast, deforestation was observed in the forest areas outside PFM. Another study suggested that a scenario of PFM provides higher forest income benefits to the local community over the longer term period than open access without PFM (Kassa *et al.*, 2009).

1.3 Overview of Ethiopian Agriculture, Food Security Situation and the Role of Rural Non-Farm Economy

The Ethiopian economy is heavily dependent on the agricultural sector, which has suffered from recurrent droughts and extreme fluctuations of output (Demeke *et al.*, 2004). Being the dominant sector, agriculture contributes about 50% of total GDP, generates 90% of export earnings and supplies about 70% of the country's raw material to secondary activities (MoFED, 2007). Over 85% of the population is employed in this sector. Smallholders cultivate 95% of the cropped area. Ethiopia's economic growths remain dependant on the subsistence rain-fed agriculture sector which is unpredictable and with generally low outputs. The government of

Ethiopia has adopted a free market economic policy since 1992. Agriculture is assumed to be the starting point, initiating the structural transformation of the economy. Sustainable development, reduction of poverty and improving the livelihoods of the people are the central focus of the policies and strategies. Agriculture in Ethiopia has the potential to play a central role in decreasing poverty and increasing economic growth, but agricultural growth will require concurrent investments, such as improved technologies, roads, irrigation and other market conditions (Otsuka, 2008; Diao & Pratt, 2007; Adenew, 2004).

Despite the potential and importance of the agricultural sector, food insecurity continues to worsen and famine vulnerability is high. The term food insecurity incorporates low food intake, variable access to food, and vulnerability– a livelihood strategy that generates adequate food in good times but is not resilient against shocks (Devereux, 2000). With the rapid population growth, the average annual growth rate of per capita food production has declined from 2.8% in 1983-92 to 1.9% in 1993-2002 (von Braun & Olofinbiyi, 2007; Ferede, 2006). Chronically food insecure households cultivate extremely small plots; they cannot produce enough food for self-sufficiency even in a good year (Devereux *et al.*, 2005). In addition, the prevalence of food energy deficiency in Ethiopia was the worst amongst twelve sub-Saharan African countries studied by Smith *et al.* (2006). Over the past 30 years agricultural production in Ethiopia has never been sufficient to feed the population and this gap has been filled by food-aid (Kirwan & McMillan, 2007). Currently, about 39% of the population lives below the poverty line (MoFED, 2007). In general, in Ethiopia, key constraints on food security are adverse climate conditions, poor rural infrastructure, limited sources of alternative income, high population pressure (linked to deforestation, soil degradation and shortage of cropland), limitations in technology, improper land-use, poverty (low purchasing power), HIV/AIDS, weak institutions (markets and land tenure), inappropriate policies and political unwillingness (Devereux, 2009; Gelan, 2007; Haan *et al.*, 2006; Nichola, 2006; USAID/Ethiopia, 2005; Dercon, 2004; Jayne *et al.*, 2003; Kaluski *et al.*, 2002; Devereux, 2000).

Although, agriculture remains the main source of livelihoods in most rural areas in developing countries, there is an increasing awareness that livelihood diversification plays a strategic role in rural systems (Niehof, 2004). For instance, Davis *et al.* (2007) reported that in four African countries non-farm employment, due to various reasons, made up 22-53 % of total income. In Ethiopia, in most cases, smallholders are trapped in declining farm productivity and therefore agriculture alone (agriculture is subject to high risk due to mainly climatic factors and price fluctuations) cannot support many farm households in rural areas (Garedew *et al.*, 2009; Devereux *et al.*, 2005). For instance, in the "Tigray" region, farm households diversify their livelihood sources into non-farm activities derived by both low farm income and availability of surplus family labor (Woldenhanna & Oskam, 2001). In less-favored areas of Ethiopian highlands, land degradation, population growth, stagnant farming technology, and drought necessitate the development of non-farm employment opportunities (Holden *et al.*, 2004). In southern Ethiopia, a high involvement of women in livelihood diversification is observed and cash income from non-farm sources was important particularly for the poor households in order to off-set low agricultural incomes (Carswell, 2002). Further, data taken by two repeated surveys from different parts of Ethiopia revealed that wealthier households tended to have more diversified non-farm income streams than those who are poorer (Block & Webb, 2001). Lemi (2005) reported that participation in non-farm activities is mainly driven by demographic factors. In the north-western highlands of Ethiopia, destitute households and female-headed households have more diversified livelihoods than nondestitute households to off-set agricultural deficits (Sharp *et al.*, 2003). From eastern highlands of Ethiopia, Legesse (2003) described different dimensions of livelihood diversification strategies pursued by the farmers to off-set the various risks, mainly agricultural shocks, of rural livelihoods.

2 Objectives

This study takes a starting point in the very difficult socio-economic situation of resource poor rural farmers living under unpredictable environmental conditions, increased demographic pressure and unsustainable use of forests and other land resources.

The general study aims towards feasible approaches of assessing and monitoring the trends of land-use and land-cover dynamics, analyzing rural livelihoods, and modeling the future major environmental, agricultural and socio-economical conditions and trends using dynamic systems method and thereby providing a platform for strategies of sustainable natural resource management in the area.

The specific aims are:

1. To explore the dynamics of land-use and land-cover (LULC) in semi-arid area under high population pressure: compare the applicability of two possibly complementary assessment methods for LULC change; analyze the LULC changes in the study sites from 1973–2006, considering the major political and policy reforms from 1974; and assess the LULC trends in relation to population growth, crop productivity, rainfall variation and other farming constraints as a basis to better understand the drivers and impacts of LULC changes. (Paper I)

2. To understand the specific issues regarding food insecurity and its causal factors based on the household and community data. The research questions were as follows: a) What are the overall perceptions of farmers related to food insecurity, its causes and possible solutions? b) How does food security status differ among households in different study sites and between different well-being categories? c) Which livelihood activities and assets are important in determining food security? (Paper II)
3. To improve our understanding of the rural livelihood system in the semiarid areas of Ethiopia where drought frequency has increased over time. The specific objectives were as follows: a) to assess the changes of livelihood strategies that households followed over time and b) to assess the current livelihood strategies, household characteristics and asset base portfolios in different well-being categories to make specific recommendations for development undertakings in the area. (Paper III)
4. To use a dynamic simulation modeling based on participatory dialogue with farmers in order to generate forward projections (from 2006-2036) of land-use, population and income under various assumptions and contribute to the debate on social-environmental changes. (Paper IV)

3 Summary of Papers

3.1 Study Area

The study was undertaken in the lowland area of "Arsi-Negele" district (7°09'-7°41' N and 38°25'-38°54' E), 210 km south of Addis Ababa along the road to "Hawasa" (Figure 3). The district is part of Ethiopian Central Rift Valley, covering an area of 1400 km^2. About 80% of the population is rural (CSA, 2006). The National Meteorological Services Agency data, Langano station, shows an annual mean rainfall of less than 700 mm (ranges between 264 and 968 mm), while the mean annual minimum and maximum temperatures are 13.5°C and 27.7°C, respectively. We adopted purposive sampling to select the study sites, namely, Gubeta-Arjo and Keraru Peasant Associations (PAs). The PAs are the lowest units in the governmental structure. Both represent a flat semi-arid dry-land climatic zone below 1800 meters ASL. Their selection was based on their differing proximity to the main road and the main market centre, which were assumed to influence the forest use and the degree of livelihood diversification in the area. The study sites are inhabited predominantly by farmers belonging to the Oromo ethnic group. Most practice Islam and live in polygamous families. Crop production, primarily rain-fed, and livestock rearing are the mainstays of their livelihoods. The major crops are maize, wheat, teff (*Eragrostis tef*) and barley.

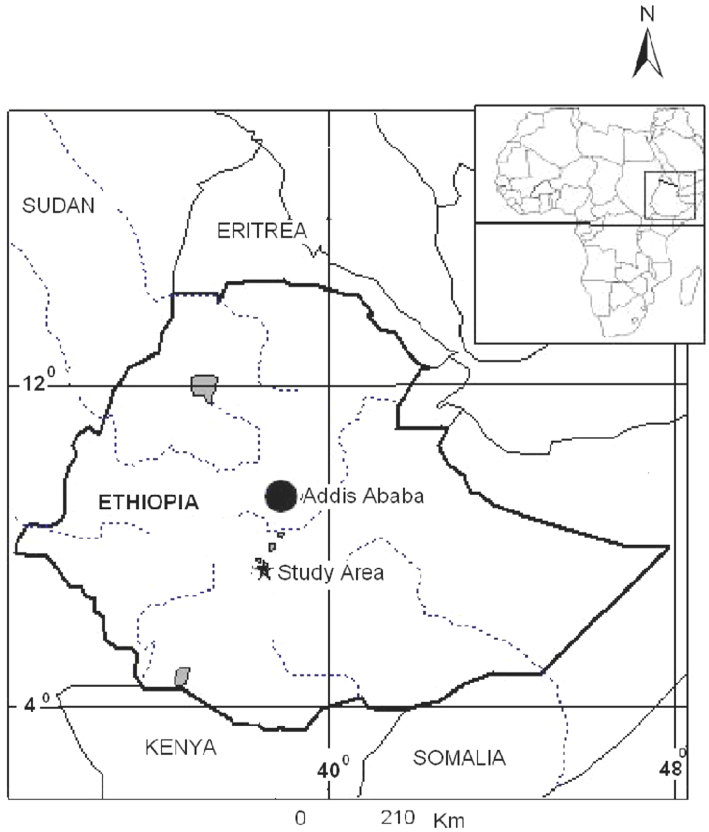

Figure 3. Map of Ethiopia, shows location of the study

These crop yields are affected by recurrent droughts. As shown in Paper II there is a high level of food insecurity. The most common coping strategy of the farmers during crop failures has been the burning and selling of charcoal. As a result, the once densely wooded area has been almost completely deforested (Garedew *et al.*, 2009). Food production was inadequate to cover the annual needs of many households even in normal rainfall conditions. This is mainly because of the poor performance of agricultural productivity, population growth and lack of productive assets to access food. During normal rainfall, number of livestock, land size, usage of improved farm inputs and household size are the major determinants of food security in the household. Food relief is also common in the area (pers. comm., district Agricultural & Rural Development Bureau). The natural woody vegetation is dominated by *Acacia Senegal, Acacia seyal, Acacia tortilis, Dichrostachys cinerea and Balanites aegyptiaca*. All are economically important species and have differing natural regeneration ability (WBISPP, 2004; Argaw *et al.*, 1999).

3.2 Methods and Approaches

3.2.1 Paper I

This study combines and compares participatory field point sampling (pfps) and remote sensing to explore the local LULC dynamics from 1973-2006.

The pfps approach used field observations and semi-structured discussions with a particular land-user on 118 evenly distributed systematic grids of sample points (57 in Gubeta-Arjo and 61 in Keraru). For each sample point the user of that land provided information on LULC, its changes and causes, circumstances and effects of those changes in crop productivity and farming constraints. In case sample points were located on common property resources or when individual land users could not give the required information, for instance because of their young age, key informants (representatives from PAs and community leaders) who were familiar with the land use were interviewed.

The basic data for the study were time series Landsat imageries: a) MSS (WRS-1, path181 and row 55, 60m resolution, from 31 January 1973), b) TM (WRS-2, path168 and row 55, 30m resolution, from 21 January 1986) and c) ETM^+ (WRS-2, path 168 and row 55, 30m resolution, from 5 February 2000). In addition, two topographic sheets of the local area from 1976 were scanned and rectified for "Adindan" UTM geographic projection to register all Landsat data and to generate the study site maps. Secondary data, population and climate, were collected from official offices and peasant associations.

3.2.2 Paper II & III

In these two studies, participatory rural appraisal (PRA) and a household survey were conducted in 2006/7. For the PRA approach, key informant selection was made together with the peasant associations (PA) councils, picking 20 individuals from each of the two study sites (PAs) reasonably able to understand the topics and express feelings, opinions and perspective on the general situations. These individuals were from a variety of households (based on wealth, age, gender) and leaders of peasant associations. Semi-structured and interactive interviews were carried out individually with key informants from each site. In addition, the district Agricultural & Rural Development Bureau experts were interviewed. The focuses in the interviews were on the changing livelihoods of communities in this area over the last three decades. A PRA households' well-being ranking was obtained by gathering all key informants in each PA and identified three well-being categories (relatively better-off, medium and poor category). In addition, Rural Livelihood Framework was used to collect and analyze relevant data (paper III).

A questionnaire-based household survey was undertaken for about 20% households selected randomly from each list of the three well-being categories. The questionnaire is found in Appendix I of this thesis. In total, 246 households (96 poor, 128 medium and 22 relatively better-off) were sampled. In the process of household's data collection five stages were involved: preparation of questionnaires, translation of questionnaires to the local language, recruitment and training of enumerators, pre testing questionnaire and feedback, and finally the actual field work was administered. The survey covered socio-economic, demographic and physical indicators, including livelihood strategies, activities, diversification, household characteristics, capital assets and income types and levels, food expenditure, food composition patterns, social networks, vulnerability and coping mechanisms.

3.2.3 Paper IV

In this study, a system dynamics model was built adopting the stock- and-flow model software (STELLA v.8) with an icon based interface and availability of array functions (Costanza & Voinov, 2001; High Performance Systems Inc., 1996). System dynamics is a concept that considers dynamic interaction between the elements of the studied system and can help to understand their behavior over time, build models, identify how information feedback governs the behavior of the system and develop strategy for better management of the studied system (Doerr, 1996). STELLA is easily understood by participants with no modeling background (Sandker *et al.*, 2009).

The study was conducted in 2009 using data inputs and assumptions from the previous studies undertaken by the same authors (Garedew *et al.*, 2009) and (paper II and III), and other sources (Table 1 a-c). It involved a process of model building with active participation of 20 key informants that represented households from the different wealth, age groups and gender. In addition, some members of the leadership of PAs were involved. The purpose was to obtain good understanding of their objectives in resource management and build on their knowledge about the local environment and its trends (Sayer & Campbell, 2004). Wherever data was lacking, information was provided through the focus group dialogue and consensus. This helped to improve the different sectors of the model for exploring reasonable socio-economical and environmental pathways.

Table 1a. *Data inputs and assumptions for 'land-use model sector' in studying the trends of land-use using various scenarios*

<table>
<tr><th rowspan="2">Data</th><th colspan="2">Assumption</th><th rowspan="2">Data Sources</th></tr>
<tr><th>With forest increase strategy</th><th>Without forest increase strategy</th></tr>
<tr><td rowspan="2">- Total area =2932 ha
- Farmland (FL)=57.6%
- Grassland (GL)=26.2%
- Woodland (WL)=6.6%
- Shrubland (SL)=5%
- Wooded-grassland (WGL)=1.6%
- Bareland (BL)=1.6%
- Settlement (S)=1.4%</td><td>1. 0.001% S transfer to WGL
2. No transfer from FL to GL
3. 5% WGL transfer to WL
4. No transfer from SL to BL
5. 10% SL transfer to WGL
6. No transfer from WL to WGL
7. No transfer from WL to BL
8. 0.1% GL transfer to BL
9. 2% GL transfer to WGL
10. 0.5% BL transfer to SL
11. No transfer from WGL to BL
12. No transfer from WL to SL
13. No transfer from WL to FL
14. No transfer from WL to GL
15. No transfer from WGL to FL
16. 0.5% GL transfer to WL
17. No transfer from GL to FL</td><td>1. No transfer
2. 0.3% transfer
3. 0.1% transfer
4. 1% transfer
5. No transfer
6. 5% transfer
7. 0.5% transfer
8. 1% transfer
9. 0.7% transfer
10. No transfer
11. 0.5% transfer
12. 0.2% transfer
13. No transfer
14. 2% transfer
15. No transfer
16. No transfer
17. No transfer</td><td rowspan="2">Garedew et al., 2009, with small modification</td></tr>
<tr><td colspan="2">- LULC conversion is mainly driven by the motivation of farmers to increase forest cover and area, and by the population growth.
- Communities' motivation for forest increase could help raise forest income to households.
- Transfer of farmland to settlement is based on the area demand from new household increases.
- The demand for additional FL can increase but no suitable land for crop is available to convert from WL, GL and WGL.
- If business continuous as usual further environmental degradation is expected.</td></tr>
</table>

Table 1b. *Data inputs and assumptions for 'human population model sector' in studying the trends of population using various scenarios*

Data	Assumption	Data Sources
- Population size=3840 in 2006		- Data interpolation from Garedew et al, 2009
- Growth rate=2.5% - Household size= 6	- Population increase is mainly determined by birth - Immigration is negligible	- Garedew et al, 2009 and 2006/07 household survey, and authors calculation
	- With better family planning strategy, projected birth rate=3.0% while current birth rate=3.86% - With better health service, death rate=0.85% while with current health service death rate=1.2% - Emigration is negligible with the current educational status while with better education, Emigration is assumed to be 0.3% - We also assumed, Emigration will likely occur due to landlessness, 0.1%	- World Population Prospects, 2008 revision

Table 1c. *Data inputs and assumptions for 'income and rainfall model sectors' in studying the trends income and rainfall using various scenarios*

Data	Assumption	Data Sources
1. Crop income - Current crop income=60%	- With micro-finance strategy farmers could able to use modern inputs (chemical fertilizer and improved seeds), we assumed crop productivity is likely doubled. Thus, crop income is increasing	Garedew et al., 2009, 2006/07 household survey and authors estimation
2. Livestock - Current livestock income=15%	- Livestock income is dependent on the number of livestock owned by each household and the amount of available fodder/feed. - Thus, the number of average livestock for the household was modelled based on the total carrying capacity of the area in terms of number of tropical livestock unit (TLU). - In turn the total carrying capacity is calculated based on the total animal feed available from different sources: grassland and crop residues (both are mainly dependent on rainfall amount and distribution) and forest land. - With micro-finance use livestock growth rate likely to double, from 0.1% to 0.2% for cattle while from 0.5% to 1% for goat/sheep and from 0.5% to 1% for chicken	
3. Non-farm income - Current non-farm income=25% - Household's involved in at least three non-farm activities - 14% households involved in petty trading - 69% households involved in forest cash income	- With micro-finance, we assumed that, every year an additional 2% households are likely to become involved in petty trading - Forest increase assumption is likely to increase cash income from the forest and an additional 2% of households are expecting to earn this additional income - Improved education is likely to result in 2% of households earning additional income from remittance	
4. Total household income=7811 Birr		
5. Rainfall data	- Annual rainfall, as a random variable based on the minimum (264 mm) and maximum (968 mm) values, likely influencing agricultural production	

The model structure included several sub-models or sectors representing components of the socio-economical and environmental systems. These are land-use, rainfall, human population, and incomes from crop, livestock and non-farm. In this study, three main scenarios were elaborated. The first one was named "business as usual" and assumed no significant change in current conditions or stakeholders´ behavior. In the second scenario, "strategies for socio-economic development", a number of assumptions reflecting government and local efforts for socio-economic change including microfinance, health and education services were made. For the third scenario, "forest increase" was put in focus and modeled as a pathway for restoring the woody vegetation and improving livelihoods by creating incomes. In land-use sector, a scenario of forest increase was initiated by farmers themselves in order to restoring the denuded natural environment. The model simulated all variables over a period of 30 years.

3.3 Data Analysis

In paper I, the LULC descriptions for both pfps and remote sensing were based on the land cover map of Africa with minor modification (Mayaux *et al.*, 2004). LULC categories of the Landsat data were delineated and classified by visual interpretation. The spatial data were checked using training areas (ground truths) from repeatedly assessed field data, independent of pfps, and visually interpreted aerial photos. Maps for both pfps and remote sensing were generated to monitor LULC changes. Arc GIS v.9 software was used where appropriate. The spatial information from the two approaches was compared in order to determine the percentage assessment of the correct classification. Areas of LULC categories, and climate and crop data were analyzed by descriptive statistics. Population growth rates assuming an exponential increase and population density were determined.

In paper II, food insecurity analysis was approached from a caloric perspective (Smith *et al.*, 2006). Firstly, the household net aggregate food was estimated by subtracting food losses from the total aggregate food accessed. Secondly, the total caloric content of the available net aggregate food for each sampled household was determined using food composition tables (Agren & Gibson, 1968) and then converted to calories per "Adult Equivalent Unit" (AEU) by dividing the total calories the household acquired by the number of AEUs in the household. The minimum daily recommended food energy intake of 2100 Kcal per AEU (Kaluski *et al.*, 2002) was used as the cut-off level for classifying households into food secure households and food insecure households. A logistic regression model was used to explore the determinants of food insecurity in the households. Food security statuses were expressed by a binary dependent variable (1 = food-insecure household and 0 = food-secure household). In addition, descriptive statistics and ANOVA were used to analyze the data.

In paper III, the quantitative data were analyzed using descriptive statistics and ANOVA. Simpson's (Livelihood) Diversity Index (DI) was computed (Vedeld *et al.*, 2007), using all of the identified livelihood incomes, to examine the degree of livelihood diversification in various households. A DI value of "0" (the lower limit) corresponds to no diversification, indicating a single livelihood source accounts for total household income while a value of "1" represents the upper limit of households using diversified sources. The relationships between DI and farm income, non-farm income and total household income were also examined using regression analysis by including a square term. Typologies of specializations were constructed based on the percent contribution of income (>50%, >66% or >75%) from a single livelihood activity or a combination of activities to the total household income.

In paper IV, the model was built for an average household whose crop landholding size is 2.5 ha, with a cropping area of maize (65%), wheat (25%) and teff (10%). The estimated average annual crop productivity of maize was1.25 ton/ha while wheat and teff were 1.1 ton/ha and 0.5 ton/ha, respectively. Crop net income (income subsistence plus cash) was determined; dry-land crop costs were subtracted from the total crop income. In addition to crops, an average household owns five cattle, three goat/sheep, one donkey and two chickens which generate household livestock incomes. In the study non-farm income comprises wage labor, forest-based, small scale fishing, sale of salt-rich soil for cattle feed, petty trading, sale of sand for construction, sale of traditional drink, remittance (currently none were reported) and government safety net transfer. A household on average engaged in at least three of these mentioned non-farm income generation sources. The simulated model outputs where tables or graphs. In all papers, the qualitative data were analyzed on site and results summarized and presented back to the communities for verification. SPSS v.17 software was used where appropriate. All monetary values are reported in Ethiopian Birr, during the survey year nine Birr was equivalent to one USD.

4 Results

4.1 LULC dynamics, the driving forces and farmers perceptions (Paper I)

The two approaches, pfps and remote sensing showed the same trends in LULC changes over the studied periods. More than 85% of the categorized units had the same classification in both methods. In both study sites, similar trends in LULC changes were revealed, although differences were identified in the magnitude of changes (Table 2). For instance, 35% woodland cover in Keraru and 54% in Gubeta-Arjo were lost during the period 1973-2000. In the same period the cropland coverage of 25% and 28% in Keraru and Gubeta-Arjo, respectively, had doubled. Over the entire study period, the annual rate of woodland area decline was 1.0±1.6% and 1.5±2.6% in Keraru and Gubeta-Arjo, respectively while the annual rate of cropland area increase was 0.8±0.6% and 1.1±0.2%, respectively. The area of wooded-grassland, grassland and shrubland respectively showed a fluctuating trend between the studied years. In both study sites, shifts in LULC among different categories, based on the remote sensing data, were multi-directional.

Table 2. *LULC change in the two study sites, for the period 1973-2006*

Study site & LULC category	Data source	1973		1986		2000		2006	
		ha	%	ha	%	ha	%	ha	%
A. Keraru									
Woodland	Landsat	1175	40	254	9	156	5	–	–
	pfps	1298	44	240	8	192	6	192	6
Cropland	Landsat	971	33	1426	49	1750	60	–	–
	pfps	721	25	1298	44	1586	54	1634	56
Grassland	Landsat	67	2	756	25	479	16	–	–
	pfps	625	21	721	24	721	24	625	20
Wooded- grassland	Landsat	548	19	293	10	273	9	–	–
	pfps	0	0	385	13	96	3	48	2
Bareland	Landsat	142	5	66	2	69	3	–	–
	pfps	144	5	48	2	48	2	48	2
Wet-grassland	Landsat	29	1	81	3	64	2	–	–
	pfps	96	3	144	5	145	5	144	5
Shrubland	Landsat	0	0	21	1	39	1	–	–
	pfps	48	2	48	2	48	2	145	5
Perennial crop	Landsat	0	0	35	1	50	2	–	–
	pfps	0	0	48	2	48	2	48	2
Cropland with trees	Landsat	0	0	0	0	52	2	–	–
	pfps	0	0	0	0	48	2	48	2
Total		2932	100	2932	100	2932	100	2932	100
B. Gubeta-Arjo									
Woodland	Landsat	789	54	0	0	0	0	–	–
	pfps	843	58	0	0	0	0	0	0
Cropland	Landsat	512	35	816	56	889	61	–	–
	pfps	408	28	639	44	817	56	920	63
Grassland	Landsat	35	2	13	1	19	1	–	–
	pfps	179	12	281	19	281	19	332	22
Wooded- grassland	Landsat	120	9	603	42	450	31	–	–
	pfps	0	0	485	33	256	18	153	11
Shrubland	Landsat	0	0	24	2	98	7	–	–
	pfps	26	2	51	4	102	7	51	4
Total		1456	100	1456	100	1456	100	1456	100

Note: Landsat data for 2006 was unavailable

Deforestation is a complex process. Population growth and declining crop productivity were the most important underlying driving forces to LULC change in the study area. Farmers suggested that the declining crop productivity was attributed mostly to recurrent drought, erratic rainfall, lack of credit to invest in fertilizers and improved seeds, lack of plowing oxen, declining soil fertility and a shortage of cropland. Private woodlots and common woodlands were openly exploited to access new croplands to provide for the increasing number of households and to compensate for low crop productivity. Interviews also confirmed that the worst years (droughts) for all farmers were 1973, 1980, 1984, 1991, 1996 and1998. Consequently, woodland forests were frontlines for livelihood coping strategies alongside the government food-aid. In addition, the subsequent changes in LULC were partially driven by the 1975 land tenure reform in the country. Thus, open access, unclear property rights and poor administration of the forestry sector were all contributing to the woodland clearance.

The effects of changes in LULC were articulated in terms of lack of fodder, scarcity of wood for household use (women in particular emphasized that they had to walk for increasingly greater distances to collect firewood), loss of forest income, loss of biodiversity and further soil degradation. The former was particularly troublesome during the long dry season when crop residues had to be used for animal fodder and domestic energy, instead of being recycled into the soil. The reduced fodder availability was believed to have reduced livestock numbers and thereby household incomes and food, while the burning of crop residues and animal dung further exhausted the soils.

4.2 Livelihood structure and food insecurity situations (Paper II)

All households in the study area were farmers and engaged in mixed farming with livestock and rain-fed crop production. Small-scale irrigation in Keraru allowed around15% of the households to generate the substantial average income of 2029 Birr per year. In the survey year, an expansion of irrigation development was undertaken by the government in order to accommodate around one hundred households. Both land distributions and livestock assets are statistically different ($P<0.01$) across well-being categories. Relatively better-off households had more cropland (3.9±0.9 ha) and livestock (12.8±11.3 in TLU) compared to the medium well-being (1.7±0.5 ha cropland and 6.7±4.9 TLU) and poor categories (0.7±0.2 ha cropland and 4.1±4.1 TLU).

In addition to farming, eight types of non-farm employment were identified as a supplement to the constrained agriculture. These are forest-based activities (sale of fire wood, charcoal and thatching grass), fishing, sand sale, safety-net transfer, sale of labor, sale of salt-rich soil, petty trading and sale of traditional drinks. Households were involved on average in three types of non-farm activities. Forest-based, non-farming activities were the most common, while fishing and sale of sand were other frequently mentioned activities.

The study period coincided with a normal rainfall season for agricultural production, even though the area is prone to low and erratic rainfall and frequent droughts. Despite the good rainfall in the survey year, about 23% of sample households were categorized as food insecure. The size of households in this food insecure category was 7.8±3.2 and was higher compared to the size of households (5.8±2.8) in the food secure category. When comparing the two sites the proportion of households who were food insecure was statistically varied (Chi-squared, $P<0.05$) and Keraru had more food-insecure households than in Gubeta-Arjo. Household sizes increased with well-being status, with poor households having 4.5±2.2 members, while medium and relatively better-off households had 7.0±2.9 and 9.3±3.3, respectively. Statistical variations were not seen across well-being categories regarding households' food security statuses. Overall, the food composition in terms of food quality was inadequate in most households, and diets were mainly composed of cereals (predominantly maize). The supply of protein, minerals, and vitamins was highly limited. A logistic regression model was used to predict the probability of household food security statuses (Table 3). Of the nine predictor variables included in the model, five were significantly correlated to the probability of a household being food insecure: household size, land holding size, number of livestock, fertilizer use and improved seeds use. Only household size showed a positive relationship with food insecurity. Age and education of household head, land quality and non-farm income did not contribute significantly to the model.

Table 3. *Parameter estimates for the effects of selected household variables on household food security status.*

Independent variables	Coefficient (B)	S.E.	Exp(B)
Constant	-2.034	0.871	0.131^{*}
Age of head	-0.004	0.016	0.996
Education of head	-0.260	0.433	0.771
Household size, AEU	0.607	0.110	1.834^{***}
Landholding size, ha	-0.558	0.282	0.573^{*}
Land quality	-0.013	0.362	0.987
Livestock ownership, no.	-0.172	0.052	0.842^{**}
Fertilizer usage	-1.307	0.610	0.270^{*}
Improved seed usage	-1.557	0.730	0.211^{*}
Non-farm income, Birr	0.000	0.000	1.000

Note: Number of observation = 246, Correct prediction = 80.1%, Likelihood ratio =65.2 (P=0.000), -2 log likelihood = 198.7 and statistically significant at * $P<0.05$, ** $P<0.01$ and *** $P<0.001$

A range of causes of food insecurity in the study area were identified during the PRA exercises and household survey. Key informants emphasized that the primary limitation on agricultural production and food security has been the poor environmental conditions. Food crop productivity regularly worsened because of recurrent droughts and low rainfall or poor distribution of rain during the rainy months of good years. Thus, farmers have been repeatedly exposed to food shortage. The second problem affecting crop productivity was soil degradation resulting from over-cultivation, wind erosion and limited use of expensive improved agricultural inputs because of the removal of agricultural subsidies and lack of micro-finance. Shortage of cropland and lack of plow oxen in the household were other factors mentioned by farmers as contributing to declining crop yield. Other inter-related socio-economic complexities were population growth, deforestation, lack of livestock fodder and farmers' poor health condition due to contagious disease and lack of clean drinking water.

Reduction of food portions, sale of charcoal/firewood to buy food and reduction of eating frequency were the coping mechanisms used as the first choice for most households during periods of chronic food insecurity. On the other hand, when households faced transitory food insecurity, most sold firewood, ate less-preferred food, sold livestock and ate seed formerly set aside for planting. Moreover, recurrent droughts gradually depleted the asset base of rural households. Receiving food-aid was also an important strategy for some of households in the second and third choices of coping mechanisms. Migration was one of the least desirable adaptation options. The agricultural officer for the district highlighted two common coping strategies used by farmers during times of food shortage- production and sale of charcoal/firewood and food-aid.

4.3 Household characteristics, income and evolving livelihood strategies (Paper III)

The average age of household head is 44. Sample households include 20% female-headed families. The average household is composed of 6.3±3.1 members, about 3.1 are aged less than 15 and 3.0 are between 15 and 65. Labor is a constraint in many households. This is due to the large number of inactive labor- under-aged children and over-aged adults. Levels of education are very low; only 46% sample household heads had formal education, out of which only 5% are above elementary and junior levels.

Households generate income from crop, livestock and various non-farm activities (Table 4a & b). The average household income ranged from 5782 Birr among poor households to 14,388 Birr among better off households. The per capita income for all sampled households was 1389 Birr and no statistical variation is found between well-being categories ($P>0.05$) due to the increase in household size with increasing wealth. For all sample households, farm income constituted 75% of the total household income, and 80% of this was derived from crop production. Income from farming was lower in poor households (69%), while medium and relatively better-off households earned 76% and 85% of household income from farming, respectively. The non-farm income comprised, on average, 25% of the total household income. There were statistical differences across well-being categories (Chi-squared, $P<0.05$, 2-sided); the poor earned the highest share (31%) from non-farm income, while the medium and relatively better-off households earned 25% and 15%, respectively. The average non-farm income was 1,937 Birr. However, there were no significant differences in non-farm income across well-being categories ($P>0.05$); poor households earned 1,812 Birr, while medium and relatively better-off households earned 2,006 Birr and 2,137 Birr, respectively.

Table 4a. *Household income (mean and standard deviations) portfolios and percentage share to the total income by study sites*

Household income portfolios	Keraru			Gubeta-Arjo			Total		
	Mean	Std. Dev	%	Mean	Std. Dev	%	Mean	Std. Dev	%
Crop	4579	3091	59.2	4985	3750	62.4	4708	3311	60.3
Livestock	1154	1884	14.9	1191	1704	14.9	1166	1825	14.9
Farm	5733	4106	74.2	6176	4598	77.3	5874	4264	75.2
Forest-base	957	309	12.4	1220	441	15.3	1041	375	13.3
Traditional drink	13	66	0.2	22	88	0.3	16	74	0.2
Petty trading	102	331	1.3	72	261	0.9	93	310	1.2
Salt-rich soil	57	103	0.7	0	0	0.0	39	89	0.5
Sand	533	839	6.9	61	174	0.8	381	731	4.9
Small scale fishery	99	371	1.3	0	0	0.0	68	310	0.9
Wage labour	115	255	1.5	58	114	0.7	97	222	1.2
Safety net transfer	132	315	1.7	376	454	4.7	209	381	2.7
Non-farm	1997	1118	25.8	1809	743	22.7	1937	1016	24.8
Per capita	1301	678		1580	902		1389	765	
Total	7730	4352	100	7985	4765	100	7811	4479	100

Table 4b. *Household income (mean and standard deviations) portfolios and percentage share to the total income by well-being categories*

Household income portfolios	Poor			Medium			Relatively better-off		
	Mean	Std. Dev	%	Mean	Std. Dev	%	Mean	Std. Dev	%
Crop	3070	2708	53.1	5092	2572	62.0	9617	4042	67.1
Livestock	914	1687	15.8	1111	1600	13.5	2583	2848	18.0
Farm	3984	3531	68.9	6203	3277	75.5	12200	5642	85.1
Forest-base	937	319	16.2	1101	398	13.4	1141	382	8.0
Traditional drink	17	73	0.3	14	68	0.2	23	107	0.2
Petty trading	71	259	1.2	88	304	1.1	218	492	1.5
Salt-rich soil	35	84	0.6	43	93	0.5	34	92	0.2
Sand	367	722	6.3	382	689	4.7	434	997	3.0
Small scale fishery	93	460	1.6	53	159	0.6	40	54	0.3
Wage labour	77	156	1.3	117	269	1.4	70	140	0.5
Safety net transfer	205	374	3.5	218	384	2.6	177	411	1.2
Non-farm	1798	1048	31.0	2008	946	24.5	2138	1224	14.9
Per capita	1441	888		1301	643		1678	785	
Total	5782	3647	100	8211	3548	100	14338	5775	100

In the past, farmers were largely dependent on livestock production for subsistence and cash income. Land was not limiting for farming and grazing, and forest land was relatively abundant in the area. In the second half of the 1960's, large scale commercial farming began in the area by members of the royal family by opening up the natural woodland forest. Farmers emphasized that this led to large scale deforestation. The 1975 Ethiopian rural land reform proclamation nationalized all rural land and put an end to private ownership. Subsistence farmers were given only use-rights. As the population pressure grew, the importance of livestock slowly declined, crop farming became common and mixed farming prevailed. Woodland forest clearance continued as a major coping strategy to offset the agricultural shocks. Farmers associated the occurrence of rapid deforestation with the 1984/85 drought that caused a major crisis in terms of crop failure and the death of a significant number of livestock in the area. In the past, farmers also expanded cultivated areas to allocate land to young couples and to cope with the declining crop yield levels. However, currently no more suitable land is available for crop expansion.

The average livelihood diversification index (DI) for all sample households was 0.50. The degree of the diversification index was different across well-being status. The DI value for the poor was 0.52 (ranges between 0.08-0.77), 0.49 (ranges 0.08-0.74) for the medium and 0.44 (ranges 0.23-0.65) for the relatively better-off households. DI values were significantly different ($P<0.05$) between the poor and the relatively better-off households. The outputs of regressions did not show statistically significant relationships for the DI values against the total household income and farm income. However, the regression of DI against non-farm income (NFI) yielded a statistically significant relationship ($P<0.001$). The possible implication of NFI was that the dependence of farmers on additional income opportunities away from agriculture is increasing. The NFI reliance rises with the diversification index up to a certain point (about 5000 Birr), above which the relationship is very uncertain because of few data points were available (see Figure 4). Three types of income specializations were identified; household's earned >50%, >66% and >75% income from single or combined livelihood strategies (Table 5). Crop production was the single main income activity, in all types of specialization, across the majority of households in all well-being categories in the survey year. Similarly, in all type of income specializations, the combined crop/non-farm and crop/livestock activities created the largest income for most households across well-being categories. Considering all types of specializations and the major livelihood strategies (crop, crop/non-farm and crop/livestock), the proportion of households' engagement increased with well-being status. The poor had the least proportion in all specializations, while the relatively better-off category had the largest household proportion.

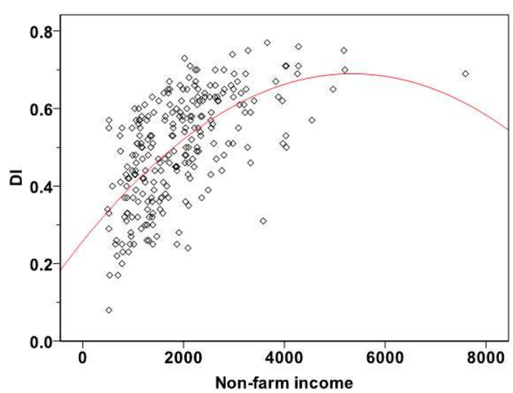

Figure 4. Non-farm income and diversification
Note: R^2 (adj.)= 0.4, F= 80.85, P= 0.000

Table 5. *Frequency of households (%) by livelihood strategies and typology of specialization strategies*

Household Strategies	Poor (n=96)	Medium (n=128)	Relatively better-off (n=22)	Overall (N=246)
1.	>50% (Typology I)			
Only crop	51	79	91	69
Only livestock	2	0	4	1
Only non-farm	18	4	0	9
Crop/livestock	79	94	100	89
Livestock/non-farm	46	18	9	28
Crop/non-farm	97	99	96	98
2.	>66% (Typology II)			
Only crop	19	46	52	36
Only livestock	1	0	0	0
Only non-farm	1	1	0	1
Crop/livestock	45	76	87	65
Livestock/non-farm	10	5	0	7
Crop/non-farm	92	94	83	92
3.	>75% (Typology III)			
Only crop	7	15	39	14
Only livestock	1	0	0	0
Only non-farm	1	0	0	0
Crop/livestock	26	49	78	43
Livestock/non-farm	4	2	0	2
Crop/non-farm	83	83	74	82

Note: Types of specialization (1-3) were explored base on >50%, >66% or >75% of the total households income earned from a single specific livelihood activity or a combination of activities.

4.4 The simulation of population, land-use and income (Paper IV)

The population model simulates the natural growth of population, number of households, and number of household increment annually. Figure 5 shows the simulation of human population increase based on different intervention strategies. Over the simulation period (2006-2036), for all strategies, population increase has seen; however the increase holds a diverse pattern of pathways. Population growth is sharp, the population of the study area increasing from 3840 to 8197 and from 3840 to 9079 with business as usual and better health strategy, respectively. On the other hand, population growth is slower with better family planning and the combined scenario, 6367 and 6462 respectively.

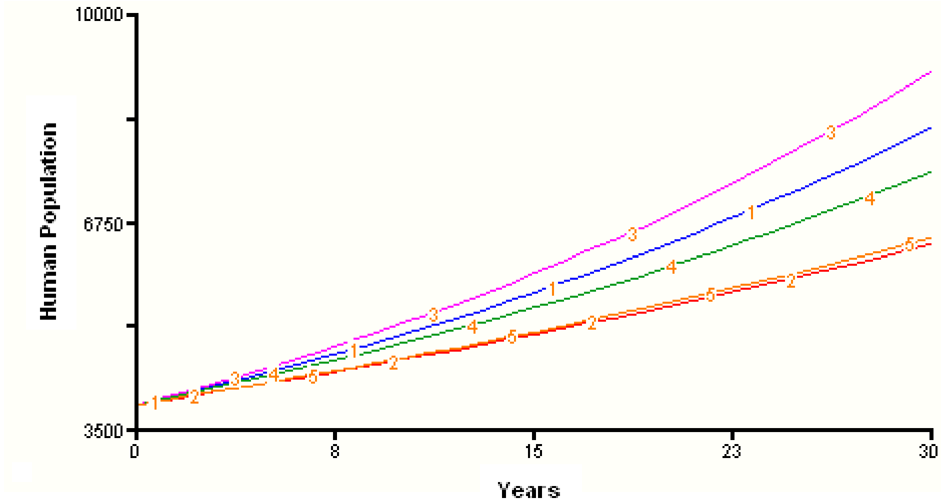

Figure 5. Simulation of human population growth based on five different strategies.

Note: 1=current, 2=better family planning, 3= better health, 4= better education, 5=combined projected scenarios (2, 3 &4)

The land-use sector simulation without the forest increase strategy resulted in grasslands declining from 769 ha to 611 ha whereas woodland and farmland declining from 192 ha to 88 ha and from 1696 ha to 1504 ha, respectively. On the other hand, shrubland, wooded-grassland and bareland were in the increase (Table 6). Using the land-use simulation with forest increase strategy both the woodland and wooded-grassland would increase from 192 ha to 583 ha and from 48 ha to 109 ha respectively in the expense of the decrease in the areas of shrubland and bareland. In the forest increase strategy farmland continues to make up a large part of the landscape over the simulation period. The area of settlements has similar trends for both with and without forest increase scenarios and would increase by about twofold.

Table 6. *Simulation of land-use types (ha) based on without (A) and with (B) forest increase strategies*

Years	Grassland	Woodland	Shrubland	Wooded-grassland	Bareland	Farmland	Settlement
A							
0	769	192	145	48	48	1696	42
3	735	174	153	89	72	1672	45
6	707	159	159	123	94	1650	49
9	683	145	163	152	115	1628	53
12	665	134	167	176	134	1608	57
15	650	123	170	196	152	1589	61
18	638	114	172	212	168	1570	66
21	628	106	173	226	184	1552	71
24	621	99	174	237	198	1536	75
27	615	93	175	247	211	1519	80
30	611	88	175	254	223	1504	85
B							
0	769	192	145	48	48	1696	42
3	756	214	123	78	44	1679	45
6	745	242	108	97	40	1660	49
9	735	274	96	108	37	1638	53
12	725	309	87	114	34	1614	57
15	716	348	81	116	31	1587	61
18	706	389	76	116	29	1558	66
21	697	433	73	115	26	1525	71
24	688	480	70	113	24	1490	75
27	679	530	67	111	22	1451	80
30	670	583	65	109	20	1410	84

We also found that the total area of settlements and farm size per household are influenced by the discrete and the combined strategies.

The simulation of the average household income from crops, livestock and non-farm followed a range of patterns between different intervention strategies (Table 7a & b). In the farm income, of all the intervention strategies, both the micro-finance and the combined scenarios considerably improved household incomes in the long-term but they have no regular patterns over the separate years of simulation. If a households' income is strictly investigated, its amount is regulated by the amount of income generated from agriculture. In turn, agricultural production is dependent on the amount of rainfall and its distribution within the growing season since agriculture is largely rainfed in the study area. The amount of annual rainfalls varies between 264 mm and 968 mm with an estimated mean of 700 mm. A rainfall model is generated by a random generator providing annual data between 264 mm and 968 mm. The simulated output shows that the magnitude of agricultural income (in particular income from crops) per household varies with the amount of rainfall in the area (Figure 6). On the other hand, non-farm income is constant throughout the simulation period and for all scenarios. There is a possibility of increasing non-farm income through the forest increase strategy and this was predicted to resulting in a doubling of non-farm income when compared to the business goes as usual strategy.

Table 7a. *Simulation of average farm household incomes (Birr) based on different strategies*

Years	Crop income		Livestock income			
	Business as usual (BAU)	Micro-finance	Business as usual (BAU)	Forest increase	Micro-finance	Combined (without BAU)
2006	3248	7307	2562	2562	2562	2562
2009	3518	8457	3043	3043	3175	4657
2012	4480	8681	3054	3054	3496	4093
2015	3297	9898	2790	2790	3195	5110
2018	3702	10270	2917	2917	3581	4342
2021	3869	9570	3007	3007	3300	3754
2024	5075	8650	2998	2998	3297	4008
2027	2844	11528	2535	2535	2742	4268
2030	3127	8805	2685	2685	2965	3810
2033	5409	5668	2405	2405	2510	3793
2036	2796	7017	2188	2188	2576	3465

Table 7b. *Simulation of average non-farm household income (Birr) based on different strategies*

Years	Business as usual (BAU)	Forest increase	Micro-finance	Better education	Combined (without BAU)
2006	795	1230	811	796	1247
2009	795	1230	811	796	1247
2012	795	1230	811	796	1247
2015	795	1230	811	796	1247
2018	795	1230	811	796	1247
2021	795	1230	811	795	1247
2024	795	1230	811	795	1247
2027	795	1230	811	795	1247
2030	795	1230	811	795	1247
2033	795	1230	811	795	1247
2036	795	1230	811	795	1247

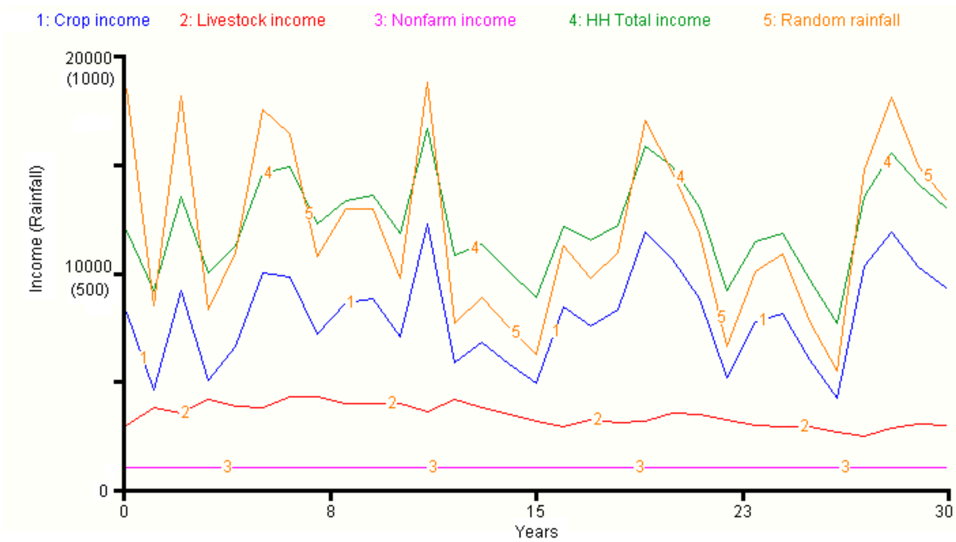

Figure 6. Relationships between the simulations of rainfall and household income under the micro-finance strategy

5 Discussion

5.1 LULC change

The local level LULC dynamics exemplify the universal dry-land processes which underlie the prolonged land degradation which is affecting the security of the natural environment and people's livelihood. The methods involved, in paper I, were remote sensing and participatory field point sampling (pfps), combining quantitative and qualitative data. Both methods presented similar trends for LULC change. Given the similarity of the results, farmers have shown that they have good knowledge and recall about LULC. The advantage of using the remote sensing method was that multi-temporal imageries for mapping and monitoring can be objectively examined. However, this bio-physical approach includes some sources of errors and gives no information on why changes occur. The participatory method provided not only the most recent LULC data that could be verified by direct observation, but also the possibility of meeting the land users, and exploring the nature of LULC change, and its drivers and consequences. The disadvantages of this interdisciplinary approach are the inherent subjectivity in historical data and its dependence on what respondents were able to recall and that data cannot always be verified. In addition the intensive nature of the field work limits the area that can be covered. This study has demonstrated the complementary nature of the two methods.

In tropical regions, deforestation is driven by multiple causative factors and varies between countries (Geist & Lambin, 2002). In Ethiopia, it has been a major problem for many decades. This study showed that there was rapid LULC change in both study sites, with cropland replacing woodland and wooded-grassland forests. Such trends are consistent with numerous studies in Ethiopia and elsewhere (Dessie & Christiansson, 2008; Ningal *et al.*, 2008; Paré *et al.*, 2008; Kamusoko, 2007; Zhao *et al.*, 2006; Zeleke & Hurni, 2001).

In contrast to our study, there are recently reported cases in Ethiopia, initiated by NGOs, to improve forest conservation and sustainable development through community participation, though many of these cases are based on access to large blocks of formerly state-managed forests and/or woodlands (Kassa *et al.*, 2009; Farm-Africa/SOS Sahel Ethiopia, 2007; Amente *et al.*, 2006). This participatory forest management (PFM) is grounded on clarifying property rights. Sunderlin *et al.* (2008) and Mekonnen and Bluffstone (2008) suggested that clear and secured forest tenure rights are now widely recognized as central in contributing to social and economic development. While clarification of property rights may provide some solutions, it is unlikely to represent the full answer (Frost *et al.*, 2007; Campbell *et al.*, 2001).

The output of the simulation model points at a further worsening of environmental degradation if business continues as usual. However, through integrated strategies such as those indicated in the modeled scenarios there could be an opportunity for environmental degradation to be reversed and population growth can be slowed. It requires, however, that the villagers are implementing their commitment to increase woody vegetation in their landscape and at the same time that the government is committed to intervening progressively in family planning, health, education, micro-finance, clearance of property rights and natural resource management. There are a number of encouraging experiences of natural resources restoration (such as woody vegetation, fauna, soil, and water storage) through local people participation in different degraded dry-land regions of the country or elsewhere. Verdoodt *et al*. (2009) reported that the communal enclosure strategy, on severely degraded semi-arid area in Kenya, proved to be successful in improving both rangeland vegetation and soil health. The role of enclosures, over the adjacent open areas, in the recovery of woody vegetation in degraded central and northern Ethiopia revealed higher composition of above-ground woody vegetation, density of woody plants, population structure of woody plants, and density of soil seed banks (Mengistu *et al*., 2005).

5.2 Causes and effects of LULC changes

In dry-land areas a major limitation for agricultural production and food security is the constrained biophysical environment in terms of erratic rainfall and drought (Appelgren, 2009). In the study area, farmers fail to produce crops and lose livestock in the seasons when low and erratic rainfall and droughts occurred. Many are driven to woodland resources to raise incomes through wood fuel sale to offset the shocks. Major woodland and wooded-grassland deforestation and forest degradation took place during the first studied period 1973-1986, where especially the severe drought in 1984 contributed. The presented data, based on individual enquiries among farmers from the pfps, about crop productivity showed that the declining trend over time has prevailed. According to farmers the declining crop productivity had contributed to the rapid exploitation of the woodland forest. Farmers also believed that the declining crop productivity was exacerbating due to soil degradation caused by the destruction of woodlands. Other key factors for the local deforestation and expansion of cropland were the rapidly increasing population pressure and compensation for the declining crop productivity. In the modeling exercises, the simulation of population sector displayed further rapid population growth if business continuous as usual. A recent study in developing countries by Jorgenson and Burns (2007) linked rural population growth to higher rates of deforestation. Rembold *et al.* (2000) noted that in the past, farmers in the lakes region of Ethiopia were able to compensate for low productivity by cropping more lands but with increasing population density the size of cropland per household is diminishing because the limits of usable land have been reached. In our study sites the population increased rapidly over the 30 years (1975-2004) by 114% in Keraru and 408% in Gubeta-Arjo. Correspondingly, the woodland areas decreased by 85% and 100% while the cropland area in both PAs roughly increased in similar rate by 126%. These figures raise questions. Assuming that people produced subsistence crops on their own farmland, how could they survive when cropland productivity declined and population continued to increase at such a high rate? We considered whether the management of land was intensified in the situation of cropland scarcity. Boserup (1965) also suggested in many situations and countries with high population pressure agricultural practices have intensified. There were no such indications in our study, a similar finding to that of Frost *et al.* (2007) for dry-land Zimbabwe. Our key-informants suggested that farmers received food aid and diversified into low-value non-farm activities. In more humid areas, for instance some of those highlighted by Boserup (1965) and Liu *et al.* (2005), the needs of a growing rural population were not even satisfied by increased land productivity, but had to rely on an expansion of croplands or other sources of income. Further discussion with farmers revealed that lack of assets, unclear property rights, and poor administration of the forestry sector were other important underlying factors in the woodland clearance. The interconnected effects of LULC change were articulated in terms of land degradation, household food insecurity, lack of fodder for livestock, scarcity of wood for household use, loss of forest income, and loss of biodiversity.

5.3 Food insecurity situation

World food crop production has been doubled in the past few decades due to the changing land-use practices, it exceed 2 billion tons per year (Mann, 1999). The human population is expected to increase by nearly one billion per decade for the next few decades, and requires a 2% increase in food production on annual bases (Bondeau *et al.*, 1999). This will result both in further conversion of natural ecosystem to agriculture and an intensifying use of the existing agricultural land. .Food security in Africa is already under stress as a result of physical factors (e.g., climatic limitations and low water availability), political factors (e.g., insufficient rural infrastructures, lack of sound governance and the need for political reform), and socioeconomic factors (e.g., distance from markets, lack of empowerment) (Rosegrant et al., 2005). Climate change has the potential for further negative impacts on food security (Schade & Pimentel, 2009; Lobell *et al.*, 2008; Schmidhuber & Tubiello, 2007). Some studies further argue that socio-economic problems pose a major obstacle for African farmers in their attempts to adapt to climate change (Bryan *et al.*, 2009; Jones & Thornton, 2009; Brown & Funk, 2008; IFPRI, 2006). In drought-prone areas of Ethiopia, the relationship between environmental degradation (unreliable rainfall, deforestation and soil degradation), declining agricultural productivity and high population growth have negatively affected the food security situation (Ezra, 2001). Garedew *et al.* (2009) documented that erratic rainfall, frequent droughts, population growth, deforestation, soil degradation, and declining crop productivity have been a major challenge for the present study area and society. The result of this study shows that food insecurity is the outcome of the interaction between these environmental factors and socio-economic conditions. Over the last 3 decades the growing local population in the study area has never produced enough food for their subsistence. In many households, even in a year of normal rainfall, food insecurity is persistent. The situation is worst in large households with small land holdings and low crop productivity. In addition, no suitable land is left for cropland expansion to any household. As a result, new households are landless or may share or acquire only small plots from their parents, meaning that per capita land holdings and food production are being diminished. A number of food security studies in Ethiopia and elsewhere have revealed similar results, high rural food poverty rates in larger households and households with smaller farm land holdings (Hailu & Regassa, 2007; Hesselberg & Yaro, 2006; Feleke *et al.*, 2005; Ramakrishna & Demeke, 2002; Rose & Charlton, 2002). Surprisingly, in the study area, statistical variations were not found with regards to food insecurity across well-being categories, given that the well-being ranking was related to farm size. This is also confirmed by the regression evidence showing a fall in food insecurity with increasing household size. Here the crucial issue is that in larger households labor is surplus or most household members are in non-productive ages. If the former is the case, livelihood opportunities in the area are limited to absorb this surplus labor. Thus, the effect of household size differs from what is observed in the literature, where household size is the key supply of more labor and encouraging the possibility of livelihood diversification (Winters *et al.*, 2009). Labor migration out of the area was not an option to many households unlike other studies (Niehof, 2004; Haan *et al.*, 2000). This was due to the negative traditional perception of the local people towards migration and secondly the discouraging nature of the governments' land policy in the past. The use of land by the farmers has required permanent physical residence.

5.4 The role of crop, livestock and non-farm activities to food security

Farmers in the study area are largely dependent on the surrounding natural capital and its services for subsistence and cash income. Crop production activities are the main livelihood strategies of households; making up over 60% of the total household income. Of the total share of crop income in the household 45% is subsistence income. Over the past decades, the agricultural sector in Ethiopia has performed poorly, the imbalance between food production and food demand has been filled by food aid (Kirwan & McMillan, 2007). Similarly, in the studied case, the temporal decline in crop productivity has a key impact on household food insecurity, there is also little evidence of agricultural intensification occurring (Garedew *et al.*, 2009).

Livestock play an important role in the farming household, through traction, improving soil fertility, serving as financial savings and through direct food products. By building this asset, individuals and households will likely enhance their capacity to cope with the food shocks they encounter and to meet their needs on a sustained basis. However, recurrent droughts and lack of livestock fodder, caused by deforestation and grassland degradation, has gradually depleted the livestock asset base and income of households in the area. The average share of livestock income to the households during the study period was 15%. The role of livestock in food security is relatively high; liquidating livestock is a common method for coping with food shocks. Even if livestock numbers and productivity vary in response to biological and biophysical factors, other studies have shown their conclusive role in determining food security in smallholder farm households

(Millar & Photakoun, 2008; Randolph *et al.*, 2007; Kassa *et al.*, 2002; de Haan *et al.*, 2001).

The frequent occurrence of agricultural shocks during drought and poor rainfall drives households into dependency on utilizing woodland resources and food-aid. Non-farm diversification and adaptation have focused around excessive natural resource mining (e.g., forest clearing) without replacement. Environmental stresses and farmers' deprived socio-economic conditions have weakened their capacity to utilize these and other resources sustainably. Low levels of income solely from agriculture do not meet the households' basic everyday expenditure. The importance of extra income besides agriculture in order to ensure food security in the households is indisputable. Another motive for non-farm incomes was risk minimization. The importance of a wide range of income-generating activities in poverty reduction has been commonly recognized in the literature as an important method of increasing household income. Davis *et al.* (2007) showed that non-farm (except crop and livestock) income is important for the four African countries they studied (Ghana, Nigeria, Madagascar and Malawi), the share ranges from 22-53% of the total income. Reardon (1997) reported that rural non-farm income shares in eighteen African countries ranged from 15% for Mozambique to 93% for Namibia. In Egypt poor households had a larger share of non-farm income than wealthier (Adams, 2002). A review study by FAO (1998) revealed similar findings for poor households in Kenya while in Niger, Rwanda and Mozambique richer households earn a larger share of non-farm income. For some studies in Ethiopian, non-farm diversification played a part in the dynamics of rural livelihoods and attained between 13-44% of household income (Shimelis & Bogale, 2007; Matsumoto *et al.*, 2006; Carswell, 2002). In our study, households' non-farm income share attains about 25%. When divided by well-being status, poor households earn the highest share while relatively better-off households earn the least non-farm share. However, the household income from non-farm activities currently is not significant in explaining food security status, given its low levels. In Ethiopia, the estimated national (rural) poverty line by MoFED (2007) is about Birr 1140. Fifty percent of households in the study area lie far below this poverty line even though the per capita average income (Birr 1389) for all sample households is above the line. As a result, poverty is widespread in the study area and the low level of per capita income has reflected the condition of severe poverty in the country.

6 Conclusion and recommendations

The present study documented a dramatic change in LULC over time and also an apparent food insecurity situation, associated with rapid population growth, recurrent drought, high rainfall variability, deforestation and loss of fodder, declining crop productivity and lack of assets. Lack of livelihood security has forced farmers to use the woodlands indiscriminately in order to cope with recurrent household biophysical shocks. The distressing nature of these trends is reflected in further deterioration of livelihood and environmental security, including the loss of woodlands, loss of biodiversity, soil degradation and food insecurity. Increased dependency on non-farm incomes is another effect of the growing population pressure. Low-return non-farm diversification is focused on natural resource mining without replacement. The situation is exacerbated by the absence of suitable land for crop production and that little agricultural intensification has occurred. If the situation remains unchanged then the people's livelihood insecurity will continue to deteriorate.

There is a growing need for appropriate policies and programs for the sustainable use of natural resources when considering the issues of poverty and climate change in resource poor regions. It requires constructive approaches that adequately address the links between environmental and socio-economic development. The interdisciplinary, participatory, system dynamics approach of this study could be one such example. Our study concludes and recommends:

1. Monitoring the past and present LULC dynamics using a combination of remote sensing and participatory field point sampling is a valuable approach for land-use inventory.
2. The dramatic trends in LULC were associated with rapid population growth, recurrent droughts, rainfall variability and declining agricultural productivity.
3. Food security is vulnerable to climatic change.
4. Even though the modeling outcomes are only rough indicators, as a supporting tool it can contribute to the debate on socio-economical and environmental changes and the decision making processes in relation to the management of the natural resources, primarily at the district level. When needed local planners can adapt the model and change variables.
5. Under the dry-land conditions, there are limited opportunities for improving livelihood and environmental security without substantial external support such as safety net transfer, provision of family planning services, micro-credit and irrigation development. Farmers require training, advice and support to diversify their livelihood and increase their income. The PFM scheme and area enclosure are possibly few options to improve the restoration, conservation and sustainable utilization of the woodlands. All efforts require investment, good will of politicians and the right policy packages by regional and local governments.

References

Adams, R. (2002). Nonfarm Income, Inequality and Land in Rural Egypt. *Economic Development and Cultural Change* 50(2), 339-363.

Adenew, B. (2004). The Food Security Role of Agriculture in Ethiopia. *e-Journal of agricultural and development economics* 1(1), 138-153.

Adger, W.N., Arnell, N.W. & Tompkins, E.L. (2005). Successful adaptation to climate change across scales. *Global Environmental Change Part A* 15(2), 77-86.

Agren, G. & Gibson, R. (1968). *Food Composition Table for Use in Ethiopia I.* Stockholm and Addis Ababa: Swedish International Development Authority and Ethiopian Nutrition Institute.

Alemayehu, N. (2007). The role of trust between actors in common-pool resource management: empirical evidence from participatory forest management scheme in Ethiopia. In E. Kebessa & C. DeStoop, eds. Proceedings of the International Conference on PFM, Biodiversity and Livelihoods in Africa. Addis Ababa, the Government of Ethiopia in collaboration with other stakeholders.

Amente, G., Huss, J. & Tennigkeit, T. (2006). Forest regeneration without planting: the case of community managed forests in the Bale Mountains of Ethiopia. *Journal of The Drylands* 1(1), 26-34.

Angelsen A. (ed.) (2008). *Moving ahead with REDD: Issues, options and implications*. Bogor, Indonesia: CIFOR. ISBN 978-979-1412-76-6

Appelgren, B. (2009). Towards Sustainable Dryland Development in Africa: Integrating Groundwater and Land Management. In: Lee, C., *et al.* (Eds.) *The Future of Drylands*. Springer.Chapter 2). pp. 199-208.

Argaw, M., Teketay, D. & Olsson, M. (1999). Soil seed flora, germination and regeneration pattern of woody species in an Acacia woodland of the Rift Valley in Ethiopia. *Journal of Arid Environments* 43(4), 411-435.

Bekele, M. (2001). *Forestry Outlook Studies in Africa (FOSA). Country Report: Ethiopia*. FAO.

Bekele, M. (2003). Forest property rights, the role of the state and institutional exigency: The Ethiopian experience, Ph.D. Thesis, Swedish University of Agricultural Sciences, Uppsala, 220 pp

Bekele, M. & Berhanu, L. (2001). *State of Forest genetic Resources in Ethiopia. Sub-Regional Workshop FAO/IPGRI/ICRAF on the conservation, management, sustainable utilization and enhancement of forest genetic resources in Sahelian and North-Sudanian Africa (Ouagadougou, Burkina Faso, 22-24 September 1998). Forest Genetic Resources Working Papers, Working Paper Forestry Department, FAO, Rome, Italy.*

Bishaw, B. (2001). Deforestation and Land Degradationin the Ethiopian Highlands: A Strategy for Physical Recovery. *Northeast African Studies* 8(1), 7-25.

Block, S. & Webb, P. (2001). The dynamics of livelihood diversification in post-famine Ethiopia. *Food Policy* 26(4), 333-350.

Bondeau, A., Bugmann, H., Campbell, B., Canadell, J., III, F.S.C., Cramer, W., Ehleringer, J.R., Elliott, T., Foley, J.A., Gardner, R.H., Goudriaan, J., Hunt, L.A., Hunt, T., Hall, D.O., Gardner, R.H., Gregory, P., Ingram, J., Körner, C., Landsberg, J., Langridge, J., Lauenroth, W.K., Leemans, R., Linder, S., McMurtrie, R., Menaut, J.-C., Mooney, H.A., Murdiyarso, D., Noble, I.R., Parton, W.J., Pitelka, L., Ramakrishnan, P.S., Sala, O., Scholes, R.J., Shugart, H.H., Schulze, E.-D., Smith, M.S., Steffen, W.L., Sutherst, B., Valentin, C., Walker, B., Woodward, F.I. & Zhang, X. (1999). *The Terrestrial Biosphere and Global Change: Implications for Natural and Managed Ecosystems*. Cambridge, UK: Cambridge University Press. (International Geosphere-Biosphere Programme

Boserup, E. (1965). *The Conditions of Agricultural Growth: The Economics of Agrarian Change under Population Pressure*. London: Allen and Unwin.

Brown, M.E. & Funk, C.C. (2008). CLIMATE: Food Security Under Climate Change. *Science* 319(5863), 580-581.

Bryan, E., Deressa, T.T., Gbetibouo, G.A. & Ringler, C. (2009). Adaptation to climate change in Ethiopia and South Africa: options and constraints. *Environmental Science & Policy* 12(4), 413-426.

Burton, I., Diringer, E. & Smith, J. (2006). *Adaptation to Climate Change: International Policy Options*. Pew Centre on Global Climate Change.

Campbell, B.M., Sayer, J.A., Frost, P., Vermeulen, S., Ruiz-Pérez, M., Cunningham, A.B. & Prabhu, R. (2001). Assessing the performance of natural resource systems. *Conservation Ecology* 5(2), 22 [online] http://www.consecol.org/vol5/iss2/art22

Carswell, G. (2002). Livelihood diversification: increasing in importance or increasingly recognized? Evidence from southern Ethiopia. *Journal of International Development* 14(6), 789-804.

Chapin, F.S., Zavaleta, E.S., Eviner, V.T., Naylor, R.L., Vitousek, P.M., Reynolds, H.L., Hooper, D.U., Lavorel, S., Sala, O.E., Hobbie, S.E., Mack, M.C. & Diaz, S. (2000). Consequences of changing biodiversity. *Nature* 405(6783), 234-242.

Cheng, S., Hiwatashi, Y., Imai, H., Naito, M. & Numata, T. (1998). Deforestation and Degradation of Natural Resources in Ethiopia: Forest Management: Implications from a Case Study in the Belete-Gera Forest. *Journal of Forest Research* 3(4), 199-204.

Costanza, R. & Voinov, A. (2001). Modeling ecological and economic systems with STELLA: Part III. *Ecological Modelling* 143(1-2), 1-7.

CSA (2006). *National Population Statistics*. Addis Ababa: Federal Democratic Republic of Ethiopia, Central Statistical Authority.

Darbyshire, I., Lamb, H. & Umer, M. (2003). Forest clearance and regrowth in northern Ethiopia during the last 3000 years. *The Holocene* 13(4), 537-546.

Darkoh, M.B.K. (2003). Regional perspectives on agriculture and biodiversity in the drylands of Africa. *Journal of Arid Environments* 54(2), 261-279.

Davis, B., Winters, P., Carletto, G., Covarrubias, K., Quinones, E., Zezza, A., Stamoulis, K., Bonomi, G. & DiGiuseppe, S. (2007). *Rural Income Generating Activities: A Cross Country Comparison*. ESA Working Paper No. 07-16, Rome: FAO.

de Haan, C., van Veen, T.S., Brandenburg, B., Gauthier, J., Gall, F.L., Mearns, R. & Simeon, M. (2001). *Livestock Development: Implication for rural poverty, the Environment, and Global Food Security*. Washington, D.C.: The World Bank.

Demeke, M., Guta, F. & Ferede, T. (2004). *Agricultural development in Ethiopa: are there alternatives to food aid?* . Adiss Ababa Department of Economics, Adiss Ababa University.

Dercon, S. (2004). Growth and shocks: evidence from rural Ethiopia. *Journal of Development Economics* 74(2), 309-329.

Dercon, S., Hoddinott, J. & Woldehanna, T. (2005). Shocks and consumption in 15 Ethiopian villages, 1999-2004. *Journal of African Economies* 14(4), 559-585.

Dessie, G. & Christiansson, C. (2008). Forest Decline and Its Causes in the South-Central Rift Valley of Ethiopia: Human Impact over a One Hundred Year Perspective. *Ambio* 37(4), 263-271.

Dessie, G. & Kleman, J. (2007). Pattern and Magnitude of Deforestation in the South Central Rift Valley Region of Ethiopia. *Mountain Research and Development* 27(2), 162-168

Devereux, S. (2000). *Food insecurity in Ethiopia. A discussion paper for DFID.* Sussex: Institute of Development Studies.

Devereux, S. (2009). Why does famine persist in Africa? *Food Security* 1(1), 25-35.

Devereux, S., Teshome, A. & Sabates-Wheeler, R. (2005). Too Much Inequality or Too Little? Inequality and Stagnation in Ethiopian Agriculture. *IDS Bulletin* 36(2), 121-126.

Diao, X. & Pratt, A.N. (2007). Growth options and poverty reduction in Ethiopia - An economy-wide model analysis. *Food Policy* 32(2), 205-228.

Doerr, H.M. (1996). Stella ten years later: A review of the literature. *International Journal of Computers for Mathematical Learning* 1(2), 201-224.

Ethiopian Forestry Action Programme (EFAP) (1994). *The challenge for development. Final report Vol. 2*. Addis Ababa, Ethiopia.

Ezra, M. (2001). Demographic Responses To Environmental Stress in the Drough and Famine-Prone areas in Northern Ethiopia. *International Journal of Population Geography* 7, 259-279.

FAO (1998). Rural Non-Farm Income in Developing Countries. In: Tucker, R. (Ed.)*The State of Food and Agriculture,* Rome: The Food and Agriculture Organization of the United Nations. pp. 283-351.

FAO (2003). Country paper: Ethiopia. In: Geldenhuys, C.*, et al*. (Eds.) *Proceedings of Workshop on Tropical Secondary Forest Management in Africa: Reality and Perspectives,* Nairobi, Kenya, 09 - 13 December 2002, Rome: The Food and Agriculture Organization of the United Nations.

FAO (2005). *Global Forest Resources Assessment 2005. Progress towards sustainable forest management. FAO forestry paper 147*[online]. Rome: Food and Agriculture Organization of the United Nations [online]. Available from: http://www.fao.org/DOCREP/008/a0400e/a0400e00.htm

FAO (2008). *Climate change and food security: a framework document*. Rome: Food and agriculture Organization of the United Nations [online]. Available from: http://www.reliefweb.int/rw/lib.nsf/db900sid/PANA-7KADCQ/$file/fao_may2008.pdf?openelement.

FARM-Africa / SOS Sahel Ethiopia (2007). *The Key Steps in Establishing Participatory Forest Management: A field manual to guide practitioners in Ethiopia*. Addis Ababa.

Farm-Africa/SOS Sahel Ethiopia (2007). Proceedings of the International Conference March 19-21, 2007 In: Kelbessa, E.*, et al*. (Eds.) *Participatory Forest Management (PFM), Biodiversity and Livelihoods in Africa*. Addis Ababa, Ethiopia: pp. 288.

Feleke, S.T., Kilmer, R.L. & Gladwin, C.H. (2005). Determinants of food security in Southern Ethiopia at the household level. *Agricultural Economics* 33(3), 351-363.

Ferede, S. (2006). *Impact of technological change on household production and food security in smallholders agriculture: The case of Wheat-Tef based farming systems in the central highlands of Ethiopia*. Cuvillier Verlag, Gottingen.

Frost, P., Campbell, B., Luckert, M., Mutamba, M., Mandondo, A. & Kozanayi, W. (2007). In Search of Improved Rural Livelihoods in Semi-Arid Regions through Local Management of Natural

Resources: Lessons from Case Studies in Zimbabwe. *World Development* 35(11), 1961-1974.
Garedew, E., Sandewall, M., Söderberg, U. & Campbell, B. (2009). Land-Use and Land-Cover Dynamics in the Central Rift Valley of Ethiopia. *Environmental Management* 44(4), 683-694.
Gebre-Selassie, S. (2004). *The Roles of Agriculture in the Development Process: Recent Experiences and Lessons from Ethiopia*. African Association of Agricultural Economists.
Gebre-Selassie, S. (2007). Cross-sectorial Policy-planning Issues in Forest Management: Lessons Learnt from Two Case Studies in Ethiopia. In: Dube, Y.C., *et al.* (Eds.) *Cross Sectoral Policy Developments in Forestry*. Cambridge, MA CABI Publications.
Geist, H.J. & Lambin, E.F. (2002). Proximate Causes and Underlying Driving Forces of Tropical Deforestation. *BioScience* 52(2), 143-150.
Gelan, A.U. (2007). Does food aid have disincentive effects on local production? A general equilibrium perspective on food aid in Ethiopia. *Food Policy* 32(4), 436-458.
Haan, A.D., Brock, K., Carswell, G., Coulibaly, N., Seba, H. & Toufique, K.A. (2000). *Migration and Livelihoods: Case Studies in Bangladesh, Ethopia and Mali. Reseach Report 46*. Brighton, Sussex: Institute of Development Studies (IDS). ISBN 1 85864 320 1
Haan, N., Majid, N. & Darcy, J. (2006). *A review of emergency food security assessment practice in Ethiopia*. Rome: United Nations World Food Programme (WFP).
Hailu, A. & Regassa, N. (2007). Correlates of Household Food Security in Densely Populated Areas of Southern Ethiopia: Does the Household Structure Matter? *Studies on Home and Community Science* 1(2), 85-91.
Hawando, T. (1997). *Desertification in Ethiopian Highlands. RALA report No. 200*. Addis Ababa, Ethiopia: Norwegian Church AID.
Hesselberg, J. & Yaro, J.A. (2006). An assessment of the extent and causes of food insecurity in northern Ghana using a livelihood vulnerability framework. *GeoJournal* 67(1), 41-55.
High Performance Systems Inc. (1996). STELLA Software Technical Documentation.
Holden, S., Shiferaw, B. & Pender, J. (2004). Non-farm income, household welfare, and sustainable land management in a less-favoured area in the Ethiopian highlands. *Food Policy* 29(4), 369-392.
IFPRI (2006). *How Will Agriculture Adapt to a Shifting Climate?* Washington, DC: International Food Policy Research Institute [online]. Available from: http://www.ifpri.org/sites/default/files/publications/if17.pdf.

IPCC (2007a). *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the*

Intergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University Press.

IPCC (2007b). *Climate Change, 2007: The Physical Science Basis. Summary for Policymakers, Contribution of Working Group I to the Fourth Assessemt Report of the Intergovernmental Panel on Climate Change (IPCC),* Paris.

Jayne, T.S., Yamano, T., Weber, M.T., Tschirley, D., Benfica, R., Chapoto, A. & Zulu, B. (2003). Smallholder income and land distribution in Africa: implications for poverty reduction strategies. *Food Policy* 28(3), 253-275.

Jones, P.G. & Thornton, P.K. (2009). Croppers to livestock keepers: livelihood transitions to 2050 in Africa due to climate change. *Environmental Science & Policy* 12(4), 427-437.

Jorgenson, A.K. & Burns, T.J. (2007). Effects of Rural and Urban Population Dynamics and National Development on Deforestation in Less-Developed Countries, 1990-2000. *Sociological Inquiry* 77(3), 460-482.

Kaluski, D.N., Ophir, E. & Amede, T. (2002). Food security and nutrition – the Ethiopian case for action. *Public Health Nutrition* 5(3), 373-381.

Kamusoko, M.A. (2007). Land use/cover change and landscape fragmentation analysis in the Bindura District, Zimbabwe. *Land Degradation & Development* 18(2), 221-233.

Karling, H.M.e. (2007). *Global Climate Change Revisited*. New York: Nova Science Publisher, Inc.

Kasperson, R.E., Kasperson, J.X. & Turner, B.L., II (1999). Risk and Criticality: Trajectories of Regional Environmental Degradation. *Ambio* 28(6), 562-568.

Kassa, H., Campbell, B., Sandewall, M., Kebede, M., Tesfaye, Y., Dessie, G., Seifu, A., Tadesse, M., Garedew, E. & Sandewall, K. (2009). Building future scenarios and uncovering persisting challenges of participatory forest management in Chilimo Forest, Central Ethiopia. *Journal of Environmental Management* 90(2), 1004-1013.

Kassa, H., Gibbon, D. & Singh, B.P. (2002). Livestock Improve Household Food Security and Sustainability of Ethiopian Small Farms. *Journal of Sustainable Agriculture* 21(2), 73 - 93.

Kirwan, B.E. & McMillan, M. (2007). Food Aid and Poverty. *American Journal of Agricultural Economics* 89(5), 1152-1160.

Kubsa, A. & Tadesse, T. (2002). Granting exclusive user rights to the forest dwellers in the state owned forest: The WAJIB approach in Ethiopia. *Proceedings of second international workshop on participatory forestry in Africa conducted in Arusha Tanzania from 18-22 February 2002*. FAO, Rome, Italy.

Lambin, E.F. & Geist, H. (2006). *Land-use and land-cover change : local processes and global impacts. The IGBP series 1619-2435*. Berlin: Springer.

Lambin, E.F., Geist, H.J. & Lepers, E. (2003). Dynamics of land-use and land-cover change in Tropical regions *Annual Review of Environment and Resources* 28(1), 205-241.

Legesse, B. (2003). Risk management strategies of smallholder farmers in the eastern highlands of Ethiopia. Doctoral diss. Dept. of Rural Development Studies, SLU. Acta Universitatis agriculturae Sueciae. Agraria vol. 404.

Legesse, D., Vallet-Coulomb, C. & Gasse, F. (2003). Hydrological response of a catchment to climate and land use changes in Tropical Africa: case study South Central Ethiopia. *Journal of Hydrology* 275(1-2), 67-85.

Lemi, A. (2005). *The Dynamics of Livelihood Diversification in Ethiopia Revisited: Evidence from Panel data* [online]. Available at SSRN: http://ssrn.com/abstract=817104.

Lewis, S.L. (2006). Tropical forests and the changing earth system. *Philosophical Transactions of the Royal Society B: Biological Sciences* 361(1465), 195-210.

Lightbourne, M. (2006). Assessing the economic implications of different models for implementing the requirement to protect plant varieties: Case study in Ethiopia. IPDEV Work Package 6. Queen Mary University of London.

Liu, J., Liu, M., Tian, H., Zhuang, D., Zhang, Z., Zhang, W., Tang, X. & Deng, X. (2005). Spatial and temporal patterns of China's cropland during 1990-2000: An analysis based on Landsat TM data. *Remote Sensing of Environment* 98(4), 442-456.

Lobell, D.B., Burke, M.B., Tebaldi, C., Mastrandrea, M.D., Falcon, W.P. & Naylor, R.L. (2008). Prioritizing Climate Change Adaptation Needs for Food Security in 2030. *Science* 319(5863), 607-610.

Malhi, Y., Roberts, J.T., Betts, R.A., Killeen, T.J., Li, W. & Nobre, C.A. (2008). Climate Change, Deforestation, and the Fate of the Amazon. *Science* 319(5860), 169-172.

Mann, C.C. (1999). Future Food:Crop Scientists Seek a New Revolution. *Science* 283(5400), 310-314.

Matsumoto, T., Kijima, Y. & Yamano, T. (2006). The role of local nonfarm activities and migration in reducing poverty: evidence from Ethiopia, Kenya, and Uganda. *Agricultural Economics* 35(s3), 449-458.

Mayaux, P., Bartholome, E., Fritz, S. & Belward, A. (2004). A new land-cover map of Africa for the year 2000. *Journal of Biogeography* 31(6), 861-877.

Medhin, Z. (2002). Sustainable Development in Ethiopia.(Report of Assessment of Activities and Issues relevant to the review process of the Earth Summit in Ethiopia for Heinrich Boell Foundation.), Institute of Biodiversity Conservation and Research. Addis Ababa, Ethiopia.

Mekonnen, A. & Bluffstone, R. (2008). *Is There a Link between Common Property Forest Management and Private Tree Growing? Evidence of Behavioral Effects from Highland Ethiopia*. Environment for Development (EfD) and Resource for the Future.

Mengistu, T., Teketay, D., Hulten, H. & Yemshaw, Y. (2005). The role of enclosures in the recovery of woody vegetation in degraded dryland hillsides of central and northern Ethiopia. *Journal of Arid Environments* 60(2), 259-281.

Mertz, O., Halsnæs, K., Olesen, J. & Rasmussen, K. (2009). Adaptation to Climate Change in Developing Countries. *Environmental Management* 43(5), 743-752.

Millar, J. & Photakoun, V. (2008). Livestock development and poverty alleviation: revolution or evolution for upland livelihoods in Lao PDR? *International Journal of Agricultural Sustainability* 6(1), 89-102.

MNRCDEP (1994). *Ethiopian Forestry Action Program*. Addis Ababa Ministry of Natural Resources Conservation and Development and Environmental Protection (MNRCDEP).

MoFED (2007b). *Ethiopia: Building on Progress: A Plan for Accelerated and Sustained Development to End Poverty (PASDEP). Annual Progress Report 2006/07*. Addis Ababa: Ministry of Finance and Economic Development (MoFED).

Moser, S.C. (1996). A partial instructional module on global and regional land use/cover change: assessing the data and searching for general relationships. *GeoJournal* 39(3), 241-283.

Nichola, T. (2006). The food security problem in Ethiopia – A supply side analysis. *South African Journal of Economics* 74(2), 315-322.

Niehof, A. (2004). The significance of diversification for rural livelihood systems. *Food Policy* 29(4), 321-338.

Ningal, T., Hartemink, A.E. & Bregt, A.K. (2008). Land use change and population growth in the Morobe Province of Papua New Guinea between 1975 and 2000. *Journal of Environmental Management* 87(1), 117-124.

Norris, D. (2004). Mosquito-borne Diseases as a Consequence of Land Use Change. *EcoHealth* 1(1), 19-24.

Otsuka, K. (2008). Strategy for agricultural growth in Ethiopia. Background note prepared for study on role of Agricultural Growth in Ethiopia [online]. Avilable from: http://www.economics.ox.ac.uk/members/Stefan.Dercon/Brief_KOtsuka%20_rev_.pdf.

Paré, S., Söderberg, U., Sandewall, M. & Ouadba, J.M. (2008). Land use analysis from spatial and field data capture in southern Burkina Faso, West Africa. *Agriculture, Ecosystems & Environment* 127(3-4), 277-285.

Parry, M., Rosenzweig, C. & Livermore, M. (2005). Climate change, global food supply and risk of hunger. *Philosophical Transactions of the Royal Society B: Biological Sciences* 360(1463), 2125-2138.

Ramakrishna, G. & Demeke, A. (2002). An Empirical Analysis of Food Security in Ethiopia: the Case of North Wello *Africa Development* 27(1-2), 127-143.

Randolph, T.F., Schelling, E., Grace, D., Nicholson, C.F., Leroy, J.L., Cole, D.C., Demment, M.W., Omore, A., Zinsstag, J. & Ruel, M. (2007). Invited Review: Role of livestock in human nutrition and health for poverty reduction in developing countries. *Journal of Animal Science* 85(11), 2788-2800.

Reardon, T. (1997). Using evidence of household income diversification to inform study of the rural nonfarm labor market in Africa. *World Development* 25(5), 735-747.

Rembold, F., Carnicelli, S., Nori, M. & Ferrari, G.A. (2000). Use of aerial photographs, Landsat TM imagery and multidisciplinary field survey for land-cover change analysis in the lakes region (Ethiopia). *International Journal of Applied Earth Observation and Geoinformation* 2(3-4), 181-189.

Rose, D. & Charlton, K.E. (2002). Prevalence of household food poverty in South Africa: results from a large, nationally representative survey. *Public Health Nutrition* 5(3), 383-389

Rosegrant, M.W., Clein, S.A., Sulser, T.B. & Valmonte-Santos, R.A. (2005). *Looking ahead: long-term prospects for Africa's agricultural development and food security*. Washington, DC: International food policy research Institute.

Sandker, M., Campbell, B., Nzooh, Z., Sunderland, T., Amougou, V., Defo, L. & Sayer, J. (2009). Exploring the effectiveness of integrated conservation and development interventions in a Central African forest landscape. *Biodiversity and Conservation* 18(11), 2875-2892.

Sayer, J.A. & Campbell, B.M. (2004). *The science of sustainable development: local livelihoods and the global environment*. Cambridge, UK: Cambridge University Press.

Schade, C. & Pimentel, D. (2009). Population crash: prospects for famine in the twenty-first century. *Environment, Development and Sustainability*. DOI 10.1007/s10668-007-9129-9.

Schlamadinger, B., Bird, N., Johns, T., Brown, S., Canadell, J., Ciccarese, L., Dutschke, M., Fiedler, J., Fischlin, A., Fearnside, P., Forner, C., Freibauer, A., Frumhoff, P., Hoehne, N., Kirschbaum, M.U.F., Labat, A., Marland, G., Michaelowa, A., Montanarella, L., Moutinho, P., Murdiyarso, D., Pena, N., Pingoud, K., Rakonczay, Z., Rametsteiner, E., Rock, J., Sanz, M.J., Schneider, U.A., Shvidenko, A., Skutsch, M., Smith, P., Somogyi, Z., Trines, E., Ward, M. & Yamagata, Y. (2007). A synopsis of land use, land-use change and forestry (LULUCF) under the Kyoto Protocol and Marrakech Accords. *Environmental Science & Policy* 10(4), 271-282.

Schmidhuber, J. & Tubiello, F.N. (2007). Global food security under climate change. *Proceedings of the National Academy of Sciences* 104 (50), 19703-19708.

Searchinger, T., Heimlich, R., Houghton, R.A., Dong, F., Elobeid, A., Fabiosa, J., Tokgoz, S., Hayes, D. & Yu, T.-H. (2008). Use of U.S. Croplands for Biofuels Increases Greenhouse Gases Through Emissions from Land-Use Change. *Science* 319(5867), 1238-1240.

Sharp, K., Devereux, S. & Amare, Y. (2003). *Destitution in Ethiopia's Northeastern Highlands (Amhara National Regional State),* Institute of Development Studies, Brighton and Save the Children (UK) Ethiopia, Addis Ababa.

Shimelis, A. & Bogale, A. (2007). Dimensions of food insecurity and livelihood strategies among rural households in Dire Dawa, eastern Ethiopia. *Tropical Science* 47(2), 73-80.

Smit, B. & Wandel, J. (2006). Adaptation, adaptive capacity and vulnerability. *Global Environmental Change* 16(3), 282-292.

Smith, L.C., Alderman, H. & Aduayom, D. (2006). *Food Insecurity in Sub-Saharan Africa: New Estimates from Household Expenditure Surveys. Research report 146.* Washington, D.C: International Food Policy Research Institute.

Soromessa, T., Teketay, D. & Demissew, S. (2004). Ecological study of the vegetation in Gamo Gofa zone, southern Ethiopia. *Tropical Ecology* 45(2), 209-221.

Steffen, W., Sanderson, A., Tyson, P., Jäger, J., Matson, P., Moore III, B., Oldfield, F., Richardson, K., Schellnhuber, H.J., Turner II, B.L. & Wasson, R.J. (2004). *Global Change and the Earth System: A Planet Under Pressure.* Springer.

Suding, K.N., Collins, S.L., Gough, L., Clark, C., Cleland, E.E., Gross, K.L., Milchunas, D.G. & Pennings, S. (2005). Functional- and abundance-based mechanisms explain diversity loss due to N fertilization. *Proceedings of the National Academy of Sciences of the United States of America* 102(12), 4387-4392.

Sunderlin, W.D., Hatcher, J. & Liddle, M. (2008). *From exclusion to ownership? Challenges and opportunities in advancing forest tenure reform.* Washington DC: Rights and Resources Initiative. http://www.rightsandresources.org/documents/files/doc_736.pdf. Assessed 5 January 2009. ISBN 978-0-615-21808-3

Teketay, D. (2001). Deforestation, Wood Famine, and Environmental Degradation in Ethiopia's Highland Ecosystems: Urgent Need for Action. *Northeast African Studies* 8(1), 53-76.

Tekle, K. & Hedlund, L. (2000). Land cover changes between 1958 and 1986 in Kalu District, Southern Wello, Ethiopia. *Mountain Research and Development* 20(1), 42-51.

Templer, P.H., Groffman, P.M., Flecker, A.S. & Power, A.G. (2005). Land use change and soil nutrient transformations in the Los Haitises region of the Dominican Republic. *Soil Biology and Biochemistry* 37(2), 215-225.

Tilman, D. & Lehman, C. (2001). Human-caused environmental change: Impacts on plant diversity and evolution. *Proceedings of the National Academy of Sciences of the United States of America* 98(10), 5433-5440.

Tiwari, P. (2008). Land use changes in Himalaya and their impacts on environment, society and economy: A study of the Lake Region in Kumaon Himalaya, India. *Advances in Atmospheric Sciences* 25(6), 1029-1042.

United Nations (2006). *United Nations Forum on Forests:Report of the sixth session*. New York: United Nations, Economic and Social Council.

Urgessa, K. (2003). Perceptions of forest cover and tree planting and ownership in Jimma Zone, Ethiopia. *Unasylana* 54, 18-21.

USAID/Ethiopia (2005). Annual report. FY 2005.

Vedeld, P., Angelsen, A., Bojö, J., Sjaastad, E. & Berg, G.K. (2007). Forest environmental incomes and the rural poor. *Forest Policy and Economics* 9(7), 869-879.

Verdoodt, A., Mureithi, S.M., Ye, L. & Van Ranst, E. (2009). Chronosequence analysis of two enclosure management strategies in degraded rangeland of semi-arid Kenya. *Agriculture, Ecosystems & Environment* 129(1-3), 332-339.

Vitousek, P.M. (1992). Global Environmental Change: An Introduction. *Annual Review of Ecology and Systematics* 23(1), 1-14.

von Braun, J. & Olofinbiyi, T. (2007). *Famine and Food Insecurity in Ethiopia. In: Per Pinstrup-Andersen and Fuzhi Cheng (eds), Food Policy for Developing Countries: The role of Government in the Global Food System: Case Study #7-4.* New York: Cornell University.

Webb, P., Braun, J.v. & Yohannes, Y. (1992). *Famine in Ethiopia: Policy Implications of Coping Failures at National and Household Levels. Reserach Report 92.* Washington DC: International Food Policy Research Institute.

Winters, P., Davis, B., Carletto, G., Covarrubias, K., Quiñones, E.J., Zezza, A., Azzarri, C. & Stamoulis, K. (2009). Assets, Activities and Rural Income Generation: Evidence from a Multicountry Analysis. *World Development* 37(9), 1435-1452.

Wøien, H. (1995). Deforestation, information and citations. *GeoJournal* 37(4), 501-511.

Woldenhanna, T. & Oskam, A. (2001). Income diversification and entry barriers: evidence from the Tigray region of northern Ethiopia. *Food Policy* 26(4), 351-365.

Wood, A.P. (1993). Natural resource Conflicts in South-West Ethiopia: State, Communities, and the Role of the National Conservation strategy in the search for Sustainable Develpoment. *Nordic Journal of African Studies* 2(2), 83-99.

Woody Biomass Inventory and Strategic Planning Project (WBISPP) (2004). *Forest Resource of Ethiopia*. Addis Ababa: WBISPP. ISBN

Worede, M., Engels, J.M.M., Hawkes, J.G., Edwards, S.B., Berhan, T., Egziabher, G., Vletter, J.D., Abebe, D., Hagos, E., Goettsch, E., Doggett, H., Mehra, K.L., Bhat, D.J., Bekele, E., Demissi, A., Hanson, J., Mengistu, S., Feyissa, E.R., Woldemariam, W., Pinto, F. & Sendek, E.E. (1991). *Plant Genetic Resources of Ethiopia*. New York: Combridge University Press.

World Bank (2007). *The Little Green Data Book 2007*. Washington, D.C: The World Bank. ISBN 0-8213-6967-9

Zeleke, G. & Hurni, H. (2001). Implications of land use and land cover dynamics for mountain resource degradation in the Northwestern Ethiopian highlands. *Mountain Research and Development* 21(2), 184-191.

Zhao, S., Peng, C., Jiang, H., Tian, D., Lei, X. & Zhou, X. (2006). Land use change in Asia and the ecological consequences. *Ecological Research* 21(6), 890-896.

Acknowledgements

First and foremost I thank my Lord to his eternal love and kindness. This thesis would not have been possible without the support of many people. I would like to thank my four supervisors: Associate Professor Ulf Söderberg, Dr. Mats Sandewall, Professor Bruce M. Campbell and Dr. Habtemariam Kassa. I am deeply grateful for all your guidance and discussions that we had over years.

I thank my wife Kasech H/Mariam and my children Elshaday and Kidus who have given me endless love, support and patience. And I am thankful to my brother in law Solomon H/Mariam who was supporting my family in my long absence.

Many thanks also go to all the Department of Forest Resource Management (SLU) personnel who have been helping in one way or another to make my PhD life and studies successful. Special thanks go to Anne-Maj Jonsson, Barbro Gunnarsson, Heather Reese, Mats Högström, Neil Cory, Bronson Bullock, Sven Hans-Olof Petersson, Johan Fransson, Sören Holm, Solveig Berg, Anna-Lena Axelsson, Ylva Jonsson, Carina Westerlund and Torgny Lind. I am grateful to all colleagues for the pleasant time we had together- Ali Salehi, Habib Ramezani, Nicole Suty, Henrik Feychting, Ylva Melin, Eva Holmgren, Eva-Maria Nordström and Maria Johansson. Ethiopian PhD students in Sweden and Norway- late Abraham, Menfese, Yemiru and Abebe, thanks for exchanging ideas and support. I thank all my Ethiopian wonderful friends and colleagues in Sweden for their warm hospitality and marvelous support- Hana Gizaw, Emebet Wada, Wudeye, Tenagne, Tsehay, Mulualem Tigabu, Belay Kassa, Mulugeta Hadis, Ayalew, Nebiyu Solomon, Dawit, Yeshewas, Mike, Jonney and Tadesse Gebiso.

My gratefulness goes towards Dr. Melaku, Dr. Zebene, Dr. Bekele, Ato Endale, Kefyalew Sahle, Tesfaye Getachew, Kebede Hersamo; drivers Ato Afework, Wario, Shaleka Tirusew, Yikber and Shubisa for their invaluable support in Ethiopia. I thank also the farmers, field-guides, and enumerators for their invaluable participation and time in the process of data collection.

Special thanks go to Wondo Genet College of Forestry and Natural Resources and the Swedish International Development Agency (Sida) for facilitating and financing the study.

Appendix I

Household Questionnaire

The respondents should clearly know that this interview has nothing to do with development assistance and any other expectations.

Identification of the respondent (Household head)

PA ________________________

Name of respondent ______________________ID No. _________

Date of interview ____________________________

Name and signature of the enumerator
____

Type of sampling category:

A. Poor farmer B. Medium farmer C. Relatively better-off farmer

Respondent (*household) characteristics*

1. Household head gender: a) Male ________b) Female_________
2. Marital status of household heads a) single b) married c) divorced d) widowed
3. Marital status of type? a) monogamy_____ b) polygamy________
4. Family size: ________
5. Family ages: 1. Household head 2. Spouse 3. Children 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 3.9… 4. Parents 5. Hired 5.1, 5.2, 5.3……6. Others, specify
6. Households' (Gatzweiler *et al.*) ethnic group a) Oromo______ b) Amhara_____ c) Kembata______ d) others, specify
7. Years of experience as a farmer: a) 5-10_______b) 11-15________c) 16-20________ d) 21-25_______ e) 26-30_______ f) 31-35_______ g) 36- 40______
8. Family division of labor 1. Household head 2. Spouse 3. Children 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 3.9… 4. Parents 5. Hired 5.1,5.2,5.3,…others, specify a) ploughing___b)sowing____c) weeding____d) cattle feeding___e) cattle feed collection____f) fuelwood collection____ g)fetching water______h) herding___i) manuring___j) marketing products___k) others, specify

9. Family Level of education: 1. Household head 2. Spouse 3. Children 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 3.9…4. Parents 5. Hired 5.1,5.2, 5.3……others, specify a)Illiterate _ b) read and write____ c)Primary school_____d) Secondary school____ e) college ____ f) others, specify
10. Health status of the family during the survey year: 1. Household head 2. Spouse 3. Children 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8… 4. Parents 5. Hired 5.1,5.2, 5.3……others, specify a) Sick sometimes____ b) Permanently sick__c) Healthy______
11. Distance to the nearest market (Km)_______
12. Distance to the nearest main road (Km)__________
13. What type of transport do you use to sell your produce? a) public transport_____ b) donkey back_________ c) donkey cart _________d) other, specify_________

Land tenure

14. Means of land acquisition (tenure) a) 1st distribution______ b) Redistribution_____ c) Inheritance ______d) Inheritance and Redistribution_______ e) Gift_____ f) Share cropping______ g) Renting _______
15. How many plots of land do you own? a) One_______ b) Two_______ c) Three______ d) Four_______ e) Five or more_________
16. What is the size of your all land in 'timad'/hectares? ________

Environmental degradation and changes

17. Have you experienced any soil degradation incidence on your farm? a) Yes_____ b) No _______
18. If you answered "Yes" to Question 15, mention the indicators or criterion used in identifying the incidence of soil degradation: a) Decreased crop productivity_______ b) Loss of topsoil______________
19. Soil fertility status of your land a) poor___b) moderate_____c) relatively fertile ____
20. Traditional land rehabilitation measures for mitigating soil fertility problems: a) Addition of soil organic matter_______ b) Crop rotation______ c) fallowing_______ d) Ploughing once_______ e) Double ploughing________ f) Ploughing thrice______

Factors influencing ecological degradation

21. What are in your opinion the main causes of reduction in crop yields? a) Decline soil fertility_______ b) Erratic rainfall________ c) Lack of capital________ d) Lack of oxen
22. What are in your opinion the major causes of damage to forests in the area? a) Over-cultivation_______ b) need of cropland______ c) Cyclic events (e.g. erratic rainfall, drought) ______ d) Illegal cutting of wood_______ f) Over-grazing_______ g) Government weak forest law enforcement
23. How do you gain access to the woodland forest reserves? a) Permission from local community leaders _______ b) Permission from local PA leader ______ c) Permission from local Gov._____ d) No permission______
24. Are you aware of the forest law? a) Conscious________ b) Unconscious______

Household energy

25. What are your main sources of fuel for cooking & heating? a) Firewood______ b) Charcoal______ c) Agricultural residues______ d) Liquefied petroleum gas________
26. How do you get supply of fuel used for cooking & heating? a) Self ______ b) Female and children members of family_______ c) Purchase_______
27. What are your main sources of forest products? a) Own farm________ b) Other farms_______ c) Common woodland_______ d) Market________
28. Part of tree used for different purposes: a) Deadwood_______ b) Living branches______ c) Deadwood and living branches________ d) Tree stumps_______ e) The whole stems_______

Crop production

29. What are your main crops grown from own plots, leased plots and sharecropping? Amount in quintal and cash equivalent a) Maize______ b) Teff______ c) wheat______ d) Sorghum______ e) Maize and Wheat _________
30. Crop productivity per hectare of cropland by crop types a) 20 yrs before__b)10 year ago__c) 5 yrs ago d) current
31. What are in your opinion the major causes of crop yield reduction and rank according to importance a) erratic rainfall__ b) improved seed scarcity and high price___ c) unaffordable price of fertilizer____ d) shortage of plowing oxen___ e) soil degradation (erosion, low fertility, etc.)____ f) pest prevalence (parasite, diseases,

weed, etc.)____ g) lack of money lenders_____ h) food aid_____ i) other, specify

32. Would you tell us the amount of grain (by grain type) that you think is sufficient to cover the requirements for your family annually? Amount (kg) and cash equivalent______
33. Food shortage with reference to production (good, medium and poor) and number of months that could not be covered from your own production?_____
34. When rainfall is adequate why not the production is self-sufficient, what are the reasons? Please rank the most important reasons, max 3. a) early sale of part of the product to return loan money and use for other expenses (e.g. school fee, etc.)__ b) soil degradation__c) lack of agricultural inputs (e.g. fertilizer, improved seeds, pest chemicals)___ d) lack of enough cropland___ e) lack or shortage of ploughing oxen__ f) other, specify

Livestock production

35. In case you own livestock, what is your major source of fodder for your animals? a) Crop residues_________ b) The forest reserves_______ c)grazing land______ d) Market_______
36. Do you observe the reduction or disappearance of palatable herbs and trees in the grazing areas? a) Yes _____b) No _____
37. Which months of the year you face shortage of livestock feed? And how do you overcome?
38. What are the types and number of livestock you own? And why do you keep them a) Cow______ b) Ox_______ c) Heifer______ d) Bulls________ e) calves_______ f) chicken _______g) Goat_______ h) Sheep________ i) Donkey_______ j) Horse________ k) Mule___________
39. What is the trend of the livestock in terms of their number and type over the past 20, 10, 5, 0 years?
40. Would you tell us the reasons, in the order of importance for the above trend? a) Lack of fodder b)Shortage of grazing land c) Disease prevalence d)Lack of veterinary services e) Shortage of water f) other, specify

Types of income

41. What is your family's main source of household subsistence income and cash? a) farm (food crops consumed, crop sold, livestock consumed and sold, labor and others, specify)______b) Non-farm (i.e. petty trading: sale of fire wood, bole soil, sand, vegetable, grain

and others, labor outside the local area, remittance, fishing, Private or Gov. job e.g. teaching, health officer)______

42. Does the income from non-farm activities enable you to buy food items and cover your household food deficiency?_______ If not why? ________
43. Income during 'good' year (Birr): a) 2500-3000 b)>3000-3500 c)>3500
44. Income during 'moderate' year: a) 1500-2000 b) 2001-2500
45. Income in 'bad' year: a) <500 b) 500-1000
46. Do you have saving in 'good' year (%): a) no_____ b) 20-30______ c) 31-40_____ d) 41-50________ e) >50________
47. Please mention household expenditures a) Purchase food___ b) Buy seeds______ c) Buy fertilizer_____ d) School fees______ e)tax and others

Local people's perception and preferences of trees and forests

48. What is your perception of trees forest? a) Source of forest products (e.g. fodder, fuel wood, and shelter for local people)_____b) Source of supplementary income______ c) Source of government revenue ______ d) Obstacles to agricultural expansion _________ e) Climatic importance_______
49. Who do you perceive owns the forest reserves? a) Private Property______ b) Government property______ c) Common property_______

Forest management and land-use and planning for tree growing activities

50. Who should manage the acacia forest reserves? a) PA_______ b) Federal government________ c) local government________ d) Immediate users at local level_______
51. Give reasons why you think the forest reserves need to be managed? a) Mismanaged by the farmers______ b) Excessive deforestation for crop, grazing and sale of fuel wood ________ c) Increase in prices of forest products_______
52. Are you willing to contribute to the management of forest reserves? a) Yes________ b) No_________
53. If the answer to question 50 is "Yes", mention the form of contribution. a) Effort only_______ b) Ideas and organization efforts__________

Integrated land-use

54. What land units are allocating for tree growing in your land-use system? a) Land set aside_______ b) Farm boundary________ c) Home stead_______ d) Trees on crop land_______

55. Suggest the best level of institutions to achieve an integrated land-use system of agriculture, forestry and grazing: a) Local level______ b) State level______ c) Local and state levels______

Forest management planning

56. What Strategies to increase forest coverage in your PA: a) Reforestation of degraded common properties of forests______ b) afforestation of unused or marginal lands _______c) Focus on existing forests to improve them__________

57. According to your own preference mark the land-use system that should be adopted in the area: a) Crop only______ b) Grazing_______ c) Forest only_______ d) Crop and forest________ e) Crop, grazing and forest__________

58. Are you willing to plant trees? a) Yes_______ b) No________

59. If you answered "No" to Question 56, what is the main reason? a) Low level of motivation_______ b) Lack of technical support_______ c) Reduction of crop yields by trees________ d) Land/tree tenure dilemma________

60. If you answered "Yes" to Question 45, what is the main purpose? a) Fuelwood and charcoal______ b) Shade_______ c) Fodder _______ d) Timber _______ e) Fruits_______

61. If you answered "Yes" to Question 56, which major tree species would you prefer to planting? a) *Acacia senegal*______ b) *Acacia seyal* _____ c) *Acacia mellifera*______ d) *Acacia tortilis*______ e) *Balanites aegyptiaca* _______ e) *Azadirachta indica*_______

Vulnerability perspective

62. What crises has the household faced in the past? (health crises, food shortage, crop failures, loss of cattle, death, legal problems, lack of capital, lack of credit, difficulty to return loans, soil fertility decline, insect pests, land scarcity, lack of drought resistance verities (seed/livestock), lack of fertilizers, high prize of crop at purchase and vice versa, lack of infrastructure (drinking water, health service, etc.), deteriorating social network, lack of animal feed, lack of farm implements, oxen shortage, lack of wood, labor shortage, and others, specify)

63. What are your coping strategies (e.g., primary and secondary) during food shortage when it is severe, moderate and low a)

Reducing consumption in each meal b) Skip/reducing the number of meal each day c) Eating famine period food or less preferred food d) Borrow grain or money to buy food e) Selling firewood f) Selling charcoal g) Rely on food aid h) Selling small animals (goat, sheep, chicken) i) Selling cattle j) Migrate to nearby urban areas for casual wage labor k) Migrate to other areas and other specify

Any comments and observations not covered?

Thank you for participating!