

**Caring for the Land**  
**Best practices in soil and water conservation in Beressa watershed,**  
**highlands of Ethiopia**

Aklilu Amsalu Taye



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**2006**

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### **Proefschrift**

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# **Chapter 1** \_\_\_\_\_

## **General Introduction**

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## **1. General Introduction**

### **1.1 Background**

Ethiopia is one of the oldest civilizations of the world. The country is endowed with a distinct geography that ranges from mountains and wetlands to valleys and deserts with a bountiful diversity in topography, climate and biological resources. Such diversity offers potentially favourable conditions for humans to live, though the potential has remained largely untapped. The country is the second most populous nation in sub-Saharan Africa, with over 70 million inhabitants (UNFPA, 2005). About 88% of the population is concentrated in the highlands, which constitute less than half of the national territory; here the population density is 141 persons km<sup>-2</sup>. Agriculture is the main source of livelihood and national income in the country. Over 85% of the population directly depends on it and about half of the GDP is generated from the sector. However, agriculture is small-scale and subsistence oriented, and it is in a very low state of development. As a result, the country has become one of the poorest nations of the world and has often failed to be self-sufficient in food. The World Bank (2005) and IMF (2005) report that agriculture in the country has barely kept up with population growth rate since 1990, despite government claims of bumper agricultural growth. Yield data indicates average per capita grain production in the range of 162 kg yr<sup>-1</sup> in bad years and 225 kg yr<sup>-1</sup> in good years (FAO, 2006), which shows that grain yields are low to meet the annual grain requirements of about 200 kg per person for food self-sufficiency (De Graaff et al., 2001). The low level of agricultural development coupled with recurrent droughts has made the country poor: the average per capita income is US \$ 110 per annum, and the proportion of the population below the poverty line is estimated at 44% (FDRE, 2002).

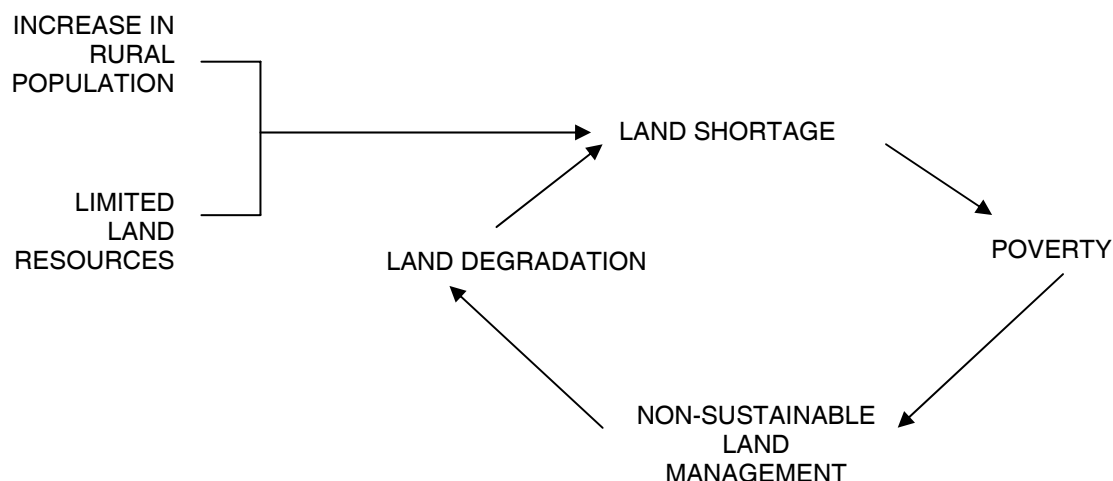
The country has been following an economic development strategy of Agricultural Development Led Industrialization (ADLI) that was adopted in the mid-1990s. ADLI is a long-term strategy and envisages agricultural development as a base for industrialization. Within the framework of ADLI, the government country further drew up the Sustainable Development and Poverty Reduction Program (SDPRP) aimed at halving poverty by 2015. Nevertheless, ADLI and its components have been criticized for relying heavily on the stagnant small-scale peasant agriculture and for being based on idealistic premises. Since 1991, the country has become land-locked and relies on neighbouring Djibouti for its imports and exports. This has created further challenges to the development of the agricultural sector, due to increases in the price of inputs such as fertilizers, improved seeds, and pesticides. At present, the country is faced with complex problems of severe poverty, low productivity, and poor natural resources management (Pender et al., 2006) in which the problem of land degradation is most pervasive.

## Land degradation

Land degradation has been a major global issue since the last century because of its adverse impacts on agronomic productivity, the environment, and its effects on food security and the quality of life (Eswaran et al., 2001; Lal, 2001b; Stroosnijder, 1995). In Ethiopia, land (which includes soil, water and vegetation) is a vital resource, since agriculture is the most important economic sector. However, research has shown that this critical resource is in a state of serious degradation: the problem largely manifests itself in the form of soil and water degradation and loss of biodiversity. With high-intensity rainstorms and extensive steep slopes, the highlands in particular suffer high rates of soil erosion and nutrient loss. Although data on the extent of the problem are patchy and inconsistent, available estimates indicate that soil erosion averages nearly 10 times the rate of soil regeneration in the highlands, and the rate of soil nutrient depletion is the highest in sub-Saharan Africa (e.g. FAO, 1993; Hurni, 1988; Hurni, 1993; Stoorvogel et al., 1993). Continuous cultivation with limited amendments and the widespread use of dung and crop residues for household energy have substantially contributed to the loss of soil organic matter.

Land degradation in the Ethiopian highlands is linked to population pressure and poverty in a complex web of cause and effect (Grepperud, 1996; Hurni, 1993; Sonneveld and Keyzer, 2003). Though population pressure could increase the intensity of labour and capital investment, intensification in agriculture is not well developed in the country, due to the influences of poverty. Hence, the increasing rural population causes land shortage and lower yields. Estimates have shown that from 1991 to 2003 crop yields rose on average by only 0.4% a year, but the cultivated area increased at an average rate of 5.7% a year (IMF, 2005). And average per capita cropland has shrunk to less than 0.5 ha. With shrinking land holding size, traditional systems of soil fertility maintenance (fallowing and crop rotations) could not stand any more and artificial amendments using chemical fertilizers have become expensive for resource-poor farmers. This has led to cultivation without sufficient amendments, which often accentuates the processes of degradation (Shiferaw and Holden, 2001b). Inappropriate policies and many years of political instability in the country have provided additional dimensions to the problem and thus have contributed to the vicious spiral of poverty and land degradation (Holden et al., 2005). Figure 1.1 illustrates the link between population pressure, poverty, and land degradation.

The implications of land degradation are extremely important, since the livelihoods of many Ethiopians are entwined with land resources. Degradation reduces the production potential of land, and thus makes it difficult to produce enough to feed the growing population. It also increases farmers' vulnerability to food shortages and becomes a threat to the mere survival of the people. The looming food insecurity in the country is mainly linked to the prevailing degradation problem. Land conservation is therefore badly needed (Sonneveld and Keyzer, 2003).



**Figure 1.1.** Link between population, poverty and land degradation (FAO, 1994).

### Land conservation and its challenges

The conventional western approach to land conservation is a recent phenomenon in Ethiopia, though farmers do use traditional measures. Since the 1960s, various conservation strategies have been introduced to enhance agricultural development and rural livelihoods (Keeley and Scoones, 2000). The 1970s and 1980s, the period when large-scale conservation projects got under way, were remarkable in the history of conservation in the country. Huge sums of money poured in from international donors for the execution of the projects. Although the achievements were remarkable in quantitative terms, the impacts of these efforts were far below expectations and land degradation continued to be a serious problem (Admassie, 2000). The measures did not help mitigate the problem, nor were they accepted by the farmers. There are several possible reasons for the failure of past conservation intervention to meet users' expectations. First, the introduction of the measures did not consider local conservation and farming practices and in many cases did not fit in with traditional methods. Second, since interventions normally include such activities as reforestation, terrace construction, etc., they are generally characterized by high initial costs that poor farmers could not afford and by benefits that only become apparent in the long run. Finally, the extensive and uniform application of similar soil and water conservation (SWC) measures disregarded local agro-ecological and socio-economic variations. The challenge, however, is to come up with a conservation approach that helps to meet the short-term needs of the farmers and long-term conservation objectives simultaneously.

## 1.2 Objectives and research questions

The main objective of this research was to understand soil and water conservation activities and identify the constraints and opportunities for better conservation intervention in the Beressa watershed of the Ethiopian central highlands. The analysis was carried out in the context of the history of land use and farming activities, livelihood and socio-economic changes, and conservation interventions during the second half of the 20<sup>th</sup> century. The specific objectives were to:

1. examine the dynamics in land resource use and resulting livelihood changes, and the implications on sustainable land management during the second half of the 20<sup>th</sup> century;
2. explore what farmers think of erosion problems and soil fertility changes and their conservation knowledge and practices;
3. analyse the determinants of farmers' adoption and continued use of introduced soil and water conservation measures;
4. evaluate, together with the farmers, the performance of soil and water conservation measures and identify best practices that suit local conditions; and
5. identify a set of enabling conditions at the different decision-making levels for successful conservation intervention

The following research questions were formulated on the basis of the specific objectives outlined above.

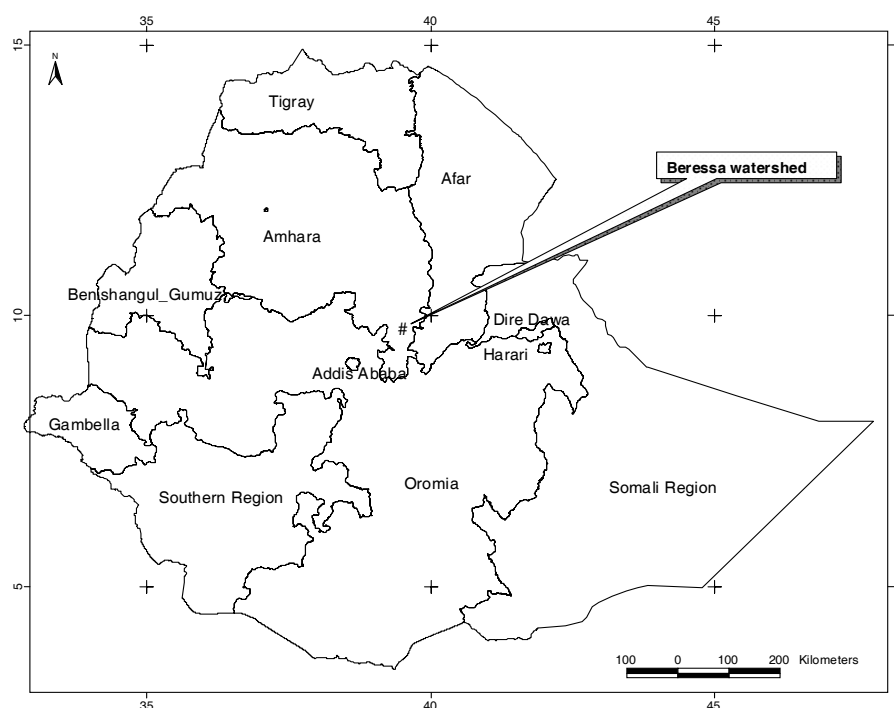
1. What have been the dynamics in land resource use and the driving forces during the second half of the 20<sup>th</sup> century and the implications for future land use?
2. What livelihood changes emerged in response to the land use changes and what are the impacts of the changes on land conservation?
3. What do farmers' think of erosion problems and soil fertility changes, and what is their conservation knowledge and practices?
4. Which factors and conditions (determinants) influence farmers' decision to adopt and continue to use recommended conservation technologies?
5. What is the performance of currently used SWC practices and what are the best practices according to farmers' evaluation criteria?
6. Which enabling conditions exist at the different levels of decision-making in order to encourage local SWC activities and promote the best practices?

## 1.3 The research site

The research was carried out in a case study watershed in the central highlands of Ethiopia: Beressa watershed. The area is located to the northeast of Addis Ababa (the capital city) on the way to Dessie within the coordinates of 9° 34' & 9° 42' latitude north and 39° 30' & 39° 45' longitude east (Figure 1.2). The watershed covers a total area of 225 km<sup>2</sup> and is inhabited

by about 24,725 people distributed within three village areas (Debele, Wushawushign and Faji).

Beressa watershed lies at relatively high altitude (2700 – 3600m asl), in a zone forming part of the central plateau of Ethiopia. The physiography is mixed with steep-sided hills, plateaus, gullies and river gorges. The watershed is drained by the headwaters of the Beressa River and its tributaries that form part of the upper Blue Nile basin. The climate is a temperate type and is influenced by both the ITCZ (Inter Tropical Convergence Zone) and the sub-tropical pressure cells. The soils are generally volcanic in origin.



**Figure 1.2.** Map of Ethiopia showing the location of Beressa watershed in the central highlands

People in the watershed area are predominantly engaged in mixed crop and livestock production. Land is a particularly scarce resource due to high population pressure and degradation. Most of the agricultural produce is for the farm household's own consumption; a very small proportion is used to generate cash income. The farming is carried out using rainfed systems, but a small-scale irrigation project was begun recently in the lower part of the watershed.

#### 1.4. Definition of terms and concepts

**Good agricultural practices (GAP).** The term “Good Agricultural Practices (GAP)” has evolved in recent years as a result of the concerns and commitments of a wide range of



stakeholders about agronomic production, food security and safety, and environmental sustainability of agriculture. As defined by FAO (2003), GAP involves a collection of principles and regulations for applying recommendations and available knowledge for agricultural production in order to meet specific objectives of food security, food quality, production efficiency, livelihoods, and environmental sustainability. GAP provides an opportunity to assess and decide which farming practices to follow in the production process. The practices are deemed to enable farmers to improve their livelihoods and take advantage of existing and new opportunities; at the same time, the farmers are required to comply with the recommendations and regulations set as good agricultural practices.

**Best practices (BP).** Though there is no universally accepted definition of the term “best practices”, it is commonly used in various disciplines to refer to proven methodologies and solutions that help to achieve an objective and demonstrate what works and what does not in different situations and contexts (e.g. FAO, Accessed April 2006; UNESCO, 1998; UNFPA, 2004). The practices indicate a set of activities, strategies, or policies that have been shown through research and evaluation to be effective and/or efficient in particular circumstances but with potential for wider dissemination. In this thesis, BP is used to refer to soil and water conservation techniques that are found to be suitable to specific local circumstances by the users (farmers) through long years of experimentation. However, the ‘Best practice’ is relative which is used to indicate the superiority a conservation measure compared to others in addressing farmers’ requirements and in its suitability to local conditions.

## 1.5 Thesis outline

Eight chapters are contained in this thesis. Each chapter has been developed as a separate paper, but in line with the objectives of the research; hence the chapters are interrelated. An outline of the contents of each chapter follows below.

After this general introduction, chapter 2 describes the dynamics of land use changes in the watershed area during the second half of the 20<sup>th</sup> century. The chapter also discusses the forces driving the land use changes and the resulting changes in farming practices and livelihoods. Chapter 3 focuses on the sale of dung-cakes, which constitute one of the most important sources of cash income in the area. The extent of farmers’ involvement in making and selling the dung-cakes and the implications on agricultural activities in general and soil fertility management in particular are presented. Estimates are presented of the amount of dung-cakes households sell annually and the loss of soil nutrients this represents.

Chapter 4 presents farmers’ views of erosion problems and soil fertility changes. In addition, their conservation knowledge and the various conservation practices they use for mitigating degradation problems are described. In chapter 5, the determinants of farmers’ adoption decision and continued use of introduced conservation measures are presented. A biprobit sequential decision-making model with sample selection is used to analyse the

determinants of farmers' conservation investments. The analysis focuses on stone terraces that have been introduced and promoted in the watershed area during the past few decades.

The results of a participatory evaluation of soil and water conservation practices in the watershed area are presented in chapter 6. Using the Regime method in multi-criteria analysis, the best conservation measures for specific local conditions are identified on the basis of farmers' evaluation criteria and rankings. Chapter 7 is devoted to the policy aspects of soil and water conservation. A differentiated approach to conservation intervention for the watershed area is presented. It consists of a framework with a set of best practices that enables the constraints identified at the different levels of decision-making to be addressed. Chapter 8 gives a synthesis of the thesis and presents the most important research findings, as well as their implications for meaningful conservation intervention.



## **Chapter 2**

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### **Long-term dynamics in land resource use and the driving forces in the Beressa watershed, highlands of Ethiopia**

**Aklilu Amsalu, Leo Stroosnijder and Jan de Graaff**  
Journal of Environmental Management, *In Press*.

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## **2. Long-term dynamics in land resource use and the driving forces in the Beressa watershed, highlands of Ethiopia**

### **Abstract**

Land degradation in the Ethiopian highlands is considered to be one of the major problems threatening agricultural development and food security in the country. However, knowledge about the forces driving the long-term dynamics in land resources use is limited. This research integrates biophysical information with socio-economic processes and policy changes to examine the dynamics of land resource use and farmers' livelihoods in the Beressa watershed for over 40 years during the second half of the 20<sup>th</sup> century. It was found that there have been substantial dynamics in land resource use in the area. The natural vegetation cover has been extensively cleared, although most of the cleared areas have since been replaced with plantations. Grazing land has expanded remarkably at the expense of cropland and bare land. However, the expansion of cropland was minimal over the 43-year period despite a quadrupling of the population density. Yields have not increased to compensate for the reduction in per capita cropland, and the soil quality appears to be not that good. Though the farmers perceived it otherwise, the long-term rainfall pattern has improved. In response to soil degradation, water shortage, socio-economic and policy changes, farmers have tended to gradually change from annual cropping to tree planting and livestock production to cope with the problems of soil degradation, water scarcity and smaller farms. Income diversification through the sale of wood and cattle dung is becoming a major livelihood strategy. Apparently, however, little attention has been paid to investments in soil and water conservation (SWC) and local soil fertility amendments. In particular, increased erosion and related high nutrient losses in sediments, as well as the removal of potentially available soil nutrients through the sale of manure threatens to damage agricultural sustainability in the area.

*Keywords:* Land use change; Population pressure; Water scarcity; Livelihoods; Policy regimes; Soil and water conservation; Ethiopia

### **2.1 Introduction**

Land resources constitute the most important natural resources for countries like Ethiopia where agriculture is the mainstay of the national economy. Agricultural production is highly dependent on smallholder rainfed farming in the highlands, and it has been practiced for

several thousands of years. Endowed with ‘thirteen months’<sup>1</sup> of sunshine’, good rainfall and fertile soils for rainfed farming, the highlands (>1500 m a.s.l.) have long supported the livelihood of a great proportion of the country’s population. Ethiopia still relies greatly on the agricultural sector. About 90 percent of the population lives by cultivating the land and more than 50 percent of the export earnings derive from the sale of farm produce. However, natural resource degradation resulting from population pressure and inappropriate land use is considered to be one of the major problems threatening agricultural development and food security in the country (Holden and Shiferaw, 2004; Hurni, 1993; Omiti et al., 1999; Sonneveld and Keyzer, 2003; Taddese, 2001).

Several studies have shown that there were significant land use changes in the Ethiopian highlands during the second half of the 20<sup>th</sup> century (Abate, 1994; Bewket, 2003; Feoli et al., 2002; Kidanu, 2004; Taddese, 2001; Tekle and Hedlund, 2000; Zeleke and Hurni, 2000). Most of these studies pointed out that deforestation and expansion of cultivation into marginal areas were the principal causes of land degradation. For instance, Zeleke and Hurni (2000) reported a serious trend of land degradation resulting from the expansion of cultivation on steep slopes at the expense of natural forests in the north-western highlands. Bewket (2003) noted the problem of downstream sedimentation caused by upstream degradation resulting from land use/cover changes in the Chemoga watershed, north-western highlands, in which the problem created extensive flooding and damage on important agricultural lands. Increases in open areas and settlements at the expense of shrub land and forests have been observed in south Welo, north-central highlands (Tekle and Hedlund, 2000). Lemenih et al. (2005) found declining soil quality attributes following deforestation and subsequent cultivation at Lapis, southern highlands. These studies have highlighted that the present land use system in highland Ethiopia is not sustainable and thus that if existing practices persist, future land resource use will be at risk.

Although previous studies provide important information, our understanding of the forces driving land use changes in Ethiopia is far from complete (Feoli et al., 2002; Reid, 2000). In particular, integrated analysis of the role of biophysical factors, socio-economic processes and policy changes on the dynamics of the use of land resources is limited. According to Veldkamp and Verburg (2004), land use changes are often driven by the interaction in space and time between biophysical and human dimensions. A more profound understanding of the changes that involve situation-specific interactions among various factors at different spatial and temporal scales is therefore needed (Lambin et al., 2003; Stoorvogel et al., 2004). Such a comprehensive assessment would be useful to better understand the interrelationships between people and their management of land resources, and for the development of more appropriate and sustainable land use systems.

The objective of the research described here was to examine the forces driving the long-term dynamics in land resource use in the Beressa watershed of the Ethiopian central

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<sup>1</sup> Ethiopia follows the Julian calendar, which consists of twelve months of thirty days each and a thirteenth month of five days (six days in a leap year). Sunshine is predominant in all the thirteen months in any one place of the country, hence the touristic slogan ‘13 months of sunshine’.

highlands in terms of biophysical and socio-economic processes, policy changes and farmers' livelihoods. The specific objectives were to: (1) determine the extent and patterns of land use changes from 1957 to 2000 (2) assess the complex role of biophysical and socio-economic processes, policy changes and farmers' livelihoods on the changes and (3) to highlight the implications of the changes for future land use.

## 2.2 Materials and methods

### 2.2.1 Site description

Covering an area of 215 km<sup>2</sup>, the Beressa watershed is located in the Ethiopian central highlands (9° 40'N, 39° 37'E) approximately 140 km north-east of Addis Ababa, the capital city. Administratively, the watershed lies within the North Shewa zone of the Amhara Regional State adjacent to the east of the town Debre Birhan, and encompasses three village areas:- Debele, Wushawushign, and Faji (Figure 2.1).

The watershed is characterized by a mountainous topography that forms part of the headstream of the Blue Nile basin. Elevation ranges between 2700 and 3600 m above m.s.l., and thus the area experiences an alpine and a temperate climate. The annual rainfall averages 887 mm (1984 - 2002), with a maximum of 1068 mm in 1986 and a minimum of 607 mm in 1984. Rainfall distribution is bimodal, with the long rains from June to September (locally called *Kiremt*) and the short rains from February to May (*Belg*). The two rainfall seasons allow two growing seasons. The long rainy season accounts for over 80% of the total annual rainfall and is more reliable for crop production than the short rains. The average annual temperature is 19.7°C, with large monthly variation.

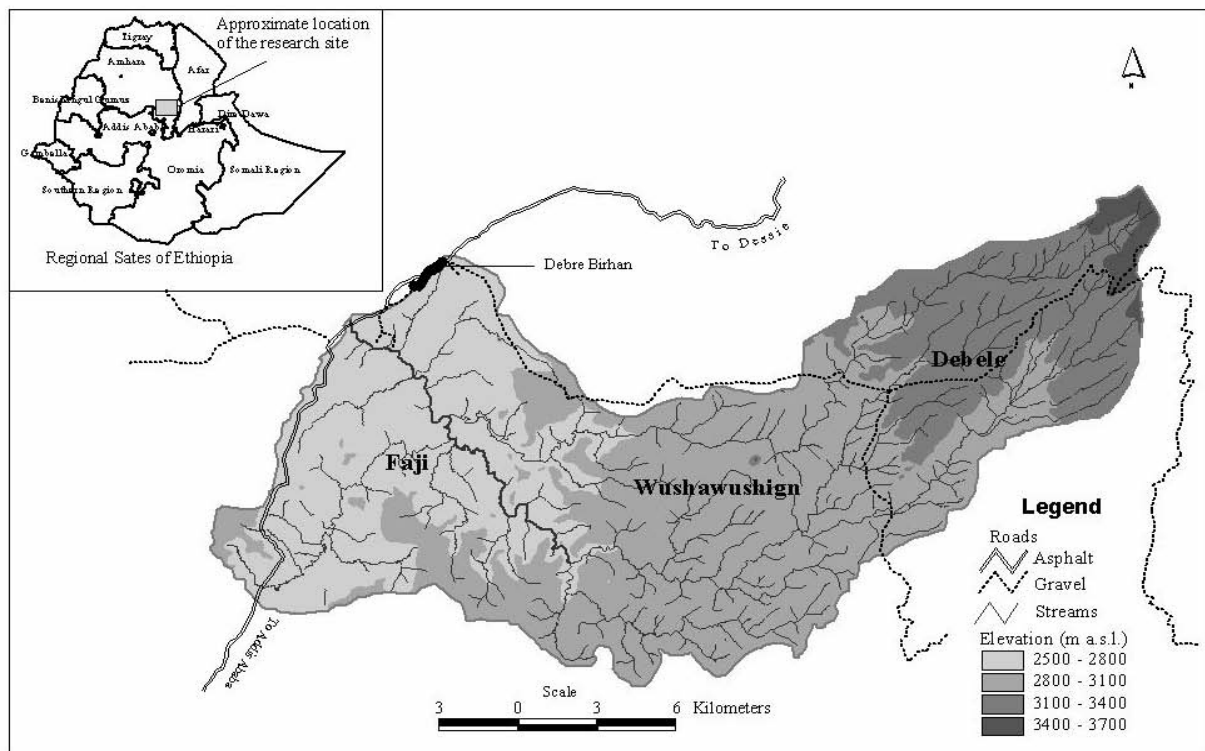
The soils of the Beressa watershed have developed from the volcanic materials that cover most of the central highlands of the country. The dominant soil types include cambisols (locally know as *Abolse*) and vertisols (*Merere*). Cambisols are predominant in the upper part of the watershed and the vertisols in the lower part. The natural vegetation is mainly composed of a few remnants of different tree species (such as *Hagenia abyssinica*, *Erica arborea*, *Acacia abyssinica*, *Olea Africana*, *Prunus Africana* and *Salix subserrata*), scrubs and grasses. As a result of past afforestation programs, eucalyptus is the dominant tree species in the upper part of the watershed. Homesteads are also surrounded by groves of eucalyptus.

The population of the watershed area is estimated at 24,650 (CSA, 2000). It is part of the more densely populated areas of the country, with a population density of 114 persons km<sup>-2</sup>. Agriculture has been the primary, perhaps the only, source of livelihood for the majority of the population since the start of human settlement in the area. It is characterized by a smallholder mixed crop and livestock production, with an average farm being 1.7 ha in size and the average livestock kept being 5.1 TLU<sup>2</sup> per household (mean household size is 5).

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<sup>2</sup> TLU refers to Tropical Livestock Unit, which is equivalent to 250 kg live animal weight.





**Figure 2.1.** Location map of the Beressa watershed, Ethiopia

The principal crops grown include barley (*Hordeum vulgare*), wheat (*Triticum aestivum*), bean (*Vicia faba*), and field pea (*Pisum sativum*), while the dominant livestock types include cattle, sheep, goats and poultry. Livestock density in the area is very high ( $1.27 \text{ TLU ha}^{-1}$ ) compared to the average for the Ethiopian highlands ( $0.36 \text{ TLU ha}^{-1}$ ). Most crop production takes place in the upper part of the watershed, while livestock production is dominant in the lower part. Agricultural production is primarily intended to meet requirements for subsistence, and it is largely sustained with local inputs such as animal manure and own labour. Off-farm employment opportunities in the area are generally very few, but farmers participate seasonally in small-scale trade and daily labour in Debre Birhan town. Overall, the average annual household income both from farm and off-farm sources amounts  $2950 \text{ Birr y}^{-1}$  (equivalent to 347 USD at the 2004 exchange rate) (Own survey, 2003).

### 2.2.2 Methods

**Land use information.** Land use and spatio-temporal changes were monitored by analyzing multi-temporal Remote Sensing images, two sets of aerial photographs and a satellite image, for the years 1957, 1984, and 2000, respectively. The data were analyzed at the Remote Sensing Department of the Ethiopian Mapping Authority (EMA), using geo-information tools. Field checks were conducted between 2003 and 2004 while analyzing and interpreting the images. Based on information obtained from field survey and the land use classes from

previous studies (e.g. Bewket, 2003; Reid, 2000; Tekle and Hedlund, 2000; Zeleke and Hurni, 2000), the following seven land use classes were established in the watershed:

- Natural vegetation; includes natural forests, woodland and scrub.
- Plantations; trees planted by households individually or collectively through the afforestation program (predominantly eucalyptus).
- Cropland; includes cultivated and fallow land
- Grazing; land under permanent pasture
- Bare land; includes rock outcrops, denuded land and badlands.
- Riparian vegetation; vegetation growing along streams.
- Settlement; includes both rural (scattered and nucleated) and urban settlements.

*Climate data.* Climate information was obtained from the National Meteorological Services Agency (NMSA) in Ethiopia. Mean monthly and annual rainfall data at Debre Birhan station were used for this research. This station, located at the outlet of the Beressa River, is the only station with long-term records dating back to the 1950s (though not complete). The rainfall pattern was studied for the two rainy seasons, *Belg* and *Kiremt*, and it was related to the changes in land use and management. Variations in the distribution of rainfall over time for the short and the long rains were analyzed.

*Soil sampling and analysis.* In 2004, soil samples were collected from the surface layer (0 – 15 cm) of the land use types within the watershed, to compare differences in soil properties across the land use types. A total of 43 composite soil samples from 119 sampling points was collected and analyzed for soil particle distribution, bulk density, soil pH, soil organic carbon (SOC), total nitrogen (TN), available phosphorus (AP), exchangeable potassium (EK) and cation exchange capacity. One-way analysis of variance (ANOVA) was used to test differences in soil properties across the land use types.

*Socio-economic data.* A socio-economic survey was carried out between 2002 and 2004. In total, 147 farm households were interviewed using a structured survey questionnaire on a range of issues pertaining to land use, climate changes, farming, soil fertility, and policy changes related to land and markets. Discussions were also held with groups of male and female farmers of various ages. In addition, farmers aged over 60 years were interviewed to obtain historical information on land use characteristics, socio-economics and policy changes, and livelihoods. Information on population size and growth and yields for the major crops grown in the area was obtained from available census reports and statistical abstracts of the Ethiopian Central Statistical Authority (CSA).

All the statistical analyses were performed using SPSS statistical software, version 10.0.

## 2.3 Results and discussion

### 2.3.1 Land use developments since the 1950s

Land use in the Beressa watershed has undergone substantial changes since the 1950s. Table 2.1 and Figure 2.2 present the proportion of land area under various uses and the changes observed for the years monitored (1957, 1984, and 2000). The transition between the major land use types is shown in Table 2.2, and Figure 2.3 depicts the relationship between the land use types and slope during the study period.

#### Land use changes and transitions

The major land use changes were deforestation and subsequent plantation, expansion of grazing, and reduction of bare land. Cropland, which has always comprised the largest portion of the watershed area, increased only slightly between 1957 and 2000.

During the period studied, the natural vegetation cover in the area progressively declined (see Figure 2.2). In 1957, 14.8% of the total land area was under natural vegetation; this had shrunk to 6.8% in 1984 and to 2.4% in 2000. Major deforestation took place between 1957 and 1984 (hereafter referred to as “the first period”), which result in the clearing of 1740 ha of the natural vegetation: at a rate of  $64 \text{ ha y}^{-1}$ . The cleared areas were converted into bare land (30%), cropland (21%) and grazing land (14%) (Table 2.2).

However, between 1984 and 2000 (hereafter referred to as “the second period”) most of the cleared areas were put under plantations through government afforestation programs. Conversion of natural vegetation into plantation (35%) and cropland (23%) were among the most important land use transitions. Consequently, the area under plantation increased from 1.8% in 1957 to 10.6% in 2000. Thus, the net forest clearance between 1957 and 2000 amounted to 755 ha.

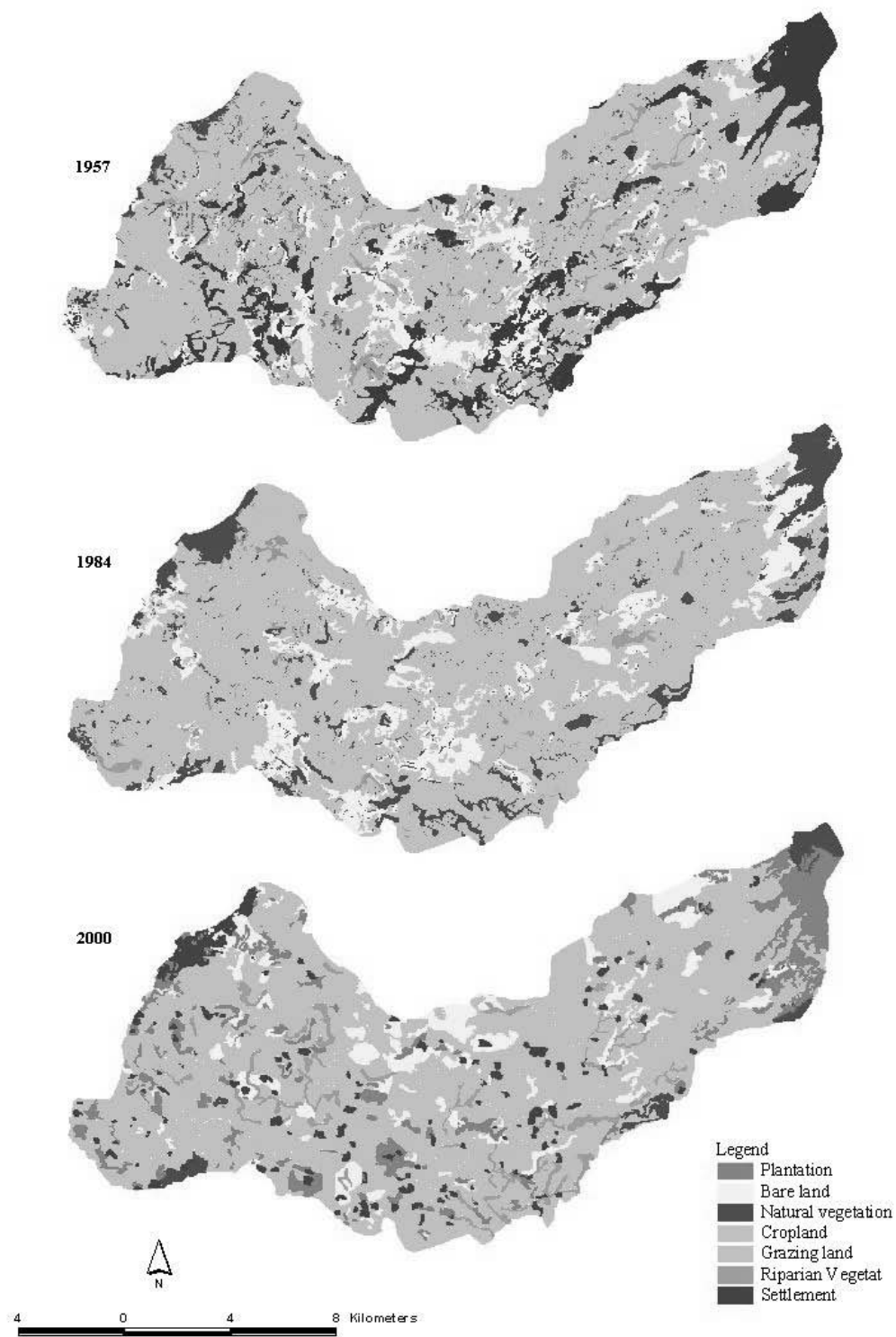
Grazing land expanded in the watershed area during the study period. In 1957, about 8.5% of the watershed area was under grazing and by 1984 this had more than doubled (to 18.7%), followed by a decline to 11.6% in 2000 (Table 2.1), partly due to reafforestation. The major land use transitions of grazing land between 1957 and 2000 were into cropland (57%) and bare land (26%) (Table 2.2). Overall, the expansion of grazing land amounted to 682 ha during the 43-years period.

The greatest expansion of grazing land occurred in the lower part of the watershed, mainly at the expense of cropland and bare land. On the other hand, bare land declined continuously, from 16.3% in 1957 to 12.8% in 1984 and to 8.0% in 2000; the decline between 1957 and 2000 was estimated at a rate of about  $42 \text{ ha y}^{-1}$  or 1788 ha in total. Bare land was converted into cropland, plantations and grazing land in order of importance (Table 2.2).

**Table 2.1:** Land use dynamics since the 1950s in the Beressa watershed, Ethiopia

Land use type	1957		1984		2000		% change	
	Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)	1957 to 1984	1984 to 2000
Natural vegetation (NV)*	3,191	14.8	1,451	6.8	527	2.4	-55	-83
Plantations (PL)	386	1.8	252	1.2	2,295	10.6	-35	495
Cropland (CL)	11,832	54.8	12,171	56.6	13,071	60.6	3	10
Grazing land (GL)	1,826	8.5	4,032	18.7	2,508	11.6	121	37
Bare land (BL)	3,520	16.3	2,769	12.8	1,732	8.0	-21	-51
Riparian vegetation (RV)	301	1.4	225	1.1	364	1.7	-25	21
Settlement (ST)	514	2.4	612	2.9	1,069	5.0	19	108

\*The abbreviations are used hereafter in tables and figures



**Figure 2.2.** Land use maps of the Beressa watershed, Ethiopia, for 1957, 1984, and 2000.

**Table 2.2.** Transition between the major land use types (area in %) in the Beressa watershed, highlands of Ethiopia

	Land use type				
	NV	PL	CL	GL	BL
<b>1957 -1984</b>					
NV	35	1	21	14	30
PL	0	44	4	22	31
CL	0	0	76	16	9
GL	3	1	24	62	10
BL	7	1	58	16	19
<b>1984 - 2000</b>					
NV	32	35	23	3	8
PL	0	32	49	12	7
CL	0	7	77	8	7
GL	1	8	49	33	10
BL	1	25	46	18	11
<b>1957 - 2000</b>					
NV	15	47	29	3	7
PL	1	13	67	11	8
CL	0	9	70	16	5
GL	0	5	57	26	12
BL	1	29	38	15	17

Compared to the changes with the other land uses, the overall expansion of cropland has been small during the study period. In 1957, about 54.8% of the total watershed area was under cultivation and this increased to 56.6% in 1984 and to 60.6% in 2000. Over the 43-years period, the expansion amounted to 1239 ha (10.5%), and the estimated annual increase was 29 ha. This is contrary to general expectations for the Ethiopian highlands where the rate of population growth has been alarmingly high since the 1950s. Further, cropland experienced the lowest conversion into other land use types. For instance, during the first period, 76% of the cropland continued to be under cultivation while the remaining 16% and 9% converted into grazing and bare land, respectively (Table 2.2). Similarly, the conversion of cropland to other land uses was little during the second period.

Land area for the expansion of cropland in the watershed has been limited because most of the remaining uncultivated land lies either on the very steep slopes in upstream area where erosion is severe or in the bottomlands of the downstream area that suffer drainage problems. Hence, intensity of cultivation increased to support the rising household food demand. Land fragmentation increased concomitantly with population growth. In response to reduced farm size and soil exhaustion, households started to diversify their income through

tree planting and livestock production. Increased involvement of households in off-farm employment and the sale of cattle manure are recent adaptations to meet their needs.

### **Relationship between land use and slope**

Figure 2.3 presents the relationship between the major land use types and slope during the study period. Cropland was the dominant land use in all slopes in the watershed area. Between 1957 and 2000, cropland increased relatively more on the steep slopes; it increased from 43% in 1957 to 63% in 2000. However, under normal circumstances, the steep lands should be kept under forest cover or used for perennial crops instead of annual crop cultivation (Zeleeke and Hurni, 2000). Considerable loss of natural vegetation was observed in all the three slope categories. Most of the deforestation took place on the steep slopes where erosion potential is very high. On the other hand, there was a dramatic increase in plantations in all slopes in 2000, and a sizeable portion of the deforested area on steep slopes was replaced with the plantations. As shown in Figure 2.3, most of the grazing area was distributed on the gentle and mid slopes, although grazing land was also observed on steep slopes.

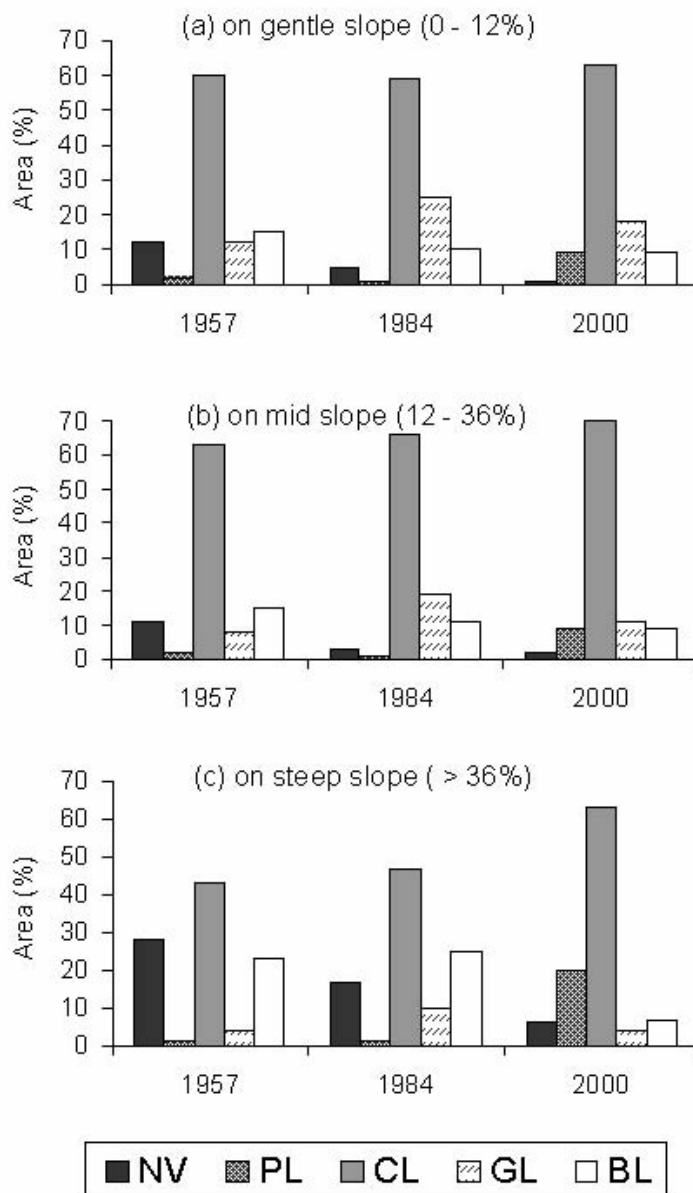
### **2.3.2 Factors influencing land resource use**

A variety of factors that include climatic, biophysical, socio-economic and political processes influenced the dynamics in land resource use in the Beressa watershed since the 1950's.

#### **The water factor: rainfall records and farmers' perception**

Rainfall is the main source of water for farming in the Beressa watershed. However, according to the farmers, water scarcity is the most important constraint to agricultural activities in the area. Of particular concern to them is the question of when the rains are likely to come and how much rain there will be; this often influences their land use decisions. Figure 2.4 presents the long-term (1954 - 2003) mean monthly rainfall distribution during the short and the long rainy seasons in the Beressa watershed.

Between 1954 and 2003, the mean annual rainfall during the short and the long rains amounted to 132 mm (16%) and 653 mm (79%), respectively. In general, the short rains fluctuate much more than the long rains in amount and distribution. As shown in Figure 2.4, the rainfall pattern during the long rains was stable; the pattern during July and August was particularly stable by comparison with the months for the short rains. This is also shown in the coefficients of variation: the distribution of rainfall was less variable during the long rains (CV=26%) than during the short rains (CV=53%) (Table 2.3). However, for both the long and short rains the long-term trend is for there to be more and better distributed rainfall in recent years. The long rains were, for instance, more variable between 1954 and 1984 (CV=30%) than between 1985 and 2003 (CV=21%). Similarly, the short rains were more variable between 1954 and 1984 (CV=63%) than between 1985 and 2003 (CV=39%).



**Figure 2.3.** Relationship between the major land use types and slope in 1957, 1984 and 2000 in the Beressa watershed, highlands of Ethiopia.

**Table 2.3.** Mean (mm) and coefficient of variation (%) of rainfall during the short and long rains and the annual totals (1954- 2003) in the Beressa watershed, Ethiopia

Period	Short rains		Long rains		Annual total	
	Mean	CV	Mean	CV	Mean	CV
1954 – 1984	107	63	626	30	778	27
1985 – 2003	159	39	682	21	877	16
1954 – 2003	132	53	653	26	825	22



Despite these rainfall statistics, the farmers in the area believe that the rainfall pattern has changed in recent years, becoming more unreliable and insufficient for crop production. They indicated that the rainfall pattern had been better before 1984. They attributed productivity decline primarily to water shortage, but the rainfall data does not support this view. What might account for the discrepancy between farmers' perceptions and rainfall records is the increased demand for water in response to population growth, and reduced availability of water due to erosion. For instance, most of the cultivated land with productive soils in the upstream area lies in the bottomlands where there is less erosion and the soils have been enriched with sediments eroded from the uplands. However, the cultivation of upstream bottomlands is possible only during the short rains due to drainage problems during the long rains although the short rains fluctuate and often cause crop failure. On the other hand, cultivation in the downstream area has been largely constrained by waterlogging. Downstream bottomlands particularly suffer severe drainage problems and thus most farmers resort to livestock production and tree planting in these areas.

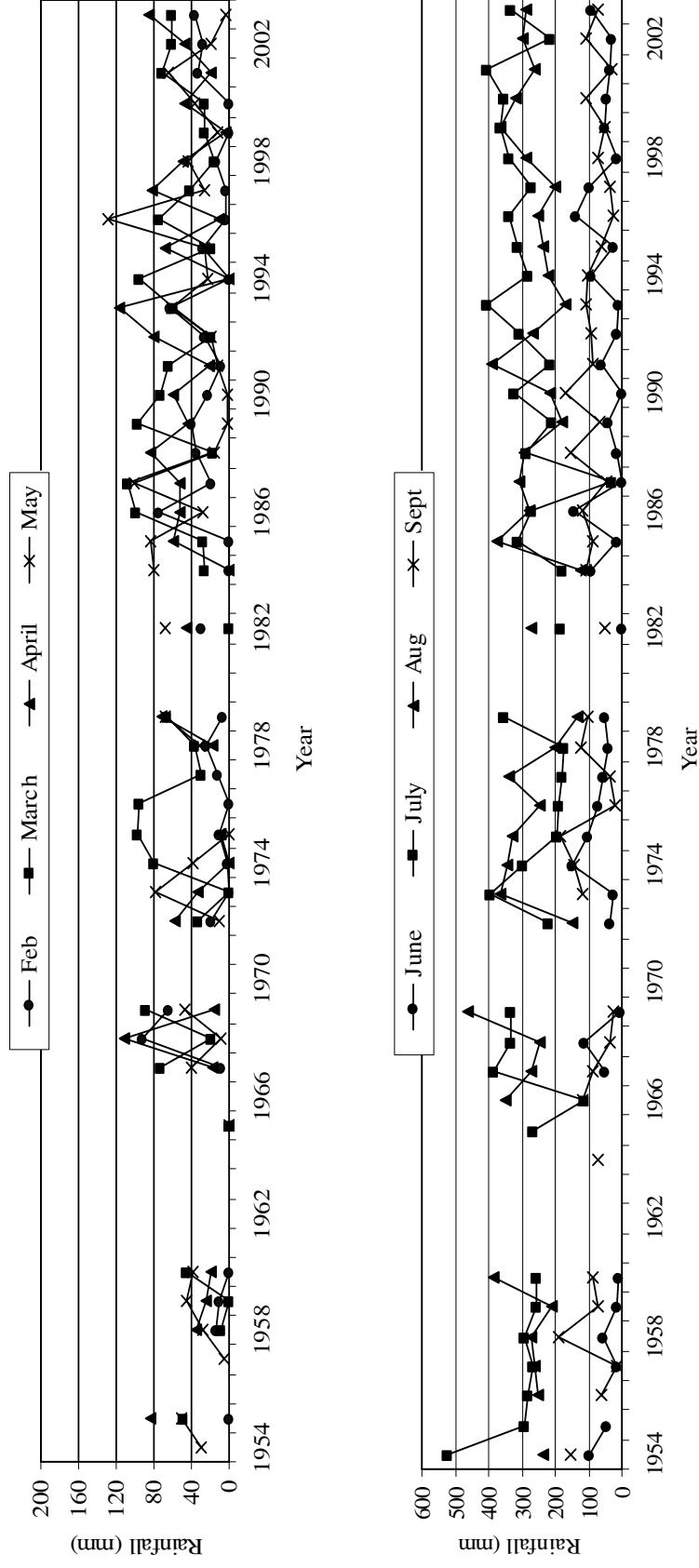
**Box 1**

**On the quality of the bottomlands**

*There are two groups of bottomlands in the watershed area; upstream bottomlands and downstream bottomlands. Upstream bottomlands lie in the valley bottoms in the upper part of the watershed. Erosion of upland soils often enriches these bottomlands with fresh sediments. The farmers consider these areas potential for cultivation during the short rainy season, but drainage problems often constrain crop cultivation during the long rains. According to the farmers, one prefers having a smaller holding in the bottomlands than a larger holding in the uplands.*

*On the other hand, the bottomlands in the downstream area suffer severe drainage problems both during the short and long rains. The farmers often mention the poor quality of these bottomlands for crop cultivation. Hence, most downstream bottomlands are used for grazing.*

Source: Interview with the farmers, 2005



**Figure 2.4.** Mean monthly rainfall distribution during the short (Feb. – May) and long (June – Sept.) rainy seasons (1954 – 2003) in the Beressa watershed, Ethiopia<sup>3</sup>

<sup>3</sup> Rainfall data were available from 1954, but complete records were available only after 1984.

### The soil condition and crop yield

Table 2.3 presents the mean and ANOVA results of selected properties of soils under the major land use types in the watershed area. Statistically significant differences ( $P < 0.05$ ) were observed in soil pH, SOC and TN across the land use types. No significant differences were found in the other soil properties. Cultivated soils had a significantly high pH compared with soils under other uses. The mean SOC content was by far the lowest in cultivated soils (1.8%) and was highest in soils under natural vegetation (5.9%). The TN was also much lower in cultivated soils and higher in soils under natural vegetation. By contrast, AP and EK were high in cultivated soils compared to soils under forests or grazing, though the differences were statistically insignificant. It seems likely that the conversion of natural vegetation into plantations and/or cropland resulted in these lower levels of pH, SOC and TN.

**Table 2.4.** Mean and ANOVA results of selected soil properties under the major land uses in the Beressa watershed, Ethiopia ( $n=43$ )

Soil Properties	Natural vegetation	Plantation	Cropland	Grazing land	<i>F</i> value
Sand (%)	29.6	27.7	23.2	21.6	1.31
Silt (%)	31.6	34.6	37.9	40.6	0.82
Clay (%)	38.8	37.7	38.9	37.8	0.27
BD (g cm <sup>-3</sup> )	1.0	1.1	1.1	0.9	1.20
EK (meq/100g soil)	0.52	0.59	0.65	0.37	0.91
CEC (meq/100g soil)	46.4	43.3	38.6	41.4	1.18
pH (H <sub>2</sub> O)	5.7	5.4	6.0	5.7	7.54*
SOC (%)	5.9	3.6	1.8	2.9	57.20**
TN (%)	0.42	0.20	0.06	0.15	70.79**
AP (ppm)	21.5	23.4	57.4	32.5	1.37

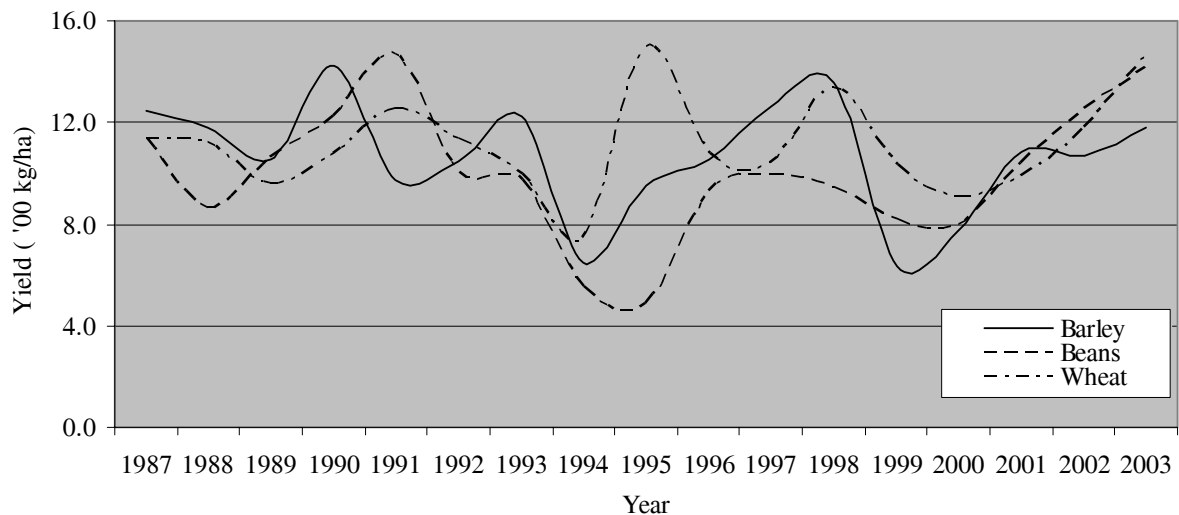
BD = Bulk density; EK = Exch. Potassium; SOC = Soil organic carbon; TN = Total Nitrogen;

AP = Available Phosphorus

\*\* Significant at 0.01 level; \* significant at 0.05 level

In general, the nutrient level of cultivated soils was low in particular that of nitrogen, perhaps because of intensive tillage, less physical protection against water erosion, and limited nutrient amendments. The farmers also recognized the poor quality of cultivated soils, attributing the decline primarily to erosion and continuous cultivation. In particular, the steep slopes have been cultivated continuously, with limited investments in soil and water conservation (SWC) and nutrient amendments. This has been leading to soil erosion and nutrient depletion thereby escalating the risk of land degradation. Indeed, the farmers use local practices, which include manure application, SWC and a mix of agronomic practices to combat soil degradation and improve productivity. However, shrinking farm size, labour shortage (due to involvement in off-farm

activities) and lack of fertilizer subsidies were often mentioned as major impediments to local initiatives. On the other hand, there is a surprisingly large outflow of cattle dung in the form of dung-cakes<sup>4</sup> which are sold as fuel in the towns. The reason seemed to be that for the cash-poor farmers, the benefits obtained from the sale of manure surpassed the benefits from investing in the soil at least in the short-run.



**Figure 2.5.** Average yields of major crops (1987 – 2003) in the Beressa watershed area, Ethiopia. *Source*; CSA (1987 - 2003)

Figure 2.5 presents the patterns of estimated yields for the major crops in the watershed area. Between 1987 and 2003, average yields of barley, beans and wheat were 1.1, 1.0 and 1.1 t ha<sup>-1</sup> respectively. Yields fluctuate so much that it is difficult to discern a trend. For instance, there was a major decline in barley yields in 1991, 1994, and 1999. One of the major causes of the decline in yields was water scarcity during the short rains (see Figure 2.4): in particular, the failure of the short rains in 1999 caused considerable damage to crop production. After 1999, yields of the three crops increased. The fluctuations in crop yield seem to follow the rainfall pattern. Unfortunately, owing to lack of historical data on soil nutrient condition in the area, we were unable to observe the impact on crop yields. As yields did not increase much to compensate for the reductions in per capita cropland, the farmers opted for other land uses. The expansion of grazing land and plantations observed during the study period was partly due to the reduction in cropland productivity.

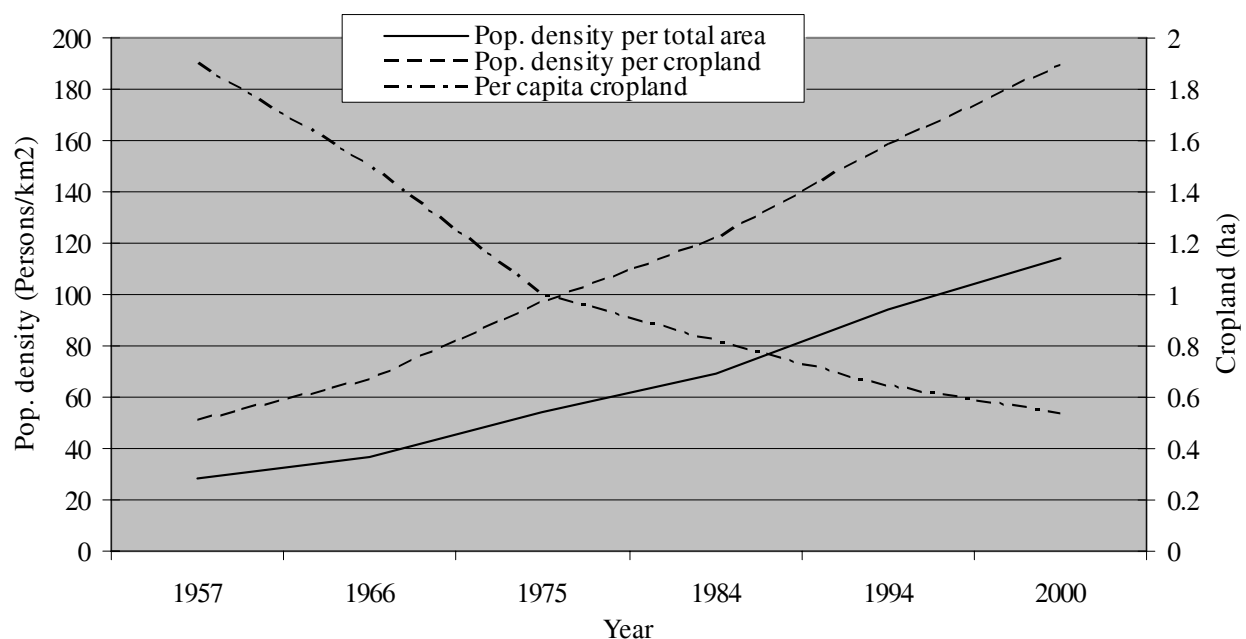
<sup>4</sup> Dung cakes are prepared by drying cattle dung in the sun. They are thin and round, on average the size of a pancake (diameter 30 cm).

## Socio-economic and policy factors

Of the socio-economic and policy factors, population pressure, introduction of cross-bred cattle, and policy regime changes were most important in influencing land resource use in the watershed area.

### *Population pressure*

Population pressure is considered to be one of the major drivers of land use change in the Ethiopian highlands (e.g. Bewket, 2003; Zeleke and Hurni, 2000). The population of the Beressa watershed quadrupled in the 43-years studied; the population density was 28 persons km<sup>-2</sup> in 1957 and increased to 114 persons km<sup>-2</sup> in 2000 (Table 2.4). The effect of increasing population pressure on land resources was apparent in the destruction of the natural vegetation cover observed during the study period. In addition, the per capita cropland declined from 1.96 ha in 1957 to 0.53 ha in 2000 since the possibility for further expansion of cropland has been minimal in the watershed area. Therefore, in order to support the rising population density, long-term fallows were abandoned and replaced gradually with intensive land use systems of continuous cultivation. Tree planting become an important activity households sought to meet their fuel wood and cash demands. This has contributed to the expansion of plantations between 1984 and 2000.



**Figure 2.6** Population density (per total area and cropland) and per capita cropland in the Beressa watershed (1957 – 2000), Ethiopia

*Introduction of cattle breeding program*

Major socio-economic changes have taken place since 1975, which was when ILCA (International Livestock Centre for Africa) initiated a project to support the smallholder system in the area with improved crop and livestock production. In particular, farmers in the downstream part of the watershed were introduced to cross-bred cattle and forage types. This eventually led to the expansion of grazing land observed during the first period. The project continued in the area for nearly 20 years. Following its termination, however, lack of access to cross-bred cattle, to markets for their products and to other technical support discouraged farmers from continuing with the dairy farming. Thus, cropland and plantations compete with grazing land in farmers' land use decisions, though waterlogging in the downstream area undermined crop cultivation. Recently, emerging market opportunities for dung-cakes have encouraged most farmers to continue to keep some cattle.

*Policy regime changes*

In 1975, Ethiopia undertook a major land reform that nationalized all land including forested areas and put it under public ownership. The reform abolished tenancy/landlordism and distributed the land to individual peasant farmers. This has created land fragmentation and a smallholder system with reduced fallows. Moreover, deforestation became widespread in government protected areas which led to the clearing of an extensive area during the first period.

In 1973 and 1984/85, major famines struck the country. The national government then realized the significance of environmental rehabilitation specifically on deforested and degraded land. This realization provided an impetus to embark on large-scale conservation and afforestation programs. The farmers were mobilized through "food-for-work" arrangements to build terraces and plant trees on degraded areas. Such changes resulted in a large-scale replacement of deforested areas by plantations during the second period.

After 1991, major changes in economic policy, from a command to a market economy, took place. A development strategy known as ADLI (Agriculture Development Led Industrialization), which viewed agriculture as the primary engine of industrial development, was adopted in the country. The new policy gave farmers the opportunity to diversify their income. Farmers were free to sell their products based on market prices. As trees have become a vital source of cash income, the farmers get involved more in tree planting. This is part and parcel of the widespread planting of trees at household level observed in many places of the Ethiopian highlands (e.g. Bekele-Tessema, 1997; Bewket, 2003; Kidanu, 2004).

**Box 2**

**How do people in Beressa survive?**

*Population increased fourfold, cropland expanded little, and yields did not show much increase during the second half of the 20<sup>th</sup> century in one of the most densely populated areas of the Ethiopian central highlands - the Beressa watershed. The question is then how do people survive?*

*Interviewed farmers refer to those old good times when crop production has not been a problem as it is today. From the 1950's to mid- 70's, most farmers were food self-sufficient. They even sell a good portion (about two-thirds) of their produce in local markets. The cash obtained was used to cover expenses such as tax, school fees and clothes. Things started to change as population continued to increase and land was recurrently redistributed to overcome emerging landlessness. Reduced farm size limited fallowing and more land was put under continuous cultivation. In the absence of proper amendments, however, this continuous cultivation caused declining soil qualities.*

*Continued pressure on the land and stagnating yields forced farmers to engage in alternative activities. Since the 1980's, dairy cattle production, tree planting, off-farm employment and manure selling became the notable sources of cash income. The dairy cattle breeding program attracted the attention of many farmers although it did not succeed much mainly due to inefficient market infrastructure for the dairy products. Most farmers focused instead on the better functioning market for cattle manure, which is processed into so-called dung-cakes. Thus, the dung-cakes become the most important source of cash income in the Beressa watershed. Furthermore, increased demand for fuel wood and construction materials in urban areas encouraged farmers to plant more trees.*

*Nowadays, more than half of the cash income is used for the purchase of basic food for household consumption. The dramatic increase in population, the limited expansion in cropland area and stagnating yields turned most farmers of the watershed area from food exporters to food buyers. However, according to the farmers, food shortages and occasional hunger has been inevitable during the recent past decades.*

Source: Interviews with farmers in the rural markets, 2005

### **2.3.3 Implications for sustainable land use**

The land use changes that occurred between 1957 and 2000 in the Beressa watershed have important implications for future land resource use in the area. As shown in the sections above, there has been enormous demographic pressure in the watershed area during the 43-years period. At the national annual growth rate of 3% (CSA, 2000), the current population of the watershed will have doubled by 2020. This implies that the pressure on land resources will increase as well, as the possibility for spatial expansion is limited. Redistribution of land to avert emerging landlessness would result in the fragmentation of holdings apart from the tenure insecurity it creates on the land users and their land use decisions. As land becomes more fragmented and more continuously cultivated, soil might also run the risk of becoming degraded (Ovuka, 2000).

Furthermore, investments in SWC seem to have stagnated in the area. The farmers focused on the cultivation of fertile grounds, tree planting and livestock production instead of rehabilitating degraded areas. For instance, in the upstream part of the watershed the bottomlands constitute the most important fertile grounds due to the supply of fresh sediments from the uplands that receive little attention from the farmers. However, excessive runoff from the uplands limits utilization of the upstream bottomlands during the long rains. This suggests the need for conservation investments in the uplands in order to be able to continue farming in the bottomlands. In addition, apart from on-site productivity improvements, conservation of the uplands could help to (1) reduce the pressure occurring in the bottomlands and (2) reduce runoff and thus regulate the hydrological disturbance occurring in the area. Water shortage is also another constraint limiting the cultivation of these bottomlands in the upstream area during the short rains, suggesting the need for water conservation practices. In this regard, the current water-harvesting initiative in the country seems a promising start. However, introduction of appropriate water conservation techniques that take local conditions into account is necessary.

On the other hand, farmers in the downstream area focus more on livestock production and tree planting than on crop cultivation. Particularly in the bottomlands, crop production is largely constrained by waterlogging. The farmers are therefore involved in cash-earning activities such as dung-cake and fuel wood selling instead of long-term conservation investments. Labour is also being taken away from the farm as the farmers seek off-farm employment opportunities in the urban areas. These practices were not without negative consequence on the future use of land resources in the area.

Therefore, emphasis should be given to land conservation and the maintenance of land quality through the adoption of better practices, ensuring that soil nutrients and water can be used efficiently and in a sustainable way. A long-term remedy must, however, rest on developing the modern sector of the economy in order to absorb the surplus rural labour force and reduce population pressure on land resources (Feoli et al., 2002).



## 2.4 Conclusions

This research, which set out to examine the long-term dynamics in land resource use and the forces driving the changes in the Beressa watershed, has revealed that there were substantial land use changes in the area during the second half of the 20<sup>th</sup> century. The most important changes were destruction of the natural vegetation, increased plantations, expansion of grazing land, and a decline in bare land. Cropland increased slightly over the 43-year period despite a quadrupling in the density of human population.

The natural vegetation cover was extensively cleared, but most of the cleared areas were gradually replaced with plantations. Grazing land expanded appreciably, at the cost of cropland and bare land. The greatest expansion of grazing land occurred in the lower part of the watershed, where drainage problems inhibit crop cultivation and improved dairy cattle have been introduced to support the smallholder system. The changes were driven by a combination of several factors: soil degradation, water shortage, socio-economic processes, and policy changes. In general, the soil condition was not good and yields have not risen to compensate for the reduction in per capita cropland. On the other hand, the long-term rainfall pattern has improved, though the farmers perceived it otherwise. Land reform and economic policy changes have considerably contributed to the land use changes occurred. These changes, coupled with the introduction of cattle breeding programs to the area, have enabled households to diversify their income.

Apparently, within livelihood strategies there has been a gradual shift from annual cropping towards tree planting and livestock production, to cope with soil degradation, water scarcity and reduced farm size. Although such a strategy offers benefits in the short-run, current practices do not seem to ensure long-term agricultural sustainability in the area. For instance, conservation investments in the uplands seem to have stagnated and instead the farmers have focused on the cultivation of the fertile grounds, tree planting and livestock production. Increased runoff and sedimentation due to upland degradation on the other hand would put the potential of fertile grounds at risk. Therefore, conservation of the uplands with appropriate practices to improve on-site productivity and reduce harmful off-site effects is necessary. The massive outflow of soil nutrients through the sale of the dung-cakes would be a major detriment to land productivity and agricultural sustainability in the area. Thus, better land resource management practices to ensure sustainable rural livelihoods are generally needed.

## Acknowledgements

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## Chapter 3

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### **The dung-cakes threaten agricultural development in the highlands of Ethiopia: the case of Beressa watershed**

**Aklilu Amsalu, Leo Stroosnijder and Jan de Graaff**  
Journal of Sustainable Agriculture, *Submitted*

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### **3. The dung-cakes threaten agricultural development in the highlands of Ethiopia: the case of Beressa watershed**

#### **Abstract**

Soil degradation is one of the major hurdles to agricultural development and food security in Ethiopia. This research assesses soil fertility degradation and local management practices in the context of rural livelihoods and agricultural sustainability in the Beressa watershed of the Ethiopian central highlands. Data were obtained by employing a combination of methods that comprise of socio-economic survey, soil sample analysis, market survey, discussions with the local farmers and literature review. Nutrient outflows from the farm through the sale of the dung-cakes are estimated. Soil chemical analysis and farmers' assessments show that soil fertility degradation is a major problem in the area. Animal manure constitutes the most important resource for soil fertility maintenance. However, most farmers process a good portion (90%) of their manure into dung-cakes and sell it at the market in Debre Birhan town. On average a farm household exports about 43.5 kg N, 9.0 kg P, and 41.4 kg K y<sup>-1</sup> through the sale of the dung-cakes. While there is increased demand for chemical fertilizers by the farmers, actual utilization is constrained by high and increasing market prices, lack of credit services and risks associated with rainfall failure. The research indicates that poverty, market access, and soil degradation are the most important factors weakening agricultural sustainability in the area.

*Keywords:* Livelihoods; N, P and K; market access; dung-cakes; cattle manure; poverty; Ethiopia

#### **3.1 Introduction**

Ethiopia is one of the poorest nations of the world. It is a land-locked country with agriculture being the main source of the national income and livelihood of a great majority of the population. Agriculture is based on rainfall and it is concentrated in the highlands (> 1500 m a.s.l.) that represent 43% of the national territory. The highlands comprise of 95% of the cropped area, 85% of the total population and two-thirds of the total livestock. Most of the agricultural production is for meeting subsistence requirements. Recently, the country has pursued Agricultural-Development-Led-Industrialization (ADLI) strategy to overcome economic stagnation and widespread poverty. However, soil degradation remains a major challenge to the development of agriculture and food security. Particularly, the highlands suffer severe rates of soil degradation due to erosion and nutrient depletion over the last years (FAO, 1986; FDRE, 1997; Hurni, 1993; Wood, 1990).

During the past decades, there has been much debate about the problem of soil degradation in sub-Saharan Africa (SSA) including Ethiopia. Several studies have been carried out on soil nutrient depletion in many places of the region. The most comprehensive study was that of Stoorvogel et al. (1993) in which nutrient balances were calculated for 38 SSA countries. This study reported negative scenarios for the soil macro-nutrients (N, P, and K) and concluded that nutrient depletion is a major problem of cultivated land in the region. Small-scale farmers are often blamed for removing large quantities of nutrients from their soils without using sufficient quantities of manure or fertiliser to replenish the soil (Sanchez, 2002).

On the other hand, Mortimore and Harris (2005) argue that the dominant narrative of soil fertility in Africa needs revision. According to these authors, the concept of soil fertility needs to be broader than implied in the nutrient depletion scenarios, and soil management needs to be understood as a part of rural livelihoods. Specifically, social and economic factors are critical in understanding patterns of soil fertility management in different contexts, over time and from one farmer to another (Scoones and Toulmin, 1998). Based on a study in southern Ethiopia, Elias et al. (1998) noted the need for a more targeted approach to soil fertility intervention that differentiates between various agro-ecological, farm and socio-economic clusters. Drechsel (2001) pointed out the significance of addressing demographic and economic root causes of soil degradation.

The fact that the farming system in Africa is so diverse and complex necessitates more research on the problem of soil degradation. While each of earlier studies has its own merit, a more comprehensive understanding of soil fertility degradation in Africa is pertinent. Under the conditions of resource poor farming communities, soil degradation undermines the yield gap, often leading to food shortages and poverty. Poverty in turn imposes constraints on soil fertility management efforts by exchanging long-term investments with short-term gains. Declining land frontiers and population pressure further complicate the problem (Shiferaw and Holden, 2001a; Sonneveld and Keyzer, 2003). Archetypical of this scenario is in the Ethiopian central highlands where population growth continues to be high (> 3 per cent), poverty is widespread and farming has reached at the margins of spatial expansion.

Farming in the central Ethiopian highlands is highly integrated with crop and livestock production. Livestock manure constitutes the most important source of nutrients and organic matter for the maintenance of soil fertility in this low-input farming system. Recently, however, cattle manure which is processed into dung-cakes<sup>1</sup> is overwhelmingly taken away from the farm to the urban market in Debre Birhan town as fuel source and thus competes with the use for soil fertility maintenance. This research was aimed at assessing soil fertility degradation, local management practices and farmers' dung-cake making and marketing activities in the Beressa watershed of the Ethiopian central highlands. In particular, farmers' dung-cake selling activities and soil nutrient outflows in the context of rural livelihoods and agricultural sustainability are examined.

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<sup>1</sup> The detail about the dung-cake and how it is processed is given in section 3.3.5.

## **3.2 Materials and methods**

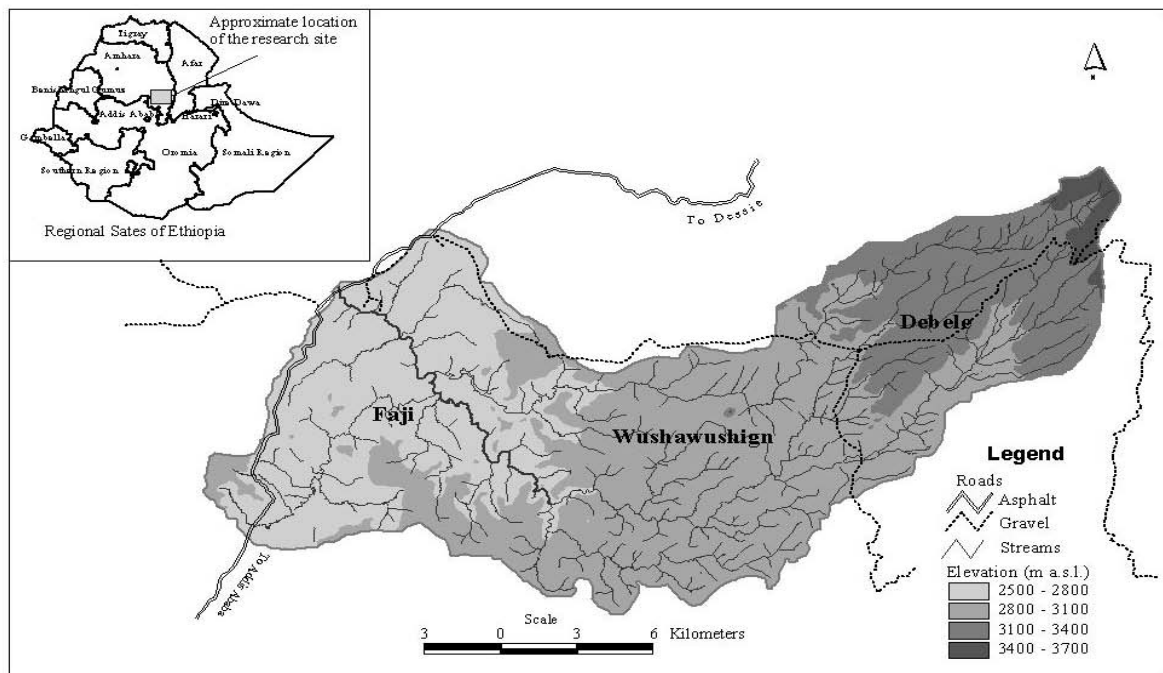
### **3.2.1 The research site**

This research was carried out in the Beressa watershed (9° 40'N, 39° 37'E) of the Ethiopian central highlands. Beressa is an agricultural watershed that covers an area of about 215 km<sup>2</sup>. The area is found in one of the most densely populated part of the country. Population density in the watershed area is estimated at 114 persons km<sup>-2</sup> (CSA, 2000). The topography is rugged with elevation ranging between 2700 and 3600 m a.s.l. The annual rainfall amount averages 887mm (1984 -2002). Rainfall distribution is bimodal; the short rainy season (*Belg*) occurs between March and May while the main rainy season (*Keremt*) starts in June and lasts around the end of September. The annual average temperature is 19.7°C. The two major soil types in the area are both derived from volcanic materials. These are cambisols (locally know as *Abolse*) and vertisols (*Merere*). The cambisols largely cover the upper part of the watershed, while the lower part of the watershed is dominated by the vertisols.

The watershed has been settled for several thousands of years, and rainfed agriculture has since been the main economic activity and source of livelihood. The main crops grown include barley, wheat, beans, field peas, and lentils. Rotating cereals with legumes is a common practice used for augmenting soil fertility in addition to the use of manure and inorganic fertilizers. Although dominated by eucalyptus, tree planting is a custom mainly around home compounds to meet firewood and cash income demands and use as wind breaks. Cattle and sheep constitute the main livestock types in the area, though goats and equines are also common. It is rare to find farming households that do not keep livestock of any sort at all.

### **3.2.2 Socio-economic and market survey**

A structured survey questionnaire was administered to 93 farm households randomly selected from the upstream and downstream parts of the watershed area by considering the relative difference in market access. Of the total households included in the sample, 21% were woman headed households. Interviews were made to the heads of the households to obtain data on household characteristics, farming and farm resources, perceptions of soil fertility changes and management practices, and participation in the local market, etc. Further, a sub-sample of 39 households was selected on purpose from the sample and an in-depth survey was carried out on dung-cake making and marketing activities and to estimate the volume of dung-cakes produced and sold out annually. A market survey was also conducted in Debre Birhan town to collect information about the dung-cake market, prices and units of measurements.



**Figure 3.1.** Location of the Beressa watershed, central highlands of Ethiopia

### 3.2.3 Soil sampling and analysis

Based on farmers assessments, cultivated plots considered to as good quality and bad quality were selected from the upstream and downstream parts of the watershed. A total of 27 composite soil samples were taken from the surface layer (0 – 15 cm) of the selected plots. The analyses were carried out at the Laboratory of the Ministry of Water Resources in Ethiopia following standard procedures. The samples were air dried, crushed and passed through a 2-mm sieve. Particle size distribution was determined using the pipette method. Bulk density was determined by collecting core samples with standard steal cylinders ( $0.0001\text{m}^3$ ) and weighed after oven dried at  $105^\circ\text{C}$ . Soil pH was determined using a pH-meter after extraction from a 1:2.5 soil-water ratio. Organic carbon was determined using the Walkley-Black dichromate method and total nitrogen with the Kjeldahl method. Available phosphorous was measured employing Olsen's method. The ammonium acetate extraction method was used to determine exchangeable potassium. In addition, dung-cake chemical analysis was carried out to determine the nutrient content (N, P and K).

### 3.2.4 Statistical methods

Quantitative information obtained from the socio-economic and market survey was summarized using frequency analysis and cross tabulations. Differences in farmers' perception of soil fertility changes and management practices were compared using the binomial test of significance. The Least Significant Difference (LSD) test at the 0.05 significance level was carried out to evaluate the differences in the mean values of soil properties in good and bad cultivated plots from the upstream and downstream parts of the

watershed. Further, a simple environmental analysis was conducted in which the costs of replacing the lost nutrients were valued at farm-gate fertilizer prices (De Jager et al., 1998). The analyses and graphical presentations were performed with the statistical software package SPSS version 10.0 and Microsoft Word Excel 2000.

### 3.3 Results

#### 3.3.1 The farming system and household characteristics

Farming is the primary source of livelihood in the Beressa watershed. The farming system is characterised by mixed crop and livestock production primarily meant for meeting subsistence requirements. Livestock provide draft power for ploughing and manure for fertilising the soils, and crop residues are the most important sources of feed for the livestock. There were however some differences in farming activities between upstream and downstream households of the watershed area. Farming in the upstream area is dominated by cereal crop production, while livestock production is much more widespread in the downstream area. Table 3.1 summarizes the characteristics of upstream and downstream households.

**Table 3.1.** Characteristics of farm households (mean values) in Beressa watershed, Ethiopia

	Upstream (n=44)	Downstream (n=49)
Age of the household head	45	44
Farm size (ha)	1.4	2.0
Household size (persons)	6	5
Livestock size (TLU)	5.6	8.2
Distance to market place (minutes)*	135	48
Households selling grains (%)	53	22
Households selling dung-cakes (%)	13	77
Off-farm income (Birr y <sup>-1</sup> )	574	1038

\* Most farmers of the watershed area reach the local market in Debre Birhan town on foot.

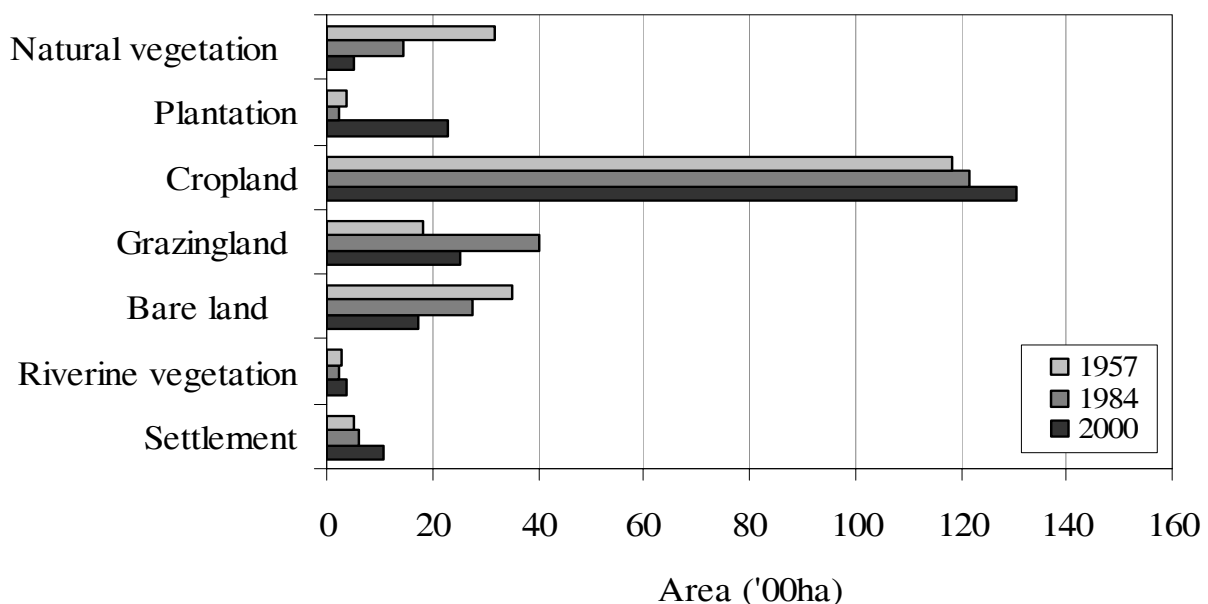
Households in the lower part of the watershed owned relatively larger farms (2 ha) than their counterparts in the upstream area (1.4 ha). Livestock size also differed among households; there were relatively more livestock owned (8.2 TLU) downstream than in the upper part of the watershed (5.6 TLU). On average, the farmers should walk for about 135 minutes to reach the urban market in Debre Birhan town from the upstream area, but it takes only 48 minutes from the downstream part. Small farm size, distance to the urban market, and limited access to grazing land probably accounted for the limited livestock production in the upstream area. Though there is more land per capita in the downstream area, crop production is largely constrained by water logging, which on the other hand provides grazing land. In addition, improved dairy cattle were introduced to the downstream area to support the livelihood of farm households during the past decades.



There is increased demand for the dung-cakes in Debre Birhan town that are used as a source of household energy. About 77% of the surveyed farmers in the downstream area participate in selling the dung-cakes in the urban market. The percentage of farmers selling dung-cakes was much lower in the upstream part (13%) than in the downstream area. Downstream households obtained more than twice as much off-farm income as upstream households, of which about 40% of their income was from the sale of the dung-cakes.

### 3.3.2 Socio-economic dynamics and land use changes

During the second half of the 20<sup>th</sup> century, major socio-economic and land use changes have taken place in the watershed area (Amsalu et al., 2006c). Most of the changes were driven by demographic pressure, land and economic policy changes, introduction of improved cattle, and soil degradation. The density of human population increased more than fourfold between 1957 and 2000. As a result, land has been frequently divided and distributed among the population since the non-farm sector developed poorly and it was unable to absorb the ever-increasing landlessness. Most notable was the land reform that took place in 1975, which caused a transition from a feudal to a peasant landholding system. Per capita land size diminished resulting in changes in the farming system from shifting cultivation to annual cropping. Moreover, there was extensive deforestation and cultivation of marginal areas. Increased land fragmentation and reduced fallow periods limited the traditional way of restoring soil fertility.



**Figure 3.2.** Land use of the Beressa watershed in 1957, 1984 and 2000, highland Ethiopia

Since 1975, the introduction of improved cattle breeds has contributed to the expansion of grazingland in the watershed area over the past decades. Households took advantage of the economic reform in 1991, from a command to a market economy, to diversify their income through the production of marketable items. Thus, livelihoods tend to gradually change from solely depending on cropping to income diversification by focusing more on livestock tending, tree planting (mainly eucalyptus) and dung-cake selling. In particular, selling fuel wood and dung-cakes become a vital source of household cash income. Currently, there is a huge outflow of dung-cakes to the urban market in Debre Birhan town, and the downstream part of the watershed is the major source area of the dung-cakes.

### 3.3.3 Assessment of soil fertility depletion

Nutrient balance studies carried out in sub-Saharan Africa indicated high rate of soil nutrient depletion in Ethiopia (Nandwa and Bekunda, 1998; Stoorvogel et al., 1993). The estimated nutrient balances for the major soil nutrients, N, P and K in 1982–1984 and the predictions for the year 2000 are presented in Table 3.2. All the soil macro-nutrients showed negative balances. The prediction was twice as high as the average value for SSA, indicating the severity of nutrient depletion in Ethiopia (Haileselassie et al., 2005). The trend suggests the need for soil fertility management to stop further degradation despite criticisms on the validity of the estimates.

**Table 3.2.** Annual nutrient balances of N, P and K ( $\text{kg ha}^{-1} \text{y}^{-1}$ ) of cultivated soils in Ethiopia

	1982 – 1984	2000
N	- 41	- 47
P	- 6	- 7
K	- 26	- 32

Source: Stoorvogel et al., 1993

Table 3.2 presents results of the soil sample analysis taken from good and bad cultivated plots in the upstream and downstream areas of the Beressa watershed. There were considerable differences in soil properties between good and bad cultivated plots within the watershed area. The soils of good plots were dominated by silt in the upstream area and clay in the downstream area. However, the least significant difference (LSD) test demonstrated that the differences in silt and clay content were significant ( $P < 0.005$ ) only between good upstream plots and the other three plot categories. There were also significant differences in soil bulk density and pH among the four plot categories.

Surprisingly, the amount of organic carbon was low in good plots and high in bad plots in the watershed area. The highest SOC content (2.42%) was in downstream bad plots and the difference from the other plot categories was significant. The level of nitrogen was significantly high in good downstream plots. Nonetheless, nitrogen levels were generally low in the watershed area. Good plots had relatively higher levels of available phosphorus than

the bad plots in both upstream and downstream areas. But the level of exchangeable potassium was significantly high in bad upstream and good downstream plots. Downstream plots had relatively high cation exchange capacity, and that of downstream bad plots was significantly different from the other three plot categories.

The analysis shows that the soils in the upstream area significantly differ in their physical properties, but significant differences in the downstream area were in soil chemical properties. The differences in soil physical properties in the upstream plots resulted primarily from erosion and sedimentation. The high level of silt content in good soils was due to the deposition of eroded sediments, as silt is the most erodible mineral component of the soil (Brady, 1984). Erosion removes topsoil, which is the richest layer of soil in both organic matter and nutrient value. According to farmers' assessments, the fertile soils in the upstream part of the watershed lie in the bottomland fields, indicating that the differences in nutrient levels were influenced by erosion and sedimentation. Haileslassie et al. (2005) also reported erosion as the major cause for nutrient depletion in Ethiopia. In the downstream area, however, soil fertility management might have accounted for the differences in soil nutrient levels of the cultivated plots.

### **3.3.4 Local perceptions of soil fertility changes and management practices**

As soil fertility decline is of particular concern to most farmers of the watershed area, we asked the farmers what they think about soil fertility changes on their cropland. Table 3.4 presents farmers' perception of soil fertility changes and management practices. Over 70% of the interviewed farmers indicated that soil fertility has declined over the past decades. And there were no significant differences between upstream and downstream farmers in their perceptions of soil fertility decline. The main reasons mentioned for the decline were continuous cultivation, soil erosion, and insufficient use of chemical fertilizers (Amsalu and De Graaff, 2006b).

Farmers use several practices for soil fertility maintenance; manuring, crop rotation, fallowing, erosion control, and application of chemical fertilisers. Manuring is an age-old practice used by most farmers of the watershed area. Particularly, upstream farmers depend most on animal manure for maintaining soil fertility. The differences between upstream and downstream farmers as regards to manuring were statistically significant ( $P < 0.1$ ). Animals, mainly cattle, graze freely on cultivated plots after harvests and on fallow land thereby contributing to the cycling of nutrients.

Crop rotation and rotational fallows also constitute the most important soil fertility management practices in the area. The main rotation system is the cultivation of cereals alternated with pulses. In addition, fallowing forms part of the rotation system. With declining per capita farm size, it becomes increasingly difficult to practice the traditional system of prolonged fallowing. Thus, most farmers leave their plots uncultivated only for one year after two or three consecutive years of cultivation. However, there were significant differences between upstream and downstream farmers in the use of crop rotation ( $P < 0.1$ ) and rotational fallows ( $P < 0.05$ ). Most downstream farmers use crop rotation compared to

upstream farmers due mainly to the relatively large farm size per capita and the possibility of growing several crop types.

Farmers also use chemical fertilizers to maintain soil fertility. However, there were significant differences in the use of chemical fertilizers between upstream and downstream farmers. Most downstream farmers prefer to use chemical fertilizers instead of manure. In the discussions, they indicated that the use of manure for land fertilisation is not profitable as the soils respond little to manuring, and it is too much labour demanding. Instead, they process a good portion of their manure into dung-cakes to generate cash income by selling it in the urban market.

### **3.3.5 Dung-cake making and marketing: selling the future to survive?**

The dung-cakes are made of cattle dung. Every day some members of the household collect dung from their cattle and process it into dung-cakes. Mostly women and children undertake the task of processing and storing the dung-cakes. The process involves forming the dung into a rounded shape (2 cm thick and 30 cm diameter on average), and let it get dried up in the sun. After dried up in about four days, the dung-cakes are collected and piled up around the home compound. Figure 3.3 shows women processing the dung-cakes and a heap of piled dung-cakes around the home compound.



**Figure 3.3.** Households, women and children, processing cattle dung into dung-cakes, heaps of piled dung-cakes around the home compound, and packing for the market in the Beressa watershed of highland Ethiopia.

**Table 3.3** Mean soil properties of good and bad cultivated plots in the upstream and downstream areas of the Beressa watershed, highland Ethiopia (n=26)

	Sand (%)	Silt (%)	Clay (%)	BD (g cm <sup>-3</sup> )	pH (H <sub>2</sub> O) 1:2.5	SOC (%)	Tot. N (%)	Av. P (ppm)	Ex. K (meq/100g soil)	CEC (meq/100g soil)
<b><i>Upstream</i></b>										
Good plots	22.2	45.0b	32.8a	1.0a	5.9b	1.61a	0.101a	63.0b	0.35a	37.8a
Bad plots	24.8	37.0a	38.2b	1.1b	6.2c	1.76a	0.110a	53.0b	0.83c	36.0a
<b><i>Downstream</i></b>										
Good plots	23.9	33.9a	42.3b	1.1b	6.1c	1.73a	0.151b	72.4b	0.68a	36.9a
Bad plots	21.6	31.9a	46.5b	1.2c	5.7a	2.42b	0.108a	26.6a	0.45b	45.3b
LSD* ( $P < 0.05$ )	ns.	4.51	4.73	0.06	0.15	0.29	0.019	18.73	0.12	2.41

\* Least significant difference (LSD) test of mean values of soil properties.  
Mean values followed by the same lower-case letters do not significantly differ from each other.  
ns = no significant difference

**Table 3.4.** Farmers' perception of soil fertility changes and management practices in the upstream and downstream parts of the Beressa watershed, Ethiopia

	No. of respondents		Z test <sup>†</sup>
	Upstream (n=44)	Downstream (n=49)	
Perception of soil fertility change			
Declining	32	36	ns.
Same	11	10	ns.
Improving	1	3	ns.
Soil fertility management practices			
Manuring	39	25	*
Crop rotation	28	42	*
Rotational fallow	25	44	**
Erosion control	1	1	ns.
Chemical fertilisers	10	39	**

<sup>†</sup> Z values were obtained based on Binomial test of significance.  
 \*\* P < 0.05; \* P < 0.1; ns.=no significant difference

Although women participate, most of the dung-cake marketing is taken care of by men since the responsibility of managing household cash income is given to men. Donkeys are the most important means of dung-cake transport from the farm to the urban market. A local unit called *Kurbet* is used for selling the dung-cakes, and a donkey carries only one *Kurbet* of dung-cakes which on average weighs 32 kg and contains 53 dung-cakes. Table 3.5 gives manure production, amount used for household energy, and amount sold out in the urban market during the 2003/4 cropping season.

It is no surprise that downstream households produce more manure than upstream households since livestock production is the most important activity in the area. Manure production was twice more in the downstream area than in the upstream area. Of the total manure produced, about 68% and 90% was processed into dung-cakes in the upstream and downstream parts, respectively (about 79% for the whole area). However, there was considerable discrepancy in the amount of dung-cakes sold between upstream and downstream households; on average 9 and 61 *Kurbets* of dung-cakes by each upstream and downstream household, respectively. The annual household income from the sale of dung-cakes also differed, which was 58 Birr<sup>2</sup> in the upstream area and 397 Birr in the downstream area (Table 3.5).

The relative difference between the upstream and downstream households in the amount of dung-cake making and marketing is attributed mainly to differences in cattle size, intensity of use for soil fertility, and access to the urban market. According to upstream farmers, the problem of grazing land is a major limitation of having more cattle. The manure available is thus shared among the various needs of the households; soil fertility, household energy, and market. Since the benefit of chemical fertilisers is marginal in the upstream area,

<sup>2</sup> 1 Eth. Birr (Ethiopian currency) = 0.12 USD

the use of manure for soil fertility is widespread. In addition, the relative use of dung-cakes for household energy was more in the upstream part as the climate is relatively very cold. Most importantly, the fact that the upstream area is distant from the urban market discouraged most farmers from participating in dung-cake selling.

**Table 3.5.** Manure production and amount of dung-cakes produced and sold out by households during the 2003/4 cropping season in the Beressa watershed, highland Ethiopia

	Upstream (n=16)	Downstream (n=23)
Annual cattle dung production (kg)	1134	2588
Dung-cakes produced ( <i>Kurbet</i> y <sup>-1</sup> )	24	73
(% of the total annual manure)	(68%)	(90%)
Dung-cakes sold out in the urban market ( <i>Kurbet</i> y <sup>-1</sup> )	9	61
(% of the total dung-cakes produced)	(38%)	(84%)
Average income obtained (Birr y <sup>-1</sup> )	58	397

On the other hand, most downstream farmers are involved in dung-cake marketing activities. Several reasons could explain this; closer distance to the urban market, more specialization in livestock production, water logging and soil properties (heavy clay soils to work with). The urban market is easily accessible to downstream farmers and there is an enormous demand for the dung-cakes by the urban households. Because most of the population of Debre Birhan town are so poor that they do not afford to use modern sources of energy. They rather depend on bio-fuel resources in which fuel wood and dung-cakes constitute the most important ones. This has created a reliable demand for the dung-cakes produced in the surrounding rural areas. The introduction of improved cattle and increased waterlogging of cropland encouraged the development of livestock production in the downstream area in the past decades. Further, the vertisols, which dominate the soils of the downstream area, happen to be too difficult to work with the traditional ox-drawn plough. Even in well drained fields, the farmers prefer to use chemical fertilizers instead of cattle manure due to the higher labour demand.

Nevertheless, the amount of dung-cakes flowing to the urban market varies seasonally. Peak seasons of dung-cake selling are in March-April and in September-October around the Easter and New Year holidays. Otherwise, there is always a market for the dung-cakes, albeit the price fluctuates.

### 3.3.6 Estimated nutrient outflow

Chemical analysis of a dung-cake showed that it contained 22.3g N, 4.6g P and 21.2g K kg<sup>-1</sup>. Table 3.6 presents the calculated nutrient outflows from the farm through the sale of the dung-cakes in the downstream area. Since the amount of dung-cakes flowing to the urban market from the upstream area was relatively small, we estimated nutrient outflows only from the downstream area. The estimates indicated that a farm household exports on average 43.5 kg N, 9.0 kg P and 41.4 kg K y<sup>-1</sup>. Considering the average farm size per household in the

downstream area, which is 2 ha (see Table 3.1), the nutrient losses amounted to 21 kg N, 4.5 kg P and 20.7 kg K ha<sup>-1</sup> y<sup>-1</sup>. Had there not been nitrogen losses while drying up and storing the dung-cakes, the estimated losses would have been even much great.

Taking into account the 2002 farm-gate fertilizer prices, the annual replacement cost of lost nutrients (N and P) amounted to 232 Birr per household. However, the costs were lower than the benefits (cash income) the farmers got from the sale of their manure, i.e. 379 Birr. This shows that the replacement cost of lost nutrients through the purchase of chemical fertilizers is relatively less than the benefits, implying that the sale of manure appears to be profitable to the farmers in economic terms. Nevertheless, the use of manure has invaluable long-term and multiple beneficial effects than the use of chemical fertilizers. Manure improves the pH of acid soils, increases soil organic matter content and cation exchange capacity, improves soil aggregate stability, soil macro-structure, infiltration, water holding capacity and erosion resistance (Bayu et al., 2004). On the other hand, the farmers are faced with enormous constraints that restrain them from the use of chemical fertilizers.

**Table 3.6.** Nutrient outflow through the sale of the dung-cakes during the 2003/2004 cropping season in the downstream area of Beressa watershed, highland Ethiopia

	Soil nutrients		
	N	P	K
Nutrient content of a dung-cake (g kg <sup>-1</sup> )	22.3	4.6	21.2
Nutrients lost through the sale of dung-cakes per household (kg y <sup>-1</sup> )	43.5	9.0	41.4
Nutrient losses per household farm area (kg ha <sup>-1</sup> y <sup>-1</sup> )*	21.0	4.5	20.7
Annual cost of lost nutrients per household (Birr) <sup>†</sup>	185.0	47.0	-

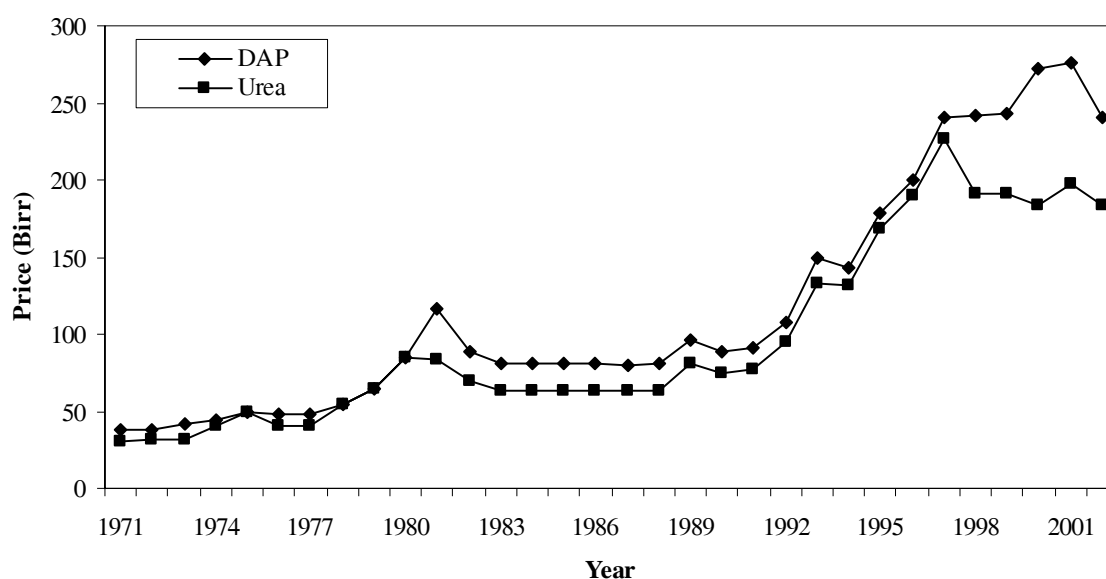
\* The estimation considered average farm size per household (see Table 3.1).

<sup>†</sup> The costs are estimated based on the 2003 farm-gate fertilizer prices.

### 3.3.7 Constraints to fertilizer use

The most important constraints to fertilizer use in the watershed area include higher and increasing market prices, risk associated with rainfall failure, and lack of access to credit services. Figure 3.4 depicts fertilizer prices between 1971 and 2002 in the country. Between 1971 and 1991 fertilizer prices were relatively stable. However, after 1991 the prices went up due to the introduction of a market economy in the country that liberalized fertilizer prices and markets, followed by devaluation of the national currency. There was fertilizer subsidy that enabled the farmers to use the chemical fertilizers until it was eliminated since 1997.





**Figure 3.4.** Fertilizer prices (DAP and Urea) between 1971 and 2002 in Ethiopia.

Promotional works have taken place to raise the level of use of fertilizers by the farmers. The most notable one was that of Sasakawa/Global 2000 program which has been demonstrating productivity increases through the use of chemical fertilisers and improved seeds since 1993. However, rising fertilizer prices and the limited access to credit facilities made fertilizer use unaffordable to most farmers. Moreover, credit allocation and collection procedures have deviated from the principles of normal banking operations, leading to distortions, delays in sales and unnecessary strains on the farmers (Demeke et al., 1998). Overall, although there is increased demand for fertilizers particularly in the downstream area, actually application is far below demand and often sub-optimally, which is below the recommended levels.

### 3.4 Discussion

This research indicates that soil fertility degradation is a major problem of cultivated land in the Beressa watershed. The maintenance of soil fertility therefore plays a central role for households' food security, poverty alleviation, and overall agricultural sustainability in the area. As agriculture is of mixed crop and livestock production, cattle manure constitutes the most important resource for soil fertility maintenance. It is a cheap source of plant nutrients and also improves soil water holding capacity, cation exchange capacity, and soil structure which all these in turn play a role in reducing soil erodibility. However, a good portion of the manure is processed into dung-cakes for household energy and to generate cash income by selling in the urban market.

Research on soil fertility management in SSA was generally criticized for ignoring farmers' management strategies and the underlying principles (Schlecht and Buerkert, 2004). Indeed, local practices contribute considerably to soil fertility management as shown in many earlier studies (e.g. Beshah, 2003; Harris and Yesuf, 2001; Mortimore and Harris, 2005).

However, the existence of local knowledge and practices *per se* would not help much to combat the problem of soil degradation in Africa. Therefore, farmers' resource management practices should be examined in a border context of livelihood strategies. Because local soil management decisions appear to be driven by immediate livelihood requirements than long-term investments.

In the Beressa watershed, farm households trapped with poverty and soil degradation seem to be more engaged in short-term activities than long-term investments in soil fertility management. In particular, dung-cake marketing has become an important survival strategy to cope with their problems. On the other hand, there is a huge demand for the dung-cakes in the urban area as most of the urban dwellers do not afford modern energy sources. This will encourage resource poor farmers to continue to supply their manure to the market, suggesting the need for alternative sources of household energy affordable to the urban population.

The outflow of soil nutrients through the dung-cakes is remarkable in the area. Since the nutrients are destined to burning in the urban area, there is little chance of being returned back to the farm. Obviously, this interrupts the nutrient cycle and result in negative nutrient balances in the area. Apparently, the farmers switched gradually from the use of manure to chemical fertilizers. However, their current economic condition does not allow for a large-scale application of chemical fertilizers that would compensate the lost nutrients (Sonneveld and Keyzer, 2003). Therefore, the outflow of nutrients through the sale of the dung-cakes seems a threat to agricultural development and sustainability in the area.

### **3.5 Conclusion**

In Beressa watershed where farming is mixed crop and livestock production, animal manure constitutes the most important resource for soil fertility maintenance. Recently, however, dung use for fuel and marketing competes with the use for soil fertility maintenance. Surprisingly, dung-cake marketing becomes an important source of cash income and livelihood of the rural households in watershed area. The research highlights that the outflow of nutrients through the sale of dung-cakes is so enormous that it is a threat to households' food security and agricultural development in the area. Among others, poverty, market access and soil degradation constitute the most important factors influencing farmers' participation in dung-cake marketing. Being part of the country's rural poor, the farmers of the watershed area are so poor that they tended to engage more in subsistence activities than in long-term investments. Due to the relative proximity to the urban market, downstream farmers are more involved in dung-cake selling activities than the upstream farmers. On the other hand, lack of cheap and alternative sources of household energy in the urban area, Debre Birhan town, has increased the demand for the dung-cakes. Such complex processes and interactions indicate that soil fertility management should be viewed in the framework of rural livelihoods instead of simplistic assumptions and analysis of inputs and outputs.

## **Acknowledgement**

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## **Chapter 4**

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### **Farmers' views of soil erosion problems and their conservation knowledge in Beressa watershed, central highlands of Ethiopia**

**Aklilu Amsalu and Jan de Graaff**

Agriculture and Human Values 23: 99 – 108 (2006)

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## **4. Farmers' views of soil erosion problems and their conservation knowledge in Beressa watershed, central highlands of Ethiopia**

### **Abstract**

Farmers' decision to conserve natural resource generally and soil and water particularly are largely determined by their knowledge of the problems and perceived benefits of conservation. In Ethiopia, however, farmer perceptions of erosion problems and farmer conservation practices have received little analysis or use in conservation planning. This research examines farmers' views of erosion problems and their conservation knowledge and practices in the Beressa watershed in the central highlands of Ethiopia. Data were obtained from a survey of 147 farm households managing 713 fields during the 2002/2003 cropping season. In-depth interviews and group discussions were also held with the farmers to obtain additional information. The results show that 72% of the farmers reported erosion problems, and they expressed that conservation was necessary. However, they considered erosion to be severe mostly when visible signs – rills and gullies – appeared on their fields. The majority of the farmers believe that erosion could be halted, and they use a range of practices for erosion control and fertility improvement. These measures include contour ploughing (83%), drainage ditches (82%), and stone terraces/bunds (73%). Nevertheless, despite decades of conservation intervention in the area, it appears that most farmers have developed negative attitudes towards externally recommended measures. The research concludes that under the conditions present in the Ethiopian central highlands, soil and water conservation interventions should consider farmers' conservation knowledge and practices to improve acceptance and adoption of the recommendations.

*Keywords:* Drainage ditches; Ethiopian highlands; Farmer perceptions; Indigenous knowledge; Natural resource management; Soil and water conservation; Soil erosion; Stone terraces

### **4.1 Introduction**

The degradation of agricultural land poses a serious threat to current and potential food production in the highlands of Ethiopia (Bekele-Tesemma, 2001; Hurni, 1988; Sonneveld and Keyzer, 2003). With fertile soils and good rainfall these highlands (>1500m a.s.l.) hold the highest agricultural potential in the country (Hurni, 1993; Shiferaw and Holden, 2001a). Constituting less than half of the national territory (43%), the highlands host large concentrations of people (over 85% of the total population) and livestock (75% of the total number), making the area the most intensively cultivated part of the country. Agriculture is the main economic activity for the majority of the population, and its contribution to the

national economy is significant. It accounts for about 45% of the GDP, 85% of the exports and 80% of the total employment (FDRE, 1997). However, in the absence of sound land use policies, this pressure coupled with many other physical, socio-economic and political factors has led to a serious degradation of land (Bewket and Sterk, 2002).

Several studies have shown that extensive areas of the highlands are in the grip of accelerated erosion. An estimate in the mid-1980s showed that 3.7% of the highlands (2 million ha) had been so seriously eroded that they could not support cultivation, while a further 52% had suffered moderate or serious degradation (Kruger et al., 1996; Wood, 1990). On arable land, soil erosion averages about 42 tones  $\text{ha}^{-1} \text{ year}^{-1}$  and causes an average annual reduction in soil depth of 4 mm (Hurni, 1988). Even though this loss will often reappear as fresh sediments deposited downstream, the areas that benefit from the transported soil are relatively small compared to those from which it is removed (Sonneveld and Keyzer, 2003). Water shortage and the loss of soil fertility are associated problems constraining productivity. Despite the fact that erosion undermines productivity in the highlands, data on erosion (productivity relations particularly) are quite scanty in the country. The deterioration of soil fertility is also related to the sale of manure for fuel in the urban markets.

Recognizing land degradation as a major environmental and socio-economic problem leading, the government of Ethiopia has made several interventions. Large-scale conservation schemes were initiated particularly after the famines of the 1970s. Since then, huge areas have been covered with terraces, and millions of trees have been planted (Admassie, 2000; Herweg, 1993). The projects have made use of farmer labour under the 'food-for-work' project funded by the World Food Program. Farmers were provided with grain and edible oil in payment for their participation in the funded conservation works. Obviously, food aid has helped to fight hunger in famine-stricken areas, but, in the long run, the programme has not been successful for improving soil and water conservation (SWC).

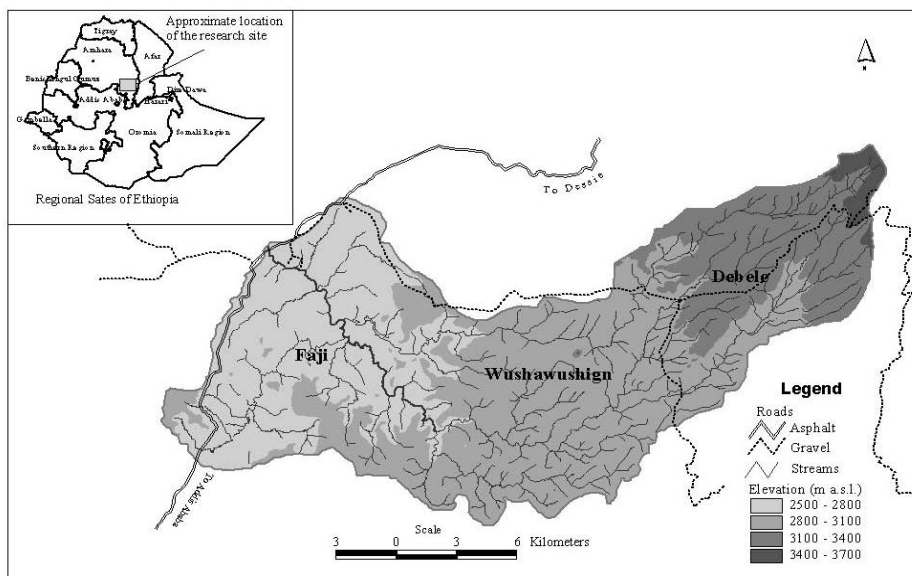
Decisions on which types of SWC measures to use and where to place them were not made by the farmers concerned, and only rarely was an attempt made to include indigenous experience and knowledge (Herweg and Ludi, 1999; Wood, 1990). Instead, donor and government officials told the rural community residents what they should do to obtain relief food, and they provided little opportunity for discussion and local participation in conservation planning (Wood, 1990). Eventually, when the supply of food-for-work discontinued, most of the participating farmers became unwilling to participate in the new conservation projects or maintaining those already established. Some farmers even removed the structures from their fields (Admassie, 2000; Taddese, 2001). In the end, the effort realized little success in combating problems.

The assumption that farmers have a poor perception of erosion problems and limited conservation knowledge has contributed to the external development of conservation technologies. Nonetheless, little confirmation exists in the literature that farmers' decisions are any more or less rational than recommendations based on professional advice (Kiome and Stocking, 1995). Thus, erosion and conservation cannot be understood without studying how people use the land and the reasoning that guides their decisions about land use (Mazzucato

and Niemeijer, 2000; Mbaga-Semgawale and Folmer, 2000; Stocking, 1993). The present research explores what farmers in the Beressa watershed of the Ethiopian central highlands think of soil erosion problems and its control. The specific research objectives were 1) to investigate farmer perceptions of the soil erosion problems and its magnitude, and 2) to document farmers' conservation knowledge and practices.

## 4.2 The research site

The Beressa watershed is located in the central highlands of Ethiopia (9°40' N, 39° 37' E) approximately 140 km to the northeast of Addis Ababa, the capital city (Figure 4.1). In administrative terms, the watershed lies within the North Shewa Zone of the Amhara National Regional State and is comprised of three villages – Debele, Wushawushign and Faji.



**Figure 4.1.** Location of the Beressa watershed

The area is situated on the edge of the western escarpment of the Rift Valley, and is characterized by a rugged topography. Elevation ranges between 2740 and 3600 m a.s.l. The watershed covers an area of about 215 km<sup>2</sup> and forms part of the headwater of the Blue Nile basin. Both the Inter Tropical Convergence Zone (ITCZ) and the sub-tropical pressure cells influence the area's climate. It experiences a temperate climate with an average annual temperature of 19.7 °C and a mean annual rainfall of 887 mm (1984-2002). About 83% of the total rain falls between May and September. Frost is common particularly between October and December when temperatures fall far below average. Soil types found in the area are predominantly volcanic in origin and belong to the Trappean series.

The area lies within the high potential cereal crop and livestock zone of the country's central highlands (Westphal, 1975; Wolde-Mariam, 1991), and agriculture is characterized by integrated subsistence crop-livestock production. The integration of crop and livestock



production has long sustained the area. Crop residues constitute the main source of feed for livestock, and livestock, in turn, provide the traction power and manure for fertilizing cultivated fields. The main crops grown include barley, wheat, beans, field peas, and lentils. Barley is the dominant crop cultivated in Debele and sometimes is rotated with wheat and beans. In Wushawushign and Faji, however, farmers often rotate barley with other crops. Cattle, sheep, donkeys, horses, mules, and poultry are among the common types of livestock raised in the area. Farming is almost entirely rain-fed, and is dependent on weather conditions. Hence, farmers worry very much about rainfall – its intensity, irregularity, or complete failure (Ezra, 1997) – as agriculture is primarily subsistence-based. Occasionally farmers sell a portion of their produce (crops and livestock) to earn cash income for covering expenses such as taxes, school fees, and household items.

### 4.3 Methods

Data were obtained from a survey undertaken in the three villages of the Beressa watershed (Debele, Wushawushign, and Faji). Table 4.1 presents characteristics of the villages and the sample households by village.

An agro-economic survey was conducted from February to April of 2003 using a structured survey questionnaire to obtain farmers' views of erosion problems and their conservation knowledge. The questionnaire comprised of both open-ended questions and questions with codified answers, and was administered after pre-testing. The questions pertained to four main topics: (1) household and farm characteristics, (2) perceptions of erosion problems and fertility changes, (3) causes of erosion and productivity decline, and (4) knowledge and use of conservation measures.

**Table 4.1.** Characteristics of the sample households

Characteristics	Villages		
	Debele	Wushawushign	Faji
Total number of households	1322	1656	819
Sample households	54	59	34
Area (hectares)	6427	8393	6688
Mean elevation (m)	3220	2940	2770
Mean slope (%)	17.6	11.6	6.1
Agro-climate	Alpine	Temperate	Temperate
Main crops*	BR, BN	BR, BN, WT, P	BR, WT, LT
Main SWC measures <sup>§</sup>	ST/B, WW, CP	ST/B, DD, WW, CP	DD, GS, CP

\* BR: Barley, BN: Beans, WT: Wheat, P: Peas, LT: Lentils,

<sup>§</sup> ST/B: Stone terraces/bunds, WW: Waterways, DD: Drainage ditches, GS: Grass strips, CP: Contour ploughing

A systematic random sample of 147 farm households was selected from the three villages for personal interviews. The sampling was done using a list obtained from the respective village administrations. Every twentieth household on the list is included in the sample. A household

in this case consists of a cohort of one family - a husband, a wife, and children with other dependents if any – living in the same house and depending on the same farmland and farm resources. The head of the household is considered to be the unit of analysis because s/he was the ultimate decision-maker with respect to farming activities. Well-trained interviewers who could understand the local language administered the questionnaire, and the head of the household was interviewed. When the head of the was unavailable (after repeated visits), interviews went to the next household on the list. Additional information was obtained through in-depth interviews and community group discussions. In each village, discussion groups were composed of eight people, both males and females of differing ages. SPSS (Statistical Package for Social Scientists, version 10) was used to analyze the data on which case summaries and cross tabulations were performed.

## **4.4 Results and Discussion**

In this section, the paper presents and discusses the results of the survey conducted in the Beressa watershed. Subsequent to the description of household and farm characteristics, farmers' perceptions of erosion problems are presented. This is followed by data on farmers' perceptions of the causes of erosion and productivity decline as well as on aspects of soil fertility change. Finally, farmers' knowledge and use of conservation measures are discussed.

### **4.4.1 Household and farm characteristics**

Table 4.2 presents the characteristics of the sample households included in the survey. Farmers ranged in age between 20 and 76 years, with an average of 45 years. Of the total respondents, 22% were female, mainly divorcees, widows, and unmarried women. The literacy rate in the area, as elsewhere in rural Ethiopia, was very low. Over half of the total respondents (59%) were illiterate while only 22% could read and write. Only 19.7% of the total had any formal education, either at elementary or secondary level. Differences literacy rates among the surveyed villages may be due to their proximity to Debre Birhan town, where there may be a more positive attitude towards and exposure to formal education.

All of the interviewed farmers owned land (in fact, land has been under public ownership since the 1975 land reform, and farmers have only insecure use rights). Overall, 713 farm plots were managed by the participating farmers. The mean holding size was 1.7 ha, which is higher than the national average of 1.29 ha. However, almost one-third of the households owned less than 1 ha and it should be noted that land holding size has been declining over time due to population increase. Considerable difference in holding size was observed across villages within the watershed. In the upper villages, where there is a greater proportion of steep slopes and limited non-farm opportunities, per household holding size was smaller. Since land holdings were not all in one piece, the number of farm plots ranged from 1 to 11 (with one exception of 25 plots). The mean was five plots per household. Farmers expressed differing views regarding the advantages of fragmented plots.

As indicated in the sections above, livestock constitutes an important component of the farming system and livelihoods in the area. All of the interviewed farmers owned livestock of some sort. The average livestock holding was 5.9 Tropical Livestock Units (TLU). Overall there is a declining trend in livestock numbers per household due to shrinking per capita land area. Over the last ten years, for instance, per household land area decreased from 2.4 to 1.7 ha, and livestock numbers decreased from 7.7 to 5.9 TLU. Nevertheless, differences were observed across villages (Table 4.2). It appears that livestock numbers increase with decreasing elevation, increasing farm size, and proximity to the urban centre of Debre Birhan town.

**Table 4.2.** Characteristics of the respondents

Characteristics	Debele	Wushawushign	Faji	Average
Age (yr.)				
Mean	46	42	47	45
SD.	11	12	14	12
Sex (%)				
Male	74	81	79	78
Female	26	19	21	22
Education (%)				
Illiterate	59	62	52	58
Write and read	26	18	21	22
Elementary	11	17	18	15
Secondary and above	4	2	9	5
Average family size	6	5	5	5
Land holding (ha.)				
Mean	1.3	1.8	2.1	1.7
SD	2.3	2.9	5.3	3.5
Number of farm plots				
Mean	4	6	5	5
SD	2	2	3	2
Average livestock number (TLU)	5.1	5.3	7.3	5.9
Oxen number				
Mean	1.3	1.5	1.6	1.5
SD	0.9	0.8	0.8	0.8

#### **4.4.2 Perceptions of erosion problems**

Soil erosion was perceived by the farmers of the Beressa watershed as a problem constraining crop production. Seventy-two percent of the interviewed farmers reported erosion problems on their farmland – 72% in Debele, 76% in Wushawushign, and 67% in Faji (Table 4.3). Most of these respondents observed the prevalence of erosion damage during the first rain showers when the soil is bare (before vegetative growth) and loose due to tillage. The farmers also reported damage due to wind erosion particularly when the aggregate stability of the soil was disturbed through tillage. Farmers expressed the opinion that the loss of soil from cultivated fields reduced the depth of the topsoil and lead to a reduced production potential.

Erosion in the form of sheet wash and rills was the dominant form of erosion mentioned by the majority of the farmers (Table 4.3). Of the farmers who reported erosion problems, 91% mentioned the prevalence of sheet and rill erosion on their farmland. Although not widespread, gully erosion was also reported by farmers along farm boundaries and waterways used to expel excess water. However, the majority (84%) of the farmers rated the extent of the problem as moderate and/or minor. Further discussions revealed that farmers considered erosion to be severe when the visible signs – rills and gullies – appeared on their fields. This shows that although farmers were aware of erosion problems, their understanding of the severity was confined mostly to visual evidence. However, it was clear from field observation that both sheet and rill erosion caused considerable damage to cropland and that farmers' limited understating of the severity of sheet erosion could influence their conservation decisions negatively. This suggests that farmers would benefit from education that would better explain erosion processes and impacts.

Farmers were asked to indicate the rate of erosion over time. Forty-eight percent of the interviewees rated erosion as increasing; 28% felt there was no change, and 24% felt it was decreasing. Those who indicated that the rate was increasing were mainly from Debele, an area where most of the farm plots lie on steep slopes.

#### **4.4.3 Causes of soil erosion and productivity decline**

The major causes of soil erosion mentioned by farmers included erosive rains, steep slope, damaged conservation structures, and tillage, which makes the soil loose and bare (Table 4.4). Rainfall leads to significant soil loss mainly at times of seedbed preparation. Over half of the farm plots managed by the total respondents were located on slopes having more than a 10% gradient. Given higher rainfall conditions, farm plots on steep slopes will exhibit a higher erosion potential (Nyssen et al., 2004). Farmers also recognized the effects of slope on soil erosion. Yet, few respondents indicated that damaged conservation structures escalated the problem. Farmers' did not refer to crop types when mentioning the causes of soil erosion.

**Table 4.3.** Farmers' views of soil erosion problems, types, and ratings of its seriousness (Percentage of the respondents)

Farmers' responses to:	Debele (n=54)	Wushawushign Faji (n=59)	(n=34)	Total (n=147)
<i>Prevalence of soil erosion</i>				
Yes	72	76	67	72
No	28	24	33	28
<i>Prevailing form of erosion</i>				
Sheet erosion	68	60	55	61
Rill erosion	21	32	36	30
Gully erosion	12	8	9	10
<i>Extent of soil erosion</i>				
Severe	13	16	18	16
Moderate	55	43	45	48
Minor	32	41	36	36
<i>The rate over time</i>				
Increasing	68	47	28	48
Same	20	23	41	28
Decreasing	12	30	31	24

**Table 4.4.** Perceptions of the causes of soil erosion and productivity decline (Percentage of the respondents)

Farmers' responses to:	Debele (n=54)	Wushawushign Faji (n=59)	(n=34)	Total (n=147)
<i>Causes of soil erosion</i>				
Erosive rains	44	40	40	41
Slope steepness	33	26	44	34
Damaged conservation structures	16	10	8	11
Tillage/lack of vegetation cover	n.r.	4	4	4
<i>Causes of productivity decline</i>				
Rainfall shortage/drought	67	73	45	62
Fertility decline	8	13	23	15
Continuous cultivation	14	7	19	13
Soil erosion	8	4	n.r.	6
Frost	2	n.r.	13	8
Others	2	4	n.r.	3

\*n.r. is for *no response*, and the average is taken only from those that responded.

Productivity decline was reported by almost all of the interviewed farmers, and they attributed the decline to rainfall shortage, fertility decline, and continuous cultivation (Table 4.4). As the farmers indicated, the rainfall pattern in recent times had become more unreliable

and incompatible with their usual farming calendar. This observation agrees with those of Bewket and Sterk (2002) in the western Ethiopian highlands, Dejene et al. (1997) in Tanzania, and Visser et al. (2002) in Burkina Faso, and reflects the recent drought in many parts of sub-Saharan Africa. However, although soil erosion can cause a reduction in infiltration and the water holding capacity of the soil as well as a loss of plant nutrients, few farmers attributed productivity decline to erosion.

#### **4.4.4 Soil fertility changes**

Next to water shortage, soil fertility was the most important production concern mentioned by the farmers of the Beressa watershed. When the quality of land was mentioned, farmers often associated it with soil fertility. A similar view was held among the farmers of Wolayta in Southern Ethiopia (Elias and Scoones, 1999).

Over 70% of the farmers reported a decline in soil fertility in their farm plots over the years. The reasons given included continuous cultivation (46%), soil erosion (24%), insufficient use of artificial fertilizers (21%), and moisture stress (5%). The remaining 4% gave no reasons. Population increases have limited the use of fallowing, and continuous cultivation has become an inevitable practice in the area. The absence of adequate inputs often results in deteriorating soil fertility and disturbs the soil structure thereby accelerating erosion. Thus, the farmers noted that resting the land for some time helps reduce erosion quite apart from its role in nutrient maintenance. Moreover, since erosion reduces the depth of the topsoil and its moisture-holding capacity, the loss of organic-rich topsoil is a constraint to improved production. Nevertheless, the effects of erosion on the loss of soil fertility were given little attention by the majority of farmers. Further, it became clear from the interviews and discussions that the farmers' understanding of soil fertility change largely influenced their management practices.

Farmers undertook a range of practices for soil fertility maintenance: crop rotation; application of organic matter (animal manure, household trash, and crop residues); use of chemical fertilizers; and erosion control. While crop rotation and erosion control were widespread practices in the area, spatial differences in the intensity of use of organic matter and chemical fertilizers were observed. The farmers in Debele depend heavily on organic matter, while those in Wushawushign and Faji use both organic matter and chemical fertilizers. Overall, farmers were well aware of the positive effects of organic matter in improving soil fertility. Apart from fertility maintenance, they indicated that organic matter improved soil structure and reduced runoff. Regarding the effects of organic matter on soil biology, farmers mentioned the proliferation of earthworms as being good indicators of soil fertility. However, the lack of fuel wood and the use of crop residues and dung for fuel limited the use of organic matter and resulted in the deterioration of biological processes in the soil (see Hurni, 1993). Most farmers were involved in selling manure in the urban market where it was in high demand as fuel. This appeared to be a "normal" practice for resource-poor farmers who used manure for cash income rather than for fertilizer. At the same time,

chemical fertilizers were unaffordable to resource- poor farmers, and poorly developed credit facilities, lack of subsidies, and unreliable rainfall conditions often prohibited the use of fertilizers. The combined effect of all of these socio-economic and institutional problems has been and is leading to deterioration of soil fertility.

#### 4.4.5 Knowledge and use of conservation techniques

When asked whether erosion could be stopped, all respondents indicated that it could be controlled. They enthusiastically expressed the belief that they could control erosion on their farm plots. Such a view agrees with the results of Tegene (1992) in the southwestern highlands and Bewket and Sterk (2002) in the northwestern highlands of Ethiopia. Indeed, the idea of soil conservation is not new to Ethiopian farmers as the many traditionally implemented techniques in various parts of the country would indicate (Herweg, 1993). Yet, little is known about this pool of local expertise of farmers, and the technical and socio-economic appropriateness of their technologies has rarely been analyzed.

Almost all of the farmers reported using SWC measures for erosion control. The measures mentioned include stone terraces/bunds, drainage ditches, soil bunds, waterways, grass strips, contour ploughing, and tree planting (Table 4.5). Contour ploughing, drainage ditches, and stone terraces/bunds constituted the most important local conservation measures, knowledge of which was acquired by farmers through years of farming experience.

Contour ploughing was widely used in the area. The practice was primarily intended for SWC, though it also helped to reduce the need for traction power. Farmers used contour ploughing irrespective of slope steepness. When asked when the practice began, the farmers explained that they inherited it from their ancestors. Contour ploughing demands no more labour than ploughing and, hence, is an efficient technique for reducing runoff mainly in moderately and gently sloping areas. On steep slopes, as farmers noted, contour ploughing needed to be used together with terraces and bunds to effectively control erosion.

**Table 4.5.** Type and use of SWC measures (*percentage of the respondents*)

Type of SWC measure	Debele (n=54)	Wushawushig (n=59)	Faji (n=34)	Total (n=147)
Contour ploughing	84	88	78	83
Drainage ditches	83	88	75	82
Stone terraces/bunds	84	72	63	73
Waterways	28	16	25	23
Tree planting	13	33	22	23
Grass strips	33	16	16	22
Soil bunds	27	11	6	15
Others	11	5	-	5

Note: Total over 100% is due to multiple responses

Drainage ditches, also known as traditional ditches, were indigenous practices widely used by almost all farmers of the area for erosion control. These are micro-channels constructed on cultivated fields to drain off excess water. Construction involves pressing the plough deep into the ground and running it diagonally across the farm plot. Ditches are different from normal plough furrows (in dimension and orientation), and their construction is executed in every cropping season (see Alemayehu, 1996). Farmers connect the ditches to waterways constructed alongside the farm plots for the safe disposal of excess water. They explained their importance as follows: “*kezera gebere yaboyew yibeltal*,” a saying which literally means “a farmer who constructs drainage ditches is better by far than one who sows without.” Ditches were one of the most favored conservation techniques for at least two reasons: (1) they demanded less labor for construction, and (2) they were effective in protecting the farm plot from upslope runoff and associated soil loss.

The use of stone terraces is an age-old conservation tradition in the area, although stone terraces also have been introduced by the Ministry of Agriculture over the past few decades. The introduced terraces do not currently retain their original design as the farmers have modified and adapted them to fit local conditions. According to most farmers, terracing is effective in erosion control, although it is labour-intensive, hosts rodents, and returns investment only gradually. Two different types of stone terraces were identified on cultivated fields – those at field boundaries and those within the farm plot. Stone terraces at field boundaries are more stable and farmers let grasses grow on the risers. These structures develop over time into stone bunds. Besides helping with soil and water conservation, the structures serve as boundaries between the adjoining farm plots of different owners. On the other hand, terraces within a farm plot are periodically destroyed and reconstructed when farmers think too much soil has become entrapped. This was an indigenous practice, which they called locally *erken meshar*, and which literally means terrace destruction. According to the farmers, *erken meshar* is practiced to redistribute the entrapped soil and help reduce rodent breeding. In addition, it helps to enhance soil fertility and improve the infiltration capacity of the soil. A new stone terrace is then constructed slightly downhill from the previous (i.e., the destroyed) terrace. Such practices illustrate the dynamics of adoption and adaptation of SWC technologies to fit local conditions.

Although not widespread, the use of soil bunds was also mentioned by farmers. This practice was promoted by past conservation projects carried out in the area. Adoption of the measure, however, was limited to less steep slopes and to areas where stone availability was limited. Farmers indicated the inappropriateness of the soil bunds on steep slopes where runoff is high.

Waterways are permanent structures constructed alongside the cultivated fields. These structures are wider and deeper than the ditches and normally require maintenance and the dredging of sediments, chores taken care of by farmers of adjacent plots. Although farmers mentioned the use of tree planting for SWC, it was observed that the trees were planted for firewood and construction purposes. Eucalyptus was the dominant species and was more



often planted in home compounds than on farmland, indicating that agroforestry practices for erosion control were limited.

In discussions, farmers indicated that they had been using stone terraces/bunds, drainage ditches, and contour ploughing since time immemorial. Many of them indicated that they inherited most of these techniques from their fathers and forefathers, though preferences largely depended on perceived effectiveness and workability. They further said that “we are well aware of how and where to install conservation measures (and where not to) as opposed to government-dictated measures, which often don’t consider appropriateness.” Since farmer preferences largely depended on perceived effectiveness and workability, spatial differences in the intensity of conservation strategies used were observed. For instance, stone terraces/bunds were predominantly used in Debele, while a wider use of drainage ditches was observed in Wushawushign and Faji (Table 4.5), perhaps due to differences in slope and the availability of stones for construction. This illustrates that the farmers of the Beressa watershed were well aware of conservation techniques.

## 4.5 Conclusions

Farmers’ decisions pertaining to SWC are largely determined by their knowledge of the problem and the perceived benefits from conservation. The results of this research show that over 70% of the farmers in the Beressa watershed in the central highlands of Ethiopia recognized soil erosion problems, and were of the opinion that conservation was necessary. Sheet and rill erosion were the dominant forms mentioned by 91% of the farmers. However, the farmers consider erosion to be severe mostly when the visible signs – rills and gullies – appeared in their fields. This shows that although farmers are aware of erosion problems, their understanding of its severity is confined mostly to visible evidence.

Farmers use a range of techniques for erosion control. Among them, contour ploughing, stone terraces/bunds, and drainage ditches constitute the most widely used techniques, although spatial differences in the intensity of use were observed within the watershed. Further, farmers have been changing and adapting techniques to fit local requirements. *Erken meshar* is an indigenous practice which farmers use to improve the effectiveness of stone terraces. It is used to redistribute entrapped soil at the edge of the terraces and to reduce rodent breeding. In addition, drainage ditches are the preferred and most widely practiced conservation measures because they are less labour demanding and more effective in expelling excess water after heavy rain showers. Apart from erosion control, farmers use a mix of fertility enhancing practices such as crop rotation and the application of animal manure. Farmers are aware of the multiple benefits of organic matter. However, the intensity of application is limited by the opportunity to market manure in urban centres and by distant farm locations that impose labour constraints.

Overall, farmers accept and use conservation technologies that enhance productivity and offer short-term benefits rather than technologies requiring long-term investments. Perhaps this is related to the subsistence nature of the farm economy and immediate demands

for improved yield. This research, therefore, demonstrates the wealth of conservation knowledge available among farmers. It suggests that conservation interventions should take into account farmer perceptions of problems, understand farmer priorities and the conditions that influence their decisions, and make good use of their indigenous knowledge.

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## Chapter 5

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### **Determinants of adoption and continued use of stone terraces for soil and water conservation in an Ethiopian highland watershed**

**Aklilu Amsalu and Jan de Graaff**  
Ecological Economics, *In Press*.

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## **5. Determinants of adoption and continued use of stone terraces for soil and water conservation in an Ethiopian highland watershed**

### **Abstract**

In the Ethiopian highlands, land degradation resulting from soil erosion and nutrient depletion is a serious environmental and socio-economic problem. Although soil and water conservation techniques have extensively been introduced over the past decades, sustained use of the measures was not as expected. Based on data obtained from 147 farming households, this paper examines the determinants of farmers' adoption and continued use of introduced stone terraces in an Ethiopian highland watershed. A sequential decision-making model using the bivariate probit approach was employed to analyze the data. The results show that the factors influencing adoption and continued use of the stone terraces are different. Adoption is influenced by farmers' age, farm size, perceptions on technology profitability, slope, livestock size and soil fertility, while the decision to continue using the practice is influenced by actual technology profitability, slope, soil fertility, family size, farm size and participation in off-farm work. Perceptions of erosion problem, land tenure security and extension contacts show no significant influence. Further, the results indicate the importance of household/farm and plot level factors in farmers' conservation decision. It is therefore concluded that 1) analysis of the determinants of adoption *per se* may not provide a full understanding of the range of factors influencing farmers' decision of sustained investments and 2) conservation interventions should not focus only on the biophysical performance of the measures but also on economic benefits that can be obtained at reasonable discount rates to the farmers in order to enhance sustained use of the measures.

*Keywords:* Stone terraces; Sustained adoption; Land tenure; Livestock production; Sequential modelling; Ethiopia

### **5.1 Introduction**

The reason for the poor performance of agriculture in many low-income countries is believed to be partly the deterioration of the natural resource base (Grepperud, 1995). Land degradation due to soil erosion and nutrient depletion is considered to be the main problem constraining the development of the agricultural sector. The problem is very serious particularly in the tropical steep lands where rainfed agriculture constitutes the main livelihood of the people (El-Swaify, 1997; Hurni, 1988; Rymshaw et al., 1997; Shiferaw and Holden, 2001a). In many of these countries, however, various soil and water conservation (SWC) programs have been unsuccessfully tried to mitigate the land degradation problem

(Shiferaw and Holden, 1998). Among others, poor adoption and transitory use of conservation techniques are often mentioned as the major factors limiting efforts aimed at restoration of ecology.

In Ethiopia, agriculture constitutes the largest share of the national economy contributing for 42% of the GDP (2003/04) and 80% of the total employment (MoFED, 2004). Nevertheless, diminishing productivity due to soil erosion induced degradation of agricultural land has been a great concern (EFAP, 1994; Hurni, 1988). The problem is serious particularly in the highlands (>1500 m a.s.l.) that comprise nearly 44% of the country's total area, 95% of the cultivated area, about 88% of the human population, and two-thirds of the country's livestock (Kruger et al., 1996). Although estimates of the extent and rate of soil erosion lack consistency, the results of various studies highlight the severity of the problem. Estimates show that 3.7% of the highlands (2 million ha) had been so seriously eroded that they could not support cultivation, while a further 52% had suffered various levels of degradation (Kruger et al., 1996; Wood, 1990).

Despite the severity of the problem, it is only very recently, in the past three decades, that land conservation has received policy attention in the country. Conservation projects have been extensively carried out under the auspices of the World Food Program's food-for-work scheme. Focus of the projects has been on the formulation of technological prescriptions for resource-poor farmers. A range of conservation practices, which include stone terraces, soil bunds and area closures, have been introduced into individual and communal lands at massive scales. However, the trend hitherto shows that the projects have had a limited success in addressing the problem. Among others, the approach pursued in the development and transfer of the conservation practices has been considered as contributing to the ineffectiveness of the projects (e.g. 2000; Shiferaw and Holden, 1998), leading to problems of adoption and continued use of the technologies already adopted.

This research is aimed at examining the determinants of farmers' adoption and continued use of introduced conservation technologies in a case study watershed in the Ethiopian central highlands. The specific technique under study is a stone terrace that has been widely promoted over the past decades in the area. The paper is organized as follows. In section 2, we provide a theoretical context to conservation investments. We specify the model in section 3. The research site and data and the variables are described in section 4 and 5 respectively. Results and discussions are given in section 6. Finally, section 7 concludes the paper.

## **5.2 Theoretical context**

The problem of technology adoption in environmental management is increasingly becoming a key issue for researchers and users of natural resources (Guerin, 1999). Hence, research on constraints to the adoption of SWC practices is gaining increasing recognition as the availability of effective technologies is of little value to the individual or society unless it is applied (McDonald and Brown, 2000; Smit and Smithers, 1992).

Experience has shown that appropriate technologies are not always adopted, even where the need is obvious (Guerin, 1999). Farmers may reject or abandon many technologies that have been useful, and adopt others in their place since they consider a variety of factors in deciding whether or not to adopt particular conservation practices (McDonald and Brown, 2000; Soule et al., 2000). This highlights the need to develop a better understanding of the conditions that encourage sustained adoption of conservation practices (Lapar and Pandey, 1999).

McDonald and Brown (2000) indicated that farmers rarely sustain the technical solutions offered by external interventions in the long term unless consideration is given to the various socio-economic, cultural and institutional, as well as biophysical and technical factors. According to Lapar and Pandey (1999), such factors could be farmer-specific, farm-specific, and technology-specific. In addition, Guerin (1999) noted problems in the transfer and adoption process, particularly the lack of testing and the limited role of extension agents, as important reasons for non-adoption of recommended technologies. Smit and Smithers (1992) give emphasis to the nature and characteristics of the innovation being relevant to improving the rates of adoption.

One reason for the lack of agreement on relevant factors and barriers is the high degree of locational and technological specificity of environmental practices (Wandel and Smithers, 2000). For instance, empirical research in the Philippines (Lapar and Pandey, 1999) revealed that adoption of conservation practices depends on several plot and farmer characteristics and the relative importance of these factors differs across sites. Nevertheless, empirical information on the factors that determine farmers' investment decision in SWC in developing countries is limited (Baidu-Forson, 1999; Pender and Kerr, 1998). There are relatively many reports on the constraints of farmers' adoption of conservation measures. The conditions that influence sustained use of the measures after adoption remain, however, little investigated.

### **5.3 Model specification**

The analytical model presented in this paper is based on the literature on conservation investments. Logit and probit models have extensively been used in the study of farmers' adoption decision of conservation technologies (e.g. Baidu-Forson, 1999; Burton et al., 1999; Franzel et al., 2001; Lapar and Pandey, 1999; Soule et al., 2000). Both of these models provide the possibility of analyzing the probability of adoption or non-adoption of introduced conservation technologies.

However, decision-making on adoption and continued use of introduced conservation measures is generally a multistage process undertaken most often sequentially (see Paudel and Thapa, 2004). De Graaff et al. (2005) divided the process of technology adoption into three phases: acceptance, actual adoption, and continued use. According to Jabbar et al (1998), the adoption process involves a sequence of learning, adoption and continued or discontinued use of introduced conservation technologies. On the other hand, Feather and



Amacher (1994) used a two-stage process model to specify varying intensity levels of use once the initial decision to adopt has been made. Similarly, Shiferaw and Holden (1998) employed a two stage conservation decision model: a model of perception of erosion problem in the first stage and a model of adoption and level of use of conservation practices in the second stage of their analysis.

We developed a sequential model using the bivariate probit estimation (biprobit) with sample selection procedure to investigate the determinants of farmers' adoption and sustained use of stone terraces. As all the farmers included in the study had prior knowledge about the stone terraces, we specified a two stage model for adoption and continued use. The model is applied sequentially in two stages to regress the variables that explain the likelihood of adoption and further investigate the variables that explain the probability of continued use of the technology. Hence, the farmers are grouped as 'adopters' and 'non-adopters' in the first stage of the analysis, and as 'continued using' and 'not continued using' in the second stage for adopters of the practice.

Therefore, we assume unobserved or latent variables  $Y_{1i}^*$  and  $Y_{2i}^*$  that generate observed variables  $Y_{1i}$  and  $Y_{2i}$ , which represent farmers' adoption decision and continued use of conservation practices, respectively. Following Greene (2000), the two equations are specified as follows:

$$Y_{1i}^* = \beta_1 X_{1i} + \varepsilon_{1i}$$

$$Y_{2i}^* = \beta_2 X_{2i} + \varepsilon_{2i},$$

where  $\beta_1$  and  $\beta_2$  are parameters to be estimated;  $X_{1i}$  and  $X_{2i}$  are vectors of explanatory variables; and  $\varepsilon_{1i}$  and  $\varepsilon_{2i}$  are normally distributed random errors. We observed data for the second stage of the analysis (continuity of use) only for adopters of the conservation practice. The bivariate probit model with sample selection is, therefore, specified as follows:

$$Y_{1i} = 1 \quad \text{if } Y_{1i}^* > 0; \quad 0 \text{ otherwise,}$$

$$Y_{2i} = 1 \quad \text{if } Y_{2i}^* > 0 \text{ and } Y_{1i}^* > 1; \quad 0 \text{ otherwise.}$$

In this case, three categories of observations with their respective unconditional probabilities can be identified.

$$Y_{1i} = 1, Y_{2i} = 1: \text{Prob}(Y_{1i} = 1, Y_{2i} = 1) = \Phi_2(\beta_1 X_{1i}, \beta_2 X_{2i}, \rho)$$

$$Y_{1i} = 1, Y_{2i} = 0: \text{Prob}(Y_{1i} = 1, Y_{2i} = 0) = \Phi_2(\beta_1 X_{1i}, -\beta_2 X_{2i}, -\rho)$$

$$Y_{1i} = 0: \text{Prob}(Y_{1i} = 0) = \Phi(-\beta_1 X_{1i})$$

where  $\Phi_2$  is a bivariate normal cumulative distribution function,  $\Phi$  is a univariate normal distribution function,  $n_{1,1}$  is the set of observations  $i$  for which  $Y_{1i} = Y_{2i} = 1$  (those who are adopters and continue using the practice),  $n_{1,0}$  is that for which  $Y_{1i} = 1$  and  $Y_{2i} = 0$  (those who are adopters but did not continue using it), and  $n_0$  is those observations for which  $Y_{1i} = 0$  (respondents who are not adopters and, therefore, did not continue using it). The corresponding log-likelihood function is then:

$$L_i = \sum \ln n_{1,1} \Phi_2(\beta_1 X_{1i}, \beta_2 X_{2i}, \rho) + \sum \ln n_{1,0} \Phi_2(\beta_1 X_{1i}, -\beta_2 X_{2i}, -\rho) + \sum \ln n_0 \Phi(-\beta_1 X_{1i})$$

The estimation was done employing Stata/SE 8.2 software. After running the model, the results were taken to the field and discussed with the farmers.

#### **5.4 The research site and data**

This research is undertaken in the Beressa watershed located in the central highlands of Ethiopia. The area lies approximately 140 km to the northeast of Addis Ababa, the capital city, on the way to Dessie. The area is known for higher levels of land degradation in the country (FAO, 1986). The average annual rainfall is 887 mm (1984-2002), with over 80% of the total rainfall between May and September. Elevation ranges between 2740 and 3600 m a.s.l. The Beressa watershed is an agricultural watershed that is settled by rainfed agriculturalists for several thousands of years. Agriculture is dominated by mixed crop and livestock farming. Yet, the area exhibits a subsistence economy where most of the agricultural production is for own consumption. The main crops grown include barley, wheat, beans, field peas, and lentils. Cattle, sheep, donkeys, horses, mules and poultry are among the common livestock types raised in the area. It is rare to find a farming household not raising livestock of any kind.

Given a population growth rate of 3% per annum (the national estimate), the pressure on land resources has led to agricultural intensification but with limited use of conservation measures and fertility amendments. As a result, soil erosion and nutrient mining becomes a serious problem in the area. On the other hand, the area is perhaps one of the most intervened areas through various conservation and rehabilitation works by governmental and donor organizations for several decades. Among others, stone terrace construction on cultivated areas was the main activity that has been undertaken through campaign works by mobilizing farmers' labour. The construction involved collecting of stones and lay them down according to prescribed dimensions and positions by the coordinating organ, which is the Ministry of Agriculture.

Data for this research was mainly obtained through a household survey that was conducted during the 2002/2003 cropping season using a structured survey questionnaire. A random sample of 147 farm households managing 713 farm plots was included in the survey. Of the total, 95 farmers were adopters of the stone terraces out of which 52 farmers continued

using the practice after adoption. Farmers were interviewed using the survey questionnaire. The instrument included questions pertaining to farmers' personal attributes, farm characteristics, the technology, socio-economic and institutional factors. Further, interviews and discussions were held with key informants and groups of farmers, and with government officials and workers of non-governmental organizations concerned in the conservation of soil and water. Table 5.1 depicts the characteristics of adopters, non-adopters and continued users of the stone terraces in the watershed area.

**Table 5.1.** Characteristics of adopters, non-adopters and continued users of introduced stone terraces in the Beressa watershed, highlands of Ethiopia.

	Adopters	Non-adopters	Continued users
Number of sample households	95	52	52
Average age of the farmer	47	39	48
Average household size	5.6	4.8	5.4
Average farm size (ha)	1.70	1.55	1.80
Total number of plots	483 (5.3)*	230 (4.7)	304 (5.4)
Total number of plots with stone terraces	163 (1.9)*	-	99 (1.7)

\* Mean values in parentheses.

## 5.5 Empirical analysis and variables

In this research, adoption is defined by considering the implementation of introduced stone terraces on farmers' plots. A farmer is considered adopter (ADOPT) of the stone terraces if s/he implemented the measure at least in one of her/his plots. Hence, non-adopters include those farmers who never used the stone terraces introduced in any of their plots. Based on this information, the farmers were classified into two categories: adopters and non-adopters of the technology. Once the response on adoption/non-adoption is obtained, further investigation was made on continued use of the practice, given a positive response on adoption. In this case, the current state of the farmers regarding continuity of use of the stone terraces is considered. Adopters were considered to be continued users (CONTUSE) if they kept the stone terraces in any of their plots and continued investing in it. In case of inconsistencies in farmers' responses, field visits were carried out for verification. The term non-adoption in this study does not take any negative connotation on the farmers for not employing introduced conservation structures.

A range of explanatory variables was considered, although the use of these variables often lacks consistency in the conservation literature. Previous studies have related farmers' conservation decisions to a range of variables that are often classified as personal, physical, socio-economic and institutional factors (Baidu-Forson, 1999; Bekele and Drake, 2003; Lapar and Pandey, 1999; Mbaga-Semgawale and Folmer, 2000). In this research, the variables considered relate to personal attributes, plot and cropping characteristics, the

technology, socio-economic and institutional factors. Taking into account the level of their effect, we classified the variables into two categories: household and/or farm level attributes and plot level attributes. Collinearity diagnostics using multivariate analysis indicated weak correlation ( $r < 0.3$ ) among the independent variables included in the analysis. Table 5.2 presents description and summary statistics of the variables used.

### **5.5.1 Household/farm level attributes**

The most important household/farm level attributes considered in the analysis include farmers' age (AGE), sex (SEX), family size (FAMSIZ), farm size (FARMSIZE), perceptions on erosion problem (PERCEROS), perceived profitability of the technology (PERPROF), off-farm work (OFFFARM), livestock holding (LIVESTOC), perceptions on land tenure security (PERCTENU) and contacts with extension agents (EXTEN).

The effect of age of the farmer on conservation decision may be either negative or positive (Baidu-Forson, 1999; Bekele and Drake, 2003; Lapar and Pandey, 1999). Older age often associated with long years of farming experience could positively influence conservation decisions. In contrast, younger farmers with longer planning horizons are likely to invest more in conservation. The difference in the level of conservation investments between male-headed and female-headed households is also examined.

Family size might have dual effects on land users' conservation decisions. Large family size may relax labour constraints needed for the construction and maintenance of conservation measures. Further, it may encourage investment in conservation practices due to the higher demand for more produce. The effect is, therefore, expected to be positive.

The influence of farmers' perception of erosion problems on their conservation decision is well documented in the literature (Mbaga-Semgawale and Folmer, 2000; Shiferaw and Holden, 1998). Farmers who perceived the problem better are expected to invest more in conservation, suggesting a positive hypothesized effect.

The effect of farm size on conservation decision is not clear. Large farms could reflect greater capacity that encourages conservation (Cramb et al., 1999). On the other hand, more land may reduce the need to conserve land (Gebremedhin and Swinton, 2003), while the potential loss of land for conservation may discourage investments on small farms.

Inclusion of perceived technology profitability variable is based on the assumption of the technology characteristics-user's context model in which the characteristics of the technology underlying land users' agro-ecological, socio-economic and institutional contexts play a central role in the adoption decision process (Scoones and Thomson, 1994). Hence, the effect on conservation decision is expected to be positive.

Participation in off-farm work could keep the labour force needed for conservation away from the farm. Further, income obtained from off-farm work may obscure the benefits accruing from investments in conservation. By contrast, income from off-farm work may be used to hire labour for stone terraces. Therefore, the effect of off-farm work on conservation is difficult to determine *a priori*.

As indicated in the sections above, livestock ownership is an important component of the farming system in the area since farming is integrated with crop and livestock production. Therefore, the fact that livestock is considered as an asset that could be used in the production process or exchanged for cash or other productive assets suggests a positive influence on conservation decision (Bekele and Drake, 2003). Conversely, more specialization into livestock away from cropping may reduce the economic impact of soil erosion, and/or increase the availability of manure needed to counter nutrient depletion (Shiferaw and Holden, 1998). The effect on farmers' conservation decision is then difficult to determine beforehand.

The effect of land tenure security on conservation investments has been conceptualized in many ways (Gebremedhin and Swinton, 2003; Soule et al., 2000). In Ethiopia, land is under public ownership and farmers have only usufruct rights. Research in various parts of the country report differing results regarding the effect of land tenure security on farmers' conservation decisions (e.g. Bekele and Drake, 2003; Shiferaw and Holden, 1998; Slegers et al., 2004). It is therefore difficult to determine its effect *a priori*.

Contact with extension agents, a proxy for access to information, is likely to contribute to farmers' conservation decisions. As indicated in innovation diffusion theory, a positive effect is expected of this variable.

### 5.5.2 Plot level attributes

Plot level attributes included in the estimation were slope (categorized into three classes), soil fertility (categorized into three levels), distance of the farm plot from homestead (DISTANCE), and actual profitability of the technology as perceived by the farmers (PERPROF). In our analysis, slope is used to proxy erosion potential. The three slope classes used in the empirical model include gentle slope (GENSLOP), moderately steep slope (MODSLOP), and very steep slope (STPSLOP). Since erosion severity is likely to increase with steepness in slope, the effect of steep slope is hypothesized to be positive on adoption decision of conservation measures (Ervin and Ervin, 1982; Pender and Kerr, 1998).

The soil fertility variable is also categorized into three levels; low fertility (LOWFERT), moderate fertility (MODFERT), and high fertility (HIGHFERT). Because marginal productivity loss due to erosion will be higher from plots with fertile soils that are expected to give high return in the short-term, soil fertility is expected to influence conservation decision positively (Bekele and Drake, 2003). Hence, the effect of high soil fertility on conservation investments is hypothesized to be positive.

**Table 5.2.** Description and summary statistics of the variables used in the biprobit estimation of farmers' adoption and continued use of stone terraces in the Beressa watershed, highlands of Ethiopia ( $n=147$ )

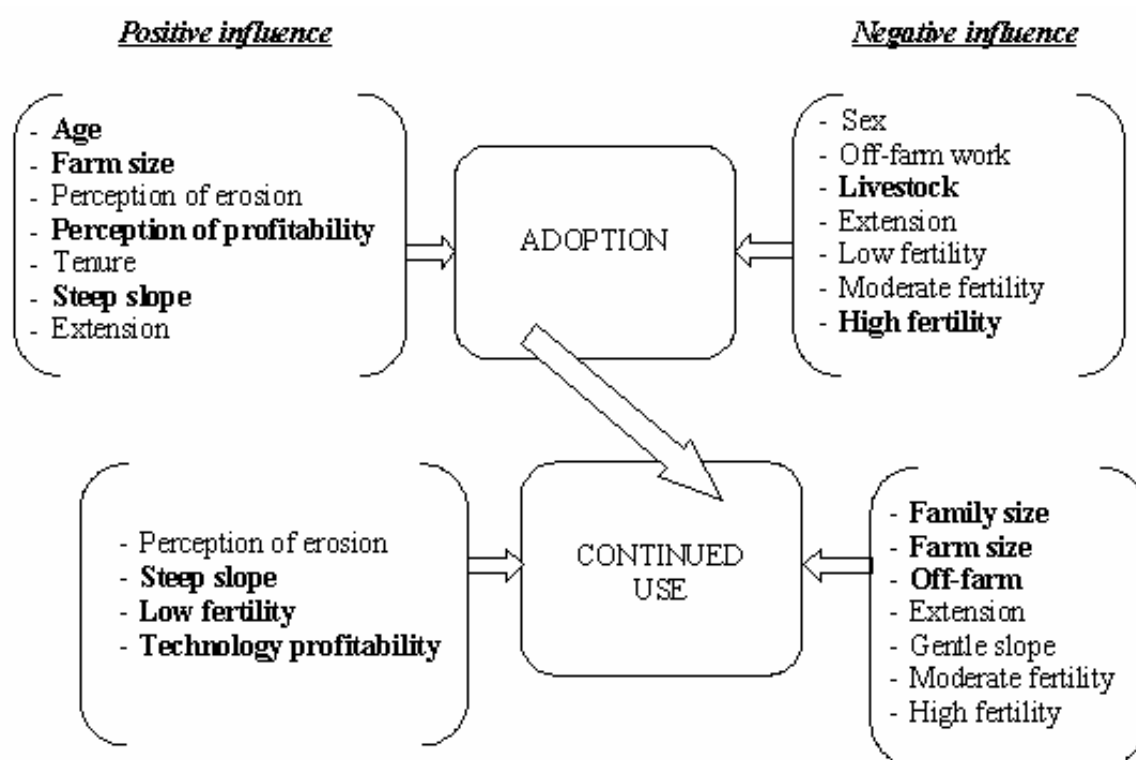
Variables	Description	Mean	SD.
<i>Household/farm level attributes</i>			
AGE	Farmer's age (in years)	44.0	12.35
SEX	Sex of the farmer (1 = male, 0 = female)	0.78	-
FAMSIZ	Household members (in number)	5.3	2.35
FARMSIZE	Size of the farm (in hectares)	1.7	0.91
PERCEROS	Perception on erosion problem (1 if erosion is perceived, 0 otherwise)	0.71	0.45
PERPROF	Perceived profitability of the technology (1 if perceived profitable, 0 otherwise)	0.7	0.46
OFFFARM	Off-farm work (1 if participate in off-farm work, 0 otherwise)	0.34	0.47
LIVESTOC	Livestock holding (in TLU)	2.7	1.69
PERCTENU	Perceptions on land tenure security (1 if feel secure, 0 otherwise)	0.25	0.44
EXTEN	Contacts with extension agents (1 if there is contact, 0 otherwise)	0.59	0.49
<i>Plot level attributes</i>			
Slope			
GENSLOP	Gentle slope (1 if slope is gentle, 0 otherwise)	0.37	0.34
MODSLOP	Moderately steep slope (1 if slope is moderately steep, 0 otherwise)	0.45	0.48
STPSLOP	Very steep slope (1 if slope is very steep, 0 otherwise)	0.18	0.20
Soil fertility condition			
LOWFERT	Low fertility (1 if soil fertility is low, 0 otherwise)	0.32	0.36
MODFERT	Moderate fertility (1 if soil fertility is moderate, 0 otherwise)	0.54	0.48
HIGHFERT	High fertility (1 if soil fertility is high, 0 otherwise)	0.15	0.19
DISTANCE	Mean distance to farm plot from home (in walking minutes)	12.3	12.9
ACTPROF	Actual profitability of the technology adopted (1 if found profitable, 0 otherwise)	0.72	0.31
<i>Dependent variables</i>			
ADOPT	Adoption of stone terraces (1 adoption, 0 non-adoption)		
CONTUSE	Continued use (1 continued use, 0 non-continued use)		

Distance of the farm plot from homestead is expected to detract from investments in conservation due to increased transaction costs (Gebremedhin and Swinton, 2003). Thus, the closer the farm plot is to the farm dwelling area the closer supervision and attention it would get from the family (Bekele and Drake, 2003).

Conservation technologies that proved effective often encourage investments in soil and water conservation technologies. Hence, the effect of actual technology profitability on farmers' conservation investment is hypothesized to be positive.

## 5.6 Results and discussion

Table 5.3 presents the results of the biprobit estimation of the determinants of farmers' adoption and continued use of introduced stone terraces. Overall, significant relationships are observed between the probabilities of the dependent variables and the set of explanatory variables included in the model.



**Figure 5.1.** Positive and negative influences of the variables on adoption and continued use of stone terraces in the Beressa watershed, highlands of Ethiopia. (*Bold in case of significant influences,  $p < 0.10$* ).

A range of variables is found to have influence on farmers' conservation decision. Unexpectedly, however, the factors influencing adoption and continued use of the stone terraces are not the same. For most of the variables the estimated coefficients differ in terms of sign and significance for adoption and continued use. Figure 5.1 illustrates the direction of effect of the variables included in the estimation. Variables with estimated coefficients below 0.10 and insignificant effects are not shown in the Figure.

### **5.6.1 Determinants of adoption**

Results of the biprobit analysis reveal that adoption of stone terraces is influenced by several variables. The variables found to have a positive and significant influence include age, farm size, perceptions on technology profitability and steep slope, while livestock size and high soil fertility are the variables with significant negative influences (Figure 5.1).

Although there is inconsistency of evidence about the relationship between age and innovativeness (Baidu-Forson, 1999), the effect of age of the farmer (AGE) on adoption is found to be positive in the Beressa watershed. This indicates that the likelihood of adoption of conservation practices is more among older farmers than the younger ones, perhaps due to the experiences of older farmers to perceive erosion problems and their limited participation in off-farm activities. Low level of adoption among young farmers could be due to their small farm size and also to their involvement in off-farm activities (Tenge et al., 2004). Thus, the argument that older farmers happen to be resistant to innovations might not hold true everywhere and at all times.

The effect of farm size (FARMSIZE) is also found to be positive and significant, suggesting that farmers who hold large farms are more likely to invest in conservation. This agrees with the argument that larger farms offer operators more flexibility in their decision-making, greater access to discretionary resources, more opportunity to use new practices on a trial basis and more ability to deal with risk (Nowak, 1987). Further, the farmers noted that the loss of land to terracing and temporal yield declines discouraged adoption of stone terraces on smaller farms. This result is in line with the findings of Tenge *et al.* (2004) in Tanzania where adoption is low among farmers with small farm size. Further, ploughing would become more difficult with a pair of oxen on smaller farms and thus limit the potentials of stone terrace adoption.

Farmers' perceived profitability of stone terraces (PERPROF) positively and significantly influenced their adoption decision. Since there has been a wider introduction of stone terraces in the highlands of the country, it appears that the farmers had prior information that somehow influenced their attitudes towards the measures promoted. In the discussions, the farmers noted that although they were well aware of the use and construction of stone terraces traditionally, they were much engrossed with the campaign works that could relieve them from labour constraints. Hence, farmers would likely adopt conservation practices if they perceived the technology profitable, suggesting the importance of demonstrating profitability of the measures. This indicates that conservation function *per se*



may not induce adoption unless the conservation practice also increased productivity and profitability.

**Table 5.3.** Biprobit estimates for adoption and continued use of stone terraces, with sample selection, in the Beressa watershed, highlands of Ethiopia.

Explanatory variables	Adoption		Continued use	
	Coefficient	Std. Error	Coefficient	Std. Error
AGE	0.020*	0.011	0.008	0.006
SEX	-0.285	0.342	-0.043	0.139
FAMSIZ	0.070	0.059	-0.023*	0.031
FARMSIZE	0.382**	0.178	-0.035*	0.106
PERCEROS	0.421	0.310	0.168	0.184
PERPROF	1.391***	0.320	-	-
OFFFARM	-0.212	0.283	-0.386**	0.126
LIVESTOC	-0.285***	0.100	-0.026	0.077
TENURE	0.275	0.342	0.081	0.156
EXTEN	-0.261	0.281	-0.101	0.118
GENSLOP	-0.049	0.330	-0.456	0.516
STPSLOP	1.424***	0.319	0.448**	0.579
LOWFERT	-0.181	0.237	0.461**	0.539
MODFERT	-0.397	0.104	-0.706	0.553
HIGHFERT	-1.016**	0.777	-0.632	0.528
ACTPROF	-	-	0.434**	0.442
DISTANCE	0.014	0.012	0.002	0.005
CONSTANT	-1.505***	0.569	1.288**	1.156
Log likelihood function= -117.404				
Number of observations = 147				
Censored observations = 52				

\*  $P < 0.10$ ; \*\*  $P < 0.05$ ; \*\*\*  $P < 0.01$ .

Note: MODSLOP is dropped from the estimation due to collinearity.

As expected, a significant positive relationship was found between steep slope (STPSLOP) and adoption of stone terraces. This is consistent with the finding of earlier studies in different parts of Ethiopia that report a positive and significant effect of the slope variable on the decision to adopt soil conservation structures (e.g. Bekele and Drake, 2003; Gebremedhin and Swinton, 2003; Shiferaw and Holden, 1998). The results indicate that farmers invest on plots where they expect more benefits from conservation. This suggests that conservation efforts should target areas where expected benefits are higher, like on the steep slopes, in order to encourage adoption.

Livestock constitutes an important component of the farming system in the area. However, the biprobit results show that the effect of livestock size (LIVESTOC) on adoption decision was significantly negative. This indicates that large livestock size discourages conservation investments, perhaps due to the tendency of households to focus more on livestock than on crop production. In addition, temporal yield gains through manure application might reduce potential productivity losses due to erosion, and thus reduce conservation efforts.

Contrary to our expectations, the effect of high soil fertility (HIGHFERT) on adoption decision was found to be negative and significant. Plots with fertile soils negatively influenced farmers' adoption of stone terraces. Perhaps the farmers did not see the negative effects of erosion on their plots, at least in the short run, and the need for conservation.

### **5.6.2 Continued use of conservation practices**

Adoption of conservation practices alone may not lead to sustained land rehabilitation unless the technologies are utilized continuously. Thus, the determinants of farmers' continued use of stone terraces among adopters of the technology are identified in the second stage of the sequential model. The biprobit estimation shows that actual technology profitability, steep slope and low soil fertility are with significant positive influence on continued use of the stone terraces while family size, farm size and participation in off-farm work are with significant negative influences (Figure 5.1).

As expected the influence of actual profitability (ACTPROF) of the technology on farmers' decision of continued use is significantly positive. This indicates that farmers who found the technology profitable retained it. Therefore, as Sain and Barreto (1996) noted, to ensure continued adoption, the conservation component must be profitable to the farmer in the medium and the long run. Particularly, farmers are very curious about the yield effect of the technology since the structures take up productive land, and maintenance is often labour intensive and costly (Shiferaw and Holden, 1998). Farmers who did not retain adopted stone terraces indicated that the benefits from adopting the technology were not as expected; perhaps they did not stay with it long enough to see accumulated benefits. Further, they complain about yield losses due to pest infestation associated with the stone terraces rather than effectiveness of the measure in erosion control. This is also found to be the case among the farmers in Wolaita and Wello (Beshah, 2003). As a result, most of the farmers switched to their 'traditional' practices instead of continuously using introduced stone terraces.

Like its effect on adoption, the effect of steep slope (STPSLOP) on continued use of the stone terraces is found to be significantly positive. Apparently, the farmers were encouraged to continue to use the stone terraces perhaps due to effectiveness of the measure in erosion control on steep slopes. This suggests that targeting the stone terraces on steep plots might induce sustained use of the measure.

The soil fertility condition of cultivated plots is an important determinant of farmers' investment in conservation practices. Our results show that low soil fertility (LOWFERT) has a significant positive effect on continued use of the stone terraces; farmers cultivating less

fertile plots continued using the stone terraces. This is contrary to expectations that farmers invest more on fertile plots in order to maximize production. Shrinking farm size might probably account for the conservation efforts put on less fertile plots.

The significant negative effect of family size (FAMSIZ) on farmers' conservation decision implies that households with large family size are not likely to continue using the stone terraces. Bekele and Drake (2003) also found similar results in the eastern highlands of the country. They noted that in a family with a greater number of mouths to feed, competition arises for labour between food generating off-farm activities, like daily labour, and investment in SWC. In the Beressa watershed, households participate in non-farm activities such as dung selling in the urban market, mainly in Debre Birhan town. Thus, households keeping more livestock considerably involve in dung-cake making and marketing, in which labour is diverted away from conservation.

Farm size (FARMSIZE) significantly influenced both adoption and continued use of stone terraces among the farmers of the Beressa watershed. While its effect on adoption is positive, the effect on continued use is found to be negative. This implies that continued use of the stone terraces is likely to be lower with increase in farm size, perhaps due to diminishing marginal returns. Otherwise this result does not support the argument that larger land holding, as associated with greater wealth and increased availability of capital, makes investment in conservation more feasible, nor are wealthier people willing to bear more risk than poorer people (Bekele and Drake, 2003). In highland Ethiopia where there is increasing population pressure and limited area for agricultural expansion, declining per capita farm area often results in production intensification.

The negative influence of off-farm income on farmers' conservation investment is in line with the findings of several studies (e.g. Gebremedhin and Swinton, 2003; Mbagwa-Semgawale and Folmer, 2000; Pender and Kerr, 1998; Tenge et al., 2004). Although the labour market outside farming in the area is generally weak, farmers engage themselves in off-farm income earning activities in the nearby urban centre, Debre Birhan town. Hence, the effect of OFFFARM on continued use of stone terraces is found to be significantly negative. Short-term benefits from off-farm activities seem to attract farmers' labour more than investments in conservation. Based on the findings in Illela region of Niger, Baidu-Forson (1999) noted that the availability of land-enhancing technologies that provide short-term profit would lead to a greater probability of adoption and intensity of use. This suggests that the lack of time for conservation measures due to involvement in off-farm work may have been more a matter of lack of cash income (Cramb et al., 1999) rather than capital accumulation.

The biprobit estimation also shows that perceptions of erosion problem, land tenure security and extension contacts show no significant influence both on adoption and continued use of stone terraces. The negative effect of extension contacts (EXTEN) implies that farmers having contacts with extension agents tend to reduce investments in conservation, which is counter intuitive. Discussions with extension staff in the area reveal that agricultural extension is more focused on crops and livestock production than on SWC. The results

suggest that SWC should be given due attention in the extension system to positively influence farmers' conservation decisions.

## **5.7 Conclusions**

As can be seen from the results of several studies, there seems to be disparity in the relative importance of the factors determining land users' conservation decisions. This suggests that for various groups of farmers under varying agro-ecological and socio-economic conditions the relative significance of influencing factors may also differ.

In the Beressa watershed, a range of factors influences farmers' conservation decision. However, the factors influencing adoption and continued use of the stone terraces are not the same. Adoption of stone terraces is significantly influenced by age, farm size, perceptions on technology profitability, slope, livestock size and soil fertility, while continued use is influenced by actual technology profitability, slope, soil fertility, family size, farm size and participation in off-farm work. Perception of erosion problem, land tenure and extension contacts show no significant influence on farmers' conservation decision.

The likelihood of adoption is higher with increase in age of the farmer, perception of technology profitability, increase in farm size and increase in livestock number. Continued use of the stone terraces is likely to be lower with increase in farm size, perhaps due to diminishing marginal returns. Participation in off-farm work negatively influenced continued use. Apparently, long-term conservation investments are traded off for short-term gains through off-farm activities. Although farmers' (adopters) have positive perception about the benefits of the stone terraces, sustained adoption could only be realized as long as the technology remains profitable in the short-run.

Therefore, the results of this research highlight that (1) analysis of the determinants of adoption *per se* may not provide a full understanding of the range of factors influencing farmers' decision of continued investments and (2) 'blanket approach' to conservation intervention could make the measures inappropriate to local conditions and eventually unacceptable by the farmers. Hence, interventions should consider not only the biophysical performance of the measures but also economic returns to investments at reasonable discount rates in order to enhance sustained use of the measures.



## Chapter 6

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### **Participatory evaluation of soil and water conservation practices on cultivated land in the Beressa watershed of the Ethiopian central highlands**

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Land Degradation and Development, *Accepted*

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## **6. Participatory evaluation of soil and water conservation practices on cultivated land in the Beressa watershed of the Ethiopian central highlands**

### **Abstract**

This research evaluates the performance of soil and water conservation (SWC) practices commonly used on cultivated land in the Beressa watershed of the Ethiopian central highlands. The evaluation was carried out in participation with the local farmers. Multi-criteria analysis was used to analyse the data and identify best conservation practices on different land categories based on farmers' evaluation criteria and rankings. The results indicate that farmers consider a range of criteria in the choice of SWC practices as opposed to recommendations that often focus on erosion control alone. And the relative importance of these criteria in the choice of conservation alternatives depends on specific attributes of the cultivated land, such as slope and soil type. Evaluation results show that stone terraces are the best measures on cultivated steep slopes, followed by the waterways. However, the stone terrace types the farmers prefer hardly match the recommendations. On medium slopes, soil bunds followed by contour ploughing were considered the most appropriate SWC measures although soil bunds are rarely seen on cultivated areas at present perhaps due to the influence of past stone terrace recommendations. Drainage ditches were preferred most over the other measures on the cultivated gentle slopes where drainage problems are more serious than soil loss. Apparently, the farmers make a trade-off between effectiveness of the measures and the costs associated with their preferences of conservation practices. The results further indicate that farmers have relevant knowledge and experience regarding suitability of the conservation measures, which can be used in conservation planning. It is therefore necessary to involve the farmers in conservation activities to utilize their knowledge and experiences, and thus facilitate wider acceptance of recommendations.

*Keywords:* Participatory evaluation; Multi-criteria analysis; Soil and water conservation; Regime method; conservation planning; Farmers; Ethiopia

### **6.1 Introduction**

Land degradation remains a major threat to agricultural production in many developing countries (Ellis-Jones and Tengberg, 2000; FAO, 2001; Lal, 2001a). Ethiopia is one of those countries severely affected by soil erosion induced degradation of agricultural land (Hurni, 1993). The problem is particularly widespread in the highlands due to the dissected nature of the topography, torrential rains, and high population pressure. Over 85% of the county's



population is engaged in subsistence rainfed farming in the highlands, which account only for about 46% of the national territory.

However, the negative effects of soil erosion and land degradation have become more discernible as population pressure limited the possibility of shifting cultivation and fallowing. The problem was recognized as a major constraint to the welfare of the people and development of the country at large since the 1970's and 1980's. This has given rise to the development of large-scale conservation plans and strategies for land rehabilitation. In the strategies, erosion control through various measures on cultivated areas and degraded land received considerable attention. However, although many farmers participated in the program and adopted some of the measures introduced initially, sustained use of the measures has been very little (Admassie, 2000; Amsalu and De Graaff, 2006a; Shiferaw and Holden, 1998). Farmers have often been blamed for their neglect in constructing and maintaining conservation measures as well as for dismantling the already introduced measures.

Despite the growing concern on adoption problems by the farmers, there exist few studies conducted on evaluation of SWC practices in the Ethiopian highlands. Herweg and Ludi (1999) studied the performance of selected SWC measures in the highlands of Ethiopia and Eritrea and they found that the measures only partially fulfil their requirements; soil loss and runoff were well reduced, but production did not compensate for the high costs of soil conservation. Gebremichael (1999) analyzed and evaluated SWC techniques in the north-central highlands of the country focusing on indigenous technologies. In Tigray, northern Ethiopia, the integration of traditional techniques with introduced ones was studied in view of farmers' current needs and long-term conservation issues (Nyssen et al., 2000). Participation of the farmers in the evaluation of the conservation measures has been limited in previous studies, however.

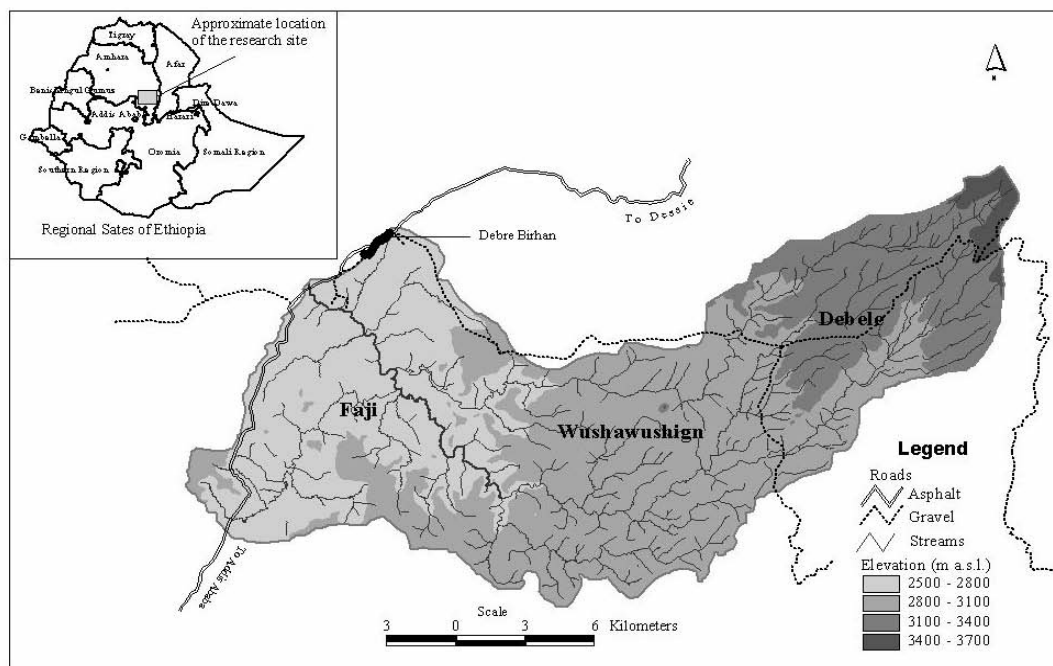
Recently, participatory approaches have become increasingly important in the fields of natural resources management and rural development (Chambers, 1997; Pretty and Shah, 1997). Essentially the methods offer a practical set of techniques that enable local people to express and share their experiences and knowledge with others for purposes of planning, action, monitoring, and evaluation (Chambers, 1997). Particularly, partnership with the farmers in SWC research and planning can result in more appropriate solutions harmonious to the local context (Pretty and Shah, 1997). Yet, farmers are rarely involved in the long-term monitoring and evaluation of conservation activities, neither did their knowledge and experience well recognized in many conservation projects especially in Africa (Ellis-Jones and Tengberg, 2000; Pretty and Shah, 1997; Reij et al., 1996).

Therefore, the main objective of this research was to evaluate the performance of SWC practices commonly used in the Beressa watershed of the Ethiopian central highlands together with the farmers. The evaluation focused on the physical SWC measures which are most commonly used on cultivated fields by the farmers in the watershed area. Farmers' evaluation criteria and rankings were the basis to identify best conservation measures for the different categories of cultivated land.

## 6.2 Materials and methods

### 6.2.1. The Research Site

The research site, Beressa watershed, is located in the Ethiopian central highlands (9° 40'N, 39° 37'E) to the east of the town of Debre Birhan, approximately 140 km north-east of Addis Ababa (Figure 6.1). The watershed covers an area of about 215 km<sup>2</sup> and forms part of the upper Blue Nile basin; it embraced three villages (Debele, Wushawushign and Faji) with an estimated total population of over 24,500. The density of human population in the central highlands in general and the Beressa watershed in particular is one of the highest in the country.



**Figure 6.1.** Map of the Beressa watershed, central highlands of Ethiopia

The average annual temperature is 19.7 °C and the mean annual precipitation is 887 mm. Rainfall is distributed over two rainy seasons; the short rainy season between February and April and the long rainy season between May and September. The long rainy season accounts for over 80% of the annual rainfall amount, but most of the rainwater drains the watershed in the form of surface flow. The soils of the area are volcanic in origin; the most common soil types include the cambisols (locally known as *Abolse*) and the vertisols (*Merere*). The cambisols largely cover the upper part of the watershed area, while vertisols are widely distributed in the lower part of downstream area. Since the watershed is characterised by a hilly topography, the soils are prone to erosion. Hence, the central highlands in general are recognized as one of the most erosion affected areas in the country (FAO, 1986; Hurni, 1988; Shiferaw and Holden, 1998). Most farmers of the watershed area also confirmed the

existence of some form of land degradation; erosion and soil nutrient depletion are the main types (Amsalu and De Graaff, 2006b).

Agriculture, which is characterised by integrated crop and livestock production, is the main source of living to the people of the watershed area. However, increased pressure on land resources has been one of the main causes of land use changes during the past decades. There has been, for instance, extensive clearing of the natural vegetation, expansion of grazing land, and increased tree planting in the watershed area between 1957 and 2000 (Amsalu et al., 2006c). However, cropland constitutes the dominant land use and crop cultivation is generally meant for meeting subsistence requirements. Farm size ranges between 0.5 ha and 3 ha. The main crops cultivated include barley, beans, wheat, peas and lentils.

### 6.2.2 Methods

#### *Multi-criteria Analysis*

The evaluation in this research was conducted by employing a multi-criteria analysis (MCA) methodology. MCA is a decision-making tool applied to choice problems in the face of a number of different alternatives and several conflicting criteria (De Graaff, 1996; Janssen, 1994; Munda et al., 1994). The method is used to identify best alternatives for decision-making on the basis of relevant criteria. The main steps in MCA include:

- Formulation of objectives
- Defining a set of criteria based on objectives
- Selection of alternatives/potential actions
- Determination of effects of alternatives on criteria
- Formulation of weight sets
- Selection of aggregation method
- Ranking of the alternatives based on criteria
- Checking for satisfactory ranking (sensitivity analysis)

The Regime Method (RM), a variant of decision-making approaches in MCA, is used in our analysis. It is a discrete multi-criteria method that allows working with ordinal and cardinal data, and weights as important coefficients of the criteria in the evaluation (Hinloopen and Nijkamp, 1990). Each alternative is ranked with regard to criteria based on by comparing the multidimensional outcomes of an impact assessment of competing objectives. A pairwise ranking is then used to establish the order of preference of alternatives and the ranking is done in a matrix, where rows and columns indicate the alternatives (i) and criteria (j), respectively.

Consider two alternatives i and i'. The pairwise comparison of these two alternatives according to criterion j ( $r_{ii',j}$ ) is therefore:

$$r_{ii',j} = 1 \text{ if } p_{ij} > p_{i'j},$$

$$r_{ii',j} = -1 \text{ if } p_{ij} < p_{i'j},$$

where  $p_{ij}$  and  $p_{i'j}$  are the ranks of alternatives  $i$  and  $i'$  according to criteria  $j$ . The regime vector ( $r_{ii'}$ ) for each pair of alternatives is then constructed by extending comparison of the alternatives  $i$  and  $i'$  to all criteria  $j = 1, 2, \dots, J$  as follows:

$$r_{ii'} = (r_{ii',1}, r_{ii',2}, \dots, r_{ii',J})$$

Positive “+” and negative “-” signs are used to indicate the relative dominance of one alternative over another, and “0” for no dominance. Based on the pairwise comparison of the alternatives is obtained, the weight dominance of alternative  $i$  with respect to  $i'$  ( $p_{ii'}$ ) is defined as:

$$p_{ii'} = \sum_{j=1}^J r_{ii',j} \lambda_c$$

where  $r_{ii'}$  is pairwise comparison of alternatives  $i$  and  $i'$ ,  $j$  is the criterion, and  $\lambda_c$  is the weight set. A positive value of  $p_{ii'}$  implies alternative  $i$  is preferred to alternative  $i'$ , and otherwise if the value is negative.

#### *Participatory approach*

Data used for this research was obtained through a participatory process with the local farmers following the steps in MCA mentioned above. The method was designed to incorporate the experiences of local farmers and their perspectives in the evaluation. A total of 30 farmers were purposively selected from an earlier household survey of 147 farm households in the watershed area (Amsalu and De Graaff, 2006b). These farmers were approached informally inviting them to participate in the evaluation. The overall objective of the evaluation process was presented to them and discussed. However, only 21 farmers (of which 4 women) were willing and eventually participated in the evaluation.

Before selecting the evaluation criteria and the alternatives, cultivated areas were classified into categories. Farmers were asked to list down the criteria they consider in the use of conservation measures. After thorough discussions, the criteria were refined and those agreed upon were considered. This was followed by assigning weights to the criteria in each of the land categories identified. We considered the average weight in our analysis to accommodate the different opinions of the farmers on the relative importance of each criterion. The alternatives were also selected using a checklist of SWC measures known to be used in the area. The alternatives were ranked according to farmers' preferences based on criteria defined in each of the land categories. The information obtained was analysed in a spreadsheet module using Microsoft EXCEL.

## 6.3 Results

### 6.3.1 Categories of cultivated land

Of the total watershed area, about 61% is under annual crop cultivation in which barley and beans constitute the dominant crops (Amsalu et al., 2006c). Farmers classified the cultivated areas into four categories (Table 6.1). They consider slope and soil type as the major criteria in their classification. They classified slope into three classes: very steep (*tedafat*), moderately steep (*zekzaka/mekakelegna*), and gentle-to-flat slope (*medama*). And the soils are basically classified by considering the colour and drainage condition: well-drained soils that are often reddish in colour (*abolse*) and the poorly-drained soils that are often black in colour (*merere*).

**Table 6.1.** Category of cultivated land, their description and approximate distribution in the Beressa watershed, highlands of Ethiopia

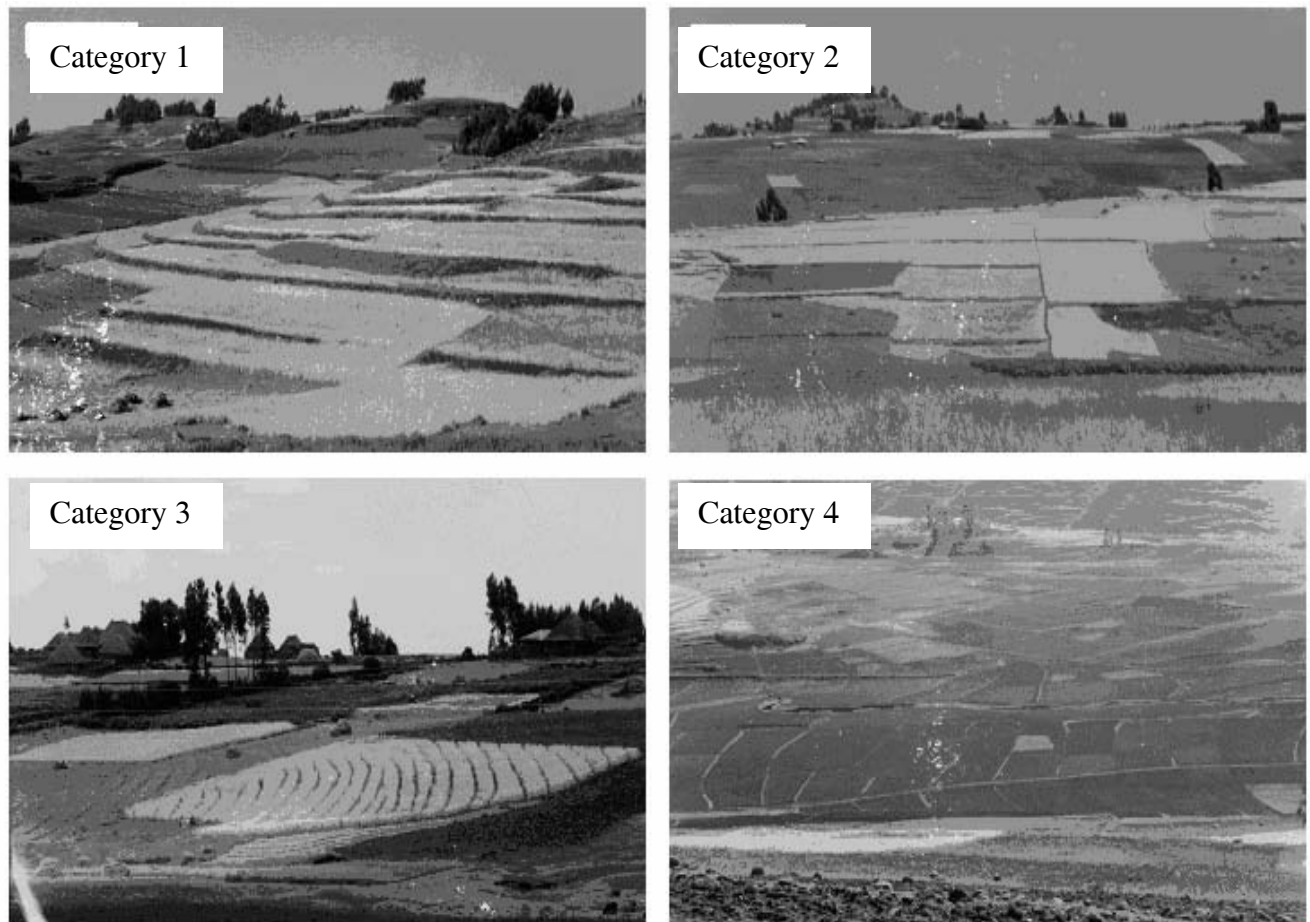
Categories of cultivated plots	Description	Distribution in the watershed area (%)*
Category 1	Cultivated land that lie on steep slopes within the watershed area	19
Category 2	Cultivated land that lie on moderately sloping areas	38
Category 3	Cultivated land lying on gentle slopes with well drained soils	18
Category 4	Cultivated land in the gentle slopes with poorly drained soils, often vertisols	25

\* Calculated from slope and land use map of the watershed area.

As shown in Table 6.1, the proportion of cultivated areas on steep slopes amounts to about 19%, and on the moderately sloping areas to about 38%. The remaining cropland area (43%) lies on the gentle slopes, but with distinct soil types: about 18% on the well drained soil and 25% on the poorly drained soils. Pictures of the cultivated areas that represent each land category are depicted in Figure 6.2.

### 6.3.2 Farmers' objectives of SWC

The Beressa watershed is one of the most erosion prone areas in the central highlands of Ethiopia. Soil erosion is one of the major challenges to farming in the watershed area. As Pimentel et al. (1995) noted, erosion adversely affects crop productivity by reducing water availability, water-holding capacity of the soil, nutrient levels, soil organic matter, and soil depth. Farmers consider these multiple effects of the problem in their conservation decisions.



**Figure 6.2.** Categories of cultivated land in the Beressa watershed of the Ethiopian highlands

Asked about their objectives of SWC, the farmers noted that SWC to them is far more than erosion control; it mainly includes soil fertility maintenance and improvement of land productivity. They further consider the costs incurred and the benefits to be obtained in their choice of conservation practices. The main objectives of the farmers are generally summarized into two main groups:

- To conserve soil and water for current as well as future crop production, while currently obtaining the highest possible net income; and
- To reduce the costs incurred in or associated with the use of SWC practices to the minimum possible.

These objectives were used as a framework in the formulation of evaluation criteria.

### **6.3.3 Evaluation criteria and weights**

The participants were asked to list criteria they consider in SWC. Eight evaluation criteria were defined after through discussions with the farmers. The criteria selected reflect the advantages and disadvantages on the basis of which the alternatives are to be judged. And the weight sets incorporate information on the relative importance of criteria in the evaluation.

Table 6.2 presents evaluation criteria and the average weight assigned to each criterion in the four land categories.

Discharge of excess water, followed by erosion control, was the most important criterion the farmers pointed out in all land categories, except in land category 2. However, their relative weights vary within as well as across the land categories. In land category 2, farmers assigned the highest weight to erosion control and the lowest to loss of cultivable area.

Remarkable differences in the weights assigned were found in land category 3 & 4. In these land categories, the highest weight was assigned to discharge of excess water followed by erosion control. It was apparent in the discussions that excess water on cultivated fields was the most important concern of the farmers because the areas lie on the gentle slopes in the bottomlands where runoff from the uplands accumulate.

**Table 6.2.** Farmers' evaluation criteria and the weight sets for each land category in the Beressa watershed, highlands of Ethiopia

Criteria	Category 1	Category 2	Category 3	Category 4
Erosion control	0.22	0.20	0.20	0.15
Moisture retention	0.05	0.15	0.10	0.00
Fertility maintenance	0.05	0.15	0.05	0.05
Discharge excess water	0.25	0.10	0.55	0.60
Labour Efficiency	0.15	0.15	0.05	0.10
Host/harbour rodents	0.10	0.10	0.00	0.00
Loss of cultivable area	0.10	0.05	0.00	0.00
Maintenance need	0.08	0.10	0.05	0.10
Total	1.0	1.0	1.0	1.0

Note: The weights indicate the relative importance of each evaluation criteria in the selection of SWC practices

#### 6.3.4 Alternatives - soil and water conservation practices

SWC is a long-standing activity among the farmers of the Beressa watershed. Most farmers in the area experience land degradation in the form of soil erosion and fertility decline (Amsalu and De Graaff, 2006b). Hence, they use several measures to combat these problems. Table 6.3 depicts the most important SWC practices widely used in the watershed area, which include stone terraces/bunds, soil bunds, drainage ditches, waterways, and contour ploughing.

In total, six alternatives – five conservation practices shown in Table 6.3 and the 'No Measure' alternative – were included in the evaluation. Since the measures compete among each other in farmers' conservation decision, a combination of the measures was not used in our analysis. In the following, description of each of the alternatives is given.

### Stone bunds /terraces

Since the 1980's, stone bunds/terraces have been widely constructed in the Ethiopian highlands. There has also been a long tradition of using the stone bunds/terraces as a SWC measure in the watershed area. The principle behind the use of the stone bunds is to reduce runoff and soil erosion by constructing elevated structures parallel to the slopes (Hengsdijk et al., 2005). Although the introduced stone terraces have been widely promoted during the past decades, it has sustained little in its original state on most of the cultivated areas. The terraces have been modified by the farmers to meet their preferences and local conditions.

**Table 6.3.** Household characteristics and use of SWC practices in the Beressa watershed, Ethiopia

	<i>n=147</i>
<i>Household characteristics</i>	
Average age of the household head	41
Average family size	5
Can read & write and above (%)	42
Per capita farmland (ha)	1.7
<i>Use of SWC measures (% of the respondents)</i>	
Stone terraces/ bunds	73
Soil bunds	15
Water-ways	23
Drainage ditches	82
Contour ploughing	83

Source: Amsalu and de Graaff, 2006

### Soil bunds

The soil bunds are made of soil or mud. On moderately sloping areas the farmers construct the soil bunds for erosion control. The bunds stabilize gradually as grasses grow on the riser. The soil bunds demand less labour and can be more easily constructed when compared to the stone terraces.

### Drainage ditches

The drainage ditches are one of the most widely used SWC practices in the watershed area. They are transitory water channels used to drain off excess water from the cultivated fields. The drainage ditches are low-cost measures in which their construction is part of the normal ploughing activity. However, unlike the plough furrows, the ditches are made wider and deeper in dimension and usually run diagonally across the field. Farmers call the drainage ditches *fesses*.

### Waterways

The waterways are locally known as *golenta* or *boy*. This conservation measure is constructed alongside the farm plots for the safe disposal of runoff. The measure takes excess water down



the slope to the streams and rivers. The waterways are semi-permanent structures that require periodic maintenance.

#### *Contour ploughing*

Tillage in the area is carried out using the ox-drawn plough. Hence, cultivated areas are often ploughed against the slope – contour ploughing. The practice is essentially meant to break the strength of runoff and thus reduce soil erosion. Since contour ploughing is part of the normal farming activity, it needs no extra labour and time for construction.

#### *No measure*

This alternative indicates the use of no measure as an option in farmers' conservation decisions. This option could be considered best to the farmers when the costs of SWC exceed the benefits with respect to the criteria defined.

### **6.3.5 Farmers' multi-criteria ranking of the alternatives**

The results of farmers' ranking of SWC measures based on the evaluation criteria are shown in Table 6.4. The values reflect perceived degree of importance of each conservation alternative with respect to the criteria defined.

SWC measures that ranked first for the erosion control and moisture retention criteria were stone terraces in land category 1, soil bunds in land category 2, and the drainage ditches in both land categories 3 and 4. In terms of fertility maintenance, the farmers' ranked soil bunds first in land categories 1 and 2, and the drainage ditches in land categories 3 and 4. Similarly, the farmers ranked the waterways first based on the drainage of excess water criterion in land category 1 and 2, while the drainage ditches were ranked first in land categories 3 and 4.

On the other hand farmers' ranking of the alternatives based on some of the evaluation criteria that represent the cost elements of conservation investments (labor efficiency, rodent hosting, loss of cultivable area and maintenance need) show notable results. With respect to these criteria, the farmers' ranked first the 'No Measure' alternative in all land categories. Against the other criteria, however, the 'No Measure' option was ranked last all across the land categories. Farmers' rankings reflect their experiences and perceptions regarding the advantages and disadvantages of the conservation alternatives under different settings.

### **6.3.6 The evaluation matrix**

Results of the pairwise comparison of the conservation alternatives against the evaluation criteria are shown in an evaluation matrix in Table 6.5. The comparison refined the complex decision problem into a series of one-on-one judgements regarding the significance of each alternative relative to each criterion (Mendoza and Macoun, 1999). Each alternative is compared with every other alternative against each criterion to assess its relative importance.

The weighted scores of the pairwise comparisons and overall assessment of the alternatives for each land category are shown in Table 6.6.

**Table 6.4.** Farmers' ranking of SWC practices based on evaluation criteria in the Beressa watershed of the Ethiopian central highlands (1 = best, 5 =worst).

<i>Category 1</i>						<i>Category 2</i>					
Criteria	Alternatives					Criteria	Alternatives				
	ST (a)	SB (b)	WW (c)	CP (e)	NM (f)		ST (a)	SB (b)	WW (c)	CP (e)	NM (f)
EC	1	4	2	3	5	EC	2	1	3	4	5
MR	1	2	4	3	5	MR	3	1	4	2	5
FM	2	1	3	1	5	FM	3	1	4	2	5
DEW	2	3	1	2	5	DEW	3	3	1	2	5
LE	4	3	2	1	1	LE	4	3	2	1	1
NR	3	3	1	1	1	NR	3	3	1	1	1
LCA	4	3	2	1	1	LCA	3	3	2	1	1
MN	2	3	3	1	1	MN	3	2	2	1	1

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<i>Category 3</i>						<i>Category 4</i>					
Criteria	Alternatives					Criteria	Alternatives				
	SB (b)	WW (c)	DD (d)	CP (e)	NM (f)		SB (b)	WW (c)	DD (d)	CP (e)	NM (f)
EC	3	1	1	2	3	EC	4	3	1	2	4
MR	2	3	1	1	4	MR	3	2	1	1	4
FM	2	3	1	1	4	FM	3	2	1	1	4
DEW	3	1	1	2	4	DEW	4	2	1	3	4
LE	4	3	2	2	1	LE	3	2	2	1	1
NR	4	3	2	2	1	NR	3	2	1	1	1
LCA	3	2	2	1	1	LCA	3	2	1	1	1
MN	3	2	2	1	1	MN	4	3	2	1	1

Note: Criteria (EC, Erosion Control; MR, Moisture Retention; FM, Fertility Maintenance; DEW, Discharge Excess Water; LE, Labour Efficiency; NR, No Rodent breeding; LCA, Loss of Cultivable Area; MN, Maintenance Need) and the alternatives (ST, Stone Terraces; SB, Soil Bunds; WW, Water Ways; DD, Drainage Ditches; CP, Contour Ploughing; NM, No Measure)

**Table 6.5.** Pairwise comparison of SWC measures based on evaluation criteria in the Beressa watershed of the Ethiopian highlands.

Regime vectors*	Criteria															
	EC	MR	FM	DEW	LE	NR	LCA	MN	EC	MR	FM	DEW	LE	NR	LCA	MN
	Category 1								Category 2							
r-ab	1	-1	1	-1	1	0	1	-1	-1	-1	-1	0	-1	0	0	-1
r-ac	1	-1	-1	1	1	1	1	1	1	1	1	-1	-1	-1	-1	-1
r-ae	1	-1	-1	-1	1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1
r-af	1	1	1	1	-1	-1	-1	-1	1	1	1	1	-1	-1	-1	-1
r-bc	-1	1	1	-1	-1	-1	-1	0	1	1	1	1	-1	-1	-1	-1
r-be	-1	1	0	-1	-1	-1	-1	-1	1	1	1	1	-1	-1	-1	-1
r-bf	1	1	1	1	-1	-1	-1	-1	1	1	1	-1	-1	-1	-1	-1
r-ce	1	-1	-1	1	-1	0	-1	-1	1	-1	-1	1	-1	0	-1	-1
r-cf	1	1	1	1	-1	0	-1	-1	1	1	1	1	-1	0	-1	-1
r-ef	1	1	1	1	0	0	0	0	-1	1	1	1	0	0	-1	-1
	Category 3								Category 4							
r-bc	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
r-bd	-1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
r-be	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
r-bf	0	1	1	1	-1	-1	-1	-1	0	1	1	0	-1	-1	-1	-1
r-cd	0	1	1	0	1	1	0	0	1	1	1	1	0	1	1	1
r-ce	1	0	0	1	0	0	-1	-1	1	0	0	1	-1	0	0	-1
r-cf	1	1	1	1	-1	-1	-1	-1	1	1	1	1	-1	0	0	-1
r-de	1	-1	-1	1	-1	-1	-1	-1	-1	-1	-1	1	1	-1	-1	-1
r-df	1	1	1	1	-1	-1	-1	-1	1	1	1	1	1	-1	-1	-1
r-ef	1	1	1	1	-1	-1	0	0	1	1	1	1	0	0	0	0

Note: EC, Erosion Control; MR, Moisture Retention; FM, Fertility Maintenance; DEW, Discharge Excess Water; LE, Labour Efficiency; NR, No Rodent breeding; LCA, Loss of Cultivable Area; MN, Maintenance Need

\*Only half of the regimes are calculated because  $r_{ij} = -r_{ji}$  in principle.

**Table 6.6.** Weighted scores of the pairwise comparison and overall assessment of the alternatives for each of the land categories in the Beressa watershed, highlands of Ethiopia.

Weighted Scores					Weighted Scores				
Category 1			Category 2		Category 3			Category 4	
P-ab	0.14	1>2	-0.75	1>2	P-bc	-1.00	2<3	-1.00	2<3
P-ac	0.80	1>3	0.00	1>3	P-bd	-0.70	2<4	-1.00	2<4
P-ae	0.30	1>5	-0.60	1>5	P-be	-1.00	2<5	-1.00	2<5
P-af	0.14	1>6	0.20	1>6	P-bf	0.60	2>6	-0.15	2>6
P-bc	-0.72	2<3	0.20	2<3	P-cd	0.20	3>4	0.90	3>4
P-be	-0.85	2<5	0.20	2<5	P-ce	0.70	3>5	0.55	3>5
P-bf	0.14	2>6	0.00	2>6	P-cf	0.80	3>6	0.60	3>6
P-ce	0.04	3>5	-0.30	3>5	P-de	0.50	4>5	0.40	4>5
P-cf	0.24	3>6	0.30	3>6	P-df	0.80	4>6	0.80	4>6
P-ef	0.57	5>6	0.05	5>6	P-ef	0.85	5>6	0.80	5>6
Overall assessment	a>c>e>b>f		b/e>a>c>f			d>c>e>b>f		d>c>e>f>b	

*Category 1:*

Evaluation results show that the stone terraces are the best alternatives followed by the waterways in land category 1. Since the cultivated plots lie on steep slopes, erosion is severe due to the high generation of runoff. Thus, these two measures are considered suitable to reduce soil loss and safely discharge excess runoff.

*Category 2:*

Soil bunds and contour ploughing come out to be the best alternatives in land category 2, followed by the waterways. The farmers apparently made a trade-off between effectiveness in erosion control and labour efficiency in the selection of the measures. On the moderate slopes, erosion could be effectively halted by using the soil bunds which require relatively less labour for construction than the stone terraces.

*Category 3:*

In land category 3, the best conservation alternative is found to be a drainage ditch followed by the waterways. This is because the area lies on the gentle slopes where the need for bund structures is minimal. The farmers consider the drainage ditches effective in draining off excess water from the cultivated fields.

*Category 4:*

Drainage ditches again come out to be the most preferred measures in land category 4. It is no surprise that the ditches are most preferred in this land category since the area lies on the gentle slopes with severe drainage problems.

### **6.3.7 Sensitivity analysis**

Sensitivity analysis was performed to explore the extent to which variation in criteria weights would affect the overall evaluation results. The analysis provides further insight about the robustness of evaluation results. We considered the extreme opinions of the farmers regarding the relative weight of each evaluation criterion. Hence, sensitivity of evaluation results to these extreme opinions of the farmers, which are the minimum and the maximum weights assigned to each criterion, is checked. The results of the sensitivity analysis are shown in Table 6.7: criteria only with an impact on the overall assessment are presented in the table. Evaluation results were found sensitive in all land categories except land category 3 to changes in the weights of some of the criteria; erosion control, discharge of excess water, fertility maintenance and labour efficiency.

In particular, considerable changes occurred in land categories 1 and 2. In land category 1, for instance, a decrease in the weight of erosion control criteria resulted in the preference of contour ploughing/no measure alternatives over the stone terraces. On the other hand, a higher weight of the labour efficiency criteria resulted in the choice of contour ploughing over stone bunds in land category 2. Overall, results of the sensitivity analysis

indicate the influence of some of the evaluation criteria in farmers' choice of the SWC alternatives.

**Table 6.7.** Sensitivity of evaluation results to changes in criteria weights in the Beressa watershed of the Ethiopian highlands

Criteria	Changes in overall assessment			
	Category 1	Category 2	Category 3	Category 4
Erosion control	e/f>c>a>b*	e>b/c>a>f*	nc.	nc.
Discharge of excess water	d/e>c/a>f c>a/e>b>f*	nc.	nc.	c>d>e>f>b*
Fertility maintenance	nc.	e>b/c>a/f	nc.	nc.
Labour efficiency	e/f>a/c>b	e>c>f>b>a	nc.	nc.

\* results based on the minimum weight values of criteria

nc. = no change

## 6.4 Discussion

### 6.4.1 Performance of SWC measures

The results obtained from the participatory evaluation reflect preferences of the local farmers that somehow meet their multiple objectives in SWC, and it appears plausible. The research indicates that farmers' selection of SWC practices is based on their multiple objectives that are reflected in the evaluation criteria. Similar results were also observed in Kenya, Tanzania and Uganda (Ellis-Jones and Tengberg, 2000). This generally implies that conservation practices that perform well in addressing farmers' requirements can have high probability of adoption and sustained use.

On steep slopes, stone terraces and waterways are the most preferred SWC measures by the farmer. The stone terraces are considered effective in erosion control in these areas. On the steep slopes particularly, cultivation without the terraces is problematical since it often leads to high runoff and soil loss. However, the farmers preferred gradual construction of the stone terraces as opposed to the recommendations in which the measures have been installed at once through community labour. This is because building the stone terraces gradually helps to enhance stability of the structures, minimize rodent breeding, and relax labour constraints for maintenance. Some of these benefits are well proven and demonstrated among the farmers of Tikurso in the Ethiopian highlands (Bekele-Tessema, 2005). In addition, land area close to the stone terraces could possibly be cultivated which offer better yield due to the accumulation of fertile soil. This illustrates that the farmers consider several criteria while using the conservation measure instead of focusing on reducing soil loss alone. Therefore, the design of SWC measures should take farmers' criteria into account so that recommendations would not face acceptance problems. The farmers consider the waterways effective in expelling excess water. However, they complain about lack of cooperation among the farmers of adjacent plots in maintaining the structures. As Ellis-Jones and Tengberg (2000) noted

inadequate maintenance of conservation measures could lead to soil erosion at an accelerated rate with the loss of the initial investment.

Although the use of soil bunds is quite limited in the watershed area (Table 6.3), evaluation results show that the measure is one of the best alternatives on the moderate slopes. According to the farmers, the soil bunds require less labour and time to construct than the stone terraces. This is because among others the excavated material is thrown downhill (Herweg and Ludi, 1999). Further, the farmers use the ox-plough to dig the land in the construction of the soil bunds. An additional benefit of the soil bunds over the stone terraces mentioned was the ease of destroying it periodically in order to redistribute the soils entrapped. This was also reported by Nyssen et al. (2000) in the northern highlands of Ethiopia where the farmers destroy smaller bunds to increase field size and recover accumulated soil. Thus, the farmers consider the soil bunds as best measures on the moderate slopes although the stone terraces have been introduced everywhere including on the moderate slopes.

The drainage ditches are one of the most widely used conservation practices in the watershed area. As evaluation results indicate, the drainage ditches become best alternatives on the gentle slope areas irrespective of soil type. In past conservation activities, however, farmers were forced to construct stone terraces in areas where there was no need for such measures, like on the gentle slopes. Apparently, this led to what Pretty and Shah (1997) called homogenization of environments. This was an evidence that clearly illustrates the extent to which the knowledge and experiences of local farmers has been marginalized in conservation activities.

Therefore, integration of local experience with scientific knowledge is pertinent to develop better and acceptable conservation options. The fact that the farmers have been using the measures so long in the area indicates that they modify and renovate them invariably to enhance effectiveness and efficiency of the measures. This knowledge and experience of the farmers should be recognized and utilized in future projects. Past experiences in the Ethiopian highlands and in many other developing countries show that top-down approaches succeeded very little (e.g. Bewket, 2003; Ellis-Jones and Tengberg, 2000). Therefore, the design and monitoring of SWC practices need to be done together with the farmers so that the measures can be incrementally improved (Herweg and Ludi, 1999). Furthermore, conservation approaches should be of multi-purpose nature to cater for all the different objectives of the farmers (Tenge, 2005), since sustainable land management is more than mere technological development (Hurni, 1993).

#### **6.4.2 Methodology**

SWC conservation in many developing countries has become more complex due to the mismatch that often exists between farmers' objectives and external recommendations. This gap has been leading to the limited use or abandonment of recommended measures by the local farmers. Evaluation of the conservation measures is therefore necessary to assess the

technical and socio-economic suitability of the measures to local conditions and identify the constraints. However, evaluation of SWC practices is expensive to undertake on experimental basis and often restricts the influences of diverse and complex factors.

Multi-criteria approaches in general provide the possibility of integrating the diverse objectives and criteria of the farmers in conservation decisions within a structured framework. The participatory approach applied in this research sets the ground for knowledge sharing through the exchange of views and mutual cooperation with the farmers in the evaluation. In particular, the method provides transparent ways to elicit farmers' objectives, priorities and preferences in conservation activities. Nonetheless, the whole activity has not been conducted without challenges. Among other, lack of trust has been the main obstacle especially at the beginning of the participatory process. The apparent mistrust observed was not only between the farmers and the researchers, but also among the farmers themselves to freely exchange views and reach at consensus. Bekele-Tessema (1997) also observed a similar problem among the farmers in Tikurso catchment in Ethiopia and noted the importance of building on trust to make conservation projects successful.

Therefore, making farmers partners instead of passive recipients of recommendations could enhance their participation in the design, evaluation and development of suitable and acceptable SWC practices. More importantly, winning farmers' trust could smoothly open up the way to creating partnership in conservation activities. In general, involvement of the farmers in local level conservation planning is vitally important in order to make the recommendations acceptable. A failure to involve the people in conservation programmes can also have considerable long-term social impacts (Pretty and Shah, 1997). In this respect, the participatory approach presented in this research has a promising potential that would contribute to conservation planning in degraded areas like the Ethiopian central highlands.

## 6.5 Conclusion

SWC remains a vital part of the farming activity in the Beressa watershed of the Ethiopian central highlands despite the limited success of conservation projects during the past decades in the area. This research presents the results of a farmer participatory evaluation of the most commonly used SWC practices in the watershed area in a way of identifying the best options on the different land categories based on farmers' evaluation criteria and rankings.

The results indicate that farmers consider a range of criteria while evaluating the performance of SWC practices as opposed to recommendations that often focus on erosion control *per se*. Most of these criteria account for the costs and benefits the farmers consider as related to the use of the conservation practices. And the relative importance of each criterion in the choice of conservation alternatives largely depended on specific attributes of the cultivated land, such as slope and soil type. The research further highlights availability of relevant knowledge among the farmers that could be used in conservation planning. The participatory approach we used in multi-criteria analysis has particularly been useful to utilize farmers' knowledge

and experiences, and capture their preferences in the choice of SWC practices. This suggests the need to design SWC practices according to local needs and in participation with the users – the farmers - to make the recommendations acceptable and sustainable.





## Chapter 7

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### **Creating enabling conditions for soil and water conservation in the Ethiopian highlands: the case of Beressa watershed**

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Land Use Policy, *Submitted*.

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## **7. Creating enabling conditions for soil and water conservation in the Ethiopian highlands: the case of Beressa watershed**

### **Abstract**

Soil and water conservation activities in the highlands of Ethiopia are faced with several challenges. Despite extensive conservation interventions during the past decades, sustained adoption of the recommended measures by the farmers has not been as expected. Based on extensive research in the Beressa watershed of the Ethiopian central highlands, this paper discusses the need for enabling conditions to encourage local level conservation activities by the farmers. A framework with a set of enabling conditions that are differentiated at the various levels of decision-makings (local/household, village/community, and national/regional) is presented.

*Keywords:* Enabling conditions; Land use history; Conservation planning; Land tenure; decision-making; Land (use) policy; Ethiopia

### **7.1 Introduction**

Land degradation in the form of water erosion and nutrient loss is a major challenge to Ethiopia. The highlands are generally recognized as areas most affected by the problem (Hurni, 1993; Taddese, 2001). The people in these highlands are primarily engaged in subsistence rainfed farming. Such degradation problems therefore not only reduce land productivity and income, but also pose a threat to household food security. Nevertheless, land conservation has become a main development issue only very recently; it was largely neglected by policy makers until the early 1970s when a dreadful famine struck the country (Shiferaw and Holden, 1999). This moment, though with bad memories, is considered as a landmark for government attention and commitment towards conservation activities. Since then, several soil and water conservation (SWC) and land rehabilitation projects were initiated with the support of donor organizations. Substantial efforts have been put in place in order to rehabilitate degraded areas and stop further degradation through better control of soil loss and runoff, as well as through improved soil fertility management and reforestation. Various SWC measures were introduced to the farmers for implementation.

In spite of all this, farmers' practices have not changed markedly, nor have they adopted most of the recommended conservation measures (Admassie, 2000; Beshah, 2003; Dejene, 2003). Coercive measures have been used when farmers became unwilling to accept the recommended measures, though it did not help much in solving the problem. Therefore, the limited success of past conservation interventions underlines the need to rethink on the approaches that have been pursued so far.

A lot of discussion has been going on regarding land resource management in general and on the limited success of past conservation activities in particular in the country. The debates mostly focused on the policy processes and conservation approaches that have evolved during the past decades. The most important critics were related to three main issues. Firstly, the recommendations were based on one-size-fits-all principle without considering local biophysical and socio-economic differences (e.g. Hoben, 1995; Keeley and Scoones, 2000). Secondly, there was a limited opportunity available for the local farmers to participate and share their knowledge and experiences in the conservation programs; they often undermined farmers' initiatives and their indigenous knowledge and practices. Thirdly, the interventions used incentives in a wrong way so that they have left negative attitudes and misconception about conservation projects (Shiferaw and Holden, 1998).

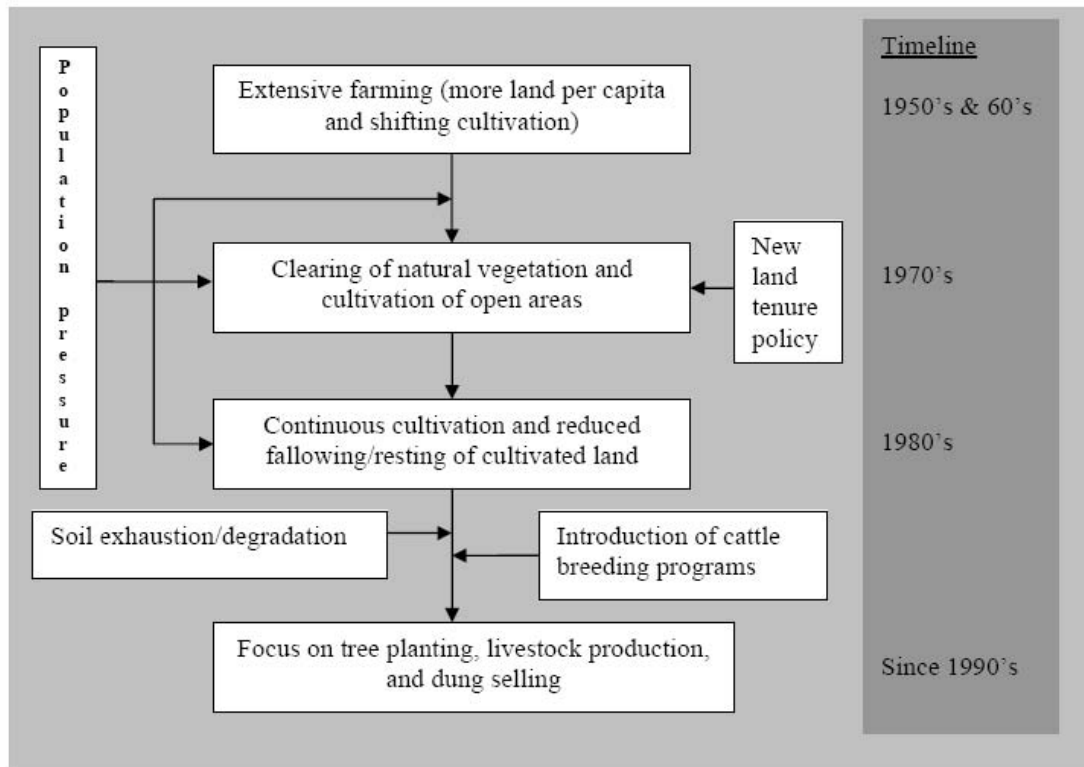
The objective of this research was to identify enabling conditions that foster SWC activities in the Beressa watershed of the Ethiopian central highlands. Based on earlier research on the long-term dynamics in land resource use and conservation practices in the watershed area (Amsalu and De Graaff, 2006a; Amsalu and De Graaff, 2006b; Amsalu et al., 2006a; Amsalu et al., 2006b; Amsalu et al., 2006c), a framework with a set of enabling conditions is presented. The enabling conditions are differentiated at three levels of decision-making in SWC (household/local, village/community, and regional/national) for a meaningful conservation intervention in the watershed area and other areas of the highlands with comparable situations.

## **7.2 The Beressa watershed**

The Beressa watershed is located in the central highlands of Ethiopia close to the town of Debre Birhan. Land degradation in the form of soil erosion, nutrient depletion and waterlogging is a major constraint to agricultural activities. On the other hand, the area has been one of the focus areas of past conservation programmes. A more detailed description of the watershed area is presented in Amsalu & De Graaff (2006b) and Amsalu et al. (2006c).

### **7.2.1 Farming and livelihood changes**

Farming in Beressa watershed is as old as the history of settled agriculture in the area several thousands of years ago, and is still a vital source of living to households. It is characterized by a highly integrated small-scale crop and livestock production system, which is at the level of meeting subsistence requirements. Barley and beans constitute the most important crops, and cattle and sheep the main livestock. Cattle provide the draught power for cultivation and threshing, and manure for fertilisation, household energy, and to obtain cash income from sales.



**Figure 7.1.** Timeline illustrating farming and livelihood changes in Beressa watershed, Ethiopian highlands.

The area is also characterized by a high population density of over 110 people km<sup>-2</sup>. The demand for agricultural land has been incredibly high due to increasing population pressure. Farm size is generally very small; it is on average 1.7 ha per household. Opportunities outside farming are very low, though farmers occasionally participate in certain off-farm activities in Debre Birhan town.

Since the 1950's the Beressa watershed has undergone through substantial changes in land use and socio-economic conditions (Amsalu et al., 2006c). The underlying causes of these changes were population pressure, soil degradation and water scarcity, introduction of cattle breeding program, and policy regime changes. In response, farming and livelihoods change gradually from largely depending on crop cultivation to more diversified activities that include livestock production, tree farming and dung selling (Figure 7.1).

## 7.2.2 Past of conservation activities

Soil and water conservation is an old practice in Beressa watershed. The area is topographically dissected and receives high rainfall, and SWC is an important aspect of the farming activity. Farmers traditionally use various conservation measures to overcome degradation problems. The conservation practices include a combination of physical and

agronomic measures (Amsalu and De Graaff, 2006b). The farmers developed these measures through a gradual, but dynamic, learning process and experimentation across generations.

As part of the large-scale past conservation programs, various forms of recommended measures have also been introduced in the area. Farmers were given specific measures to install on their cultivated land under the supervision of agricultural extension personnel and village administrations. Food-for-work was largely used for mobilizing community labour. Conservation structures were built on cultivated areas that were considered erosion prone, whether the farmer cultivating the land liked it or not.

Eventually, most of the recommendations were not appreciated by the farmers. While some farmers modified the recommendations to adapt to local circumstances, others completely removed the structures and returned back to their own ways of land conservation. As Keeley and Scoones (2004) noted the interventions in the country have been supported by simplistic, often unjustified, claims, and that these have had potentially negative impacts on poor people's livelihoods through their blanket application. Furthermore, these efforts have been little supported with appropriate policies, such as land tenure security, that encourage local farmers to commit themselves to long-term conservation investments.

### **7.2.3 The situation now**

Currently, the farmers in Beressa watershed are confronted with several interrelated problems. In general, there is a growing need for more production to cope with increasing population. On the other hand, they are faced with degradation problems that constrain sustained production. Some of the most pressing problems include:

- Soil erosion particularly on the hillsides and sloping areas
- Low level of, and generally declining, soil fertility conditions
- Waterlogging of low-lying areas
- Diminishing land holding size due to population pressure and degradation
- Inadequate and inactive extension service
- Lack of trust between farmers on the one hand and local officials and extension agents on the other
- Lack of motivation and reluctance among the farmers to participate in conservation activities
- Heavy dependence on cattle dung as a means of living and cash income
- Unaffordable fertiliser prices and limited access to credit services

These problems indicate the extent to which farmers are trapped in a complex web of challenges. The situation becomes worse to the subsistence economy in which vulnerability to risks is so enormous. However, addressing these problems depends not only on local level actions by the farmers, but also on the decisions of all the stakeholders at the different levels of decision-making.

### **7.3 Towards creating enabling conditions – a framework for intervention**

In this section, we present a framework for successful conservation intervention and sustainable land management in the Beressa watershed. The framework comprises of a set of enabling conditions that are differentiated at three levels of decision-making: local/household, village/community, and national/regional level (Figure 7.2). The three decision-making levels are however interconnected to each other. The choices and activities of the farmers at the local level (e.g. fertilizer use, improved seeds, and conservation) for instance influence policies at the national/regional level (e.g. fertilizer imports, extension, and land policy), and vice versa.

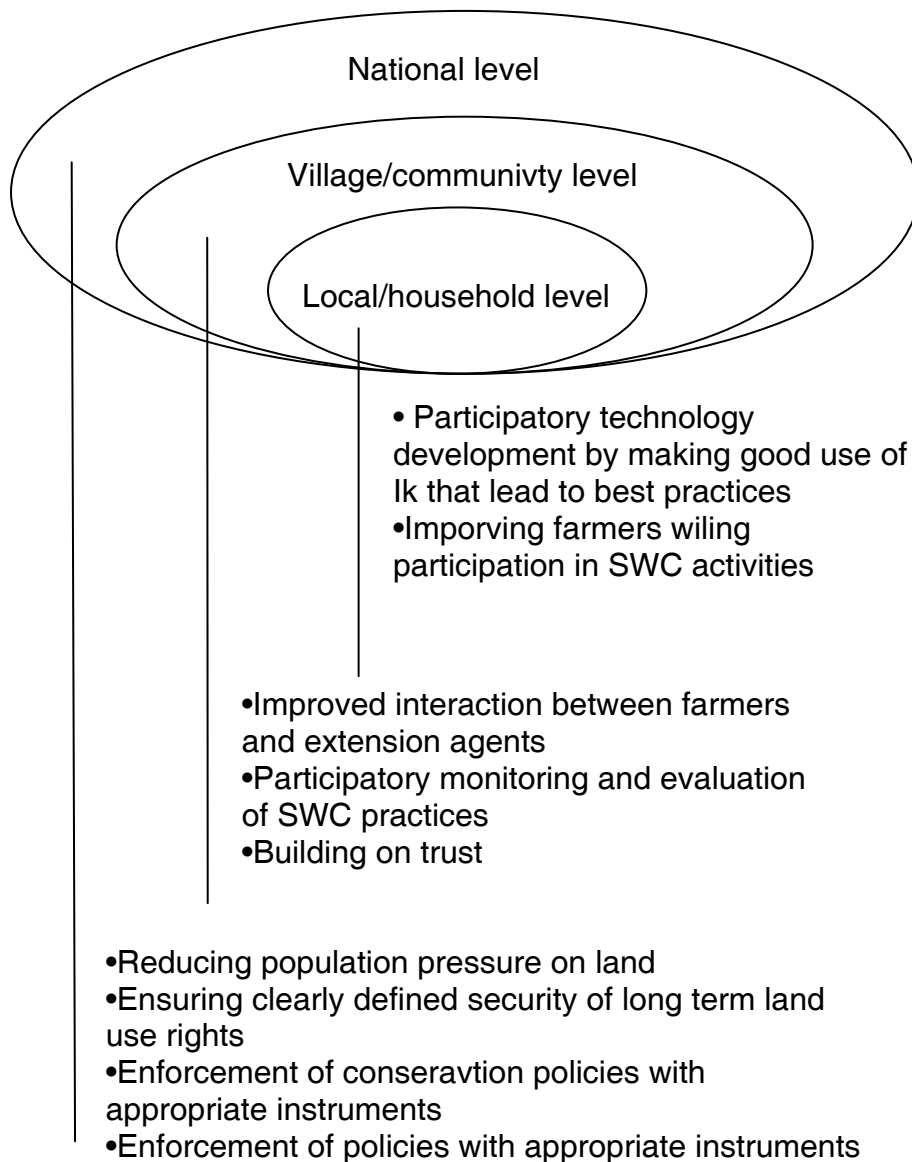
#### **7.3.1 Local/household level**

The farm household is the level at which most resource use and conservation decisions are made. This underlines the fact that conservation activities that fail to involve farm households from the decision-making process would have little chance of success. Local initiatives and farmers' conservation decision in the watershed area has been interfered by top-down recommendations. Therefore, involvement of the farmers in technology development and local conservation activities is necessary. Such specific interventions would enable the farmers to make appropriate decisions in land use and conservation.

##### *Participatory technology development – making good use of indigenous knowledge*

Sustained adoption of introduced SWC technologies by the farmers in the watershed area has not been as expected due to the influence of a combination of factors (Amsalu and De Graaff, 2006a). Appropriateness of the technology to local conditions was one of the main constraints that discouraged farmers from using the measures continuously. Farmers mention several problems associated with the recommended measures, such as high labour demand, long return period, loss of cultivable area, and pest infestation. In many cases, they modified the measures in a way of adapting it to fit local conditions. This clearly illustrates the knowledge base that is available among the farmers which could be used for the development of suitable and acceptable conservation technologies. The farmers know their situation better in which they gained it through long years of farming and conservation experimentation. This was evident in the range of measures they applied for erosion control and fertility maintenance (Amsalu and De Graaff, 2006b). However, this knowledge and experience has been scarcely appreciated in past conservation activities.





**Figure 7.2.** A framework for creating enabling conditions for soil and water conservation in the Beressa watershed, highlands of Ethiopia.

Research in many parts of Africa confirmed the important role of indigenous knowledge (IK) in sustainable land management (Critchley et al., 1994; Pretty and Shah, 1997; Reij et al., 1996; Reij and Waters-Bayer, 2002). It is therefore necessary to use this knowledge base as a starting point for the development of effective and acceptable conservation technologies. In this regard, participatory technology development (PTD) could enable to make use of locally available knowledge in developing best practices that meet local requirements together with the end users – the farmers. Apart from allowing farmers' knowledge and experiences to be taken on board, PTD helps create confidence among the farmers in the measures developed,

by demonstrating meaningful results. PTD emerged in response to the recognition that farmers failed to adopt recommendations because the technologies were not appropriate to their situation (e.g. van Veldhuizen et al., 1997). Furthermore, it could enable the farmers to use locally available resources (such as their manure) to fight degradation problems by increasing their skills to innovate and modify their practices. It should be noted however that technical guidance in development technologies should be more farmer-sensitive, less rigid, and easy to understand for the farmers (Critchley, 1991). Because without active participation of the farmers, conservation activities and recommendations are less likely to be appreciated and used. Therefore, farmers need to learn from experts about the technicalities of conservation, and so do the experts learn from the farmers about the practical aspects and dynamics of conservation technologies for a better impact in land conservation.

*Improving farmers' participation in conservation activities*

The role of farmers' participation in conservation activities is well documented in the literature (Ashby et al., 1996; Chambers, 1997; Stocking, 1996). And there is no doubt that participation is crucial to the success of conservation projects. However, farmers' willing participation in the Beressa watershed has been very low. A survey in the watershed area showed that 73% of the farmers were participated in past conservation activities of stone terrace construction against their will (Gebeyehu, 2004). Similar problems were reported elsewhere in the Ethiopian highlands (e.g. Bewket and Sterk, 2002) indicating a wider prominence of lack of farmers' participation. The farmers were in many cases forced to participate in the conservation works through by using incentives and/or regulations. For instance, food-for-work has been widely used to mobilize farmers' labour for constructing conservation structures, although the impact has been disappointing in many cases. Since the farmers expect the incentive to continue, the conservation structures are commonly left to deteriorate in the post-project phase (Critchley, 1991; Shiferaw and Holden, 1998). Furthermore, the incentive distorted farmers' understanding of conservation projects, in which they focus on the current benefits obtained from the incentive rather than on the benefits that can be obtained from investments in the future.

Therefore, willing participation of the local farmers is a necessary that should be considered in local level conservation decision. This could be achieved by educating the farmers and by demonstrating meaningful results in order to raise their motivation and commitment. In the watershed area, the farmers clearly noted that they were not unwilling to participate in project activities, but they were unsure about the success of the conservation activities and thus become reluctant to participate. Moreover, participation of the local people should not be seen, nor treated, in isolation to other constraints at the village/community and national/regional levels such as lack of markets, land tenure, and others.

### 7.3.2 Village/community level

Local level conservation decisions by the farmers are considerably influenced by village level decisions and activities. Resolving these constraints and thus creating enabling conditions would therefore help to motivate local farmers to use sustainable practices. The most important constraints identified at the village/community level in the watershed area include poor interaction between farmers and extension agents, absence of monitoring and evaluation of conservation activities, and lack of trust among the stakeholders in land conservation (farmers, extension staff, and village administrators).

#### *Enhancing interaction between farmers and extension agents*

Since its inception in the 1960's, the Ethiopian extension system has been following a formal approach, which is characterized by a top-down delivery system. Research is carried out at the universities and research centres and transferred to the local farmers through the extension agents, as is well explained in the transfer of technology model. This has been widely criticised for the lack of farmers' involvement in the process of technology generation and for the limited interaction between the farmers and the extension agents in the transfer process (Beshah, 2003; Kassa, 2003; Kassa and Abebaw, 2004).

The interaction between farmers and extension agents in the Beressa watershed was very poor and did not develop much. Farmers received little advice about SWC since the extension service was mostly focused on the promotion of improved cattle and crop varieties (De Wolf, 2004). An additional constraint to the existing extension system is the involvement of the extension agents in village administration including tax collection, which is outside their normal task. And extension advice is mostly given at the offices of village administrations while the farmers gathered for other purposes (Figure 7.3). This has created a communication gap between the farmers and extension workers and thus weakened their interaction. For instance, about 27% of the farmers have never met an extension agent and only 12% indicated they meet the extension worker at their own farm land (Table 7.1). On the other hand, lack of incentives and absence of proper supervision of the extension staff made the extension agents less committed to their activities. In addition, the number of extension worker was incompatible with the size of the farming community in the area. The average farmer to extension agent ratio was 980:1, which has been practically beyond one's reach.

**Table 7.1** Contact between farmers and extension workers in the Beressa watershed, Ethiopia

Farmers' Response	% of respondents (n=74)
Not met an extension agent in the last 2 years	27
Meet an extension agent only at office	66
Meet an extension agent in the village	30
Meet an extension agent at own farmland	12

Source: De Wolf, 2004

Total over 100% is due to multiple responses

Although the government launched PADETES (Participatory Agricultural Demonstration and Extension Training System) to ensure farmers' participation, farmers perceived the extension system top-down due to the affiliation of extension workers to the village administration. In a study in south-western Ethiopia, Kassa and Abebaw (2004) reported that the extension work was not participatory in its nature, little consideration was given to farmers' experiences and knowledge, and extension workers lacked practical skills. Studies elsewhere in the country (Beshah, 2003; Kassa, 2003) also present similar evidence, which is contrary to government claims that the extension program in the country has been carried out with no hitches.

Farmers need to be educated to raise the level of their awareness of problems and benefits of interventions in order to enhance their interaction with the extension workers. Moreover, farmers should not be considered as receivers of recommendations only, but also as good extensionists. This could curb at least the two major constraints facing the extension system in the area:

- The scanty number of extension agents in the area
- Existing poor interaction between farmers and extension agents



**Figure 7.3.** Farmers' meeting with village administrators and extension workers in a village administration compound in Beressa watershed, highlands of Ethiopia

#### *Monitoring and evaluation*

Once conservation projects are put in place, monitoring and evaluation of their impacts is necessary (De Graaff, 1996). For several reasons, which include changes in land use and socio-economic circumstances, the measures introduced may not be appropriate to the needs and aspirations of the farmers as well as to local conditions. And this might eventually lead to abandonment of the measures as it was seen with the introduced stone terraces in the watershed area (Amsalu and De Graaff, 2006a). Farmers might also lack the confidence to

participate in future conservation activities due to the failures they might have experienced in the past.

Therefore, monitoring and evaluation of conservation activities could enable to check compatibility of technologies and thus make necessary corrective measures. Since farmers can contribute in identifying the problems they faced while using the measures and in the development of suitable alternatives, participation of the local farmers in monitoring and evaluation is crucial. Further, this could help to integrate farmers' criteria and preferences in the making of conservation alternatives. In a participatory evaluation conducted in the watershed area, the farmers were active in identifying criteria and alternatives in the selection of best SWC measures for different categories of cultivated land (Amsalu et al., 2006a). The measures were identified based on the needs of the farmer as well as their suitability to local circumstances. Thus, conservation measures that meet the needs of the local farmers could have a high probability of adoption and continued use. In addition, farmers' participation in monitoring and evaluation can lead to empowerment and thus strengthen a sense of ownership of the conservation program among the farmers.

#### *Trust-building*

Trust-building is very instrumental to get local farmers participate in conservation activities. In Beressa watershed, there exists mistrust between farmers on the one hand and extension agents and village administrations on the other. Similar problems were also reported by Bekele-Tessema (1997) in a nearby watershed area. This often becomes a barrier for knowledge transfer and mutual cooperation in land conservation. However, trust-building is not an easy task; it is a rather gradual process and requires working closely with the farmers, getting involved in their situation, and demonstrating tangible results of interventions. It also requires the prominence of fundamental democratic traditions in village governance, which should be based on the principles of equitable resource use and development.

### **7.3.3 National/regional level**

The policy environment within which the farmers operate is crucial for soil and water conservation and sustainable land management (Blaikie, 1985; Kuyvenhoven, 2004). Major concerns that need policy attention at the national/regional level include reducing the pressure on land, security of land tenure, efficient markets (for agricultural inputs and outputs) and credit services, and enforcement of policies related to land conservation.

#### *Reducing the pressure on land*

Growing rural population has generally increased the demand for agricultural land in highlands of Ethiopia. In a period of 43 years, the population of the Beressa watershed increased fourfold and this has led to a decline in per capita farm size from 1.96 ha to 0.53 ha (Amsalu et al., 2006b). Land reform and redistribution of holdings have been the strategies used to overcome emerging landlessness. Apart from land fragmentation and dispersion of holdings, increasing pressure on the land further intensified continuous cultivation. Soils have

thus run the risks of degradation due to limited investments in conservation and fertility maintenance. Given the smaller per capita holding size and looming soil degradation, the potential for further land redistribution in the watershed area seems unpromising. Therefore, whilst investments in land conservation are very essential, other options outside farming should be sought for a longer-term solution. The development of off-farm employment opportunities that helps to absorb the huge rural labour force is badly needed in order to increase labour productivity, reduce poverty, and fight land degradation.

#### *Security of long-term land use rights*

In Ethiopia, land is under public ownership administered by the state, and farmers have only usufruct use rights. This has caused tenure insecurity among the majority of the farmers in the country, and becomes an obstacle to long-term investments in conservation (e.g. Adal, 1999; Admassie, 2000; Nega et al., 2003; Rahmato, 1994). Hence, land tenure has become an issue of high controversy in the country.

Insecurity of land tenure was also evident in the Beressa watershed as it is the case in many other places of the Ethiopian highlands. About 95% of the farmers were uncertain for how long in the future they would hold their current farm land (Adimassu, 2005). Such insecurity shortens farmers' planning horizon related to investments in conservation. The recent land redistribution in the area was carried out in 1997, and farmers had different opinions about it. Landless farmers and those holding a smaller farm size and/or cultivate bad quality farms supported the land distribution policy because of the expectation of getting more and/or good quality land from future redistribution. Conversely, farmers holding a larger farm size and/or good quality farms were against it. Nevertheless, redistribution always causes tenure insecurity among the right holders because of the high probability of losing part of the land they have been cultivating (Rahmato, 2003).

Furthermore, there were various types of informal land contracts by the farmers in the watershed area as a means to access land, such as rental for a short period of time and different types of sharecropping arrangements. Adimassu (2005) found that such informal arrangements negatively influenced conservation activities: SWC investments were very limited in non-owner (share cropped and rented) operated plots. Therefore, a clear definition of long-term land use rights is necessary in order to encourage farmers invest in conservation and care for the land. As the risks of losing the right increase, farmers become less likely to invest in or conserve the land (Holden and Yohannes, 2001). Without solving this key concern of the farmers in the watershed area and other areas of the Ethiopian highlands, it would thus be unrealistic to expect successful conservation programs.

#### *Pro-poor market and credit services*

Inefficient market for agricultural inputs such as fertilizers, pesticides, and improved seeds are among the main constraints to farming and conservation activities in the watershed area. In particular, high and rising fertilizer prices often inhibited soil fertility management practices. Limited credit services and short payoff periods discouraged most farmers from using chemical fertilizers. The farmers therefore gradually switched to other activities (e.g.

tree planting, dung selling, and livestock production) to cope with reduced land productivity instead of continuing to invest in land conservation (Amsalu et al., 2006c). This underlines the need to support resource-poor farmers by creating an efficient market and credit services so that they would be able to use fertilizers and boost production. In addition, such services would encourage the farmers to devote themselves to sustainable farming practices and care for their land resources.

#### *Enforcement of policies*

Policy is presumed to be put into practice. In most instances, however, this has not been the case in Ethiopia, particularly when it comes to land conservation. As Asfaw (2003) rightly put it, the question of conservation in Ethiopia is usually the subject of a great deal of talk but very little action. Policy formulation by itself does not bring any change unless the policy is translated into action. Especially when other enabling conditions are present (such as secure land tenure, credit, and efficient market for inputs and outputs), policies should be enforced using appropriate instruments. In this regard, a great deal of experience could be learnt from the Good Agricultural Practices (GAP) strategy that has evolved in recent years with the aim to enhance production and environmental sustainability of agriculture. In the strategy, the farmers are offered with opportunities to improve their livelihoods, while at the same time they are required to comply with the recommendations and regulations set by the stakeholders (including the farmers themselves).

### **7.4 Concluding remarks**

Soil and water conservation activities in the Beressa watershed are faced with multiple problems. Though the farmers have a good knowledge of the problems and they apply different measures against them, their activities are constrained by obstacles that exist at the different levels of decision-making. Most of these constraints are related to their important levels, viz. local/household, village/community, and national/regional. A set of enabling conditions related to the three decision-making levels are identified in order to encourage the local farmers and promote best practices in SWC. The most important enabling conditions at the local/household level include participatory technology development and improving farmers' participation in conservation activities. These would help to use farmers' knowledge and experiences in the generation of best practices as well as foster adoption of recommendations by demonstrating meaningful results. At the village/community level, enhancing the interaction between the farmers and the extension workers, monitoring and evaluation of conservation activities, and building on trust among the stakeholders in land conservation require considerable attention. Improved interaction between farmers and extension workers facilitates knowledge transfer and thus raises the level of farmers' awareness of problems and benefits of conservation. Farmer' participation in monitoring and evaluation empowers the farmers, develops a sense of ownership of the conservation activities, and further promotes trust among the stakeholders. The most important concerns

that need policy attention at the national/regional level include reducing the pressure on land, security of land tenure, efficient market and credit services, and enforcement of policies related to land conservation. Development of employment opportunities outside farming could help to reduce the pressure on land and emerging landlessness. Security of land tenure encourages farmers to invest in long-term conservation activities. Furthermore, efficient market and credit services are needed to support smallholder production and resource conservation. These enabling conditions would help to enhance better farming and sustainable land use in the watershed area and other areas of the Ethiopian highlands with comparable situations.

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## **Chapter 8**

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### **Synthesis**

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## **8. Synthesis**

It is generally recognized that the Ethiopian highlands experience severe rates of land degradation in the form of soil erosion and nutrient depletion and that this has constrained agricultural development and food security in the country. However, despite persisting for several decades, the problem did not receive policy attention until after the 1970s. Since then, large-scale conservation projects have been initiated and carried out by the government with the support of donor organizations, though the conservation measures introduced have not been sustained by most farmers and land degradation remains unabated. Hence, the projects have been widely criticized for failing to reverse the situation and for the huge squandering of labour and financial resources (Admassie, 2000; Dejene, 2003).

It will be recalled that the objective of this research was to examine soil and water conservation activities in the Beressa watershed of the Ethiopian highlands and identify the constraints and opportunities for better conservation intervention. The analysis was carried out in the context of the history of land use and farming activities, livelihood and socio-economic changes, and conservation interventions during the second half of the 20<sup>th</sup> century. This chapter of the thesis presents a synthesis of the main findings of the research and their implications for conservation intervention.

### **8.1 Land use dynamics and the driving forces**

The main land use types in the Beressa watershed include cropland, grazing land, forested areas, plantations, and bare land. These land uses underwent substantial changes between 1957 and 2000. The most important changes were deforestation and subsequent plantation, expansion of grazing land, and reduction of bare land. Cropland comprised the largest portion of the watershed area, but despite population increase it increased very slightly during the 43-year period compared with other land uses. Destruction of the natural vegetation cover and gradual replacement with plantations through afforestation programmes were additional notable changes. The expansion of grazing land was also remarkable; it was greatest in the lower part of the watershed.

The land use changes were driven by several factors; demographic pressure, soil degradation and water scarcity, introduction of improved breeds of cattle, and policy (land and economic) regime changes. The population of the watershed area quadrupled during the 43-year period and created enormous pressure on land resources, resulting in the destruction of the natural vegetation and expansion of cultivation into marginal areas (chapter 2). Cultivation of steep slopes without appropriate conservation measures led to soil degradation. When degraded, these areas were converted into other land uses, such as grazing and plantations. In addition, runoff from the steep slopes affected the hydrology of the low-lying areas, particularly in the downstream part of the watershed area. These areas were eventually taken out of cultivation and used for grazing and tree planting. On the other hand, water

scarcity due to fluctuation in the rainfall pattern is reducing yields, since farming is entirely dependent on rainfall. It is revealed that fluctuations in crop yield follow the rainfall pattern (chapter 2), indicating the direct influences of rainfall on crop production and farmers' land use decisions. The expansion of grazing land and plantations has been partly driven by unreliable rainfall.

As a consequence of the introduction of a cattle-breeding program in the 1980s, grazing land started to compete with cropland and plantations in farmers' land use decisions. This, coupled with the problem of waterlogging, led to the expansion of grazing land. After the land reform in 1975, per capita farm size diminished, resulting in the farming system change from shifting cultivation to continuous cropping. Deforestation has also been widespread, especially in government protected areas, and open areas have been brought into cultivation. Increased pressure on the land and shortened fallows limited the traditional ways of restoring soil fertility. In response to the catastrophic famines of the 1970s and 1980s, conservation programs were carried out to rehabilitate degraded areas; they led to a large-scale replacement of deforested areas by plantation and the construction of terraces on cultivated areas. The change in economic policy after 1991 liberalized markets for agricultural inputs (fertilizers) and outputs. Functioning rural markets stimulated farmers to diversify their income mainly through tree planting and selling dung-cakes. As trees have become a vital source of cash income, the farmers have become more involved in tree planting, which has contributed to the expansion of the plantations.

## **8.2 Changes in farming practices and livelihoods**

As a consequence of the changes in land resource use, changes have emerged in farming practices and farmers' livelihoods in the watershed area. The most important include more intensive cultivation, a focus on the cultivation of the bottomland, a focus on livestock production and tree planting, a focus on dung-cake making and selling, and an increased demand for chemical fertilizers.

### *Intensive cultivation*

Increased population pressure in the watershed area has reduced per capita cropland because in the area there have been limited economic opportunities available outside farming. Between 1957 and 2000, per capita cropland declined from 1.96 ha to 0.53 ha (chapter 2), and land fragmentation increased along with population pressure. Most of the remaining uncultivated land lies either on the very steep slopes in upper watershed area, where erosion is severe, or in the bottomland of the watershed, which suffers from drainage problems. Since the possibility for further expansion onto uncultivated areas was limited, long-term fallows were gradually abandoned and replaced with intensive land use systems of continuous cultivation. However, yield data for the major crops showed no improvements between 1987 and 2003, in spite of increased intensity of cultivation (chapter 2). This contradicts the

contention that farmers invest in land management as land becomes scarcer (e.g. Benin and Pender, 2001; Tiffen et al., 1994).

*Focus on the fertile bottomland*

The deforestation and cultivation of marginal areas increased the risks of soil degradation. Steep areas were particularly affected. As returns to investments on degraded steep lands diminished, farmers focused on the cultivation of fertile fields in the bottomland. This has particularly been the case in the upper part of the watershed where the bottomland is the most fertile area due to the supply of fresh sediments from the steep areas that receive little attention from the farmers. However, cultivation of the bottomland is limited to the short rainy season, because of drainage problems during the long rains. In the downstream area, it is difficult to cultivate the bottomland due to the problem of waterlogging during the short and long rains.

*Focus on livestock production and tree planting*

In response to reduced farm size, soil degradation, and water scarcity, there has been a gradual shift from sole dependence on annual cropping, to livestock production and tree planting (mainly eucalyptus) – particularly in the lower part of the catchment. In the latter area, the two factors influencing farmers have been cattle breeding programs and the waterlogging hampering crop cultivation in the bottomland. The farmers have reacted by becoming much more involved in cash-earning activities like selling dung-cakes and fuel wood, instead of making long-term conservation investments. However, these practices have not been without negative consequences on the future use of land resources in the area.

*Dung-cakes as a vital source of cash income*

An important livelihood change that has emerged in the watershed area is increased farmer participation in making and selling dung-cakes. The downstream part of the watershed is the major source of the dung-cakes sold in the market in Debre Birhan town. The farm households in this area get about 40% of their annual income from the sale of the dung-cakes (chapter 3). Remoteness from the urban market is the major constraint preventing farmers from the upstream villages from selling dung-cakes. However, they make dung-cakes for their own fuel needs. Manure is a vital and cheap source of soil fertility maintenance, but the rising urban demand for the dung-cakes has created competition between using manure for soil fertility maintenance and using it to generate cash income. Manure use for energy results in organic matter and soil nutrients being removed from the farm. This interrupts the nutrient cycle and results in negative nutrient balances in the area, thus increasing the demand for chemical fertilizers to augment the nutrient losses. This underlines the fact that when farmers are resource-poor, market access (mainly distance to markets) may not always lead to sustainable agricultural practices.

#### *Increased demand for chemical fertilizers*

Soil degradation resulting from continuous cultivation, limited conservation practices, and selling manure often increases the demand for artificial amendments. The farmers in the upper part of the watershed rely less on chemical fertilizers than the farmers further downstream. Most downstream farmers prefer to use chemical fertilizers instead of manure, because the soils respond little to manuring and manuring is too labour intensive and thus unprofitable. The manure is therefore used instead to make the dung-cakes. Nevertheless, most farmers cannot afford chemical fertilizers. The major impediments to the use of chemical fertilizers are high fertilizer prices, the risks associated with rainfall failure, and limited credit services; hence, soil degradation is a real threat.

### **8.3 Soil and water conservation**

Soil and water conservation constitutes an important component of the farming activity in the watershed area and farmers apply various traditional measures to combat degradation problems. Measures have also been introduced during past conservation efforts in the area. The research attempted to answer the following important questions with regard to soil and water conservation activities: what farmers think of soil erosion problems and fertility changes, and which conservation practices they use; why introduced measures have been poorly sustained by the farmers and what were the determinants; and what is the performance of currently used conservation measures and which criteria the farmers consider when choosing measures.

#### *Farmers' knowledge and practices*

Farmers in Beressa watershed have a good knowledge of erosion problems and soil fertility changes and they use various conservation practices to combat these problems (chapter 4). About 72% of the farmers interviewed reported erosion problems, and they expressed the opinion that conservation was necessary. They further expressed the opinion that the loss of soil from cultivated fields reduced the depth of the topsoil and led to a reduced production potential. The main causes of soil loss they recognized were erosive rains, steep slopes, damaged conservation structures and the effect of tillage that make the soil loose and bare. However, although farmers were aware of erosion problems, their understanding of erosion severity was confined mostly to visual evidence (appearance of rills and gullies). Such views could negatively influence farmers' efforts to combat sheet erosion. Therefore, farmers need education in this regard, to make them better aware of erosion processes and impacts. Unfortunately, however, the extension service in the watershed area is very weak and the farmers obtain little assistance in SWC from the extension officers (chapter 7). Farmers also indicated problems of soil fertility decline in recent decades; they attributed these to continuous cultivation, soil erosion, and insufficient use of chemical fertilizers.

The majority of the farmers believed that erosion could be halted, and were using a range of practices against it, such as stone terraces/bunds, drainage ditches, waterways, and contour ploughing. They have changed and modified the measures to fit local requirements. This clearly indicates they have knowledge that could be used for the development of appropriate conservation measures (Critchley et al., 1994; Reij and Waters-Bayer, 2002). The farmers also apply practices for maintaining soil fertility: manuring, crop rotation, fallowing, erosion control, and application of chemical fertilisers. Though the farmers are aware of the multiple benefits of organic matter, their manure application was limited by manure being used for fuel (for their own use, or sold in the town) and by the remoteness of their farm plots (which imposes labour constraints). An important observation is the tendency of the farmers to accept and use conservation practices that enhance productivity and offer them short-term benefits, instead of technologies requiring long-term investments. From this it is clear that conservation activities need to consider farmers' priorities and the conditions that influence their decisions, as well as their indigenous knowledge and associated practices.

#### *Problem of sustained adoption*

Despite decades of conservation intervention in the watershed area, sustained adoption by the local farmers has not been as expected. Of the 147 farmers interviewed, 95 had initially adopted introduced stone terraces, but only 52 of them had continued using the measure (Chapter 5). Several factors influenced adoption and continued use of the conservation measure. Adoption was found to be influenced by the farmer's age, farm size, perception of the technology's profitability, slope, livestock number, and soil fertility. The results indicate that the likelihood of adoption is higher with older age of the farmer, perception of the technology's profitability, large farm size and large livestock number. And continued use was influenced by the technology's profitability, slope, soil fertility, family size, farm size, and participation in off-farm work. Although farmers have a positive perception about the benefits of conservation, sustained adoption could only be realized as long as the technology was profitable in the short run. The results further showed the negative influences of off-farm work on continued use of the measures. It appears that long-term conservation investments were traded off in favour of short-term gains from off-farm activities.

The findings therefore indicate that conservation interventions should focus not only on the technical performance of the measures but also on the economic benefits to the farmers in the short and the long run in order to enhance adoption and sustained use. Furthermore, analysis of the determinants of adoption *per se* may not provide a full understanding of the range of factors that influence farmers' decisions on sustained investments.

#### *Performance of conservation measures*

At present, the farmers in the Beressa watershed use a range of conservation practices. Farmer participatory evaluation of the performance of these practices showed that farmers consider a range of criteria when choosing the conservation practices (chapter 7). Most of these criteria account for the costs and the benefits relating to the use of the measures unlike



the recommended measures which often focus on erosion control alone. However, the relative importance of each criterion in the choice of the measures largely depended on specific attributes of the cultivated land, such as slope and soil type.

Stone terraces were the most appropriate measures considered on cultivated steep slopes, followed by the waterways. On medium slopes, the SWC measures considered most appropriate were soil bunds followed by contour ploughing (although soil bunds were rarely seen on cultivated areas, perhaps due to the influence of previous recommendations to build stone terraces). Drainage ditches were the most preferred measure on the cultivated gentle slopes where drainage problems were more serious than soil loss. The results indicated farmers' preferences in the use of conservation measures. It is therefore necessary to integrate local experience with scientific knowledge, in order to develop suitable measures that fit local circumstances and thus become acceptable to the farmers.

Furthermore, the participatory approach we employed in the evaluation proved helpful for sharing knowledge with the local farmers. It was particularly helpful to elicit farmers' conservation objectives, priorities, and preferences. However, a major obstacle was lack of trust, especially at the beginning of the evaluation. The apparent mistrust observed was not only between the farmers and the researchers, but also among the farmers themselves, where it constrained the free exchange of views and the reaching of consensus. This underlines the importance of building on trust in order to motivate farmers to participate in conservation activities.

#### **8.4 Implications for conservation intervention**

Soil and water conservation activities by the local farmers in the Beressa watershed are faced with several problems. Though farmers have a good knowledge of degradation problems and apply a range of conservation practices, their activities are largely constrained by problems that exist at the different levels of decision-making. Therefore, creating enabling conditions to local conservation activities would lead to best practices that bring about meaningful results. A necessary precondition for the success of conservation projects is the participation of local farmers. Another important issue that is often ignored in interventions is the suitability of recommended measures for local circumstances. In this regard, participatory technology development (PTD) with the local farmers would help when designing suitable and acceptable measures (Veldhuizen et al., 1997). The poor interaction existing between farmers and extension officers in the area requires serious attention. Separating the extension service from village administration could relieve the administrative burden on extension staff, allowing them to focus instead on their intended activities. Monitoring and evaluation of conservation activities is necessary for checking the progress of interventions; this should be done together with the farmers. Farmer participation can lead to empowerment and to farmers developing a sense of ownership of the conservation activities, as well as further promoting trust among the stakeholders in land conservation.

The policy environment within which the farmers operate is also a serious constraint that needs attention at the national/regional level. Major concerns that need policy attention include reducing demographic pressure on land, security of land tenure, efficient market (for agricultural inputs and outputs) and credit services, and enforcement of policies related to land conservation. Development of the modern sector of the economy could enable to absorb the surplus rural labour force and reduce demographic pressure on land resources. As has been widely argued (e.g. Adal, 1999; Rahmato, 1994), the land tenure issue in Ethiopia requires clear definition in order to encourage farmers to invest in conservation and care for the land. Furthermore, existing policies relating to land conservation need to be translated into action. Policies should be enforced using appropriate instruments, especially when other enabling conditions are present (such as secure land tenure and an efficient market for inputs and outputs). Punitive measures could be sought, if necessary, to get land users to fulfil their responsibilities, but this strategy requires further investigation. Above all, government commitment to implement the existing policies and to be flexible whenever change is needed is imperative. In sum, there is a need for a more meaningful approach to conservation intervention that takes into account the constraints at the different levels of decision-making (local, village, and national/regional level) in order to address local problems successfully (Chapter 7). This would motivate farmers to apply conservation activities and would encourage sustainable land management.



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## **Summary**

Land degradation in the form of soil erosion and nutrient loss is a major constraint to farming activities and agricultural development in the highlands of Ethiopia. Though large-scale conservation projects have been initiated and carried out by the government during the past few decades, the conservation measures introduced have not been sustained by most farmers and land degradation continued to be a problem. The main objective of this research was to examine soil and water conservation practices in the Beressa watershed of the Ethiopian central highlands and identify the constraints and opportunities for a better conservation intervention. The analysis was carried out in view of the history of land use dynamics, farming and livelihood changes, past conservation activities, and policy regime changes.

### **Chapter 2: Long-term dynamics in land resource use and the driving forces**

The dynamics in land resources use between 1957 and 2000 was analysed. It was revealed that the watershed area underwent through substantial land use changes during the 43-year period. The most important changes were destruction of the natural vegetation cover, increased plantations, and expansion of grazing land. Cropland, which comprised of the largest proportion of the watershed area, increased slightly despite a quadrupling in the density of human population. The land use changes were driven by a combination of several factors; demographic pressure, soil degradation and water scarcity, introduction of cattle breeding program, and policy (land, economic) regime changes. It was indicated that farmers tended to change gradually from sole dependence on annual cropping to tree planting and livestock production to cope with the problems of soil degradation and smaller farm size. Functioning rural markets stimulated farmers to participate in tree planting and selling dung-cakes. Apparently, little attention has been paid to investments in SWC and local soil fertility amendments to combat degradation problems. It was concluded that increased erosion and related nutrient losses due to limited conservation investments as well as the removal of potentially available soil nutrients through the sale of manure are real threats to the future of agriculture in the area.

### **Chapter 3: The dung-cakes threaten agricultural development**

The extent of farmers' involvement in making and selling dung-cakes and the implications on agricultural activities in general and soil fertility management in particular was investigated. Estimates of the amount of dung-cakes households sell annually and the loss of soil nutrients was analysed. Data were obtained by employing a combination of methods that include socio-economic survey, soil sample analysis, market survey, discussions with the local farmers and literature review. It was shown that farmers in the downstream part of the watershed area were more involved in dung-cake selling. Most farmers process about 90% of their cattle manure into the dung-cakes. It was revealed that 40% of the household income was obtained from the sale of the dung-cakes in the market in Debre Birhan town. On average a farm household exports about 43.5 kg N, 9.0 kg P, and 41.4 kg K y<sup>-1</sup> through the

sale of the dung-cakes. While there is increased demand for chemical fertilizers by the farmers, actual utilization is constrained by high and increasing market prices, lack of credit services and risks associated with rainfall failure. It was concluded that poverty, market access, and soil degradation were the most important factors influencing farmers' participation in selling dung-cakes.

#### **Chapter 4: Farmers' knowledge and practices**

A survey was conducted to explore farmers' perception of erosion problems and soil fertility changes as well as their conservation knowledge and practices in the watershed area. The results showed 72% of the 147 interviewed farmers recognized erosion problems. But most of the farmers associated severity of erosion problems with the appearance of visual evidence (rills and gullies) only. It was indicated that the majority of the farmers believe erosion could be stopped, and they applied a range of practices for erosion control and fertility improvement; stone terraces/bunds, waterways, drainage ditches, and contour ploughing. It was found that farmers have been changing and adapting the measures to fit local requirements. Apart from erosion control, the farmers also applied various practices for soil fertility maintenance which include crop rotation and animal manure.

Though farmers were aware of the multiple benefits of organic matter for fertility improvement, intensity of manure application was largely limited by the use for fuel and sale as well as distant farm locations that impose labour constraints. Farmers tend to accept and use conservation practices that offer them short-term benefits instead of technologies that require long-term investments. It was concluded that conservation interventions should consider farmers' knowledge and practices in the design of conservation technologies.

#### **Chapter 5: Determinants of adoption and continued use of stone terraces**

In this section, the determinants of sustained adoption of introduced stone terraces that have been widely promoted in past conservation interventions were analysed. A sequential decision-making model using the bivariate probit approach was employed to identify the factors influencing farmers' adoption decision and continued investments. The results revealed that adoption was influenced by farmers' age, farm size, perception of the technology's profitability, slope, livestock number, and soil fertility, while the decision to continue using the practice is influenced by actual technology profitability, slope, soil fertility, family size, farm size and participation in off-farm work. The results indicated the importance of household/farm and plot level factors in farmers' conservation decision. It was concluded that:

- analysis of the determinants of adoption *per se* may not provide a full understanding of the range of factors influencing farmers' decision of continued investments
- conservation interventions should not focus only on the biophysical performance of the measures but also on economic benefits that can be obtained to the farmers in the short run

- a ‘blanket approach’ to conservation intervention could make the measures inappropriate to local circumstances and eventually unacceptable by the farmers

### **Chapter 6: Participatory evaluation of soil and water conservation practices**

A farmer participatory evaluation of currently used SWC practices was carried out. The Regime method in multicriteria analysis was employed to identify the best measures on the different categories of cultivated land based on farmers’ evaluation criteria and rankings. It was revealed that farmers consider a range of criteria in choosing the conservation measures. Most of these criteria account for the costs and the benefits relating to the use of the conservation practices. The results indicated stone terraces the best measures on the steep slopes, followed by the waterways. On the medium slopes, soil bunds were considered best measures followed by contour ploughing. And on the gentle slopes where drainage problems were more serious than soil loss, drainage ditches were found to be the best measures. The results further underlined the relevance of farmers’ knowledge and experience in the development of appropriate conservation technologies.

### **Chapter 7: Creating enabling conditions for soil and water conservation**

A framework for better conservation intervention in the watershed area and other areas of the highlands with comparable situations was developed. The framework comprised of a set of enabling conditions that should be considered at three levels of decision-making, viz. local/household, village/community, and national/regional levels. Participatory technology development and farmers’ participation in local level conservation activities were indicated most important. At the village/community level, the interaction between the farmers and extension workers should be improved. In addition, monitoring and evaluation of conservation activities, together with the farmers, was indicated necessary for checking the progress of interventions. It was also noted that national/regional level decisions should support and encourage local level actions by the farmers. Policies related to demographic pressure, security of land tenure, and efficient market and credit services require serious attention.



## Samenvatting

Land degradatie in de vorm van bodemerosie en nutriëntverliezen is een belangrijke beperkende factor in de landbouw ontwikkeling in de hooglanden van Ethiopië. Hoewel er op grote schaal conserveringsprojecten zijn opgestart en uitgevoerd door de overheid gedurende de afgelopen decennia, zijn de geïntroduceerde maatregelen door de meeste boeren niet goed onderhouden en blijft land degradatie een probleem. De belangrijkste doelstelling van dit onderzoek is om de bodem- en waterconservering (BWC) maatregelen in het Beressa stroomgebied in de Ethiopische centrale hooglanden te beoordelen en de beperkingen en mogelijkheden voor betere conserveringsingrepen te identificeren.

De analyse is uitgevoerd in het licht van de historische landgebruik dynamiek, de veranderingen in de landbouw en levensomstandigheden, conserveringsactiviteiten in het verleden, and politieke koerswijzigingen.

### **Hoofdstuk 2: Lange termijn dynamiek van land gebruik en stimulerende factoren.**

De dynamiek van het landgebruik tussen 1957 en 2000 is geanalyseerd. Er kwam naar voren dat het stroomgebied substantiële landgebruikveranderingen ondergaan heeft in die 43 jaar. De belangrijkste veranderingen waren het teloorgaan van de natuurlijke vegetatie, de toegenomen bos aanplant en de uitbreiding van weidegronden. Akkerbouwland, dat het grootste deel bestrijkt van het stroomgebied, nam maar enigszins toe, ondanks een verviervoudiging van de bevolkingsdichtheid.

De landgebruikveranderingen werden veroorzaakt door een combinatie van verscheidene factoren: de bevolkingsdruk, bodemdegradatie en waterschaarste, de introductie van een veefokkerij programma, en politieke en economische veranderingen.

Het bleek dat boeren geleidelijk veranderden van een volledige afhankelijkheid van akkerbouwgewassen naar het planten van bomen en naar veeteelt productie om de problemen van bodemdegradatie en afnemende bedrijfsgrootte het hoofd te bieden. Goed functionerende rurale markten stimuleerden boeren om bomen te planten en gedroogde mest schijven te verkopen. Kennelijk is er weinig aandacht besteed aan investeringen in bodem- en waterconservering en aan verbetering van de bodemvruchtbaarheid om de bodemdegradatie te bestrijden. Geconcludeerd wordt dat de toegenomen erosie en nutriëntverliezen als gevolg van een gebrek aan conserveringsmaatregelen en de verwijdering van potentiële bodem nutriënten door de verkoop van mest reële bedreigingen zijn voor de landbouwontwikkeling in het gebied.

### **Hoofdstuk 3: De verkoop van gedroogde mest plakken bedreigt de landbouw ontwikkeling**

De mate waarin boeren betrokken zijn bij de productie en verkoop van gedroogde mest schijven werd onderzocht en de gevolgen daarvan op landbouw activiteiten en op het behoud van bodemvruchtbaarheid in het bijzonder. De jaarlijkse hoeveelheden door huishoudens verkochte mest schijven werd geschat en het verlies aan nutriënten werd geanalyseerd. De

gegevens werden verkregen door een combinatie van sociaal-economisch onderzoek, analyse van bodemonsters, marktonderzoek, gesprekken met lokale boeren en literatuuronderzoek. Aangetoond werd dat boeren in het benedenstrooms deel van het stroomgebied meer betrokken zijn bij de verkoop van mest schijven.

De meeste boeren verwerken ongeveer 90 % van hun koeienmest in droge mest schijven. En het is gebleken dat 40 % van het huishoudinkomen verkregen wordt door de verkoop van de mest schijven op de markt in de stad Debre Birhan. Gemiddeld exporteren landbouwhuishoudens ongeveer 43.5 kg N, 9.0 kg P en 41.4 kg K per jaar door de verkoop van mest schijven. Terwijl er een toenemende vraag is bij boeren naar kunstmest, wordt het actuele gebruik beperkt door de hoge en toenemende markt prijzen, het gebrek aan kredietmogelijkheden en de risico's vanwege regentekorten. Geconcludeerd wordt dat armoede, toegang tot de markt en bodemdegradatie de belangrijkste factoren zijn, die bepalen of boeren al of niet betrokken zijn bij de verkoop van mest schijven.

#### **Hoofdstuk 4: Boeren kennis en praktijken**

Een onderzoek onder boeren werd uitgevoerd om hun perceptie van de erosie problemen en veranderingen in bodemvruchtbaarheid te analyseren, en ook hun kennis en praktijken m.b.t. conservering in het stroomgebied. De resultaten toonden aan dat 72 % van de 147 geïnterviewde boeren erosie problemen onderkennen. Maar de meeste boeren associëren de ernst van erosie problemen alleen met het voorkomen van visuele kenmerken, zoals geulen.

De meerderheid van de boeren bleek van mening te zijn dat erosie voorkomen kan worden, en zij hebben diverse erosiebestrijding- en bodemvruchtbaarheid bevorderende maatregelen getroffen, zoals stenen terrassen en rijen, afvoerkanalen, drainage geulen en ploegen langs de hoogtelijnen. Boeren bleken maatregelen te veranderen en aan te passen aan de lokale omstandigheden. Behalve voor erosiebestrijding pasten de boeren ook diverse maatregelen toe voor het behoud van de bodemvruchtbaarheid, onder meer gewasrotaties en het gebruik van dierlijke mest.

Ofschoon boeren zich bewust waren van de veelvoudige baten van organisch materiaal voor bevordering van bodemvruchtbaarheid, werd het gebruik van mest op de velden beperkt door het gebruik en de verkoop ervan als brandstof, en door de afgelegen locaties van de velden, hetgeen de inzet van arbeid bemoeilijkte. Boeren accepteren en gebruiken in het algemeen die maatregelen die korte termijn baten opleveren, in plaats van lange termijn investeringen. Als conclusie kwam naar voren dat bij conserveringsmaatregelen de kennis en praktijken van boeren in aanmerking genomen moeten worden bij het ontwerpen van conserveringstechnologieën.

### **Hoofdstuk 5: Factoren die de adoptie en het continue gebruik van stenen terrassen bepalen.**

In dit hoofdstuk werden de factoren geanalyseerd die het duurzame gebruik bepalen van geïntroduceerde stenen terrassen zoals die in ruime mate gestimuleerd werden in voorgaande conserveringsprogramma's. Een opeenvolgend besluitvormingsmodel, dat gebruik maakt van de "bivariate probit" benadering is gebruikt om de factoren te identificeren die de adoptie beslissing en de voortzetting van conserveringactiviteiten door boeren bepalen. De resultaten geven aan dat adoptie werd beïnvloed door leeftijd, bedrijfsgrootte, perceptie t.a.v de het profijt van de technologie, de helling, aantal stuks vee en bodemvruchtbaarheid, terwijl de beslissing om de maatregel te blijven gebruiken werd beïnvloed door het actuele profijt van de technologie, helling, bodemvruchtbaarheid, familie grootte, bedrijfsgrootte en betrokkenheid bij werk buiten de landbouw. De resultaten tonen het belang aan van factoren op landbouwhuishouden en veld niveau, bij conserveringsbeslissingen. Er werd geconcludeerd dat:

- de analyse van de factoren, die adoptie als zodanig bepalen, geen volledig begrip geeft van de reeks van factoren die de beslissing van boeren bepalen om maatregelen te blijven gebruiken
- conserveringinterventies niet alleen gericht moeten zijn op de biofysische prestaties van de maatregelen, maar ook op de economische baten die op korte termijn behaald kunnen worden
- een 'blanket approach' t.a.v conserveringsinterventies tot gevolg kan hebben dat maatregelen niet geschikt zijn onder lokale omstandigheden en uiteindelijk onacceptabel zijn voor boeren.

### **Hoofdstuk 6: Participatieve evaluatie van bodem- en water conservering (BWC) praktijken**

Met boeren werd een participatieve evaluatie van huidige BWC maatregelen uitgevoerd. De Regime multicriteria analyse methode werd gebruikt om de beste maatregelen te identificeren voor de verschillende categorieën akkerbouwland, gebruikmakend van de eigen evaluatiecriteria en rangordes van boeren. Het bleek dat boeren een reeks van criteria hanteren bij de keuze van conserveringsmaatregelen. De meeste van deze criteria hebben betrekking op kosten en baten van het gebruik van de conserveringsmaatregelen. De resultaten gaven aan dat stenen terrassen de beste maatregelen zijn op steile hellingen, gevolgd door afvoer kanalen. Op middelmatige hellingen zijn stenen rijen de beste maatregel, gevolgd door bewerking langs de hoogtelijnen. En op zwakke hellingen, waar drainage problemen belangrijker zijn dan bodemverlies, bleken drainage geulen de beste maatregel te zijn.

De resultaten onderstrepen het belang van de kennis en ervaring van boeren in de ontwikkeling van conserveringstechnologieën. Er werd aangegeven dat het noodzakelijk is om boeren te betrekken bij het ontwerpen van conserveringsactiviteiten en hun kennis en

ervaring te gebruiken, teneinde te komen tot het op ruime schaal accepteren van de aanbevelingen.

### **Hoofdstuk 7: Creëren van voorwaarden om bodem- en waterconservering mogelijk te maken**

Een kader werd ontwikkeld voor de stimulering van de beste conserveringsactiviteiten in het stroomgebied en in andere vergelijkbare gebieden in de hooglanden. Het kader bestaat uit een geheel van bepalende voorwaarden, die in beschouwing genomen moeten worden op drie niveaus van besluitvorming, d.w.z. op lokaal/huishoud, dorpsgemeenschap en regionaal/nationaal niveau. Participatieve technologie ontwikkeling en participatie van boeren bij lokale conserveringsactiviteiten werden als heel belangrijk gezien. Op dorpsgemeenschap niveau zou de interactie tussen boeren en voorlichters verbeterd moeten worden. Daarbij werd de monitoring en evaluatie van conserveringsactiviteiten, gezamenlijk met boeren, nodig bevonden voor het volgen van de voortgang van interventies. Vervolgens werd aangegeven dat beslissingen op regionaal en nationaal niveau lokale activiteiten door boeren moeten ondersteunen en aanmoedigen. En beleid t.a.v. bevolkingsdruk, zekerheid over landrechten en efficiënte dienstverlening m.b.t. markten en krediet vereisen serieuze aandacht.



## **Curriculum vitae**

Aklilu Amsalu Taye was born on the 6<sup>th</sup> of October 1973 in north-western Ethiopia. He received a B.A. degree (with great distinction) in Geography from Addis Ababa University in 1997. After graduating, he was employed as a lecturer in the Department of Geography and Environmental Studies at Addis Ababa University in which he still holds the position. He continued his studies in the same University and received his M.A. degree in Physical Geography in 2000. The topic of his master thesis was focused on rill erosion processes and conservation techniques on cultivated areas in the central highlands of Ethiopia. In October 2001, he obtained a scholarship from the joint project between Addis Ababa University in Ethiopia and the Institute of Social Studies and Wageningen University in the Netherlands for a PhD study. He then joined the Erosion and Soil & Water Conservation Group of the Department of Environmental Sciences at Wageningen University in October 2001 to start his PhD study. He conducted an interdisciplinary research in the field of soil and water conservation and sustainable land management. He followed several courses and participated in local and international conferences. This dissertation presents the results of his PhD study which also contains peer-reviewed articles in scientific journals.

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## **PE&RC PhD Education Statement Form**

With the educational activities listed below the PhD candidate has complied with the educational requirements set by the C.T. de Wit Graduate School for Production Ecology and Resource Conservation (PE&RC) which comprises of a minimum total of 22 credits (= 32 ECTS = 22 weeks of activities)



### **Review of Literature (4 credits)**

- Land degradation problems and conservation techniques (2001-2002)

### **Writing of Project Proposal (5 credits)**

- Best soil and water conservation practices in highland watershed management in Ethiopia (2002)

### **Post-Graduate Courses (2 credits)**

- Surface processes (2003)
- Environmental degradation and management sessions (2003-2004))

### **Deficiency, Refresh, Brush-up and General Courses (4 credits)**

- Processes and models (2001)
- Impact assessment of land and water management (2002)
- Soil technology (2002)
- Rural households and livelihood strategies (2002)

### **PhD Discussion Groups (4 credits)**

- Sustainable land use and resource management (2002)
- Seminars and discussion groups at Addis Ababa University (2003-2005)

### **PE&RC Annual Meetings, Seminars and Introduction Days (1.5 credits)**

- PE&RC weekend (2005)
- PE&RC seminar series (2006)

### **International Symposia, Workshops and Conferences (3 credits)**

- World congress of soil science, Bangkok, Thailand (2000)
- Conference of the Association of American Geographers, Chicago, USA (2006)

### **Laboratory Training and Working Visits (1 credit)**

- ETC-Ecoculture, Indigenous knowledge in soil and water conservation (2002)



