Land management in the north-western highlands of Ethiopia: adoption and impact

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Propositions

1. There is a need for a land consolidation concept given the fact that land fragmentation can both be a blessing and a curse for smallholder farmers in the highlands of Ethiopia.
   (this thesis)

2. Intensification of agricultural production increases the profitability of land management interventions.
   (this thesis)

3. The popularity of the present mass mobilization of farmers in Ethiopia is surprising given the past experience.

4. The social costs of Khat (*Catha edulis*) production are higher than the economic benefits for Ethiopian society.

5. Leasing agricultural land to foreign investors, which is considered a development opportunity in Africa, worsens environmental degradation.

6. Policy makers suffer from too many recommendations.

Akalu Teshome Firew

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Wageningen, 2 December 2014

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Chapter 1

Introduction

Introduction

1.1 Land management in the highlands of Ethiopia

Ethiopia is the second most populous country in Sub-Saharan Africa, with a total area of 1,104,300 km^2 (FAO, 2011a). The estimated population was 84,320,987 in 2012 (CSA, 2012). Subsistence smallholder agriculture has continuously dominated economic development policy in Ethiopia (Mellor, 2014). This sector contributes about 41% of the country's Gross Domestic Product (GDP), 80% of its employment and 90% of its export earnings (FAO, 2011b). Despite its pivotal role, the performance of this sector has remained largely unsatisfactory (Gregory, 2013).

Agricultural development in Ethiopia is hampered by many factors; a major one among these is land degradation (Dethier and Effenberger, 2012; Haileslassiea, 2005; Taddese, 2001). Among all forms of land degradation processes in Ethiopia, soil erosion by water is the most severe threat to food security, environmental sustainability and prospects for rural development in the country (Vagen et al., 2013; Taye, 2013; Shiferaw and Holden, 1999). The country loses about 3% of its agricultural GDP per year due to land degradation (World Bank, 2007).

Land degradation is most severe in the highlands of Ethiopia (Pender and Gebremedhin, 2007; Hurni, 1988). Degradation in the highlands of Ethiopia is mainly the result of mismanagement, overpopulation, and historical dynamics of the political-ecological system and regional land policies (Lanckriet et al., 2014). A variety of traditional physical land management practices, including cut-off drains, traditional ditches and waterways, are part and parcel of the farming systems of the highlands. Although these and other traditional soil and water conservation practices are widely practiced, they do not match the severity and intensity of the soil erosion problem (Bekele, 2003). Some traditional soil and water conservation practices even aggravate gully formation rather than control erosion.

Despite the expansion of the land degradation problem, investment in soil conservation was largely neglected in Ethiopia prior to 1974. A countrywide large-scale resource conservation project was launched only in reaction to the 1973/74 famine. These activities were financed with support from various international donor organisations including the World Food Programme (WFP). The interventions were mainly focused on treating arable lands with a range of soil and water conservation (SWC) measures, afforestation, and enclosure of highly degraded areas (Ludi, 2004). Between 1976 and 1988, about 800,000 km of soil and stone bunds constructed on cropland, 600,000 km of hillside covered by trees and 100,000 ha of land were put under area closure for natural regeneration countrywide (Hurni, 1988). However, most of the SWC works were either partially or even entirely destroyed and abandoned by farmers during a change of government in 1991 (Shiferaw and Holden, 1998; Ludi, 2004, Bewket, 2007).

Since the 1990s, soil and water conservation practices have been implemented as part of agricultural extension programmes. In 2005 the Ethiopian Ministry of Agriculture and Rural Development (MoARD), in collaboration with several international development organisations, published guidelines for the first time, for 'Community Based Participatory Watershed Development' (MoARD, 2005). Besides summarising technical details of SWC measures, the guidelines emphasised the integration of land users in the SWC design and implementation process.

Since 2010, the government of Ethiopia has embarked again on a massive SWC campaign using mass mobilisation at watershed level. Concurrently, a conservation-based, agricultural development-led industrialisation development strategy is focusing on promoting conservation of natural resources and improvement of agricultural productivity (GTP, 2010).

Soil fertility control practices, such as the application of inorganic and organic fertiliser, are the major land management (LM) practices employed in the highlands of Ethiopia to replenish and/or improve the fertility of the soil. Land fallowing and crop rotation practices, which were traditionally used to maintain soil fertility, have been gradually reduced due to high population pressure and limited availability of cultivable land. The use of manure to add organic materials to the soil is also hampered by the increased use of dung and crop residues as a source of energy (Amsalu, 2006). Thus, in order to restore plant nutrients to the depleted soils, one of the major activities of the extension programmes in Ethiopia has been provision of chemical fertiliser to farmers. DAP (Di-Ammonium Phosphate) and urea are the only types of mineral fertiliser currently available in Ethiopia. Fertiliser use in Ethiopia increased from 3,500 tons in the early 1970s to about 650,000 tons in 2012 (Rashid, 2013). However, fertiliser use is still quite limited. Only 30 – 40 % of smallholders use fertiliser. They apply an average of only 37 – 40 kg ha^{-1}, which is significantly below recommended rates (Spielman, et al., 2013). Since the 2000s, compost has also been an integral part of the extension packages in the highlands of Ethiopia to reverse soil fertility depletion.

1.2 Problem statement

Investments in land management practices can mitigate land degradation and increase agricultural productivity (Abdulai and Huffman, 2014; Adgo et al., 2013; Kassie et al; 2010; Kabubo-Mariara et al., 2006). Over the last four decades, huge resources and efforts have been invested by the government of Ethiopia and donor partners to promote various LM practices to halt land degradation. In the highlands of Ethiopia in particular, various LM practices have been transferred to farmers in a top-down manner to control erosion and increase production and productivity. These technologies include soil bunds, *Fanya juu* bunds, stone bunds, compost and inorganic fertiliser. Still, the adoption rate of these measures has been minimal (Teklewold et al., 2013; Tesfaye et al. 2013, Tefera and Sterk, 2010, Bewket, 2007). This problem can be explained by the fact that investments in LM practices are influenced by many different institutional and socio-economic factors, which in turn often hamper the adoption of LM practices (Shiferaw et al., 2009; Amsalu and de Graaff, 2007; Ervin and Ervin, 1982).

Most previous adoption studies on SWC practices in Ethiopia and elsewhere focused mainly on assessing the determinants of adoption versus non-adoption (Tesfaye et al., 2013; Kassie et al., 2009; Bewket, 2007; Shiferaw and Holden, 1998). These studies assumed homogenous adopter categories (all adopters being at the same stage) and did not consider the different adoption phases of SWC measures. A substantial proportion of the literature also explored the component/single LM practice adoption (Tesfaye et al., 2013; Amsalu and de Graaff, 2007; Asfawa and Admassie, 2004; Bekele and Drake, 2003), an approach which fails to account for an interrelation effect among different LM practices. Furthermore, earlier adoption studies did not thoroughly investigate the effects of land quality, land fragmentation, tenure arrangements, and different dimensions of social capital on adoption of the LM practices.

Investigation of the on-site costs of soil erosion and the profitability of different SWC measures is important for understanding the economic constraints to smallholder farmers. However, there are mixed outcomes regarding the benefits of SWC measures in the Ethiopian highlands. Some studies revealed that SWC measures have positive effects on crop productivity (Adgo et al., 2013; Nyssen et al., 2007). Contrarily, investments in SWC have no impact on productivity and profitability (Adimassu et al., 2012; Kassie et al., 2011). Often the impacts of SWC at farm household have been measured by using an economic criterion (e.g. crop productivity and/or income). According to this criterion, some of the SWC measures may not be feasible; however, they may generate positive benefits if other criteria — such as ecological and social ones — are also considered. To better understand the full benefits of such interventions, it is important to evaluate the different SWC alternatives concerning their ecological, economic and social impacts, based on evaluation criteria from farmers and other stakeholders. The need for such an evaluation indicates that the issues of the profitability of SWC technologies and farmers' perceptions and decision-making criteria are not yet sufficiently well understood.

The aforementioned gaps indicate that the impact of some institutional, socio-economic and bio-physical factors on LM investments still requires thorough investigation. The general aim of this research is to fill these gaps and thereby contribute to enhancing the adoption and impacts of land management in the Ethiopian highlands.

1.3 Objective and research questions

The main objective of this scientific study is to investigate the impact of institutional, socio-economic and bio-physical factors on investments in LM. It focuses on such issues as the drivers of the different stages of adoption, the profitability of SWC measures, land quality, land fragmentation, tenure arrangements and social capital. To achieve this objective, the following research questions have been formulated:

RQ1: What are the main institutional, socio-economic and bio-physical drivers for the different stages of adoption of SWC technologies?

RQ2: What are the on-site costs of soil erosion and benefits of SWC measures?

RQ3: What is the influence of land quality, land fragmentation and tenure systems on interrelated LM investments?

RQ4: What is the relationship between the different dimensions of social capital and investments in LM practices?

RQ5: What are the evaluation criteria of farmers and experts for different SWC alternatives?

1.4 Conceptual framework

Our conceptual framework is based on decision-making processes for the use of soil conservation practices (Ervin and Ervin, 1982) but it also incorporates important elements from theoretical models on property rights and investment incentives (Besley, 1995), the role of social capital (Foster and Rosenzweig, 1995; Nyangena, 2008; Njuki et al., 2009), the effects of land fragmentation on LM (Burton, 1988) and the financial viability and the continued use of soil and water conservation measures (de Graaff et al., 2008). This analytical framework includes the major institutional, socio-economic and bio-physical aspects of LM (Figure 1.1).

1.4.1 *Institutional factors*

Institutions have a large impact on the decisions of farmers on LM investments. Land tenure, social capital, extension and research, credits and markets are the major institutional factors which affect investments in LM technologies (Besley, 1995; Cramb, 2006; Shiferaw; et al., 2009). While the impacts of extension, credit and market services on LM have already been analysed at length in Ethiopia (Anley et al., 2007; Bekele and Derak, 2003; Shiferaw and Holden, 1998), the impact of land tenure (e.g. tenure arrangements) and social capital on LM has received less attention so far.

Investments in soil conservation may be undertaken when sufficient returns are expected for a considerable period of time in comparison to the situation if such investments are not made (Soule et al., 2000). For such long-term returns a secure land tenure system may be required. The absence of tenure security is highly linked to poor land use, which in turn leads to environmental degradation (Otsuka and Place, 2001; Gavian and Fafchamps, 1996). This is because lack of secure rights to land generally decreases farmers' incentives to invest in land improvement (Besley, 1995).

Ethiopia has implemented different types of land tenure systems since the beginning of the twentieth century. Currently, land belongs to the state and farmers have only usufruct rights. However, they informally exchange land through sharecropping and rental arrangements. The main tenure arrangements in the rural areas of Ethiopia are ownership (obtained from the state), sharecropping and rental arrangements (Pender and Fafchamps, 2005). The effects of these tenure arrangements on LM investments are still not well understood.

The investment behaviour of farmers is also shaped by the level and type of social capital (Nyangena, 2008). This is because social capital influences farmers' preferences, transaction costs and information exchange. Rural communities that are characterised by strong social capital have faster rates of technology diffusion and improved environmental management (Njuki et al., 2009). Social networks are especially important for small-scale farmers who have less access to formal institutions. These networks enable farmers to overcome economic constraints, and thus facilitate adoption of technology (Di Falco and Bulte, 2013; Posthumus, 2005). Despite the availability of different forms of social capital (e.g. networks, institutions and norms) in rural Ethiopia, most of the adoption studies in Ethiopia have not seriously investigated the role of social capital for LM investments.

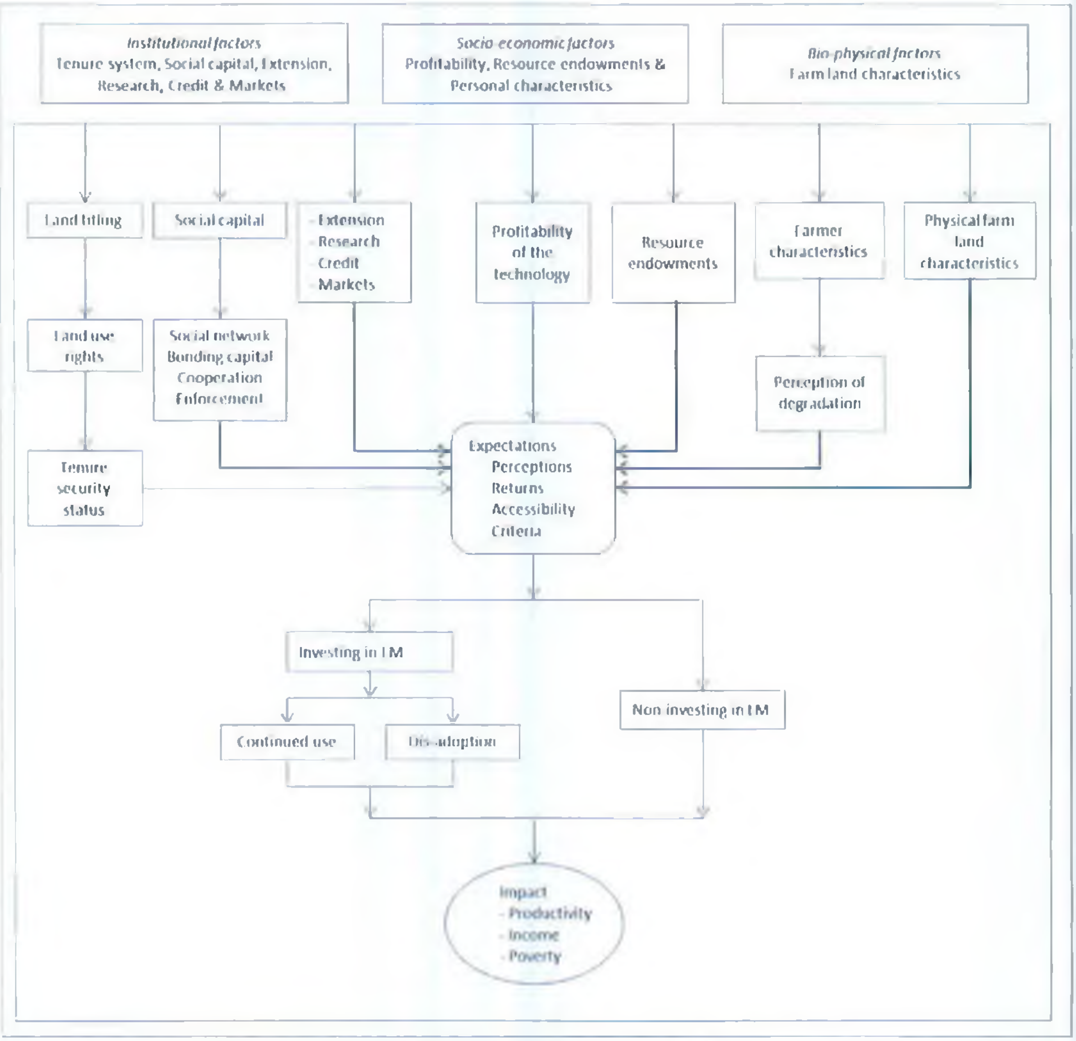

Figure 1.1. Conceptual framework of the institutional, socio-economic and bio-physical aspects of land management

1.4.2 *Socio-economic factors*

The adoption of LM technologies is also influenced by socio-economic factors. Profitability of the technologies (Sattler and Nagel, 2010; Cary and Wilkinson, 1997), resource endowments (Tefera and Sterk, 2010; Mekonnen, 2009), farmers' characteristics (Tenge et al., 2004) and perception of erosion (Amsalu and de Graaff, 2006; Shiferaw and Holden,1998) are among the major socio-economic factors which affect the adoption of LM technologies. Most of these factors have already been thoroughly investigated and analysed in the highlands of Ethiopia. However, the issue of profitability of SWC technologies and farmers' perceptions and decision-making criteria are still not well understood.

Profitability of the technologies is a precondition (necessary but not sufficient) for adoption, and other factors become less relevant without sufficient profitability. Therefore, estimating the on-site costs of soil erosion and profitability of investments in SWC measures is crucial to increase awareness of the losses caused by soil erosion and the potential benefits of investments to facilitate the adoption of SWC. A number of studies in this respect have been undertaken in Ethiopia, but there are mixed results regarding the benefits of SWC measures in the Ethiopian highlands (Kassie et al., 2011; Nyssen et al., 2007); this shows that profitability of SWC technologies is still not well understood.

Farmers' investment objectives concerning SWC measures may be very different from those of researchers and extension personnel. Farmers have other objectives in addition to reducing soil loss and maximising financial benefits of SWC measures (Amsalu, 2006; Tenge, 2005). These objectives are often conflicting, which implies that there is no single SWC measure that can give the best results for all farmers. Therefore, the availability of several SWC alternatives, conflicting objectives and a range of farmer evaluation criteria hamper decision-making and the adoption of SWC measures (Tenge, 2005). Consequently, there is a need to evaluate the objectives and criteria of farm households and experts in SWC decision-making based on ecological, economic, social and other factors.

1.4.3 *Bio-physical factors*[1]

Land management investments are also affected by bio-physical factors such as land quality (soil fertility, soil depth, soil type and slope level) and land fragmentation (Pender and Gebremedhin, 2007; Niroula and Thapa, 2005). This is because the effects of soil erosion, and hence LM practices vary according to the various land quality aspects (Adimassu et al., 2012). Some studies have been undertaken at household level in Ethiopia on the influence of soil fertility and parcel slope on SWC investments (Bekele and Drake, 2003; Amsalu and de Graaff, 2007).

The feasibility and profitability of LM practices also depend on the size of the parcels of land to be treated, or on the extent of land fragmentation. This is because land fragmentation increases the investment transaction cost (Burton, 1988). Population growth and redistribution of agricultural land are the major causes of the high extent of land fragmentation in rural Ethiopia (EEA, 2002).

The influence of land quality and land fragmentation on investments in LM on the parcel level still requires thorough investigation.

[1] Rainfall is not the major production limiting factor in the study areas.

1.5 Methodology

1.5.1 Description of study areas

The study was undertaken in three selected watersheds (Debre-Mewi, Anjeni and Dijil watersheds) of East and West Gojam Zones of Amhara Region, Ethiopia (Figure 1.2). These watersheds are part of the north-western highlands of Ethiopia. These watersheds were selected because of their specific experience with LM activities. Moreover, the watersheds have diverse bio-physical and socio-economic characteristics (Table 1.1). Agricultural systems in these watersheds are small-scale subsistence crop-livestock mixed farming systems. The watersheds differ in average annual rainfall, soil pH, level of degradation, dominant crop in the farming system, productivity, access to transport and distance from market place.

The Anjeni watershed (Minchet sub-watershed) is located in the Dembecha district of West Gojam Zone, 260 km south-east of Bahir Dar. The watershed lies at 10.68°N and 37.53°E, covers an area of 113 ha and is home to 95 households. Anjeni is a high rainfall area, with an average annual rainfall of 1,790 mm (Table 1.1). The crops grown are barley, tef, maize, wheat, faba bean, potato, noug, field pea, lupine, and linseed. The major soil types in the watershed are Nitosols (red soil), Alisols, Regosols, and Leptisols. Soil and water conservation measures have a long history in this watershed (SCRP, 1991).

The Digil watershed is found in the Gozamen district of East Gojam Zone at 10.24°N and 37.43°E. The watershed (which comprises the villages of Melit, Enerata, Yaya and Yedenigia) covers an area of 936 ha and has a total of 628 households. The major crops grown are oats, wheat, tef, barley, faba bean and potato. Nitosols (red soils) are dominant in the watershed. The watershed is close to Debre Markos town (district and zonal capital). SWC measures were implemented in this watershed in 1999 by the District Agriculture Office with financial support from the Swedish International Development Agency (SIDA) as part of its on-farm research programme in Amhara Region. Currently, various NGOs are involved in SWC activities in the area, such as SLM-GIZ (The German Society for International Cooperation) and Megibare Senay.

The Debre Mewi watershed is located in the Yilmana Densa and Bahir Dar Zuria districts of West Gojam Zone. It is located at 11.34°N and 37.43°E, situated slightly lower than the other watersheds at an altitude of about 2,300 m.a.s.l. and receives an average annual rainfall of about 1,260 mm. The total area of the watershed is estimated to be 523 ha and it is home to about 324 households. Major crops grown in the watershed are tef, maize, barley, finger millet, wheat, faba bean, potato, grass pea and niger seed. The dominant soil types are Nitosols (red), Vertisols (black) and Vertic Nitosols. Debre Mewi is a high crop production area and is close to a regional market.

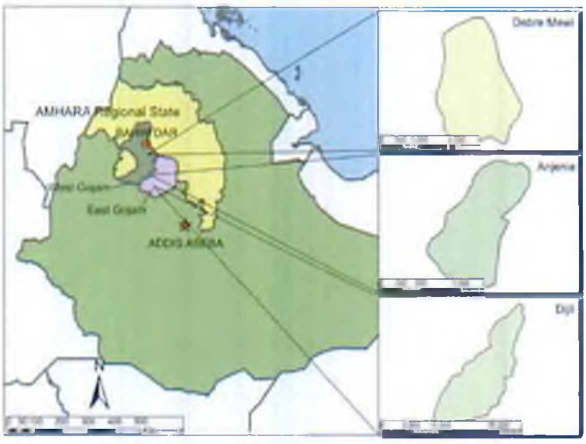

Figure 1.2. Map of study areas in Amhara regional state, Ethiopia

Table 1.1. Socio-economic and physical characteristics of the study areas

Features	Anjeni	Dijil	Debre Mewi
Altitude (m.a.s.l.)	2,450	2,480	2,300
Average annual rainfall (mm)	1,790	1,300	1,260
Dominant soil types	Alisols, Nitosols, Regosols, Leptisols	Nitosols	Vertic Nitosols, Nitosols and Vertisols
Soil pH	5.7	4.3	6.7
Degradation	Degraded	Very degraded	Not heavily degraded
Dominant crop in farming systems	Barley	Oats	Tef
Productivity	Low	Low	High
Number of households	95	628	324
All-weather road and transport access	Poor	Good	Good
Availability of local market	Yes	No	Yes
Distance to district market (km)	20	8	12
Distance to zonal market (km)	265	8	30
Distance to regional market (km)	265	285	30
SWC projects	SCRP (long-term)	SIDA, SLM-GIZ	No specific project
Land certification	Since 2008	Since 2004	Since 2008

Source: Aemro 2011; Tesfaye 2011; Zegeye 2009; Zeleke and Hurni 2001

1.5.2 Sampling and data collection

A two-stage procedure was employed to select sample households. In the first stage of the sampling procedure, as mentioned earlier, the watersheds were selected purposively based on their specific experience with LM activities and diverse bio-physical and socio-economic characteristics (Table 1.1). In the second stage, farmers from each watershed were selected randomly from lists of all households in the watershed. A total of 60, 125 and 115 farmers were selected randomly from Anjeni, Dijil and Debre Mewi watersheds, respectively. The sample size was based on watershed size and heterogeneity of farm resources in the respective watersheds.

Primary data from these 300 farm households were collected from the three watersheds in 2011 using a general agro-socio-economic survey. The survey collected detailed information about household characteristics and labour resources, institutions and social capital, household assets, land resources and plot characteristics, and land management investments.

Detailed data about cost and benefits of SWC measures were collected in 2011 from a sub-sample of 60 households from Debre Mewi and Anjeni (30 households per watershed).

Data about the perceptions of farmers regarding land fragmentation and consolidation, and the advantages and shortcomings of implementation approaches of SWC, were collected in 2012 from a sub-sample of 110 households (40 from Debre Mewi, 30 from Anjeni and 40 from Dijil).

In 2013, a total of 50 farm households (20 from Debre Mewi, 15 from Anjeni and 15 from Dijil) were selected from the larger household survey to collect information about farmers' evaluation criteria for SWC alternatives. In addition, 16 experts were interviewed from different levels of the Department of Agriculture (kebele, district, zone and region). A Participatory Rural Appraisal (PRA) was used to collect supplementary qualitative data.

1.5.3 Methods of data analysis

Various descriptive statistics and econometric models were applied for analysing the data. The ordered probit model was employed to analyse the drivers of different stages of adoption of soil and water conservation (SWC) technologies. A multivariate probit (MPV) model was used to analyse the effects of land-related factors on the interdependent investment decisions regarding LM practices.

Moreover, factor analysis was used to reduce the social capital variables to six non-correlated factors. Then the relationship between the different dimensions of social capital and investments in land management

Chapter 2

Household level determinants of soil and water conservation adoption phases: Evidence from north-western Ethiopian highlands

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Environmental Management

Household level determinants of soil and water conservation adoption phases: Evidence from north-western Ethiopian highlands

Abstract

Soil and water conservation (SWC) practices have been promoted in the highlands of Ethiopia during the last four decades. However, the level of adoption of SWC practices varies greatly. This paper examines the drivers of different stages of adoption of SWC technologies in the north-western highlands of Ethiopia. The study is based on a detailed farm survey among 298 households in three watersheds. Simple descriptive statistics were applied to analyse the stages of adoption. An ordered probit model was used to analyse the drivers of different stages of adoption of SWC. This model is used to analyse more than two outcomes of an ordinal dependent variable. The results indicate that sampled households are found in different phases of adoption, i.e., dis-adoption/non-adoption (18.5%), initial adoption (30.5%), actual adoption (20.1%) and final adoption (30.9%). The results of the ordered probit model show that some socio-economic and institutional factors affect the adoption phases of SWC differently. Farm labour, parcel size, ownership of tools, training in SWC, presence of SWC program, social capital (e.g. cooperation with adjacent farm owners), labour sharing scheme and perception of erosion problem have a significant positive influence on actual and final adoption phases of SWC. In addition, the final adoption phase of SWC is positively associated with tenure security, cultivated land sizes, parcel slope and perception on SWC profitability. Policy makers should take into consideration factors affecting (continued) adoption of SWC such as profitability, tenure security, social capital, technical support and resource endowments (e.g. tools and labour) when designing and implementing SWC policies and programs.

Keywords: Adoption phases, Soil and water conservation, ordered probit, Ethiopia, Africa

2.1 Introduction

2.1.1 Background and research objective

The Ethiopian economy is heavily dependent on agriculture which is dominated by subsistence smallholder farmers that are partially integrated into markets. The fate of the agricultural sector directly affects economic development, food security and poverty alleviation. However, the role of this sector in alleviating poverty and food insecurity is undermined by land degradation such as soil erosion and nutrient depletion (Bekele and Drake 2003; Girma 2001; Tekle 1999).

Over the last four decades, the government of Ethiopia and a consortium of donors have been promoting soil and water conservation (SWC) technologies for improving agricultural productivity, household food security and rural livelihoods, while simultaneously mitigating environmental degradation. Smallholders' agriculture in the country is nonetheless characterized by widespread failure to make adequate SWC and soil replenishment investments in order to sustain the productivity of farmlands (Shiferaw and Holden 1998; 1999; Bewket 2007; Tefera and Sterk 2010; Kassie et al. 2010). In some cases farmers have dis-adopted (abandoned) earlier adopted technologies (Shiferaw and Holden, 1998; Tadesse and Kassa 2004; BoARD 2010). Moreover, farmers also modify or adapt the technology to their own real situations, among others by reducing the area occupied by SWC line interventions (e.g. soil bunds or stone bunds along the contour lines to reduce soil erosion).

A better understanding of constraints that condition farmers' adoption behavior is therefore important for designing promising pro-poor policies that could stimulate and sustain adoption of SWC and agricultural productivity. A substantial literature has explored the adoption process of SWC technologies in order to understand the failure to make these critical investments (Ervin and Ervin 1982). Most previous adoption studies in Ethiopia and elsewhere (e.g., Tesfaye et al. 2013; Kassie et al. 2009; Tiwari et al. 2008;

Bewket 2007; Shiferaw and Holden 1998) assumed homogenous adopters (all adopters are at the same stage) while farmers are at different stages of adoption. Adoption analyses made without considering the different stages of adoption in a complex farming system may underestimate or overestimate the influences of various factors on the decision to adopt. Like other technologies farmers pass through different stages in adopting SWC measures and also these measures are long-term investments which require continuous maintenance. This suggests that it is important to understand the different adoption phases (dis-adoption/non-adoption, initial adoption, actual adoption and final adoption; defined in Table 2.1) instead of focusing on binary adoption decision. In this paper, we study the driving forces of different stages of adoption of SWC in three watershed areas of north-western Ethiopian highlands. The SWC technologies considered in this study include soil bunds, *Fanya juu* bunds (made by digging a trench and throwing the soil uphill to form an embankment) and stone bunds.[1]

2.1.2 Soil and water conservation practices in Ethiopia

The importance of soil conservation was largely neglected in Ethiopia prior to 1974. The problem attracted the attention of policy makers and international donors only after the disastrous drought and famine of 1974. An effort to halt the problem of soil erosion started after the Ethiopian government initiated massive soil conservation programs following the 1975 land reform. A large number of conservation and afforestation projects were undertaken by Food-For-Work programs (FFW) (Hurni 1988). This massive campaign in soil conservation under FFW did not bring a wide dissemination and adoption of the practices by farmers. This is because farmers constructed SWC practices during the campaign but they had no interest to implement or expand these without food for work (Shiferaw and Holden 1998). Most of the conservation measures were removed after the government changed in 1991 (Shiferaw and Holden 1998).

Between 1995 and 2009 soil conservation activities have been undertaken as part of the agricultural extension package of the present government through mass mobilization with a top-down approach and without incentives for the time farmers spent on SWC activities. The approach was to construct conservation measures at individual level but not at watershed level. Emphasis was given to the quantity of measures rather than the quality of measures. SWC is mainly limited to physical measures. Dis-adoption and non-adoption of SWC measures were common phenomena in this period. This indicates that the extension system did not bring about behavioral changes among farmers probably because the focus was on changing the farmland rather than farmers' behavior.

Since 2010, the government of Ethiopia has embarked again on a massive SWC campaign. The current approach is also mass mobilization, but then at watershed level. And there is an attempt to make such SWC program more participatory. In each watershed area agricultural offices along with local administrators organize a 15 days farmers' workshop to create awareness about the problems of soil erosion and its causes. During the workshop farmers prioritize their major natural resource problems, causes and possible solutions. Then, they reach consensus about the natural resource problems that require collective action. Farmers participate in SWC activities in nearby sub-watershed areas.

2.2 Conceptual framework

Our conceptual framework is based on the adoption process of investment in SWC measures (de Graaff et al. 2008) and on the concept of dis-adoption (abandonment) of the earlier adopted technologies (Neill and Lee 2001). This framework also incorporates important elements from decision-making processes for the use of soil conservation practices (Ervin and Ervin, 1982), property rights and investment incentives (Besley 1995) and the role of social capital (Foster and Rosenzweig 1995; Nyangena 2008; Njuki et al. 2008). This analytic framework includes all major institutional and socio-economic aspects of SWC (Figure 2.1).

[1] The three measures are not that different, they all three have the same function: line interventions along the contour lines to reduce soil erosion.

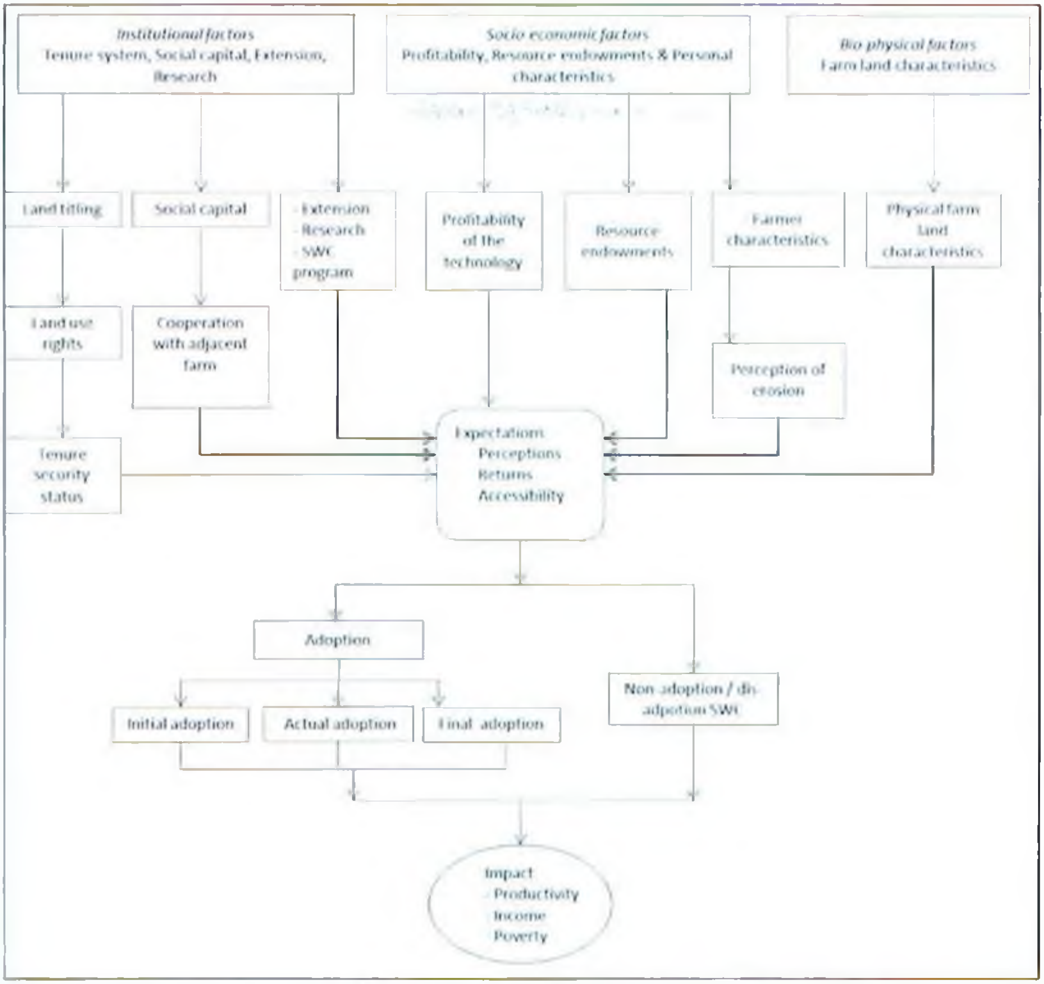

Figure 2.1. Conceptual framework of the institutional, socio-economic and bio-physical aspects of the adoption phases

Adoption is a sequential decision process and one could distinguish three major phases, i.e., the acceptance phase, the actual adoption phase and the continued use phase (de Graaff et al. 2008). The acceptance phase generally includes the awareness, evaluation and the trial stages and eventually leads to starting investment in certain measures. We will refer to this as the initial adoption phase, which is basically a pilot phase in which farmers experiment with SWC measures. The actual adoption phase is a stage whereby SWC investments are already made on part of the land since a few years, on more than a trial basis. The third phase, final adoption, is a stage in which the existing SWC measures are maintained over many years and farmers are intrinsically motivated to expand these measures to untreated plots. In addition, some farmers may dis-adopt (or abandon) once adopted technologies, while some farmers will not adopt SWC measures at all for various reasons. Therefore, there are four major categories in the adoption process as defined below: initial adopters, actual adopters, final adopters, non-adopters/dis-adopters[2] (Table 2.1).

[2] It would have been good to separate non-adoption and dis-adoption groups; however, there are not enough observations that enable us to treat these two variables separately. The number of observations for dis-adopters are very small (15 observations) and not enough to independently include in the model.

Table 2.1. Soil and water conservation adoption phases and their indicators

Categories	Indicators
Dis-adopters/Non-adopters	Abandoned the SWC measures and/or never used SWC measures on any of their plots
Initial adopters	Established SWC line interventions on up to 25% of sloping farm land (experimentation phase) and did not yet expand them to other plots.
Actual adopters	Established and maintained the initial SWC measures during past four years, and started to expand them on at least 26-50% of the vulnerable farm land.
Final adopters	Continued use, expanded and more than 5 years maintained on their own motivation, and in total covering 51-100 % of sloping farm area

2.3 Methodology

2.3.1 Description of Study areas

The study was undertaken in three selected watersheds (Debre-Mewi, Anjeni and Dijil watersheds) of East and West Gojam Zones of Amhara Region, Ethiopia (Figure 2.2). These watersheds are part of the north-western highlands of Ethiopia. The Zones and the watersheds are selected purposively because of their specific experience with SWC development activities, and they differ in the extent of SWC measures that have actually been implemented. Moreover, the watersheds have diverse physical and socio-economic characteristics (Table 2.2). Agricultural systems in these watersheds are small-scale subsistence crop-livestock mixed farming systems.

Table 2.2. Socio-economic and physical characteristics of the study areas

Features	Anjeni Watershed	Dijil Watershed	Debre Mewi Watershed
Altitude (m.a.s.l)	2,450	2,480	2,300
Average annual rainfall (mm)	1,790	1,300	1,260
Dominant soil types	Alisols, Nitosols, Regosols, Leptosols	Nitosols	Vertic Nitosols, Nitosols and Vertisols
Degradation	Degraded	Very degraded	Not heavily degraded
Dominant crop in farming systems	Barley	Oats	Tef
Average number of TLU (tropical livestock units) per farm	5.2	6.0	4.6
Productivity	Low	Low	High
Number of households	95	628	324
All weather road and transport access	Poor	Good	Good
Availability of local market	Yes	No	Yes
Distance to district market (Km)	20	8	12
SWC projects	SCRP (long term)	SIDA; SLM-GIZ	No specific project

Source: Aemro 2011; Tesfaye 2011; Zegeye 2009; Zeleke and Hurni 2001; own surveys

Anjeni Watershed

This watershed is situated in Dembecha district of West Gojam Zone at 260 km south east of Bahir Dar. Anjeni lies at 10.68°N and 37.53°E at an altitude of approximately 2,450 m.a.s.l. The watershed covers an area of 113 ha. It is home to 95 households. Anjeni receives an average annual rainfall of around 1,790 mm. The crops grown are barley, tef, maize, wheat, faba bean, potato, niger seed (Guizotia abyssinica), field pea, lupine, and linseed.

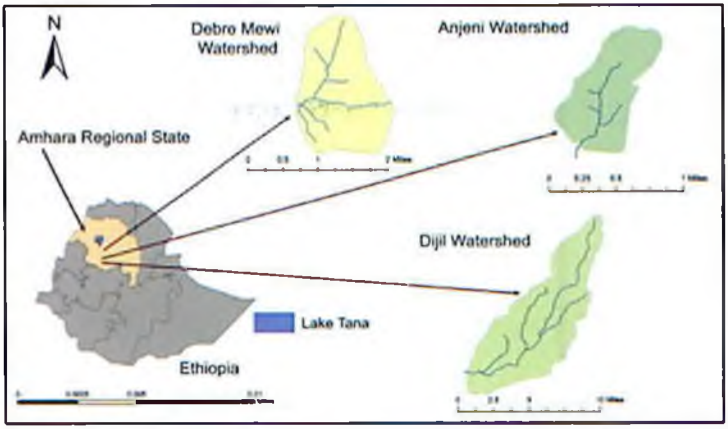

Figure 2.2. Map of study areas

Soil and water conservation measures have a long history in this watershed. *Fanya juu* soil conservation bunds were introduced in 1984 by the then Soil and Water Conservation Project (SCRP) which was initiated by Bern University of Switzerland in collaboration with the Ethiopian Ministry of Agriculture. The construction of bunds was done by local communities without payment for individual participating farmers. As an incentive, a health clinic was constructed by the project to compensate for labour and material contributions by the community. The Anjeni watershed has been one of the six SWC research experimental stations of the country. Moreover, SWC measures have also been disseminated in the watershed by the government extension program.

Digil Watershed

The Digil watershed is found in Gozamen district of East Gojam Zone. It is located at 10.24°N and 37.43°E at an altitude of approximately 2,480 m.a.s.l. and 285 km southwest of Bahir Dar. Dijil watershed (Melit, Enerata, Yaya and Yedenigia villages) covers an area of 936 ha. The total number of households in the watershed is 628. The average annual rainfall of the watershed is 1,300 mm. The major crops grown in the watershed are oats, wheat, tef, barley, faba bean and potato.

There was an attempt to introduce soil and water conservation measures in the mid 90's in Dijil watershed areas with the regular extension program. Rigorous SWC activities were implemented specifically in *Melit* village in 1999 by the District Agriculture Office with financial support from the Swedish International Development Agency (SIDA) as part of its on-farm research program in Amhara Region. The conservation measures such as soil, stone and *Fanya juu* bunds were introduced by the project. Moreover, along with the SWC structures (*Fanya juu* and soil bunds) multipurpose trees like Sesbania, Grevillea and different Acacia trees were planted for stabilizing the structures. Currently, different NGOs are involved in SWC activities in the area, such as SLM-GIZ (The German Society for International Cooperation) and *Megibare Senay*.

Debre Mewi Watershed

This watershed is located in Yilmana Densa and Bahir Dar Zuria districts of West Gojam Zone. It is located at 11.34°N and 37.43°E. It is situated at an altitude of about 2,300 m.a.s.l. and receives an average annual rainfall of about 1,260 mm. The total area of the watershed is estimated at 523 ha and about 324 households are living in the watershed. Major crops grown in the watershed are tef, maize, barley, finger millet, wheat, faba bean, potato, grass pea and noug (Guizotia abyssinica).

In Debre-Mewi areas, SWC measures were introduced in 1990's with the regular government extension program. Different approaches have been followed to disseminate SWC practices in the area. Before 2005, farmers were participating in SWC programs through mass mobilization with a top down approach. The approach was not watershed based but it was *Kebele* based (the lowest administrative body). Thus, farmers constructed bunds for other villages (at distance) in their *Kebele*. Some of the farmers were not the beneficiaries of what they constructed. They constructed bunds without incentives. Between 2005 and 2009, individual level implementation rather than mass mobilization of SWC was advocated. However, it was also not effective. Currently, the watershed approach is being used again through community mass mobilization. There is a SWC experimental site in the Debre-Mewi area which is handled by Adet Research Centre in collaboration with the SWHISA (Sustainable Water Harvesting and Institutional Strengthening in Amhara) project since 2008. Adet Research Centre and the District Agricultural Office are involved in the dissemination of SWC measures in the area. Although Debre-Mewi is a high production area, soil erosion is now a severe problem. Currently, gully erosion is threatening cultivated and grazing land in the watershed. The common type of physical SWC measure introduced in the area is soil bunds, and very recently also *Fanya juu* bunds.

2.3.2 Sampling and data collection

The data for this study were obtained from 298 farm households surveyed in the three watersheds in 2011 (actually the data were collected from 300 households but two households could not recall the years on which they constructed their bunds). The survey was conducted on a one-to-one interview basis using a structured survey questionnaire. A pre-test survey was also conducted in order to customize the questionnaire more to the situation in each study site. In the first stage of the sampling procedure, the watersheds were selected purposely based on their SWC experience. In the second stage, farmers from each watershed were selected randomly from lists of all households in the watershed. A total of 60, 125 and 113 farmers were selected randomly from Anjeni, Dijil and Debre Mewi watersheds, respectively. We used a formula for selecting sample size, with farm size and variation in farm size as determining factors. We found that the farm size in Digil and Debre Mewi appeared to be more skewed, and therefore required a larger sample. The coefficient of variation (CV) of farm size is 0.77, 1.11 and 1.06 for Anjeni, Dijil and Debre Mewi, respectively.

The survey collected detailed information about household characteristics and labour resources, institutions and social capital, household assets, land resources and plot characteristics and soil and water conservation (SWC) investments (see Table 2.3 below).

2.3.3 Analytical model

Some multinomial choice variables are inherently ordered. For example, the adoption phases of SWC measures (non-adoption/dis adoption, initial adoption, actual adoption and final adoption). In this case, although the outcome is discrete, the multinomial logit or probit model would fail to account for the ordinal nature of the dependent variable. The use of the ordered probit is appropriate when the dependent variable involves more than two alternatives that must take a logical ordering form as it is in our case.

Following Greene (2003) the ordered probit model can be determined by Equation 2.1.

$$y_i^* = X_i\beta + \varepsilon \qquad i = 1,....N \ farmer \tag{2.1}$$

Where:

i refers to the observation (i.e., a farmer);

y_i^* is a latent variable (i.e. unobservable) that represents the adoption phases of farmer i;

X_i is a vector of socio-economic and institutional variables including a constant;

β is a vector of parameters to be estimated, and

ε are random error terms assumed to be standard normal distributed.

Since y_i^* is latent (unobserved), we observe discrete responses of the variable y_i as follows:

$$y_i = 0\,(dis\,(non) - adopters)\; if\; y_i^* \leq 0 \quad [2.2]$$

$$y_i = 1\,(initial\ adopters)\; if\; 0 < y_i^* \leq \mu_1 \quad [2.3]$$

$$y_i = 2\,(actual\ adopters)\; if\; \mu_1 < y_i^* \leq \mu_2, \quad [2.4]$$

$$y_i = 3\,(final\ adopters)\; if\; \mu_2 < y_i^* \leq \mu_3 \quad [2.5]$$

The μ_js are unknown ordered threshold parameters to be estimated with the unknown coefficients β. The probability that the ordered dependent variable y takes the different possible values is:

$$prob(y = 0 / X) = \phi(-X'\beta) \quad [2.6]$$

$$prob(y = 1 / X) = \phi(\mu_1 - X'\beta) - \phi(-X'\beta) \quad [2.7]$$

$$prob(y = 2 / X) = \phi(\mu_2 - X'\beta) - \phi(\mu_1 - X'\beta) \quad [2.8]$$

$$prob(y = 3 / X) = \phi(\mu_3 - X'\beta) - \phi(\mu_2 - X'\beta) \quad [2.9]$$

Where:

ϕ indicates a cumulative normal distribution.

The cut points μ_j divide the categories of the dependent variable.

The marginal effect is used to determine the influences of the independent variable per unit change on the dependent variable while everything else constant. Computation of marginal effects is meaningful for the ordered probit model because estimated parameter coefficients do not represent the magnitudes of the effects of independent variables on the categories of dependent variable. Therefore, the marginal effects of changes in the regressors are:

$$\frac{\partial\, prob(y = 0 / X)}{\partial X} = -\phi(X'\beta)\beta. \quad [2.10]$$

$$\frac{\partial\, prob(y = 1 / X)}{\partial X} = [\phi(-X'\beta) - \phi(\mu_1 - X'\beta)]\beta. \quad [2.11]$$

$$\frac{\partial\, prob(y = 2 / X)}{\partial X} = [\phi(\mu_1 - X'\beta) - \phi(\mu_2 - X'\beta)]\beta. \quad [2.12]$$

$$\frac{\partial\, prob(y = 3 / X)}{\partial X} = [\phi(\mu_2 - X'\beta) - \phi(\mu_3 - X'\beta)]\beta. \quad [2.13]$$

2.4 Empirical Results

2.4.1 Data and Descriptive statistics

The results of the descriptive analysis indicate that sample households are found in different stages of adoption (Table 2.4). Among the sample households, initial adopters (30.5%) and final adopters (30.9 %) form the largest groups. Most of the initial adopters have implemented SWC measures in the last two years. About 21.2 and 18.5 % of the sample households fall under actual adopter and non-adopter/dis-adopter categories. Reasons for dis-adoption (according to farmers) are: measures were built by mass mobilization without farmers' willingness, lack of cooperation with adjacent farm owners (low social capital), free grazing, difficult for oxen ploughing and reduction of cultivable land.

The high percentage of farmers (81.6%) involved in SWC does not mean that so much land is protected with SWC measures. There is a large difference in the intensity of SWC adoption among adopter categories.

Table 2.4. Distribution of SWC adopters by watershed

Adoption Phase	Watersheds							
	Anjeni		Dijil		Debre Mewi		Total	
	N	%	N	%	N	%	N	%
Dis-adopter/Non-adopter	0	0	11	8.8	44	38.9	55	18.5
Initial adopter	0	0	49	39.2	42	37.2	91	30.5
Actual adopter	1	1.7	42	33.6	17	15.0	60	20.1
Final adopter	59	98.3	23	18.4	10	8.8	92	30.9
Total	60	100	125	100	113	100	298	100.0

And there is also a large difference among the adopter categories across the watersheds. Almost all households in Anjeni are already final adopters of SWC practices. This is the result of long term SWC project interventions in the area. In addition, bio-physical factors, and social capital may have influenced the adoption of SWC measures. On the other hand, more non-adopters/dis-adopters are found in the Debre Mewi watershed. This is probably because of limited project assisted SWC interventions compared to the other watersheds. This could also be explained by the watershed level physical factors to invest in conservation practices (e.g. degradation level and rainfall amount). High percentages of initial adopters are also found in Debre Mewi and Dijil watersheds.

Table 2.5 shows the unconditional mean analysis of the socio-economic and institutional factors determining the different categories of adoption. The F-test analysis shows significant differences among the four adopter categories for age of the household heads, average parcel size, size of cultivated land, parcels' slope and number of farmers participating in labour sharing (assistance). There are no significant differences among the adopter categories in amount of farm labour, distance from road, total farm size, size of corrugated roof houses and off-farm income.

Table 2.5. Descriptive statistics of the explanatory variables for the adoption of SWC line interventions

Variables	Mean/percentages proportion of adopter category				F/ χ2-value[2]
	Initial Adopter (N=91)	Actual Adopter (N=60)	Final Adopter (N=92)	Non-Adopter/ Dis-Adopter (N=55)	
Household characteristics and labour resources					
Age	43.51	43.28	45.55	50.32	0.005***
Family size	5.79	5.83	5.98	5.58	0.606
Farm labour	2.14	2.18	2.30	2.03	0.141
Distance from road	13.57	14.26	16.96	15.23	0.362
Land resources					
Average parcel size	0.19	0.24	0.29	0.23	0.001***
Cultivated land	0.94	1.19	1.11	0.89	0.001***
Farm size	1.08	1.27	1.20	1.15	0.157
Parcels slope -Flat	11.0	1.7	4.3	27.3	0.001***
-Medium	45.0	61.0	50.0	54.5	0.268
-Steep	44.0	37.3	45.7	18.2	0.005***
Other resources					
Size of iron roof	56.7	57.1	53.3	55.1	0.640
Tools -Yes	54.9	70.0	76.1	27.3	0.001***
Off-farm income	72.6	34.3	49.9	66.7	0.423
Institutions and social capital					
Tenure security -Yes	81.3	88.3	81.5	67.3	0.037**
SWC training -Yes	28.6	49.2	46.7	16.7	0.001***
SWC program -Yes	41.2	70.0	85.9	9.1	0.001***
Cooperation -High	40.4	42.4	67.0	26.4	0.001***
-Medium	24.7	33.9	26.4	35.8	0.394
-Low	34.8	23.7	6.6	35.8	0.001***
Formal position -Yes	13.2	6.8	9.9	1.9	0.119
Labour sharing (assistance)	5.9	6.1	7.1	3.4	0.022**
Perceptions					
Erosion problems –Yes	95.6	100	100	90.9	0.007***
SWC profitability -Yes	97.8	96.7	100	96.3	0.361

*, ** , ***significant at 10, 5 and 1% level of significance, respectively.

2 F-test is used to compare the means difference of more than two continuous variables but Chi-test (χ2) is used to measure an association between discreet variables

The average age of non-adopters and dis-adopters is higher compared to the other categories. On the other hand, the average size of total cultivated land of dis-adopters/non-adopters is somewhat smaller than the other categories. This might affect adoption of physical SWC measures, since it involves some loss of cultivable land. On the other hand, initial adopters, actual adopters and final adopters have a larger number of farmers assisting in labour sharing (during the time of labour shortage, because of weddings and harvesting activities) as compared to non-adopters/dis-adopters. This indicates the importance of labour for adoption of soil and water conservation practices.

The chi-square analysis shows a significant systematic association among adopter categories in parcel slope, ownership of tools (e.g. shovels), tenure security, training in SWC, cooperation with adjacent farm owner, presence of SWC program and perceived problems of erosion. On the other hand, there is no systematic association among adopter categories in perceived profitability of SWC and position in formal institutions.

Dis-adopters/non-adopters (27.3%) have fewer tools (e.g. shovels) compared to other adopter categories. Initial adopters (81.3%), actual adopters (88.3%) and final adopters (81.5%) feel more tenure secure than non-adopters/dis-adopters (67.3%). This shows that households who feel a certain tenure security are more likely to invest or maintain the soil conservation measures. Moreover, initial adopters (28.7%), actual adopters (49.2%) and final adopters (46.7%) have more training exposure on SWC compared to the dis-adopters/non-adopters category. Training is one means to create awareness about the problems of erosion and the benefits of SWC measures to motivate farmers to investment in SWC measures.

Non-adopters/dis-adopters are less exposed to project assisted SWC interventions as compared to the other categories. Project based SWC intervention may increase farmers ability to investment in SWC through giving incentives (tools and training). Moreover, non-adopters/dis-adopters (37.7%) have percentage wise less collaboration with adjacent plot owners compared to other categories of adopters. Higher percentages of initial adopters (95.6%), actual adopters (100%) and final adopters (100%) perceived the problems of soil erosion compared to dis-adopters/non-adopters (90.9%).

Although the above unconditional descriptive statistics show that there are significant differences in covariates means among the different adoption categories, a systematic rigorous analysis that considers all variables together is important to examine whether these variables have a different influence on each group of adopters.

2.4.2 Results of econometric analysis

The results from the ordered probit models with marginal effects are presented in Table 2.6. The magnitude and sign of the structural coefficients allow no direct interpretation; only that an increase in a variable with a positive coefficient increases the probability in the highest category (final adoption) and decreases in the lowest category (non-adoption/dis adoption) (Greene and Henscher 2010).. The marginal effects are estimated in order to provide an indication of the relative magnitude of a unit increase in the explanatory variables on the probability of being in either category. The interpretation is direct. For instance, a one unit increase in parcel size will decrease the probability of non-adoption by 7%. The signs of the marginal probability effects can only change once when moving from the smallest category to the largest one.

The highest categories (i.e., actual and final adoption phases) are discussed in detail in this paper. The results of the first and the second categories are almost the same. This is due to bell-shaped density functions of the standard normal and the logistic distribution.

The chi-square results show that likelihood ratio statistics are highly significant (P<00001) suggesting that the model has a strong explanatory power. Endogeneity bias (casual relation) is suspected between tenure security and investments (initial, actual and final adoptions). Thus, an endogeneity test is undertaken. To investigate the relationship between investment and tenure security, we used a simultaneous probit equation model which consists of two simultaneous binary choice equations. The estimation procedure comprises the following steps: First, the reduced form of tenure security (exogenous variable) is estimated and then its predicted value obtained. Second, the predicted value of tenure security is used as a regressor in the investment (all adopter categories) equation. The process is repeated for the tenure security equation using the predicted value of investment (adoption). Two-stage probit estimation results reveal that tenure security is an important factor that affects the probability of investing in soil conservation technologies. However, the reverse relation is insignificant. This shows that there is an uni-directional causal-effect relationship between investments and tenure security. The reason may be that during the previous redistribution, investments did not guarantee tenure security and most farmers have lost what they invested and were denied of their rights to compensation and payments for their investment. Investments may influence tenure security in flexible indigenous and customary land tenure systems. The same step was applied to investigate the relation between investment and ownership of tools (e.g. shovels). There is also an uni-directional causal-effect relationship between investment and ownership of tools (e.g. shovels).

Non-adoption/dis-adoption and initial adoption phases

The study shows that the non-adoption/dis-adoption of SWC practices is higher when there is a decrease of the farm labour, average parcel size and cultivated land size. Lack of tools and SWC training and lower degree of cooperation with adjacent farm are also the major reason for non-adoption/dis-adoption of SWC. In addition, low level of perception about the erosion problems also contributes to non-adoption/dis-adoption of SWC practices.

The initial adoption phase is also influenced by a decrease of parcel size, lack of tools, absence of tenure security, absence of SWC program, low cooperation with adjacent farms, decreasing labour assistance and low perception of SWC profitability.

Actual and final adoption phases

Some variables are equally important for the actual and final adoption phases of SWC. Farm labour, average parcel size, ownership of tools (e.g. shovels), training in SWC, presence of SWC assisted program, cooperation with adjacent farm owners, labour sharing (assistance) and perception of erosion problem have a positive and significant influence on actual and final adoption phases of SWC. These factors are important for a farmer to decide whether to go from the initial phase to the actual and final adoption phases.

The amount of farm labour has an influence on the actual and continued use of SWC measures. This suggests that households who have more persons fulltime involved in agriculture are more likely to invest and maintain SWC measures. This can be explained by the fact that labour inputs constitute the largest cost factors for SWC line interventions. In addition, the average parcel size positively influences the actual and final adoption phases. The result suggests that a unit increase in parcel size results in a 5% increase in the probability of actual adoption and a 14% increase in the final adoption of SWC. On average, the households managed 4.5 parcels (total farm size divided by average parcel size (Table 2.3). Managing 4.5 parcels each at some distance from each other is cumbersome.

Ownership of tools needed for the construction of SWC measures (e.g. shovels) is found to have a significant and positive influence on actual and final adoption stages of SWC measures. The result of the marginal effect suggests that farmers who have SWC equipment are more probably to be actual (5%) and final (13%) adopters. This is because the availability of (conservation) tools is a prerequisite for construction and maintenance of SWC measures.

Presence of SWC assisted programs has a significant positive influence on the actual and final adoption stages of SWC. SWC project assisted farmers are 11% and 32 % more likely to belong to actual and final adoption phases of SWC, respectively. This shows the importance of project assisted SWC interventions for diffusion and adoption of soil and water conservation measures. Projects generally provide training, tools and knowledge to implement SWC measures.

Training on SWC is positively related to the actual and final adoption phases of SWC measures. The marginal effect confirms that farmers who received trainings on SWC are 3% and 10% more likely to fall in actual and final adoption phases of SWC, respectively. Training (e.g. training delivered by the Agricultural Office) is one means to create awareness about the problems of erosion and the benefits of SWC measures to motivate farmers to investment in SWC measures.

Cooperation with adjacent farm owners in erosion control has also a positive influence on actual and final adoption stages of SWC. The result of the marginal effect indicates that farmers who have a high degree of cooperation with adjacent farm owners are more likely to be actual (4%) and final (13%)

adopters. This shows the role of social components of SWC measures and particularly the importance of cooperation and willingness of neighboring farmers for the construction of SWC measures.
In addition, the number of farmers participating in labour sharing (assistance) scheme influences the actual and final adoption phases of SWC measures. This suggests that farmers who work together with many farmers in their labour sharing activities (during labour shortage time) are more likely to replicate and continue the use of SWC measures. Labour sharing is one way of smoothing labour constraints through social networks in rural areas of Ethiopia. In addition, the perception of the economic significance of erosion is positively related to the actual and final adoption phases of SWC. The marginal effect shows that farmers who perceive the problem of erosion are 19% and 21% more likely to belong to actual and final adoption phases of SWC, respectively.

Table 2.6. Ordered probit results of adoption phases of SWC

Variable	Ordered probit		Marginal effects			
	Coef.	Robust Std. Err.	Pro (y_i=0) (Non adopter)	Pro (y_i=1) (Initial adopter)	Pro (y_i=2) (Actual adopter)	Pro (y_i=3) (Final adopter)
Household characteristics and labour resources						
Age	-0.01	0.01	0.01	0.01	-0.01	-0.01
Family size	-0.02	0.04	0.01	0.01	-0.01	-0.01
Farm labour	0.31**	0.13	-0.05**	-0.08	0.03**	0.01*
Distance from road	0.00	0.01	-0.01	-0.01	0.01	0.01
Land resources						
Average parcel size	0.47***	0.16	-0.07***	-0.12***	0.05**	0.14***
Cultivated land size	0.16*	0.09	-0.02*	-0.04	0.02	0.05*
Farm size	-0.17*	0.09	0.02*	0.04*	-0.02*	-0.05*
Flat slope	-0.53*	0.28	0.10	0.10***	-0.07	-0.13**
Steep slope	0.08	0.16	-0.01	-0.02	0.01	0.02
Other resources						
Size of iron roof	-0.01	0.00	0.01	0.01	0.01	-0.01
Tools	0.44***	0.17	-0.07**	-0.11***	0.05**	0.13***
Off-farm income	-0.00	0.00	0.01	0.01	-0.01	-0.01
Institutions and social capital						
Tenure security	0.33*	0.19	-0.06	-0.07**	0.04	0.09*
SWC Training	0.33*	0.17	-0.05**	-0.08	0.03*	0.10**
SWC program	1.15***	0.19	-0.19***	-0.24***	0.11***	0.32***
Medium cooperation	0.02	0.20	-0.01	-0.01	0.01	0.01
High cooperation	0.43**	0.18	-0.06**	-0.11*	0.04*	0.13**
Formal position	0.31	0.24	-0.04	-0.01	0.02*	0.10
Labour sharing (assistance)	0.03***	0.01	-0.01***	-0.01***	0.01***	0.01***
Perceptions						
Erosion problems	1.21***	0.41	-0.19***	-0.07	0.19***	0.21***
SWC profitability	0.56	0.34	-0.12	-0.10***	0.08	0.13**
cut1	2.23***	0 .64				
cut2	3.60***	0.64				
cut3	4.38***	0.65				

Number of observations = 272
Wald chi2(21) = 194.48
Prob > chi2 = 0.0000
Pseudo R2 = 0.2489

Log pseudo likelihood = -277.58386

*, ** , *** significant at 10, 5 and 1% level of significance, respectively

Final adoption phase

The study results show that the final adoption phase is specifically influenced by different factors. The effect of cultivated land size is found to be positive and significant (p< 0.10) on the final adoption phase of SWC. The result of the marginal effect indicates that a unit increase in cultivated land would increase the probability of the continued use of SWC measures by 5%. This is because the potential loss of land for SWC and temporal yield decline do not constrain the adoption of SWC for large holdings.

The slope degree of parcels influences the final adoption stage of SWC measures and statistically significant. The finding illustrates that farmers who operate on fields with gentle slope are 13% less likely to invest, replicate and maintain SWC technologies. This may be explained by the positive relationships between slope level and severity of soil erosion. (Amsalu and de Graaff 2007; Anley et al. 2007).

Farmers' perceived profitability of SWC measures has a positive (P<0.01) influence on the final adoption phase of SWC measures. The marginal effect indicates that farmers who perceive SWC measures to be profitable are 13% more likely to maintain SWC measures. This is because financially viable SWC measures encourage adoption (continued use) of SWC measures.

Tenure security is positively (P<0.10) related to the final adoption phase of SWC. More specifically, the result of the marginal effect shows that tenure security significantly increases the likelihood of final adoption of SWC by a margin of 9%. This result is consistent with findings of other studies (Neill and Lee 2001; Soule et al., 2000). On the other hand, total farm size, a proxy variable of wealth, has a negative influence on the final adoption phase of SWC measures. A unit increase in the total farm size reduces the probability of maintaining SWC measures by 5%. This is because wealthy farmers may focus on other income generating activities and they may give less attention to SWC measures.

We made a rerun of the model excluding the dis-adopter group (i.e., only considering the non-adopter groups) and the results are presented in Appendix 1. The estimates are quite similar.

For a robustness check we have run multinomial logistic regression, the results of which are shown in Appendix 2. The estimates of the two models (ordered and multinomial) are almost similar.

2.5 Discussion

As mentioned earlier the adoption of SWC measures is a sequential process. The factors that influence (the stages of) adoption are highly context-specific, which makes generalizations difficult (de Graaff et al. 2008; Lapar and Pandey, 1999). This study found that final adoption depends mostly on the size of a parcel and the size of cultivable land (land fragmentation), resource endowments (labour and tools), tenure security, technical support (availability of training and SWC program), perceived erosion problems and profitability of SWC and social capital.

On average, the sample households managed 4.5 parcels (Table 2.3). This study shows that land fragmentation negatively influences the continued adoption of SWC; suggesting that farmers who have a smaller parcel size and/or fragmented parcels are less likely to invest and maintain SWC measures. This is probably because it increases the transaction cost for investments, which is in line with previous findings (Gebremedhin and Swinton, 2003; Tenge et al. 2004; Sklenicka et al. 2014).

The study further revealed that technical support (availability of training and SWC programs) and resource endowments (farm labour) influenced the continued use of SWC measures. This is because these interventions are knowledge and labour intensive. These results are consistent with the findings of Bekele and Drake (2003); Posthumus et al. (2010) and Adimassu et al.(2012).

Tenure security is important to undertake long-term land improvement investments (Besley, 1995). Our result is consistent with findings of Neill and Lee (2001) in Northern Honduras, Gavian and Fafchamps (1996) in Nigeria and Geberemedehin and Swinton (2003) in the Tigray region of North Ethiopia. Conversely, Holden and Yohannes (2002) revealed that tenure insecurity had in Southern Ethiopia no negative effect on long term investment. This difference could be explained by the differences of socio-economic and land re-distribution experiences between Amhara and Southern regions.

The significance of farmers' perception of how soil erosion affects their land productivity indicates that high awareness about soil erosion problems is crucial to increase the likelihood of adoption of SWC measures.). Amsalu and de Graaff (2006) and Ervin and Ervin (1982) found similar results. Perceived profitability is also important in the adoption of SWC. Bunds have effect on crop productivity (Nyssen et al., 2007). Promoting technologies that increase the productivity and income of farmers is therefore important to speed up the adoption process. This result is consistent with findings of Cary and Wilkinson (1997) and Amsalu and de Graaff (2007).

Cooperation with adjacent farm owners in erosion control is important for the continued adoption of SWC. There is a strong physical interdependency between adjacent farms with respect to hydrology and soil erosion. This result is in line with findings of Beekman and Bulte (2012) in Burundi.

2.6 Conclusion

A better understanding of factors affecting adoption behavior is vital for designing promising pro-poor policies that could stimulate and sustain adoption of SWC. In this study, the adoption process of SWC measures is categorized into four major phases, i.e. non-adoption/ dis-adoption, initial adoption, actual adoption and final adoption. The study indicates that sample households find themselves in different phases of adoption due to different institutional and socio-economic factors. Among other things, these findings indicate that adoption studies should not only focus on the classic comparison between adopter and non-adopter categories but rather investigate the adoption process of SWC measures at different phases of adoption.

The study shows that the non-adoption/dis-adoption and initial adoption of SWC are mainly due to land fragmentation, lack of technical support and resource endowment, low social capital and low level of perception of erosion problems and profitability of SWC.

The results of the study indicate that availability of labour is very important for the actual and final adoption phases of SWC. Specifically, the maintenance costs for the final adoption stage are very important. This implies that conservation structures need to be made less labour demanding by reducing the maintenance costs, i.e., by stabilizing bunds through biological measures. The study results also indicate that ownership of tools (e.g. shovels) and project assistance for SWC interventions are very important factors that affect the actual and final adoption phases of SWC. This implies that there is a need for technical support and resources (tools for SWC measures) for farmers to increase their investment capacity and know-how in order to facilitate the adoption process.

In addition, the study reveals that social capital and specifically cooperation with adjacent farm owners is a key factor for the actual and final adoption phases of SWC. This means that conservation on one farm will have little spill over impact when farm land on adjacent farm areas is not conserved. This implies that the adjacent farm owners need to work together to avert the problems of erosion. Thus, a watershed approach applied at community level is the remedy for the problems of cooperation between adjacent farms. With a watershed approach, SWC measures are implemented more comprehensively at community level. The average parcel size is also influencing the actual and final adoption stages positively. The average parcel size is an indication of the fragmentation of the farm parcels. On dispersed and fragmented small parcels, the cost of investing in SWC measures may be excessive. Either land consolidation or alternative SWC measures are important to enhance the productivity of farm land.

The final adoption phase of SWC is positively associated with cultivated land size and farmers' perceived profitability of SWC measures. Thus, investigation of the economic efficiency of the different SWC measures under different circumstances is of paramount importance to select feasible measures. In addition the results of the analysis show that tenure security is an important factor that affects the final adoption phase of SWC. Secure land rights increase the planning horizon of farmers to undertake long term investments. Therefore, the land policies should provide long-term and lasting tenure security to the farmers.

The overall results of this empirical analysis indicate that institutional and socio-economic factors functioning at national, regional, watershed, village, farm and household level play a strong role in shaping farmers' investment behavior at the different phases of SWC adoption. Thus, policy makers should take into consideration factors affecting adoption (continued) of SWC such as profitability, tenure security, social capital, technical support and resource endowments (e.g. tools and labour) when designing and implementing SWC policies and programs.

Chapter 3

Financial viability of soil and water conservation technologies in north-western Ethiopian highlands

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Financial viability of soil and water conservation technologies in north-western Ethiopian highlands

Abstract

Soil erosion by water is a major threat to food security, environmental sustainability and prospects for rural development in Ethiopia. Successive governments have promoted various soil and water conservation (SWC) measures in order to reduce the effects of land degradation, but adoption rates vary considerably. The profitability of SWC measures is an essential condition for their adoption. The objective of this research was to determine the economic efficiency of three different types of SWC technologies (soil bunds, stone bunds and *Fanya juu*) in the watersheds of Debre Mewi and Anjeni in the north-western Ethiopian highlands. A farm household survey was carried out among 60 farmers in both watersheds and the Universal Soil Loss Equation (USLE) was used to assess erosion risk on farmers' fields. A cost-benefit analysis (CBA) was then carried out to determine the profitability of the measures under different conditions. Erosion estimates for the fields suggest that adapted SWC structures were successful in reducing soil erosion. The cost-benefit analysis indicates that all SWC measures are profitable under 'standard' conditions, except soil bunds in Anjeni without grass cover. However, the study shows that different underlying assumptions change the CBA results considerably and consequently also change the conclusions regarding circumstances under which SWC measures are or are not profitable. This illustrates the volatility of the profitability of SWC measures.

Keywords: soil erosion, soil and water conservation (SWC), cost-benefit analysis (CBA).

3.1 Introduction

Subsistence smallholder agriculture has continued to dominate economic development in Ethiopia. This sector contributes about 41% of the total GDP and provides employment to about 85% of the population (FAO, 2011). This subsistence agriculture is almost entirely rainfed and yields are generally low. However, the role of this sector in alleviating poverty and food insecurity is constrained by a multitude of factors such as land degradation (depletion of soil organic matter, soil erosion, and lack of adequate plant-nutrient supply) and recent climate change, resulting in droughts and floods (Grepperud, 1996; Pender et al., 2006). As a cumulative effect of land degradation, increasing population pressure, and low agricultural productivity, the country has become food insecure. In most parts of the densely populated highlands, cereal yields average less than 1 metric ton per hectare (Pender and Gebremedhin, 2007). Such low agricultural productivity, compounded by recurrent drought, contributes to food insecurity and extreme poverty.

Ethiopia has experienced exponential population growth accompanied by massive deforestation and land degradation in the highlands (Hurni et al., 2010). Farmers are forced to cultivate marginal lands on steep slopes that are highly susceptible to soil erosion (Hurni,1993; Taddese, 2001; Sonneveld and Keyzer, 2003). About 1.5 million tons of topsoil are lost from the Ethiopian highlands each year due to erosion. Preventing this loss has the potential to add about 1.5 million tons of grain to the country's harvest (Tamene and Vlek, 2008).

To alleviate the problems of soil erosion, a number of massive soil conservation programmes have been launched since 1975 (Shiferaw and Holden, 1998). Within these programmes much attention has been paid to the establishment of SWC line interventions, such as stone bunds, regular soil bunds, and a specific form of soil bunds referred to as *Fanya juu*. This paper focuses on these three measures.

The adoption rate of these soil and water conservation (SWC) measures varies considerably within Ethiopia (Shiferaw and Holden, 1999; Bewket, 2007; Tefera and Sterk, 2010; Teshome et al., 2013). This is because investments in SWC practices are influenced and constrained by various institutional and socio-economic factors (Ervin and Ervin, 1982; Amsalu and de Graaff, 2007; Kessler, 2006; Shiferaw et al., 2009). Profitability of the technologies appears to be one of the major economic factors which affect the adoption of SWC technologies (de Graaff et al., 2008; Sattler and Nagel, 2010; Kassie et al., 2010).

Profitability is a necessary, but not sufficient, condition for adoption, and other factors become less relevant without sufficient profitability. Soil and water conservation measures may increase crop yield by reducing erosion and improving water and nutrient availability, but they should also offer sufficient financial gain for farmers. However, the profitability of SWC structures is highly situation-specific and depends on characteristics of the farming system as well as ecological, economic and institutional factors (Posthumus and de Graaff, 2005; Bizoza and de Graaff, 2012). The costs of these measures consist largely of their labour-intensive establishment and maintenance (Tenge et al., 2005). Benefits, on the other hand, accrue due to a reduction of the yield decline as the result of erosion (without the investment) and the increase of yields, as a result of better water and nutrient efficiency on the land conserved by the measures (with the investment). Besides negative on-site effects, soil erosion also leads to off-site effects like the siltation of reservoirs and waterways (Lal, 2001). The latter, however, is not discussed in this paper.

The objectives of this research are to investigate the profitability of three types of SWC line interventions in two different watershed areas in the north-western Ethiopian highlands.

3.2 Materials and methods

3.2.1 Research areas and SWC technologies

Research areas

The research area consisted of the watersheds of Anjeni and Debre Mewi in the West Gojam Zone in the Amhara Regional State in north-west Ethiopia. The two sites represent typical watersheds in the Ethiopian highlands. Other reasons for this choice are the availability of long-term data on soil erosion and extensive experience with SWC development activities. See Figure 3.1 for the location of the study sites.

Figure 3.1 Debre Mewi and Anjeni watersheds in Amhara Regional State.
Source: Own compilation with map material from maplibrary.org.

Debre Mewi watershed

Debre Mewi watershed lies about 30 km southeast of the regional capital Bahir Dar, and is located at 11.34°N and 37.43°E. The total watershed area is estimated at 523 ha, and is situated at an average altitude of about 2,300 m.a.s.l. Administratively it is located partly in Bahir Dar Zuria District and partly in Yilmana Densa District (Figure 3.1). Debre Mewi receives an average annual rainfall of about 1260 mm. The topography of Debre Mewi watershed is characterized by moderate slopes between 2 and 15%. Next to the rivers, there are steeper slopes of more than 50% inclination. In these areas land use is dominated by public and private grazing land (Figure 3.2).

The soils of Debre Mewi watershed are dominated by Vertic Nitosols, Nitosols (red) and Vertisols (black) (Zegeye, 2009). Only a limited amount of empirical data on soil loss is available for Debre Mewi watershed. Soil erosion experiments conducted in Debre Mewi by the Adet Agricultural Research Centre observed soil erosion rates from 23.8 t to 46.9 t ha^{-1} on fields treated with SWC measures. Soil loss on untreated fields was observed to be 71.4 t ha^{-1}.

The total number of households in Debre Mewi is estimated to be 324. The farming system of Debre Mewi is characterized by small-scale subsistence crop-livestock mixed production. Major crops grown in the watershed are tef (Eragrostis tef), maize and barley. These major cereals are followed in production area by finger millet and wheat. Faba bean, potato, noug (Guizotia abyssinica, also known as niger seed) and gomen (Brassica carinata) are cultivated on an even smaller area. Grass pea (Lathyrus sativus) is cultivated by exploiting the residual moisture available after either the cultivation of barley or late planting.

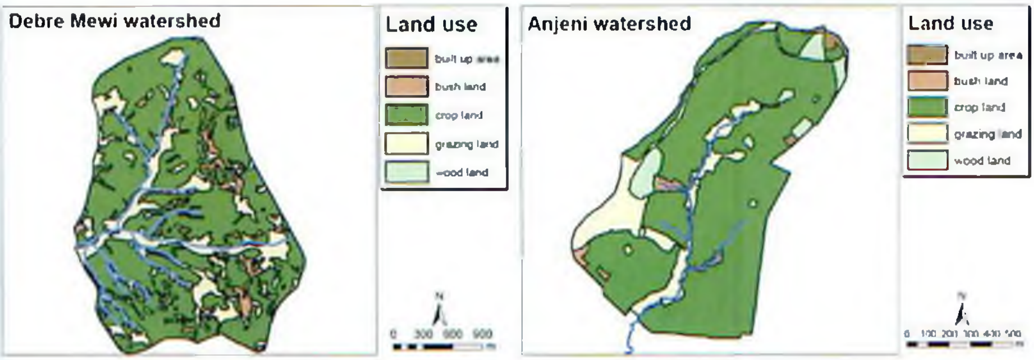

Figure 3.2. Land use in Debre Mewi and Anjeni watersheds.
Source: Own compilation with data from SCRP database and Getahun (2009).

Anjeni watershed

Anjeni watershed lies about 260 km southeast of Bahir Dar. The watershed area covers about 113 ha, and is located at 10.68°N and 37.53°E at an altitude of about 2,450 m.a.s.l. Anjeni lies in Dembecha District (Figure 3.1). Anjeni receives an annual average rainfall of around 1790 mm, and exhibits slightly steeper slopes than Debre Mewi watershed. Nevertheless, 50% of the Anjeni catchment is not steeper than 15% (Ludi, 2004). Land use in the watershed is dominated by crop land on the more moderate slopes. Grazing land, bush land and woodlot are found on the steeper slopes (Figure 3.2).

The soils in Anjeni are dominated by Alisols, Nitosols, Regosols and Leptosols. All soils in Anjeni have a high clay content. They are generally acidic and low in organic carbon content. Moreover, they have low to medium total nitrogen and plant-available phosphorus content. These facts indicate overexploitation of soils and leaching processes (Ludi, 2004; Haile et al., 2006). Soil erosion measurements in an experimental setup have been conducted in Anjeni watershed since 1984. Soil losses in the period from 1983 to 1999 have been observed to range from 17 t ha^{-1} to as high as 176 t ha^{-1} (Herweg and Ludi, 1999).

Anjeni watershed lies about 17 km away from the town Denbecha, which is situated along the main highway leading from Addis Ababa to Bahir Dar. Like in Debre Mewi, the farming system of Anjeni is characterized by small-scale subsistence crop-livestock mixed production. Major crops grown in the watershed are barley, tef, maize and wheat, followed by faba bean and potato. Noug, field pea, lupine (*Lupinus* spp.) and linseed (*Linum usitatissimum*) are of minor importance in terms of area cultivated.

Anjeni watershed has a long history of introduced SWC technologies, starting during the reign of the *Derg* regime. A research site was established in the watershed by the Swiss Soil Conservation Research Programme (SCRP) in March 1984. In 1985 the first SWC measures were constructed outside the watershed. During a campaign from February to April 1986 the watershed was finally treated with graded *Fanya juu* bunds. Participation by the local community was ensured by the promise of building a clinic as an incentive (Ludi, 2004).

Soil and water conservation technologies

This research focuses on three different structural SWC technologies, since these are the most often implemented in the Ethiopian highlands. The principal task of these technologies is to protect uncovered cultivated parts of agricultural fields from surplus overland flow, the so-called run-on. In addition, these structures help to interrupt or reduce the slope length, thereby diminishing the velocity of water leaving the field, the so-called run-off. Topsoil will accumulate behind these structures, reducing the slope angle and run-off velocity, while at the same time increasing water infiltration on the field (Haile et al., 2006). The most commonly implemented mechanical SWC structures are stone and soil bunds as well as *Fanya Juu* - type terraces (Herweg and Ludi, 1999).

Stone bunds are usually constructed where suitable stones are available on or near the field. If they are well maintained, stone terraces are stable and durable; pure soil bunds, on the other hand, can be easily eroded by wind and water, especially during heavy rainfalls. Moreover, excess water can pass more easily through stone terraces than through compacted soil bunds (Haile et al., 2006).

Soil bunds and *Fanya juu* (Swahili for 'throw uphill') terraces follow very similar design principles. They are embankments along a field's contour. In the case of soil bunds a trench is dug and the excavated soil material is thrown downhill, while for *anya juu* it is thrown uphill. With ongoing erosion, a terrace forms behind these barriers and prevents the soil material from moving further downhill (Herweg and Ludi, 1999). See Figure 3.3.

Soil bunds require less labour input for construction than *Fanya juu* because the excavated soil is thrown downhill, not uphill. However, the accumulated soil in the ditch behind the soil bund may cause waterlogging or be washed away. Moreover, the accumulated soil will be used in subsequent years to raise the bunds instead of being put to use for crop production. The bunds of *Fanya juu* terraces, on the other hand, are mainly built from subsoil material. Drainage behind the bund is therefore much less affected than in the case of normal soil bunds (Herweg and Ludi, 1999).

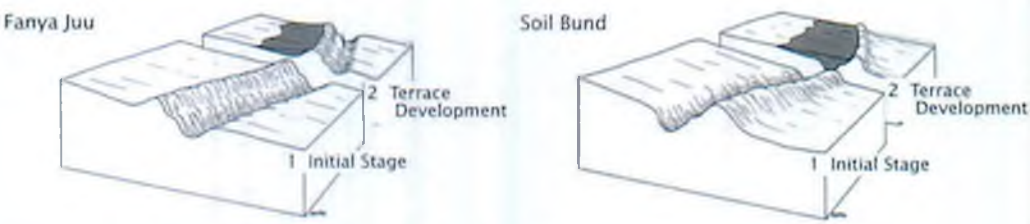

Figure 3.3. Different types of SWC terraces. Left: Fanya juu, right: soil bund.
Source: Haile et al. (2006).

3.2.2 *Research methodologies*

Farm household survey

A structured survey and Participatory Rural Appraisal tools (PRA) were used to collect primary data. In each of the two watersheds a farm survey was undertaken on a sample of 30 farmers, who were asked detailed questions about the implementation and costs and benefits of their SWC measures. These samples actually consisted of sub-samples of a larger farm survey which included 113 and 60 households in Debre Mewi and Anjeni respectively, and which provided much more data about the households, their land, labour and other resources, and the extent to which they had implemented SWC measures. The survey also devoted attention to the perceptions of farmers regarding soil erosion and other aspects of land degradation, and regarding the design, implementation and profitability of the respective SWC technologies in the two areas.

Soil erosion assessment

For soil erosion assessment, use was made of the empirical USLE formula: $A = R*K*LS*C*P$, in which the estimated annual soil loss (A) is a function of rainfall erosivity (R), soil erodibility (K), slope length and steepness (LS), crop cover (C) and land management practices (P). The USLE was used to estimate soil erosion on 77 agricultural plots (27 from Debre Mewi and 50 from Anjeni) and a hypothetical plot cultivated with crop rotations typical for the watershed. Values for the K and P factors were taken from Hurni (1985) and LS factors from Bewket and Teferi (2009). Values for the R and C factors were taken from the latest adaption of the USLE to Ethiopian highland conditions by Kaltenrieder (2007). Soil loss in t ha^{-1} was subsequently converted into reduction of soil depth in mm by using average bulk densities of soils in the watersheds. For Anjeni an average bulk density of 1 g cm^{-3} was assumed (Ludi, 2004). The average bulk density of soils in Debre Mewi was assumed to be 1.21 g cm^{-3} (Zegeye et al., 2010).

Cost-Benefit analysis

For this research a financial cost-benefit analysis (CBA) was carried out to determine the economic efficiency of stone bunds, soil bunds and *Fanya juu* terraces. CBA is a monetary evaluation method centred on the quantification and measurement of the costs and benefits of an intervention with long-term effects. It is based on applied welfare economics (Perman et al., 2003). CBA consists of an impact analysis and a subsequent valuation of the impacts. The eventual aim of a CBA is to compare the present value of the stream of benefits (positive effects) and the present value of all investments and recurrent costs (negative effects). A CBA can be carried out either for individual enterprises (financial CBA) or society as a whole (economic and social CBA). Unlike an economic CBA, a social CBA also takes into account equity of income distribution as an objective (Kuyvenhoven and Mennes, 1989).

A CBA process consists of the following analytical steps: determination of evaluation criteria; identification of effects (costs and benefits); quantification in physical terms of the effects; valuation of effects; determination of time horizon; weighing of the costs and benefits in time (discounting) and sensitivity analysis (de Graaff, 1996). The most commonly used CBA evaluation criteria are the benefit/cost ratio (B/C ratio), the net present value (NPV) and the internal rate of return (IRR). For this research, NPV and IRR are used as evaluation criteria.

Sensitivity analysis

In order to test the robustness of the outcome of the cost-benefit analysis, a detailed sensitivity analysis was carried out. The most important assumptions were reconsidered and the financial viability of each SWC measure was recalculated with different opportunity costs of labour, other yield declines in the 'without' case, other yield increases in the 'with' case and with and without grass cover of bunds.

3.3 Results and discussion

In order to assess the viability of the three SWC technologies in the two watersheds, first an overview of the present farming systems will be given. Next, the results of the erosion measurements will be shown and compared with other erosion research in the region, and an analysis of the effects of soil erosion on crop yields will be presented. Then the design and implementation of the SWC technologies will be discussed, along with their effects on cultivable land, soil erosion and land productivity. This will be followed by the quantification and valuation of all the effects of the technologies, which constitute the respective costs and benefits. In addition, the perceptions of farmers regarding soil erosion, and also technical and financial aspects of the SWC technologies will be discussed. Finally, the cost-benefit analysis (CBA) will be presented, followed by the sensitivity analysis.

3.3.1 Farming systems

Farm households in Debre Mewi and Anjeni watersheds are characterized by a high level of subsistence production and small and fragmented landholdings. The average farm size is 1.18 ha in Debre Mewi and 1.22 ha in Anjeni watersheds. In both watersheds, farmers possess from one to twelve individual parcels, scattered throughout the respective watersheds.

Crop rotations are an integral part of Ethiopian farming systems. Barley, tef, maize and wheat are major crops in the main season. After barley, a second crop is grown on residual moisture: grass peas in Debre Mewi and a second barley crop in Anjeni. Farmers in both watersheds often also intercrop maize with gomen, noug (niger seed), faba bean and/or potatoes. During the household survey and group interviews, no evidence was found that farmers change their cropping patterns depending on whether or not the plot was treated with SWC measures. This can be explained by the subsistence character of the production.

The most common crop rotations practised in the watersheds and used in the CBA were:

Debre Mewi: Barley I (Grass pea) - Tef - Maize - Wheat - Finger Millet

Anjeni: Barley I (Barley II) - Tef - Maize - Wheat

The only types of mineral fertilizers generally available in Ethiopia are Di-Ammonium-Phosphate (DAP) and urea. Farmers in Debre Mewi and Anjeni applied on average about 100 and 80 kg ha^{-1} DAP and about 50 and 30 kg ha^{-1} urea respectively. Apart from inorganic fertilizers, farmers also use animal manure (mostly on parcels adjacent to their homesteads). On average there was not much difference between parcels with and parcels without SWC measures (though the SWC measures reduce the size of the parcels). Labour inputs ranged from about 43 person days (PD) for barley, to 113 PD for maize (sown in rows) and 166 PD for finger millet. Finger millet requires frequent ploughing, just like tef, and needs more labour for threshing. The average wage rate during times of crop production in the year 2010 was around 15 EtB ($ 0.88) per day in both of the watersheds.

Soil and water conservation measures in the two areas

The practice of stone- and soil bund construction was first introduced in Debre Mewi watershed in 1996. According to the chairman of the local farmer research group, these first attempts were based on campaign work and neither aimed to raise, nor succeeded in raising, awareness about the problem of soil erosion. People were forced to participate in these programmes. As a consequence, some farmers refused to implement introduced SWC measures on their farms. The chairman further claimed that, today, all farmers see the different types of terraces as being beneficial for their production. However, farmers supposedly fail to construct them because of a lack of technical assistance from local development agents (DAs) and due to a lack of cooperation between farmers of neighbouring fields. Previous field observations in Debre Mewi showed that many of the bunds were not properly constructed and only poorly maintained (Zegeye et al., 2010).

During group discussions in Anjeni, farmers pointed out that twenty-five years ago the problem of erosion was so severe that not enough crops could be produced for farmers to survive. This high food insecurity caused farmers to migrate to other areas. After the introduction of new SWC line interventions, food-security could again be reached and seasonal migration was reduced. They further stated that Anjeni watershed now is a model for soil and water conservation activities for the Amhara region and the nation at large.

During the farm household survey, information was obtained from a total of 143 agricultural plots in Debre Mewi watershed and 170 plots in Anjeni watershed, along with the respective SWC measures (Table 3.1).

Table 3.1. Number of sampled plots with and without SWC measures.

SWC	Debre Mewi	Anjeni
No SWC	104	25
Soil bund	28	9
Fanya juu	-	102
Stone bund	8	10

Source: Data from farm household survey.

The stone bunds in Debre Mewi were constructed between 2003 and 2011, and the soil bunds between 1996 and 2011. The earliest stone bunds in Anjeni were constructed in 1984 and the most recent in 2011. The age of the *Fanya juu* bunds varied between 1 and 27 years. Field observations in Anjeni have shown that most of the older *Fanya juu* bunds have stabilized into bench terraces. This results in a diminution of slope angles and increased topsoil depth behind the bunds, which has a positive effect on yields.

The number listed in Table 3.1 of plots with different kinds of SWC line interventions does not represent exactly the frequency of treated plots at the watershed level. In the Debre Mewi watershed the percentage of plots treated with stone bunds is very low, due to a shortage of stones, while in Anjeni there are almost no plots that are not treated with introduced SWC.

Yields of the major crops with and without the measures

Table 3.2 provides information about the yields of the major crops obtained in 2011 on the respective plots with and without SWC measure.

Table 3.2 Crop yields in Debre Mewi and Anjeni watersheds on plots with and without SWC measure.

Crop	Crop yields (kg ha^{-1})													
	Debre Mewi						Anjeni							
	No SWC		Stone bund		Soil bund		No SWC		Stone bund		Soil bund		*Fanya juu*	
	n	Avg.	n	Avg.	n	Avg.	n	Avg.	n	Avg.	n	Avg.	n	Avg.
Tef	19	879	3	833	13	1101	5	618	3	735	3	637	30	756
Wheat	9	1289	1	1176	3	931	4	625	3	719	3	637	23	863
Barley I	17	1403	-	-	6	983	5	941	1	980	1	1765	32	924
Maize	24	1334	3	1667	11	1511	7	1919	2	588	2	956	25	1249
Finger millet	7	1492	2	1471	2	1176	-	-	-	-	-	-	-	-
Grass pea	19	879	-	-	2	846	-	-	-	-	-	-	-	-
Barley II	-	-	-	-	-	-	1	147	-	-	-	-	6	719

Note: Barley I is grown in the rainy season; Barley II is grown after barley I on residual moisture.
Source: Data from farm household survey 2011.

From the data presented in Table 3.2, no general conclusion can be drawn whether SWC measures increase crop yields: unfortunately, the samples are too small, the data only reflects one year, and the farmer estimates are too rough. Furthermore, there are various physical and socio-economic factors involved, including soil type, slope and use of fertilisers. This is discussed further in Section 3.2.

Despite higher annual precipitation, yield levels in Anjeni are lower than in Debre Mewi. Several explanations for this fact are possible:

- Farmers in Debre Mewi generally apply more mineral fertilizers than farmers in Anjeni.
- Use of improved seed varieties is much lower in Anjeni than in Debre Mewi.
- Soil depth in Anjeni is lower than in Debre Mewi, which is also likely to have negative effects on yields, and was one reason why soil and water conservation in this watershed was already initiated in the 1980s.

3.3.2 Erosion assessment and effects on yields

For a total of 77 plots, details were collected and measurements taken regarding plot size, main crop, SWC technology, slope and slope length. Subsequently, calculations were made using the USLE formula in order to arrive at average soil erosion rates for the different situations. Because of the requirements of a fine seedbed, land under tef is ploughed quite often and is very vulnerable to soil erosion; hence the C-factor for tef is very high. But the average C factor is brought down by much lower values for the other crops in the crop rotation. Table 3.3 shows that soil erosion risk on non-protected fields is almost twice as high (on the sampled plots) in Anjeni than in Debre Mewi (122 as opposed to 64 t ha^{-1} y^{-1}), but thanks to the much higher coverage with SWC measures (also represented in this sampling), the average soil erosion rate is now lower. These data correspond very well with the data on soil loss from experimental plots in the two areas, as shown in Section 3.2.1.

Table 3.3 Assessment of soil erosion with different SWC measures, using USLE formula.

	N	Plot size (ha)	Slope (%)	Slope length (m)	R-factor	K-factor	LS-factors	C-factor	P-factor	Erosion (t ha^{-1} y^{-1})
Debre Mewi										
Soil bund	10	0.18	9.7	35	501	0.26	1.4	0.27	0.30	10.5
Stone bund	6	0.15	17.0	36	501	0.30	3.3	0.15	0.20	17.4
None	11	0.26	10.2	131	501	0.21	3.0	0.29	1.00	64.3
Average		0.21	11.1	84	501	0.24	2.5	0.26	0.64	38.9
Anjeni										
Fanya juu	45	0.08	10.8	29	692	0.24	1.4	0.35	0.15	12.3
None	5	0.16	17.1	86	692	0.22	5.1	0.08	1.00	122.3
Average		0.09	11.9	39	692	0.24	2.1	0.30	0.31	32.7

Effects on yields, without SWC measures

It is difficult to assess the loss of agronomic productivity due to soil erosion, because of the confounding effects of rainfall and other climatic factors during the growing season and also management factors (Lal, 2001). For Debre Mewi watershed, no long-term data on yields and soil loss are available. For Anjeni watershed, a relationship between soil loss and crop yields was established by Ludi (2004). Based on 11 years of yield data, she found that yields decreased by 0.23% per cm of soil lost on plots not treated with SWC. Taking into account both measured soil loss due to erosion and the average bulk density of soils in the two watersheds, this would mean that yields decrease by 0.14% and 0.21% annually in Debre Mewi and Anjeni, respectively. Other authors have also estimated productivity losses due to soil erosion in Ethiopia. Bojo (1996) reports that, according to these various sources, productivity losses range between 0.4 and 3% annually.

In the standard cost-benefit analysis a 1% decline of yields in the 'without' case will be assumed in Debre Mewi watershed and a 1.5% decline in Anjeni watershed, since the soil depth is lower there, leading to an earlier decline of yields. In the sensitivity analysis, some lower and higher values will be considered.

3.3.3 SWC technologies and their effects

Standard design versus implementation in the field

In 2005 the Ethiopian Ministry of Agriculture and Rural Development (MoARD), in collaboration with several international development organizations, published its first guidelines for 'Community Based Participatory Watershed Development', commonly known as the 'Watershed Development Guidelines' (MoARD, 2005).

According to the Watershed Development Guidelines, the vertical interval (VI) – the vertical distance between two **soil bunds** – should "follow a flexible and quality oriented approach". Ludi (2004) states that the horizontal interval (HI) between bunds should be chosen by dividing the VI in cm by the slope angle expressed as a percentage, see Equation 3.1.

$$HI = \frac{VI * 100}{Slope} \quad [3.1]$$

For slopes exceeding 15%, the guidelines advise against soil bunds and instead recommend constructing stone bunds or stone-faced soil bunds. According to guideline work norms, 150 person days (PD) are required to construct one km of soil bunds, regardless of slope. Table 3.4 shows the soil bund design recommendations and resulting labour requirements based on MoARD (2005).

Table 3.4 Soil bund design recommendations.

Slope (%)	VI (m)	Distance (m)	Labour for construction (PD ha^{-1})	Area loss (%)
3-8	1-1.5	50 - 12.5	30 - 120	2 - 8
8-15	1-2.0	25 - 6.7	60 - 225	4 - 15
15-20	1.5-2.5	16.67 - 7.5	90 - 200	6 - 13.3
15-30[a]	1.5-2.5	16.67 - 5	90 - 300	6 - 20

[a] only graded soil bunds.

Source: adapted from Watershed Development Guidelines by MoARD (2005).

***Fanya juu* bunds** should not be constructed on land with slope inclinations of less than 3% or more than 15% according to the watershed development guidelines. Labour requirements for *Fanya juu* bunds are higher than those for conventional soil bunds. According to the guidelines, it takes 200 person days to construct one km of these bunds (MoARD, 2005). Herweg and Ludi (1999) observed that the *Fanya juu* construction is much more labour intensive because the excavated soil material has to be thrown uphill rather than down (see Table 3.5).

Table 3.5 *Fanya juu* design recommendations.

Slope (%)	VI (m)	Distance (m)	Labour for construction (PD ha^{-1})	Area loss (%)
3-8	1-1.5	50 - 12.5	40 - 160	2 - 8
8-15	1-2.0	25 - 6.67	80 - 300	4 - 15

Source: adapted from Watershed Development Guidelines by MoARD (2005).

Table 3.6 Stone bund design recommendations.

Slope (%)	Height of bund (m)	VI (m)	Distance (m)	Labour for construction (PD ha^{-1})	Area loss (%)
5	0.5	1	20	125	5.0
10	0.5	1.5	15	167	6.7
15	0.75	2.2	12	208	8.3
20	0.75	2.4	10	250	10.0
25-50	1-1.15	2.5-2.8	8-4	312.5-625	12.5-25.0

Source: adapted from Watershed Development Guidelines by MoARD (2005).

The Watershed Development Guidelines suggest that **stone bunds** should not be constructed on slopes steeper than 35%. Moreover, the guidelines estimate the necessary labour requirements for stone bunds at 250 PD km^{-1} (MoARD, 2005), as shown in Table 3.6.

Tables 3.4-3.6 also show the loss of cultivable area as a result of bund construction; these vary in slope from a mere 2% to as much as 25% of the field concerned.

SWC implementation in Debre Mewi and Anjeni

Not only field observations and measurements, but also farmer estimates indicate that the actual implementation of SWC interventions differs considerably from official design recommendations. Farmers in Anjeni altered the original layout as implemented within the scope of the SCRP. These alterations mainly concerned the removal of some of the bunds to facilitate oxen-ploughing and increase the area available for crop production. In Debre Mewi the differences between official recommendations and actual implementation also concern the distances between bunds and the resulting total length of bunds per area.

Farmer estimates on distances between SWC structures show a great variability. In the farm household survey, farmers were asked to indicate the slopes of their plots on a chart representing different slope classes. These slope estimates, combined with estimates on the distances between bunds, did not show a pattern with regard to how distances between bunds are actually chosen with respect to the slope of a field.

Measurements of fields with SWC line interventions in Debre Mewi and Anjeni watersheds produced a picture similar to that of the interview data with regard to the design of SWC structures. The spacing between bunds is wider than in the MoARD recommendations, and the area occupied by the bunds is thus less than it would be if the guidelines were followed. The minimum distance observed between two bunds was 10.5 m and the maximum distance 50 m. The distance between *Fanya juu* bunds in Anjeni watershed ranged from only 7 m (which is probably a remnant of the original SCRP design) to 53 m.

Labour inputs for SWC line interventions and their valuation

During the farm household survey, farmers were asked to estimate the average length of SWC bunds on their field and the total labour input for their establishment on that field. Where SWC structures were constructed as part of a mass mobilization scheme, farmers could not give estimates on labour input. The average length of bunds was multiplied by the total number of bunds on the field. Subsequently, the total labour input was divided by the figure resulting from the previous calculation in order to come up with a number of Person Days (PD) spent on the construction of one km of bunds.

Labour inputs estimated by the respondents of this research are considerably lower than all previously reported labour inputs to SWC in the Ethiopian highlands (Shiferaw and Holden, 1999; Ludi, 2004); especially the values based on estimates by farmers from Anjeni were very low. This discrepancy can be explained by the fact that most of the SWC structures in Anjeni were constructed long ago. For example, 90% of the labour estimates for *Fanya juu* are for structures that were built five or more years ago and 42% for structures that were built even 10 or more years ago. For this reason, standard figures by the Ethiopian Ministry of Agriculture and Rural Development as reported in the Watershed Development Guideline (MoARD, 2005) are used in the financial CBA of SWC measures. Finally, labour for the maintenance of SWC structures is estimated to be 10%, 7.5% and 5% for soil bunds, *Fanya juu* and stone bunds, respectively, of the initial labour to construct the measures.

SWC activities are usually carried out in the dry season when no, or only little, labour is needed for agricultural activities. Because labour for their establishment constitutes the greater part of investments in SWC measures, its valuation is critical to a CBA. According to Stocking and Abel (1989) and Posthumus and de Graaff, (2005), the valuation of labour inputs to SWC is dependent on the circumstances. If no other activity is reduced for the construction of SWC, the opportunity costs of labour could be valued at zero. Ludi (2004), on the other hand, argues that "farmers do not necessarily consider this period as a slack season per se. In the Ethiopian highlands, this is the time when other non-farm or off-farm activities are carried out".

Given these arguments, opportunity costs of labour for SWC construction were chosen at 50% of the market wage rate during the agricultural season. This is equivalent to 7.5 EtB PD^{-1}. This valuation of labour inputs gives consideration to both the fact that SWC construction takes up time that could have been spent on other activities, and to the fact that the same wages that can be earned during the agricultural season cannot be earned during the dry season. In contrast, labour for maintenance of SWC structures was valued at 100% of the market wage rate, as it is usually carried out at the same time as seed bed preparation.

Table 3.7 gives an overview of the situation on the sample plots, with regard to calculated soil losses, cultivable area losses and labour requirements in person days per ha. Considering that the majority of the bunds are established on slopes of 7% to 15%, in the cost-benefit analysis an average slope of 10% is assumed, with an area loss that is linked to that slope. The figures in Table 3.3 show the results of physical research, measuring USLE parameters, on a sample of 77 actual fields, with and without SWC measures in the watersheds. In Table 3.7, the USLE was applied on a hypothetical field (but characteristic for fields as found in the large farm household survey) with a slope inclination of 10%, a slope length of 100 m and the dominant soil type (Nitosols and Vertisols). Thus, the soil loss amounts differ from the field level USLE results (Table 3.3).

Table 3.7 Number of sample plots with/without SWC measures, calculated soil losses*, area losses due to SWC, distances between bunds and labour requirements for establishment of SWC measures.

SWC *Watershed*	Sample	Calculated soil loss[a] ($t\ ha^{-1}$)	Area lost, due to SWC (%)	Median distance between bunds (m)	Labour requirements[b] Establishm. ($PD\ ha^{-1}$)	Maintenance ($PD\ ha^{-1}\ y^{-1}$)
Debre Mewi						
No SWC	104	85	-	-	-	-
Soil bund	28	38	6.0	20	75	7.5
Stone bund	8	38	5.0	20	125	6.25
Anjeni						
No SWC	25	118	-	-	-	-
Soil bund	9	37	9.0	10	150	15
Fanya juu	102	46	6.7	15	133	10
Stone bund	10	53	5.5	20	125	6.25

Notes: -Width of bunds is 1 m for stone bunds and 1.2 m for soil bund and *Fanya juu*.

[a] slope 10%, slope length without SWC 100 m.

[b] On average, 150, 200 and 250 PD km^{-1} respectively.

Sources: Data from farm household survey and MoARD (2005) (Labour requirements).

Effects of SWC on yields

Crop yield increases due to SWC measures are difficult to explain. An interdisciplinary study by Nyssen et al., (2007) evaluated stone bunds in a dry region of northern Ethiopia. The bunds were constructed between three and 21 years prior to the research. The study found that on plots with stone bunds, cereal yields in general, and tef yields in particular, increased (after a few years) by 8 and 11%, respectively. These yield increases already take into account the area lost due to the conservation structures (Nyssen et al., 2007).

An evaluation of SCRP data by Herweg and Ludi (1999) found that crop yields rarely increased in the first three to five years after the construction of SWC measures. Nonetheless, crop yields and biomass from plots with SWC structures remained stable and exhibited only slight changes (decreases and increases) compared to control sites. In the first few years, yield declines on conserved plots ranged from 4 to 50%, while subsequent yield increases ranged from 4 to 15%. The authors attribute the stabilization of yields to the accumulation of topsoil behind the bunds and the initial reduction of yields to higher incidence of waterlogging on conserved plots.

The SWC technologies contribute not only to reduced soil loss, but also to reductions in soil nutrient loss, including those nutrients brought through fertilisation. Furthermore, SWC technologies also contribute to more water infiltration, and thus to better use of (green) water. No detailed information is available regarding water and nutrient balances, but in the cost-benefit calculations it will be assumed (for the standard case) that crop yields will increase by 10% for Debre Mewi and 15% for Anjeni from year 3, as compared to the original yields. This difference is due to the fact that soil depth is lower in Anjeni watersheds and that SWC measures will therefore have more effect on future yields. Since there will be some disturbance of the soil and the soil management just after implementation of the measures, it will be assumed that the yields initially decline by 25% in year 1 and 10% in year 2.

3.3.4 Farmer perceptions

When asked to judge the benefits of the SWC technologies, all 60 farmers stated that they have a large effect on reducing soil and nutrient losses, and most farmers (80%) mentioned that they have also large positive effects on soil fertility and crop yields (Table 3.8). The perceived water retention benefits are somewhat less pronounced. And while all farmers in Anjeni do have great appreciation for the grass grown on the bunds, this is somewhat less so in Debre Mewi. While a high percentage of farmers acknowledge the various benefits of the SWC technologies, farmers in Anjeni are the most enthusiastic.

In Debre Mewi watershed, farmers were asked to estimate yield increases due to the construction of terraces. They estimated that tef yields on terraced plots increase by 50%, from 200 to 300 kg timad^{-1} (800 to 1200 kg ha^{-1}) and maize yields by 100%, from 200 to 400 kg timad^{-1} (800 to 1600 kg ha^{-1}). However, these high yield increase estimates are supported neither by yield estimates from the household survey nor by the available literature on the subject.

Table 3.8 Frequency distribution of perceived benefits (in %) of introduced SWC technologies in Debre Mewi and Anjeni watersheds (n= 2 x 30).

Perceived benefits	Debre Mewi watershed				Anjeni watershed			
	None	Small	Medium	Large	None	Small	Medium	Large
Minimized soil/nutrient loss	0	0	0	100	0	0	0	100
Increased water retention	6.7	6.7	26.7	60	0	10	16.7	73.3
Improved soil fertility	3.3	3.3	13.3	80	0	3.3	16.7	80
Increased yields	6.7	3.3	20	70	0	3.3	10	86.7
Grass on terraces for livestock	6.7	13.3	20	60	0	0	0	100

Source: Data from farm household survey 2011.

Some farmers remarked that stone or soil bunds not only minimize soil erosion but also prevent seeds and fertilizers from being washed away during heavy rainfall events. Farmers also stated that there are "no yields without fertilizers".

Farmers were also asked to give their opinion on the disadvantages of the SWC technologies (Table 3.9). The most important problem involving stone or soil bunds concerned the high labour requirements for their establishment. Farmers did not encounter weed infestation problems, and only a few farmers had problems with rodents (particularly nesting in stone rows). Less than 50% of farmers found that the measures complicated the ploughing with oxen, which is sometimes considered to be a constraint. Similarly, less than 50% of the farmers perceived the loss of cultivable land as a problem. However, during a later field visit, in March 2012, some farmers in Debre Mewi complained about the loss of land due to newly established (and perhaps too closely spaced) *Fanya juu* terraces.

Table 3.9. Frequency distribution of perceived problems (in %) with introduced SWC technologies in Debre Mewi and Anjeni watersheds (n= 2 x 30).

Perceived problems	Debre Mewi watershed				Anjeni watershed			
	None	Small	Medium	Large	None	Small	Medium	Large
Complicated ox-ploughing	50	23.3	13.3	13.3	72	24	3	0
Much labour for establishment	20	6.7	0	73.3	45	7	0	48
Problems with rodents/pests	72.4	6.9	6.9	13.8	62	17	7	14
Increased weed infestation	100	0	0	0	100	0	0	0
Reducing cultivable area	50	40	3.3	6.7	76	17	7	0

Source: Data from farm household survey 2011.

3.3.5 Financial Cost-Benefit Analysis

Inputs, revenues, gross margins and construction and maintenance costs of SWC

The first step towards the evaluation of the economic profitability of SWC measures was to determine the annual labour and material inputs, crop revenues and the resulting gross margins of a typical crop rotation in Debre Mewi and Anjeni, respectively. Table 3.10 shows these annual data for the original situation without SWC as reflected in the farm survey results. In the cost-benefit analysis of SWC measures, a comparison is made between the 'with SWC' situation, including the initial construction and maintenance costs and considering slightly increased production levels on the cultivable land (considering area lost due to SWC), and the 'without' situation, in which production levels are likely to decrease gradually as a result of soil erosion.

Table 3.10 Overview of annual inputs, revenues and gross margins of crop production of the most common crop rotation in the original situation.

	Debre-Mewi	Anjeni
	Original situation	Original situation
Labour inputs (PD ha^{-1})	101	115
Labour inputs (EtB ha^{-1})	1509	1729
Material inputs (EtB ha^{-1})	1839	1738
Crop revenues (EtB ha^{-1})	6262	5638
Gross margin (EtB ha^{-1})	2914	2172
Gross margin/man-day (EtB)	1.93	1.26

Source: Data from farm household survey 2011.

Table 3.11 shows the construction and annual maintenance costs of the three SWC measures for the two areas. The construction costs of stone bunds are the same in both areas, but the construction costs of soil bunds are higher in Anjeni because of the narrower spacing between the bunds (Table 3.7). The maintenance costs are based on the initial construction costs, but differ by SWC measure. Stone bunds generally require less maintenance than soil bunds.

Table 3.11 Construction and maintenance cost of SWC measures.

	Debre Mewi		Anjeni		
	Soil bund	Stone bund	Soil bund	*Fanya juu*	Stone bund
Construction labour cost (EtB ha^{-1})	563	938	1125	1000	938
Cost of tools for construction (EtB ha^{-1})	100	100	100	100	100
Annual maintenance cost (EtB ha^{-1}. yr^{-1})	113	94	225	150	94
Additional grass revenues (EtB ha^{-1} yr^{-1})	84	n.a.	320	213	n.a.

Note: Opportunity cost of labour for construction is 50% of market wage rate but labour for maintenance is valued at market wage rate. The maintenance costs are 10, 7.5 and 5% of the market wage value (100%) of the initial construction costs for soil bunds, *Fanya juu* and stone bunds, respectively.

n.a. - not applicable.

Source: Data from farm household survey 2011.

Cost-benefit analysis results

Financial CBA is used to examine under which socio-economic and physical conditions SWC measures are profitable for the stakeholders concerned. In the financial analysis, the major factors affecting the costs and benefits of SWC measures are: slope, soil depth, loss of cultivable area, yield loss due to erosion ('without'case), yield increase due to SWC ('with' case), labour for establishment and maintenance, opportunity costs of labour, grass or legumes as cover in the bunds. In the financial CBA, the following assumptions have been made for what we refer to as the 'standard cases':

- A discount rate of 12.5% and a lifetime of 20 years.
- The width of a soil bund and *Fanya juu* is assumed to be 120 cm and the width of a stone bund 100 cm.
- In the case of Debre Mewi, the following further assumptions are considered: 10% slope; medium soil depth; 1% yield decline ('without' case); 10% yield increase (in 'with' case) in third year and 25% and 10% yield reduction in years 1 and 2 due to disturbance; opportunity costs of labour for establishment (at 50% of local wage rate); and with or without grass cover.
- Likewise in the case of Anjeni: 10% slope; more shallow soil depth; 1.5% yield decline ('without' case); 15% yield increase (in 'with' case) in third year and 25% and 10% yield reduction respectively in years 1 and 2 due to soil disturbance; opportunity costs of labour for establishment (at 50% of local wage rate); and with or without the grass cover.

The results of the cost-benefit analysis show that the net present values (NPV) of SWC measures for the standard cases are positive for all measures except soil bund in Anjeni ('without grass' scenario) under the above standard conditions. And the internal rates of return (IRR) of the SWC practices are – in all cases except one –higher than the discount rate of 12.5% (Table 3.12). This indicates that SWC measures are in most cases financially viable. In other words, SWC measures do enable the farmers to improve and increase their agricultural productivity. The soil bunds can become financially more attractive for farmers with grass cover on the bunds. In Anjeni, *Fanya juu* and stone bunds are financially viable for farmers but soil bunds without grass cover are not. So farmers could increase the benefits of SWC measures by planting grass on the bunds. This financial analysis is in line with the benefits of SWC as perceived by farmers in the study areas, such as minimized soil/nutrient loss, increased yield, improved soil fertility, increased water retention, and availability of grass on terrace for livestock.

Table 3.12. Results of cost-benefit analysis for standard situation.

Measures	Debre- Mewi				Anjeni			
	Without grass		With grass		Without grass		With grass	
	NPV (EtB ha^{-1})	IRR (%)	NPV (EtB ha^{-1})	IRR (%)	NPV (EtB ha^{-1})	IRR (%)	NPV (EtB ha^{-1})	IRR (%)
Soil bund	1276	**17.8**	1819	**20.3**	-158	12.0	1902	**18.8**
Fanya juu	-	-	-	-	1345	**17.0**	2718	**21.9**
Stone bund	1265	**17.3**	n.a.	n.a.	2217	**20.1**	n.a.	n.a.

Note: The bold numbers indicate the financially viable measures.
n.a. - not applicable.
Source: Data from farm household survey 2011.

Sensitivity analysis

A sensitivity analysis is used to investigate the effects of changes in the respective underlying assumptions, such as the value for opportunity costs of labour, yield decline ('without' case) and yield increase ('with' case), on profitability. Other factors, however, such as slope, discount rate and time horizon are not subjected to sensitivity analysis here. When changing the assumption for one factor for the sensitivity analysis, the standard assumptions are used for the other factors.

Opportunity costs of labour

For this research, the sensitivity analysis was carried out to determine the influence of the opportunity costs of labour (for construction) on the NPV of the considered SWC technologies in the two watersheds (Tables 3.13 and 3.14). With the exception of soil bunds in Anjeni, the three SWC measures remain financially viable for farmers when the opportunity costs of labour are raised to 75% and 100% of local wage rate. This indicates that increasing the opportunity costs of labour to the current market wage rate of 15 EtB PD^{-1} does not substantially affect the profitability of the SWC measures.

Table 3.13. A sensitivity analysis of SWC technologies at Debre-Mewi under different assumptions.

	Without grass		With grass	
	NPV (EtB ha^{-1})	IRR (%)	NPV (EtB ha^{-1})	IRR (%)
Soil bunds				
Standard case	1276	**17.8**	1819	**20.3**
'Without' case				
Yield decline 0.2%	-628	8.9	-85	12.0
Yield decline 1.5%	2466	**21.7**	3009	**24.0**
'With' case				
Yield increase 0%	-1635	5.0	-1092	7.4
Yield increase 20%	4186	**28.9**	4729	**31.4**
Labour value				
Opportunity costs 75%	1026	**16.5**	1569	**18.7**
Opportunity costs 100%	776	**15.3**	1319	**17.3**
Stone bunds				
Standard case	1265	**17.3**		
'Without' case				
Yield decline 0.2%	-639	9.3		
Yield decline 1.5%	2455	**20.8**		
'With' case				
Yield increase 0%	-1677	5.4		
Yield increase 20%	4206	**27.4**		
Labour value				
Opportunity costs 75%	848	**15.4**		
Opportunity costs 100%	432	**13.8**		

Standard case: slope = 10%; yield in 'without' case will decline by 1%; yield in 'with' case will increase by 10% in year 3 and be 75% in year 1 and 90% in year 2 due to disturbance; lifetime 20 years; discount rate of 12.5%.
Note: The bold numbers indicate the financially viable measures.

Yield decline in 'without SWC' case

As mentioned earlier, the relation between erosion and productivity is highly complex and uncertain. In a second sensitivity analysis, different yield reductions due to on-going erosion were assumed in the 'without' case. Based on the relation between soil erosion and productivity found by Ludi (2004), annual yield declines of 0.2 and 0.5% were assumed in Debre Mewi and Anjeni, respectively. In contrast, higher yield declines of 1.5 and 2.5% were assumed following results by Bojo (1996). Results of the sensitivity analysis show that annual yield declines of only 0.2% or less do not justify the investment in SWC technologies except *Fanya juu* with grass cover.

Table 3.14 A sensitivity analysis of SWC technologies at Anjeni under different assumptions.

	Without grass		With grass	
	NPV (EtB ha^{-1})	IRR (%)	NPV (EtB ha^{-1})	IRR (%)
Soil bunds				
Standard case	-158	12	1902	**18.8**
'Without' case				
Yield decline 0.5%	-2301	2.4	-241	11.5
Yield decline 2.5%	914	**15.1**	2973	**21.6**
'With' case				
Yield increase 0%	-963	-1.9	-1903	5.5
Yield increase 25%	2379	**19.6**	4439	**26.6**
Labour value				
Opportunity costs 75%	-658	10	1402	**16.7**
Opportunity costs 100%	-1158	9.5	902	**14.9**
***Fanya juu* bunds**				
Standard case	1345	**17**	2718	**21.9**
'Without' case				
Yield decline 0.5%	-798	9	576	**15**
Yield decline 2.5%	4861	**22.4**	4861	**27**
'With' case				
Yield increase 0%	-2557	3	-1184	8.0
Yield increase 25%	3947	**25**	5320	**30.1**
Labour value				
Opportunity costs 75%	901	**15.2**	2274	**19.5**
Opportunity costs 100%	456	**13.8**	1830	**17.6**
Stone bunds				
Standard case	2217	**20.1**		
'Without' case				
Yield decline 0.5%	75	**12.8**		
Yield decline 2.5%	4360	**25.4**		
'With' case				
Yield increase 0%	-1734	6		
Yield increase 25%	4852	**28.4**		
Labour value				
Opportunity costs 75%	1801	**18.1**		
Opportunity costs 100%	1384	**16.4**		

Standard case: slope = 10%; yield in 'without case' will decline by 1%; yield in 'with' case will increase by 10% in year 3 and be 75% in year 1 and 90% in year 2 due to disturbance; lifetime 20 years; discount rate of 12.5%.

Note: The bold numbers indicate the financially viable measures.

Yield increase in 'with SWC' case

A third sensitivity analysis employed optimistic and pessimistic assumptions about yield increases due to SWC measures, using 20% and 0% and 25% and 0% in Debre Mewi and Anjeni, respectively. This analysis shows that SWC measures are highly profitable when yields are increased substantially, and that none of them are profitable at all when there are no yields increases. This outcome indicates that the increase of yields with SWC measures is the most crucial factor for its profitability. Of course, it remains difficult to estimate such yield increases beforehand, as yields are not only determined by better soil nutrient and water use, but also by variables such as rainfall patterns, pests and diseases, and agronomic practices.

3.4 Conclusions

This research investigates the on-site costs of soil erosion and the profitability of three different SWC line interventions in north-western Ethiopian highlands. The results of the USLE estimates reveal soil erosion rates on unprotected fields in Debre Mewi and Anjeni watersheds of 64.3 and 122.3 t ha^{-1} y^{-1}, respectively, indicating that both watersheds suffer considerably from soil erosion. Correspondingly, farmers in both watersheds perceive soil erosion as detrimental to their crop production.

It is assumed that these farmers base their SWC investment decisions on on-site effects (their own farm), and not taking into account the off-site effects on their investments. Hence, financial cost-benefit analysis is undertaken based on the farmers' estimations and measurements on individual farms. The results of the cost-benefit analysis indicate that SWC measures are profitable under 'standard' conditions, except soil bunds in Anjeni without grass cover. This is in line with farmer perception of SWC line interventions as beneficial for crop production.

However, the study indicates that different underlying assumptions change the CBA results considerably and consequently also change the conclusions regarding the circumstances under which SWC measures are or are not profitable. This indicates the volatility of the profitability of SWC measures. The sensitivity analysis shows that an increase of the opportunity costs of labour does not substantially alter the profitability of the SWC measures. In contrast, annual yield declines in the 'without' case of 0.2% or less, and the lack of yield increases in the 'with' case, do not justify the investments in SWC technologies. On the other hand, SWC measures are very profitable when the yields are increased with more than 10% in the 'with' case, which indicates that increased yields on plots with SWC measures are a key factor that affects the profitability of SWC measures. Consequently, intensification of agricultural production is of paramount importance to make SWC measures more profitable. The results further indicate that another option for increasing the benefits of SWC measures is to plant high value fodder crops on the bunds.

Farm household interviews and field measurements showed that design and implementation of SWC measures differ considerably from official design recommendations. Therefore, future studies should empirically determine the effect of the locally adapted SWC measures on soil erosion. Moreover, time series of measured soil erosion and crop yield data should be used to establish an empirical relation between soil erosion and agricultural productivity.

Finally, because off-site effects of soil erosion are not included in this study, it is recommended that future studies include these effects. While a conservation measure might not be profitable from a private-economic point of view, it is very possible that an investment is profitable at another level, e.g. at the watershed level. According to Hengsdijk et al., (2005) "agro-ecological tools are hardly available to assess effects of soil and water conservation practices in an integrated way at different spatial and temporal scales". These tools may not be available, but in order to assess the effects of SWC technologies at different scales, not only at the farm level, the tools are needed. Future studies should therefore focus on developing suitable methodologies and on incorporating off-site costs and benefits of SWC measures.

Agricultural land is a scarce resource in the highlands of Ethiopia. It constitutes the fundamental base of rural livelihoods. However, its sustainable use is highly affected (among other factors) by bio-physical and institutional aspects of land such as land quality, land fragmentation and tenure systems.

This paper explores farmers' view about the effect of land quality, land fragmentation and land tenure on the adoption of a combination of SLM practices as opposed to the adoption of a single component of SLM practices. This is because a successful farm production system requires a portfolio of practices. A major novelty of this paper is that it deals with a variety of land related aspects affecting the adoption of SLM. These various aspects are discussed in some detail hereunder.

Earlier studies did not thoroughly investigate land-related factors influencing land management investments. A substantial literature has explored the specific SLM technology adoption decision-making (Tesfaye et al., 2013; Amsalu & de Graaff, 2007; Asfaw & Admassie, 2004; Bekele & Drake, 2003), which fails to account for a synergic and/or complementarity and/or substitution effect among different SLM practices.

Sustainable Land Management investments are shaped by **land quality**, i.e., soil fertility, soil depth, soil type, and slope level. This is due to the fact that the effects of soil erosion and hence SLM practices vary according to the land quality (Adimassu, 2012). Land quality is a central issue for questions related to SLM investment. Investments in SLM are undertaken to improve the land quality and consequently to increase production and productivity. Land quality, as used in the context of this research, refers to soil fertility, soil depth, soil type and slope level of a plot of land. Land quality is assessed qualitatively by farmers (Tesfahunegn et al., 2013). Farmers mostly use crop productivity as a proxy for land quality (Nabahungu & Visser, 2013; Karltun et al., 2013).

Soil fertility indicates the nutrient (mineral) status of the soil. It is an indicator of the agricultural potential of the parcel. The effect of soil fertility of the parcel on SLM investments decisions may be either positive or negative (Bekele & Drake, 2003; Amsalu & de Graaff, 2007). Parcels with fertile soils influence conservation decisions positively. Marginal productivity losses due to erosion from parcels with fertile topsoil will be higher than those with less fertile topsoil, and thus conservation practices on fertile soils are expected to give higher returns in the short-term. In contrast, plots with fertile soils can also negatively influence farmers' decisions on SLM. Farmers might not perceive the negative effects of erosion on their plots in the short run, and ignore the need for conservation (de Graaff, 1993).

Soil depth refers to the thickness of the soil cover or soil root zone. Farmers relate soil depth to suitability for ploughing of a soil. Deep soils are easier to till than shallow soils. **Soil type** refers to different sizes of particles (Sand, Silt and Clay) in a particular soil. Soil colour is perceived by farmers to correspond to soil type. The **slope of a parcel** is a proxy indicator for erosion potential. The steeper the slope, the more likely it is that the land will be eroded. Hence, investment in SLM tends to be undertaken more often on steeper slopes (Lapar & Pandey, 1999, Amsalu & de Graaff, 2007).

Population growth and re-distribution of agricultural land are the major causes of **land fragmentation** in rural Ethiopia (EEA, 2002). Land fragmentation has a stranglehold on SLM investments (Sklenicka et al., 2014; Niroula & Thapa, 2005; Burton, 1988). Land fragmentation increases the transaction cost of investments. Moreover, an uneconomic small size of separate parcels may hinder investments. Land consolidation offers a solution to the fragmentation problem (Lisec et al., 2014; van Dijk, 2002). In line with this, different policy options are issued by the Ethiopian government regarding rural land administration. Especially, consolidation of farms and exchange of parcels among farmers based on their willingness are supported and put forward as a policy option in Amhara region (BEPLAU, 2002). Land fragmentation is defined as the presence of a number of spatially dispersed parcels of land which are farmed as a single unit (FAO, 2003). Fragmentation may weaken a farmer's interest and motivation to invest in SLM practices due to increased transaction costs (Gebremedhin & Swinton, 2003). On the other hand, land fragmentation allows farmers with scattered plots to benefit through risk reduction, crop scheduling, and use of multiple ecological zones (Sikor et al., 2009; Tan et al., 2006; Bentley, 1987;). Two broad perspectives with regard to the cause of land fragmentation can be distinguished: supply-side causes and demand-side causes (Blarel et al., 1992; Bentley, 1987). Proponents of supply-side causes explain fragmentation as an exogenous imposition on farmers resulting from population pressure, inheritance and land scarcity. The demand side cause explains land fragmentation as a free choice made by farmers to reduce risks and diversify crops (Tan et al., 2006).

Land consolidation is a land use policy tool designed to overcome the difficulties of land fragmentation (Sabates-Wheeler, 2002; van Dijk, 2002; Burton, 1988). Land consolidation is a planned readjustment and rearrangement of land parcels. Land consolidation can assist farmers to amalgamate their fragmented parcels. It can also facilitate the creation of competitive agricultural production arrangements by enabling farmers to have farms with fewer parcels that are larger and better shaped. In turn, this may allow the farmer to introduce better farming techniques (FAO, 2003). However, land consolidation may lead to higher runoff coefficients and sediment flows due to longer slopes and thus higher erosion rates (Morgan, 2005). And land consolidation is expensive. It has both public and private costs. The economic advantages of any land consolidation scheme must therefore be compared with the costs of its implementation (Bentley, 1987).

Land tenure systems (e.g. tenure arrangements and tenure security) also influence the investment in SLM technologies (Mekonnen, 2009; Deininger & Jin, 2006; Besley, 1995). Ethiopia has implemented different types of land tenure systems since the beginning of the twentieth century. Currently, land belongs to the state and farmers have only usufruct rights. However, they informally exchange land through sharecropping and rental arrangements. The main tenure arrangements in the rural areas of Ethiopia are: ownership, sharecropping and rental arrangements. The effects of these tenure arrangements on SLM investments are still not well understood. Furthermore, the stronghold of the state over rural land and subsequent actions of land allocation through redistribution has given rise to tenure insecurity by rural farmers (Rahmato, 2004). Cognizant of this problem, the government of Ethiopia introduced land certification to increase tenure security and farmers' propensity to investment.

Institutions have a great impact on the decisions of farmers on SLM investments. **Land property rights** rank among the most important of these institutions. Rights to land are a bundle of rights which comprise property rights, use rights, transfer rights and disposal rights. Property rights to land are a crucial factor in shaping productivity, efficiency and distribution in agrarian societies (Heltberg, 2002). They are also the main incentives to increase agricultural production and farm investments (Meinzen et al., 2002). Therefore, land property rights have a vital role for socio-economic development by increasing production and productivity through creating incentive for investment.

Secure, individual and transferable land titles (rights) are usually regarded as highly important for rural development because they induce immobile land related investment (Deininger & Feder, 1998). Uncertainty in property rights often leads to insecurity and reduced investment in land.

It is widely claimed that perception of tenure insecurity hinders better use of land resources. Specifically, investments in soil conservation are only likely to be undertaken when sufficient returns can be expected over a sufficiently long period of time. For such long term returns a secure land tenure system may be required. The absence of tenure security is highly linked to poor land use, which in turn leads to environmental degradation (Otsuka & Place, 2001). This is because a lack of secure rights on land decreases farmers' incentives to invest in land improvement (Mekonnen, 2009; Besley, 1995).

Land use rights are incompletely defined and enforced in some African countries. Consequently, land registration and land certification initiatives are underway to address land use right problems and tenure insecurity. This is because land registration and titling can increase tenure security, promote investment and encourage better natural-resource management (Deininger et al., 2011). Land titling and registration will also increase efficient land use and agricultural production by easing land transfers, providing collateral for agricultural loans, and increasing incentives to adopt new technology, on-farm investment, and soil conservation practices (Toulmin, 2008; Feder & Nishion, 1999).

The influence of land quality, land fragmentation and land tenure aspects on investment in SLM still requires some thorough investigation. Therefore, the **major objectives** of this research are to investigate farmers' perceptions about the influence of land quality, land fragmentation and tenure systems on interrelated SLM investments in the north-western Ethiopian highlands. For policy implementation it is important to know how farmers perceive various land management aspects. We use multiple parcel survey to jointly analyse land related factors that facilitate or impede the probability of investments in SLM practices. We particularly investigate interdependent investment of bunds (soil bunds, stone bunds and *Fanya juu* bunds), compost/manure and chemical fertilizer.

4.2 Materials and methods

4.2.1 Description of study areas

The study was undertaken in three selected watersheds in the north-western highlands of Ethiopia, i.e., Anjeni, Dijil and Debre-Mewi watersheds (Figure 4.1). The watersheds are selected purposively because of their specific experience with SLM activities, their land re-distribution experiences and the large number of households that have already received land certificates for their plots. Moreover, the watersheds have diverse bio-physical and socio-economic characteristics (Table 4.1). The dominant farming system of the watersheds is characterized by crop-livestock mixed farming.

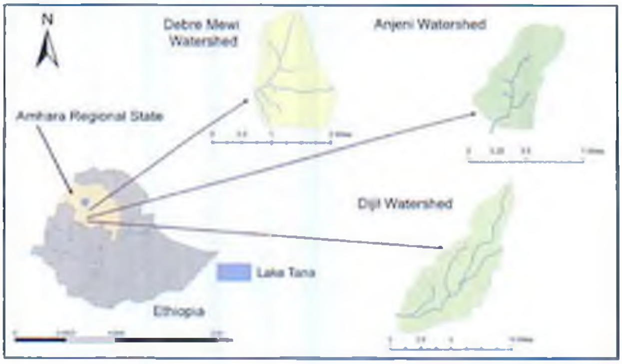

Figure 4.1. Map of study areas

Table 4.1. Socio-economic and physical characteristics of the study areas

Features	Anjeni Watershed	Dijil Watershed	Debre Mewi Waterhed
Altitude (m.a.s.l)	2,450	2,480	2,300
Average annual rain fall	1,790 mm	1,300 mm	1,260 mm
Dominant soil type	Alisols, Nitosols, Regosols, and Leptisols	Nitosols	Vertic Nitosols, Nitosols and Vertisols
Soil pH	5.7	4.3	6.7
Degradation	Degraded	Very degraded	Not heavily degraded
Dominant crop in farming systems	Barley	Oats	Tef
Productivity	Low	Low	High
Average number of TLU (Tropical livestock unit) per farm	5.2	6.0	4.6
Average total farm size (ha.)	1.22	1.13	1.18
Land certification	Since 2008	Since 2004	Since 2008

Sources: Aemro, 2011; Liu et al., 2008; SCRP, 1991;Tesfaye, 2011; Zegeye, 2009; Zeleke and Hurni, 2001; Own surveys.

Anjeni Watershed

Anjeni watershed is located in Dembecha district of West Gojam Zone at 260 km south east of Bahir Dar. The watershed lies at 10.68°N and 37.53°E at an altitude of approximately 2,450 m.a.s.l. It covers an area of 113 ha. The watershed is home to 95 households. Anjeni receives an average annual rainfall of around 1,790 mm. The crops grown are barley, tef, maize, wheat, faba bean, potato, noug, field pea, lupine, and linseed. The major soil types in the watershed are Nitosols (red) Alisols, Regosols, and Leptisols (Kejela, 1995). Soil and water conservation measures have a long history in this watershed. *Fanya juu* soil conservation bunds were introduced as early as 1984 by the then Soil Conservation Research Project (SCRP) which was initiated by Bern University of Switzerland in collaboration with the Ethiopian Ministry of Agriculture (SCRP, 1991; Kejela, 1995; Bosshart, 1997).

Digil Watershed

The Digil watershed is found in Gozamen district of East Gojam Zone. It is located at 10.24°N and 37.43°E at an altitude of approximately 2,480 m.a.s.l. and 285 km southwest of Bahir Dar. Dijil watershed (Melit, Enerata, Yaya and Yedenigia villages) covers an area of 936 ha. The total number of households in the watershed is 628. The average annual rainfall of the watershed is 1,300 mm. The major crops grown in the watershed are oats, wheat, tef, barley, faba bean and potato. Nitosols (red soils) are dominant in the watershed (Tesfaye, 2011).

Debre Mewi Watershed

Debre Mewi watershed is located in Yilmana Densa and Bahir Dar Zuria districts of West Gojam Zone. It is located at 11.34°N and 37.43°E. It is situated at an altitude of about 2,300 m.a.s.l. and receives an average annual rainfall of about 1,260 mm. The total area of the watershed is estimated at 523 ha and about 324 households are living in the watershed. Major crops grown in the watershed are tef, maize, barley, finger millet, wheat, faba bean, potato, grass pea and niger seed. The dominant soil types in the watershed are Nitosols (red) and Vertisols (black), Vertic Nitosols (Zegeye, 2009).

4.2.2 Sampling and data collection

A two stage sampling procedure was employed to select sample households. In the first stage of the sampling procedure, as mentioned earlier, the watersheds were selected purposely based on their specific experience with SLM activities and diverse bio-physical and socio-economic characteristics (Table 4.1). In the second stage, farmers from each watershed were selected randomly from lists of all households in the watershed. A total of 60, 125 and 115 farmers were selected randomly from Anjeni, Dijil and Debre Mewi watersheds, respectively.

Primary household and parcel data from these 300 farm households and 1,700 parcels were collected using a general agro-socio-economic survey in 2011. Additional, very specific, data about the perceptions' of farmers on land fragmentation and consolidation were collected in 2012 from a sub-sample of 110 households. Through these surveys detailed information was collected about land quality, land fragmentation, tenure arrangements, tenure security, perceptions about land certification and land consolidation and sustainable land management practices such as bunds, compost, manure and fertilizer. A participatory Rural Appraisal (PRA) was used to collect supplementary data through group interviews, key informants and transects.

The perceptions of farmers about their land quality were validated by field observations (e.g. on soil types and shape of parcels). Some measurements were also undertaken during the survey to cross check the interview results such as walking time, degrees of slopes, and size of parcels. We discussed our results with researchers and extension personnel. Moreover, we verified our results with findings of previous studies in the respective watersheds.

Research was also undertaken, with lists of questions, on the perceptions of farmers about tenure security and the impact of land certification.

4.2.3 Method of Analysis

Descriptive statistical analysis

Distribution of land quality, extent of land fragmentation and type of tenure arrangement at watershed and parcel level were analysed by means of frequencies and percentages. In addition, frequencies and percentages were used to compute the information on the perceptions of farmers about tenure security, land certification, land fragmentation and land consolidation. Simple descriptive statistics as T-test, F-test and Chi-square were also employed to compare a mean/association of land quality, land fragmentation and tenure arrangement with SLM practices. A t-test is used to compare the mean of two continuous variables and F-test (ANOVA) is used to analyse mean differences more than two groups. But Chi-test is used to measure an association between binary/discrete variables. We have checked normality and homogeneity of variance using Shapiro-Wilk and Dunnett tests, respectively. The variables included in the econometric analysis were first analysed by simple descriptive analysis (e.g. means and standard deviations).

Econometric model

A multivariate probit (MVP) model is applied to analyse the interdependent investment decisions of the SLM practices (bunds, compost/manure and chemical fertilizer) by smallholder farmers. Investment decisions by smallholder farmer are multivariate in nature and so the appropriate modelling procedure should not be univariate, but must instead take into account the interactions and possible simultaneity of the investment decision. This is because farmers are more likely to invest in a mix of technologies than in a single technology to cope with multiple agricultural production constraints (Kassie, et al., 2013).

The multivariate probit model simultaneously models the influence of the set of explanatory variables on each of the different practices while allowing the error terms to be freely correlated (Green, 2008). In contrast to multivariate probit models, univariate probit models ignore the potential correlation among the unobserved disturbances in the investment equations as well as the relationships between the investments of different SLM practices. Farmers might consider a combination of practices as complementary and others as substitution. Failure to capture unobserved factors and inter-relationships among investment decisions regarding different practices will lead to bias and inefficient estimate (Greene, 2008).

The multivariate probit econometric model is described by a set of binary dependent variables Y_{ij}^{*}. The model is specified according to Equation 4.1 and Equation 4.2.

$$Y_{ij}^{*} = X_{ij}\beta' + \varepsilon_{ij} \qquad j = 1,\ldots,m \ \ and \qquad [4.1]$$

$$Y_{ij} = \begin{cases} 1 \ if \ Y_{ij}^{*} > 0 \\ 0 \ otherwise \end{cases} \qquad [4.2]$$

Where:

Y_{ij}^{*} for j = 1, 2,..., m represents an unobserved latent variable of the SLM practices j invested by farmer i,

X is a matrix of independent variables reflecting parcel specific and household characteristics,

β is a vector of parameter estimates, and

ε_{ij} are error terms.

Error terms have a standard normally distribution with mean vector zero and a covariance matrix with diagonal elements equal to 1.

The dependent variables (SLM) in the econometric analysis are bunds, compost/manure and fertilizer. Based on the adoption/investment literature of SLM (Besley, 1995; Deininger et al., 2011; Kassie et al., 2013; Teklewold et al., 2013); the explanatory variables were identified. Although we focused in this paper on the effects of land related factors on SLM investment, we also included a few socio-economic factors in the analysis. The institutional and socio-economic aspects of SLM were already studied in two previous studies (Teshome et al., forthcoming). The description and summary statistics of the variables are given in Table 4.2.

Table 4.2. Description and summary statistics of the variables used in the analysis

Dependent Variables	Type	Mean	St.Dev.
Bunds	Parcels with bunds (1=yes; 0=no)	0.44	0.49
Compost/manure	Parcels received compost/manure (1=yes; 0=no)	0.26	0.43
Fertilizer	Parcels received fertilizers (1=yes; 0=no)	0.71	0.45
Explanatory variables			
Land quality			
Slope status			
Flat to gentle	Farmers' perception that parcel has gentle slope (1=yes; 0=no)	0.23	0.42
Moderate	Farmers' perception that parcel has moderate slope (1=yes; 0=no)	0.36	0.48
Steep	Farmers' perception that parcel has steep slope (1=yes; 0=no)	0.40	0.49
Soil depth			
Shallow	Farmers' perception that parcel has shallow soil depth (1=yes; 0=no)	0.43	0.49
Medium	Farmers' perception that parcel has medium soil depth (1=yes; 0=no)	0.34	0.47
Deep	Farmers' perception that parcel has deep soil depth (1=yes; 0=no)	0.23	0.41
Fertility status			
Low	Farmers' perception that parcel has low fertility status (1=yes; 0=no)	0.62	0.48
Medium	Farmers' perception that parcel has medium fertility status (1=yes; 0=no)	0.30	0.46
High	Farmers' perception that parcel has high fertility status (1=yes; 0=no)	0.07	0.26
Soil type			
Black	Farmers' perception that parcel has black colour (1=yes; 0=no)	0.14	0.35
Red	Farmers' perception that parcel has red colour (1=yes; 0=no)	0.70	0.45
Brown	Farmers' perception that parcel has brown colour (1=yes; 0=no)	0.07	0.26
Yellowish	Farmers' perception that parcel has yellowish colour (1=yes; 0=no)	0.08	0.27
Land fragmentation			
Parcel size	Parcel size (ha)	0.26	0.62
Distance of parcel	Distance of parcel from home (walking minutes)	16.18	17.16
Tenure arrangement			
Own	Own parcel (1=yes; 0=no)	0.76	0.42
Shared in/rented in	Shared in/rented in parcel (1=yes; 0=no)	0.21	0.40
Shared out/rented out	Shared out/rented out parcel (1=yes; 0=no)	0.03	0.18
Socio-economic			
Age	Age of household heads (in years)	45.35	12.34
Farm labour	Persons working fulltime in agriculture (It includes the hired labourer on annual base);(in numbers)	2.18	0.70
Number of livestock units	In Tropical Livestock Units (TLU) (Continuous)	5.35	2.97
Off-farm income	Monthly income in Birr[1] (Continuous)	56.72	147.29
Watershed			
Debre Mewi (reference)	Debre Mewi watershed (1=yes; 0=no)	0.38	
Anjeni	Anjeni watershed (1=yes; 0=no)	0.20	
Dijil	Dijil watershed (1=yes; 0=no)	0.42	
Number of parcel (household) observations	1700 (300)		

[1]Birr is the unit of Ethiopian currency. It is equal to 0.059 Dollar (2011).

4.3 Results and discussion

4.3.1 Descriptive analysis

We first provide a description and the summary statistics of the various variables used in the analysis (Table 4.2), as derived from the main survey, with 300 households and 1,700 parcels. This shows among others what farmers think about the slopes of their parcels, their soil depth and their soil fertility (as discussed below). It also shows that the average size of parcels is 0.26 ha and that 76% of the parcels are owned.

4.3.2 SLM investments

The study results further show that the implementation of SLM technologies or practices is moderate and varies considerably by watershed (Table 4.3). On average at household level farmers covered 47.4% of their farm area with bunds, applied 123 kg ha^{-1} of inorganic fertilizer (DAP and urea) and used about 0.70 ton ha^{-1} of compost. It is very difficult to know the amount of manure farmers use at household level because farmers apply manure daily on a plot adjacent to the homestead from the stables.

In Anjeni watershed a large amount of bunds are constructed at the household level due to the long term SWC intervention in the area (Table 4.3). On the other hand, more fertilizer is applied in Debre Mewi watershed. This watershed has a high crop production area. Compost application is higher in Dijil area. This is due to the presence of a relatively large number of livestock (TLU) in the area (Table 4.1) and to an extension service striving for a long period of time to improve the pH of acid soils.

Table 4.3. Intensity of SLM investments at household and watershed level.

		N	Mean	P-value
Total farm area covered in bunds (%)	Debre Mewi	115	22.2	0.000***
	Anjeni	60	98.0	
	Dijil	125	46.3	
	Total average	300	47.4	
Total amount of fertilizer (kg ha^{-1})	Debre Mewi	106	167.0	0.000***
	Anjeni	58	127.0	
	Dijil	121	83.0	
	Total average	285	123.0	
Total amount of compost (t ha^{-1})	Debre Mewi	107	0.53	0.019**
	Anjeni	58	0.78	
	Dijil	117	0.82	
	Total average	292	0.70	

*, **, *** significant at 10, 5 and 1% level of significance, respectively.

Compost utilization is increasing in the last few years due to the rigorous extension programme. However, the adoption of compost is influenced by availability of labour for preparation and transportation, availability of livestock, and the presence of trees (e.g. Eucalyptus) for fire wood so that the competing use of animal manure for fuel is reduced. Accordingly, most of the farmers who have Eucalyptus prepare compost with no resource limitation as compared to other farmers who completely rely on dung cake for fuel. The bulkiness of compost and lack of transport restrict the application of compost to the homestead areas. Most of the compost technology is of low quality due to lack of watering (sprinkling water) and turning over (mixing) of compost material during preparation process.

Application of manure is an age-old practice used by most farmers in the three watershed areas. It is used for soil fertility management purpose and household fuel. However, the application of manure is decreased due to the dwindling livestock herds.

A new development with regard to investment in land is the shift from the use of inorganic fertilizer to other alternative options due to the sudden increase of the costs of inorganic fertilizers. From the production season 2010/11 to the production season 2011/12 fertilizer prices have increased in the three watersheds. These prices were obtained from the respective cooperative offices. In Debre Mewi the price for 100 kg of DAP has risen from 740 EtB to 1,200 EtB (currency Ethiopian Birr) which is equivalent to an increase of around 62%. In Anjeni the price for 100 kg has increased by about 67% from 764 EtB to 1,278 EtB. In the same period the price of urea in Debre Mewi increased from 660 to 900 EtB for a bag of 100 kg, which is equivalent to an increase of more than 36%. In Anjeni the price increase was less pronounced. Here, the price for 100 kg urea increased by only about 10% from 651 to 718 EtB. This is because the Anjeni cooperative supplied urea which was purchased and stored in the previous year. In Dejil, the price of DAP and urea in 2010/11 cropping season was 710 and 576 EtB 100kg^{-1}, respectively. But in 2011/12 the price of DAP and urea was 1,200 and 900 EtB 100kg^{-1}. In light of this recent spike in fertilizer prices, farmers design their strategies to cope with the price increase. The major strategies are: decreasing the use of mineral fertilizer, decreasing the land shared in/rented in, shifting from cereal to pulse crop cultivation, increasing the use of manure and compost and increasing livestock activities.

4.3.3 Land quality

Distribution of land quality by watershed and parcel level

A sample of farmers in all three watersheds qualitatively assessed the quality of their parcels. In total 1,700 parcels were investigated (Table 4.4). The results of the study show that farmers have parcels with different soil type, slope class, soil depth and fertility status. This is mainly due to the land distribution and redistribution policy of the last two consecutive governments to bring land quantity and quality equity at the community level.

Farmers partly associate soil colour with soil fertility and the degree of soil erosion. They are able to relate changes in colour to the removal of top soil by erosion. According to farmers, a whitish/yellowish colour is an indicator of an eroded soil. Locally these types of soils are known as *Shihala*. The parcels of all the three watersheds are dominated by red soils (70.5%) and followed by black soils (13.9%). Specifically, black soils are largely found in Debre Mewi watershed. In line with this Kaltenrieder (2007) lists typical Ethiopian soils associated with the topsoil colours: black (e.g. Andosol, Vertisol), brown (e.g. Cambisol, Phaeozem), red (e.g. Lixisol, Nitosol) and yellow (e.g. Fluvisol, Xerosol).

Moreover, the slope of their parcels influences farmers' decisions to control soil erosion. The farmers identified 23.3, 36.1 and 40.6% of the parcels as belonging to the categories gentle, medium and steep slopes, respectively. This suggests that a large number of parcels in the study areas are exposed to erosion and that soil erosion is a major problem in the study areas.

Farmers also classify their parcels on the basis of soil depth. Accordingly, about 22.6, 34.3 and 43.0% of the parcels of the three watersheds are considered to be deep, medium and shallow, respectively. This indicates that shallow soils dominate in all watersheds as the result of continuous erosion problems.

Similarly, respondents have identified the fertility of their parcels into three categories, i.e., low, medium and high. Based on this classification from the total of 1,700 farm parcels, 62.2, 30.4 and 7.4% are considered as having low, medium and high soil fertility, respectively. This suggests that the majority of soils of the study areas are depleted and that the soil fertility problem is a major bottleneck of the agricultural production of the farming systems of the study areas. For example, farmers of Dijil grow oats as their main crop due to the soil fertility problem.

According to farmers, most of the parcels in the study areas generally have a poor land quality characterized by a steep slope, shallow soil depth and low soil fertility. This is due both to the inherent nature of the soils as well as to the poor land management practices (lack of contour tillage and fertilization). Thus, land management practices are essential to improve the land quality. Moreover, based on the perception of the queried, the study shows a local scale spatial variability of soil quality.

Table 4.4. Percentage distribution of land quality by watershed and parcel level.

Land Quality	Variables	Debre Mewi (%)	Anjeni (%)	Dijil (%)	Total (%)
Soil type	Black (mostly Vertisol, Andosol)	24.8	4.3	6.7	13.9
	Red (mostly Nitosol, Lixisol)	55.0	85.5	80.2	70.5
	Brown (mostly Cambisol, Phaeozem)	8.4	5.0	7.3	7.3
	Yellowish/Whitish (mostly Fluvisol, Xerosol)	11.8	5.3	5.8	8.3
	Total	100	100	100	100
Slope class	Flat to gentle slope	30.5	13.9	19.7	23.3
	Medium	28.6	41.4	41.9	36.1
	Steep plot	40.9	44.7	38.4	40.6
	Total	100	100	100	100
Soil depth	Deep (> 1 meter)	29.5	16.2	18.5	22.6
	Medium (between 20 cm and 1 meter)	30.0	38.3	37.1	34.3
	Shallow (less than 20 cm)	40.5	45.5	44.5	43.0
	Total	100	100	100	100
Fertility status	Low	60.9	50.2	69.0	62.2
	Medium	29.8	43.6	25.2	30.4
	High	9.4	6.3	5.8	7.4
	Total	100	100	100	100

Source: Own parcel level survey

Land quality and SLM

The chi-test analysis indicates a significant association between soil type and investments in bunds, compost/manure and fertilizer (Table 4.5). Farmers invest in SLM practices mostly on parcels with red soils. Investments in SLM practices on plots with black soils are very low due to certain bio-physical characteristics of these soils. Black soils crack in dry season and swell during rainy season. These results show that the soil type influences the farmers' behaviour in SLM investments. Consequently, there is a need to identify appropriate SLM practices with respect to the soil type of a parcel of land.

The study results also reveal that there are significant associations between slope classes and investment in bunds and compost/manure application. Farmers construct bunds mainly on steep land to control the soil erosion problem. This is because parcels with steep slopes are highly vulnerable to erosion. On the other hand, farmers apply compost/manure mainly on gentle and medium slope areas. This indicates that farmers do not apply long term fertility enhancing practices on erosion prone parcels. Surprisingly, the results indicate that farmers apply inorganic fertilizer irrespective of the slope classes. This showed that farmers are applying fertilizer just to increase production and productivity and thus harvest immediate benefits. Apparently farmers are already adapting their SLM practices to the slope of the parcel. They are implementing different SLM practices depending on the slope of the parcel. They construct physical soil erosion control measures on steep parcels and apply soil fertility enhancing practices on more gentle parcels. Therefore, the extension services need to introduce SLM measures that are appropriate for the respective slope classes.

The results further showed that there were also positive associations between soil depth and investment in bunds and compost/manure. Farmers construct bunds mostly on shallow parcels (Table 4.5). This indicates that farmers construct bunds to avoid a further decline of the soil depth. On the other hand, farmers apply compost/manure on deep and medium soil depth parcels. The fact that farmers do not apply compost/manure on shallow parcels may be attributed to the small margin of benefit of investing in shallow parcels. No significant association between soil depth and fertilizer application could be found.

Table 4.5. Land quality characteristics of investing and non-investing households

	Bunds			Compost/ manure			Fertilizer		
	Yes (N= 736)	No (N= 934)	P-value	Yes (N= 426)	No (N= 1201)	P-value	Yes (N= 1147)	No (N= 465)	P-value
Soil type									
Black (%)	7.9	18.7	0.000***	10.6	14.8	0.023**	15.5	9.3	0.001***
Red (%)	78.2	64.9		72.9	70.1		69.0	76.5	
Brown (%)	7.1	7.7		10.1	6.1		6.9	8.2	
Grey (%)	6.8	8.7		6.4	9.0		8.7	6.0	
Slope class									
Flat to gentle (%)	10.3	32.9	0.000***	28.0	21.5	0.004***	23.3	22.7	0.206
Medium (%)	41.6	32.5		41.9	34.5		35.6	39.8	
Steep plot (%)	48.2	34.6		30.1	44.0		41.2	37.4	
Soil depth									
Deep (%)	17.8	26.9	0.000***	31.2	19.8	0.000***	23.3	21.9	0.282
Medium (%)	35.3	32.8		35.3	34.4		35.6	32.6	
Shallow (%)	46.9	40.3		33.6	45.8		41.2	45.5	
Soil Fertility									
Low (%)	64.3	60.6	0.021**	42.4	68.6	0.000***	61.4	62.1	0.968
Medium (%)	30.5	30.8		44.9	26.1		31.2	30.8	
High (%)	5.2	8.8		12.7	5.4		7.4	7.1	

*, **, *** significant at 10, 5 and 1% level of significance, respectively.

Systematic associations are also observed between soil fertility status of parcels and investments in bunds and compost/manure. Farmers are mainly investing in lower and medium fertile parcels to improve the soil fertility status. Despite these findings, there is no significant association between soil fertility status and fertilizer application. This indicates, as based on farmers' perceptions, that even fertile soils need additional nutrients for crop production and to increase productivity.

The aforementioned results indicate that farmers choose different SLM practices on the basis of different quality of their parcels.

4.3.4 Land fragmentation

Farm size

Land is a scarce resource in the study watersheds mainly due to population pressure. The average landholding of the sample households is 1.17 ha (Table 4.6). Farmers underscored during survey and PRA, that farm households are reaching the point where they cannot give land to younger family members wishing to set up their own farm. Moreover, land scarcity creates shortage of grazing and forest land and absence of fallow.

Farm size varies between 0.125 and 3 ha. There is a considerable variation in land holding among the sample households. This showed that there was an inequality in holdings among farm households despite the egalitarian objectives of the 1975 land reform (during the Derg regime, when land was redistributed through peasant associations). This land holding inequality among the community may increase tenure insecurity.

During the group discussions, farmers pointed out that young farmers and other landless people have no chance of obtaining land due to the prohibition of land redistribution since 1999, as well as a general shortage of farmland. These farmers usually obtain land access through land transaction systems (sharecropping and renting). In line with this, around 56.3% of the households share in or rent in some land from female household heads, elderly people, physical disabled people and town dweller farmers. On the other hand, around 8.3% of the sample households share out/rent out of their lands. This shows that there is a large difference in number between shared in and shared out households. This gap can be attributed to the fact that most of the owners that share out their farmlands reside in nearby towns. Hence, they were not part of the survey among the farm households in all three watersheds.

Number, size and distances of parcels

The number of parcels, size of parcels and distance of parcels from homestead are good indicators of land fragmentation.

The farmers as a whole managed 1,700 parcels in 2011. On average households managed 4.54 parcels in different locations (Table 4.6). Besides their own plots, 56.3% of the respondents cultivated 352 farm parcels through sharecropping and renting. About 96% of the sample households have a farm with more than three parcels scattered over areas with various distances from their homesteads. This implies that a large number of parcels across locations lead to considerable travelling time between fields and higher transport costs for inputs and outputs.

The size of the parcels across location is analysed. The sample survey result shows that the average area of a parcel (total area of parcels divided by the total number of parcels) was 0.26 hectare (Table 4.6). However the size of all parcels ranged from 0.0025 to 2 hectares.

Distance of parcels from home is also one of the important factors in analysing land fragmentation. The distance of a parcel from a homestead is described by the estimated time needed by an adult person to walk from homestead to parcel (minutes). Parcel distances range from 0 to 120 minutes with an average of 16.7 minutes (Table 4.6). This indicates that land fragmentation incurs high transaction cost for investments (Gebremedhin & Swinton, 2003).

The aforementioned results of the indicators of land fragmentation show that the current level of farm fragmentation is very high.

Table 4.6. Extent of fragmentation of farms by watershed, household and parcel level.

	Debre Mewi		Anjeni		Dijil		Total	
	N	Mean	N	Mean	N	Mean	N	Mean
Number of parcels (own land)	115	4.85	60	4.33	125	4.36	300	4.54
Number of parcels (own + shared in/rented in)	115	6.35	60	4.98	125	5.4	300	5.69
Total farm size (ha); (own land)	115	1.18	60	1.22	125	1.13	300	1.17
Total farm size (ha);(own land +shared in/rented in)	115	1.65	60	1.45	125	1.4	300	1.51
Total amount of land rented in or shared in (ha)	69	0.78	24	0.50	46	0.78	139	0.73
Total amount of land rented out or shared out (ha)	14	0.58	2	0.19	9	0.63	25	0.56
Size of parcels (ha)	730	0.26	299	0.29	671	0.27	1700	0.26
Distance of parcels from home (walking minutes)	697	14.29	301	16.87	645	16.71	1649	16.7
Total amount of land rented in or shared in (ha)	69	3.13	24	2.01	46	3.11	139	2.93
Total amount of land rented out or shared out (ha)	14	2.3	2	0.75	9	2.5	25	2.25

Land fragmentation and SLM

The study reveals that there are significant differences in parcel size between households investing in bunds, compost/manure and fertilizer technologies and households that did not invest (Table 4.7). Investing households have generally larger parcels. Households investing in compost/manure have significantly shorter average parcel distances from home than non-investing households. This is because compost and manure are very bulky to transport and thus it is very difficult to apply them on distant plots. But there are no significant differences in parcel distance from home between investing and non-investing households in bunds and fertilizer.

Table 4.7. Parcel distance and parcel size of investing and non-investing households.

	Bunds			Compost/ manure			Fertilizer		
	Yes (N= 731)	No (N= 930)	P-value	Yes (N= 424)	No (N= 1195)	P-value	Yes (N= 1142)	No (N= 464)	P-value
Parcel distance from home (In min.)	17.31	15.93	0.103	6.03	18.91	0.000***	16.03	16.98	0.308
Parcel size (ha)	0.29	0.25	0.000***	0.28	0.26	0.063*	0.28	0.25	0.000***

*, ** , ***significant at 10, 5 and 1% level of significance, respectively

Perceptions' of farmers about land fragmentation and consolidation

Out of 111 households, 79% apparently prefer to have fragmented plots of land because they want to spread risks (e.g., pest, disease, hail) and want to diversify crops based on land suitability that varies spatially. In addition they prefer to allocate labour over different times due to different crop growing stages across location. On the other hand farmers realise that a fragmented farm requires more labour input (time to walk from one plot to the other), and also is more difficult to manage with regard to the application of material inputs such as fertilizer, compost and manure. This indicates that subsistence farmers attach more importance to risk minimization than to profit maximization.

A minority of the respondents (28.8%) support the policy option of land consolidation/land amalgamation/land exchange. However, they pointed out that the major challenges to implement land consolidation are lack of similar land quality (68.8%), lack of awareness especially due to endowment effect (consider his/her land is worth more) (25%), and presence of different trees on the land (6.2%).

4.3.5 Tenure system

Tenure arrangements

The survey results indicate that there are different forms of land tenure arrangements in the farming systems of the study areas (Table 4.8). The main tenure arrangements are owned farm parcels, shared in/rented in farm parcels and shared out/rented out farm parcels. Considering all watersheds 75.5% of the parcels are owned, 20.6% of the parcels are shared in/rented in and the other 3.7% are shared out/rented out. This indicates that the size of the land rental market (sharing and renting) is high both in terms of the number of market participants and size of land supplied to the market. Specifically, sharecropping and renting in are important means of land acquisition for young and small farm holders in the study areas. On the other hand, the main reasons for sharing out/renting out are related to lack of oxen (40%), lack of labour by female headed household and elderly people (32%), lack of cash to buy fertilizer (12%), physical disability (8%), long distance of the parcels from home (4%) and to obtaining cash to buy fertilizer for own managed parcels (4%).

Table 4.8. Tenure arrangement by watershed and parcel level.

Arrangement type	Debre Mewi		Anjeni		Dijil		Total	
	N	%	N	%	N	%	N	%
Owned	506	69.7	262	86.5	517	77.1	1285	75.6
Shared in/rent in	180	24.8	39	12.9	133	19.8	352	20.7
Shared out/rent out	40	5.5	2	0.7	21	3.1	63	3.7
Total	726	100	303	100	673	100	1700	100.0

Tenure arrangements and SLM

The study identified significant differences in SLM investment among different tenure arrangements (Table 4.9). In line with this, the chi-square test indicates that there is a systematic relationship between the application of long term investments (bunds and compost/manure) and tenure arrangements. This shows that farmers give more attention to their owned parcels for the long term investments (bund and compost/manure). However, the application of fertilizer is relatively the same for the different tenure arrangements. It is obvious that the land rental market has a positive impact on improving the efficiency of this factor of production but it does not encourage long term investments. This is because the farmers get land in the form of share in/rent for a short period of time and thus the lessees or the renters do not feel secure to apply long term investments.

Table 4.9. Tenure arrangements characteristics of investing and non-investing households.

Tenure arrangement	Bunds			Compost/ manure			Fertilizer		
	Yes (N= 735)	No (N= 932)	P-value	Yes (N= 426)	No (N= 1179)	P-value	Yes (N= 1277)	No (N= 349)	P-value
Owned (%)	82.0	70.8	0.000***	91.8	70.8	0.000***	74.3	80.4	0.017*
Shared in/rent in (%)	15.9	24		7.7	25.8		23.2	16.8	
Shared out/rent out (%)	2.0	5.2		0.5	3.4		2.5	2.8	

*, ** , *** significant at 10, 5 and 1% level of significance, respectively

Although the above unconditional descriptive statistics show that there are significant differences in covariates means between land quality, land fragmentation and tenure arrangements and SLM investments, a systematic rigorous analysis that considers all variables together is crucial to investigate whether these variables have a different influence on investing and non-investing households.

Tenure Security

Perceptions of farmers about tenure security are presented in Table 4.10. The majority of the farmers in the study areas (79.2%) are sure that their (own) current landholding will still belong to them in twenty five years' time. This indicates that the majority of farmers feel tenure secure. This may be due to the fact that the landholdings of these farmers are very small and do not allow further redistribution. However, a majority (51.5%) expects re-distribution of land (among all other larger farmers) in the future. The main reason for their expectation is the presence of landless youth in the community (85.6%). This indicates that expectation of land redistribution does not totally lead to tenure insecurity. This is because farmers expect that there will be land redistribution for landless youth from large size holders or land from dead people or from grazing areas. On the other hand, tenure insecurity in the study areas is highly triggered by holding of large farm size and presence of landless youth in the community (population pressure).

One of the most interesting results of this study is that more than 92.9% (Table 4.10) of the sample households do not want to sell their land even if the government changes its current policy that prohibits land selling. Farmers in Ethiopia have a bundle of land rights except selling (EEA, 2002; FDRE Constitution, 1995). Farmers underscore the argument that says that the provision of the right of land selling will push farmers to migrate into urban centres due to distress sale of their land. They said that selling of land is just like 'selling their children'.

Table 4.10. Perceptions' of farmers about tenure security.

Perception		N	%
Do you expect that you will lose your land in the next 25 years[a]?	Yes	54	18.1
	No	239	80.2
	I do not know	5	1.7
Do you expect that you will keep your land throughout your life[a]?	Yes	236	79.2
	No	55	18.5
	I do not know	7	2.3
Have you lost part of your land during 1989 re-distribution?	Yes	56	18.8
	No	242	81.2
Do you expect that there will be land re-distribution[b]?	Yes	153	51.5
	No	118	39.7
	I do not know	26	8.8
Reason for expectation of redistribution (N= 153)			
Presence of landless youth		131	85.6
Land size inequality among the community		8	5.2
From people who died land might be redistributed		8	5.2
Land is government property		5	1.3
If the government is changed		4	2.6
Do you agree if the government allows the farmers to sell their land?	Yes	19	7.1
	No	250	92.9
Have you received land certification?	Yes	251	84.2
	No	47	15.8

a= own land, b= own land and other land (e.g. large size holders)

Land certification

Registration of landholdings and granting land use certificates to holders has recently become government policy in Ethiopia. The objective of land registration and title certification is to improve tenure security to promote better land management and more investment. Land certification has been implemented since 2003 in the Amhara regional state of Ethiopia and the majority of the households (84.2%) have received a land certificate. The results of the survey reveal that the majority of farmers perceive the importance of land certificates in providing tenure security, increasing investments, reducing border conflict with neighbours, facilitating land renting and increasing women land rights (Table 4.11).

Certificates are issued jointly by the names and photographs of husband and wife mentioning the names of other family members and also the parcel size (using traditional measuring devices such as rope or tape) (BEPLAU, 2002). This indicates that the land certificate increases the land rights of women. Previously, women did not have land rights and thus they did not get any land after divorce. Moreover, joint titling reduces divorce due to the fear of losing land by men. In addition, female headed households were afraid to share out/rent out their land due to forceful eviction from their land by shareholders. Land certification has also facilitated land rental transactions by decreasing fear of land expropriation. Previously, farmers were sharing out/renting out their lands only to their relatives and friends to be secure.

Table 4.11. Perception of farmers about the impact of land certification.

	Total N	Completely disagree (%)	Slightly disagree (%)	Slightly agree (%)	Agree (%)	Completely agree (%)
Does land certificate improve the feeling of tenure security?	251[a]	2.0	12.7	8.4	23.5	53.4
Does land certification increase land investments?	250[a]	11.2	10.0	14.8	25.6	38.4
Does land certification decrease land dispute?	248[a]	5.2	8.1	19.8	27.0	39.9
Does land certification improve renting in/out of land?	105[b]	16.2	18.1	2.9	6.7	56.2
Does the land certification increase women rights?	249[a]	2.8	2.4	2.8	15.3	76.7
Does the land certification decrease divorce?	105[b]	33.3	4.8	1.9	8.6	51.4

a=number of households from large farm survey, b=number of households from a sub-sample survey

4.3.6 Econometric analysis

Results of the multivariate probit model are presented in Table 4.12. The regressions are estimated at the parcel level. The likelihood ratio test (chi2(3)) = 16.44, p-value < 0.0001) for independence between the disturbances is strongly rejected, implying correlated binary responses between different SLM practices and supporting the use of a MVP model. This test result is in line with significance of the error correlation coefficients between compost/manure and fertilizer ($\rho C/MF$ = -0.02). This supports the idea of interdependence between the different SLM practices investment decisions. The study reveals that compost/manure and fertilizer are substituting each other in the farming system of the study areas. However, bunds have no substitution and/or complementary effect with compost/manure and fertilizer (Table 4.12).

Influence of land quality

The results indicate that the slope of parcels is positively related to the decision of the bund investment and statistically significant. This implies that farmers who operate on parcels with steeper slope are more likely to invest in bunds than the others. This may be explained by the positive relationships between slope and severity of soil erosion. This result is consistent with the findings of Shiferaw & Holden (1998) and Gebremedhin & Swinton (2003) in Ethiopia. Therefore, the level of the slope of the parcel is an important factor for the decision to invest in bunds. Compost/manure is more likely to be applied on low and medium fertile soils to improve the soil fertility status. This may be due to the high margin of benefit investing in low and medium fertile parcels (Table 4.12).

Influence of land fragmentation

The results reveal that parcel size has a positive and significant impact on investments decisions for all the SLM practices (bunds, compost/manure and fertilizer). This result suggests that farmers who have a larger parcel size are more likely to invest in SLM practices. This could be explained by the economies of scale of these investments. This shows that parcel size is a crucial factor in the intensification of smallholder farming systems (Table 4.12).

Investment in compost/manure is negatively and significantly related to the distance of parcels from home. This implies that households who have parcels that are far from the homesteads have a lower probability of investing in compost/manure. Compost and manure are bulky and difficult to transport to distant parcels. Thus, such practices require additional farm tools that are currently unavailable on many farms. For example, to apply compost on distant farm plots farmers require mule/donkey carts to transport the compost. Therefore, introduction and dissemination of farm tools are of paramount importance to transport bulky SLM practices (Table 4.12).

The above results indicate that the current level of farm fragmentation hinders sustainable intensification of smallholder agriculture.

Influence of tenure arrangements

The results indicate a significant positive effect of parcel ownership on bunds and compost/manure investment decisions, implying that farmers are more likely to invest in SLM practices on their own parcels. This is because investment is undertaken when the household is assured that he/she will reap the benefits for a considerable time. On the other hand, the probability of chemical fertilizer application is not negatively affected by sharecropping/renting tenure arrangement. This is because the costs and benefits of chemical fertilizer application occur in the short run and hence renters undertake short-term decisions rather than long term. Specifically, farmers apply more long term soil fertility management practices (e.g., compost/manure) on their own parcels and short term soil fertility management on shared in/rented in parcels. This implies that factors affecting subsistence farmers' short term (variable inputs) decisions are different from the long term investments decisions. This indicates that land tenure arrangements influence farmers' decisions with regard to land management practices (Table 4.12).

Socio-economic factors

The age of heads of households is negatively related to bunds investment decision. This result suggests that older farmers are less likely to invest in bunds. This can be explained by the fact that older farmers have a short planning horizon compared to younger colleagues. This is in line with the findings of Anley et al. (2007) and Shiferaw & Holden (1998). Investment of bunds is also found to be negatively influenced by off-farm activities. This is because farmers who are involved in off-farm activities may encounter time and labour constraints for investing in bunds. This is in line with other findings (Amsalu & de Graaff, 2007; Tenge et al., 2004). The number of Tropical Livestock Units (TLU's) is positively related to the decision of compost/manure investment. This is because animal manure is one of the major inputs for compost/manure production.

Watershed differentials

The results of the study show that investment in SLM also varies by watersheds. The positive coefficients sign for Anjeni and Dijil watersheds for investments in bunds do suggest that farm households located in these two watersheds are more likely to invest than those in Debre Mewi (reference watershed). This could be explained by the watershed level physical incentives to invest in conservation practice (e.g. degradation level and rainfall amount). Moreover, farmers in Dijil and Anjeni are more likely to invest in compost/manure. This is due to the presence of a relatively large number of livestock (TLU) in the Dijil and Anjeni areas. Farmers in Anjeni are more likely to use fertilizer, but farmers in Dijil have a lower probability of investing in fertilizer compared to Debre Mewi farmers.

The above results suggest that both parcel and household characteristics are significant in influencing the households' decisions to invest SLM practices.

Table 4.12. Results of a multivariate probit analysis of investments in SLM practices.

	Bunds		Compost/manure		Fertilizer	
		Robust		Robust		Robust
	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Land quality						
Slope status						
Moderate	0.77***	0.11	-0.03	0.11	0.03	0.11
Steep	0.88***	0.11	-0.09	0.11	0.06	0.11
Soil depth						
Medium	-0.09	0.11	-0.10	0.12	0.10	0.10
Shallow	-0.11	0.11	-0.17	0.12	-0.10	0.12
Fertility status						
Low fertility	0.24	0.17	0.85***	0.17	0.18	0.16
Medium fertility	0.12	0.17	0.31*	0.17	-0.04	0.16
Soil type						
Black	-0.15	0.17	-0.02	0.21	0.06	0.18
Red	0.13	0.14	0.16	0.17	-0.15	0.15
Brown	0.13	0.19	0.22	0.22	-0.20	0.20
Land fragmentation						
Parcel size	0.38***	0.06	0.19***	0.06	0.26***	0.07
Distance of parcel	0.00	0.00	-0.06***	0.01	- 0.00	0.00
Tenure arrangement						
Own	0.60***	0.28	0.67*	0.38	0.35	0.24
Shared in/rented in	0.30	0.28	0.02	0.39	0.46**	0.26
Socio-economic						
Age	-0.10***	0.00	-0.00	0.00	-0.00	0.00
Farm labour	0.10	0.07	-0.00	0.00	-0.05	0.07
TLU	0.00	0.01	0.03**	0.02	-0.00	0.01
Off-farm	-0.00**	0.00	-0.00	0.00	0.00	0.00
Watershed						
Anjeni	1.81***	0.12	0.28*	0.06	0.24*	0.12
Dijil	0.46***	0.08	0.70***	0.10	-1.04***	0.09
Constant	-2.20***	0.33	-0.51	0.49	0.47	0.36
$\rho_{BC/M}$			-0.037			
ρ_{BF}			0.037			
$\rho_{FC/M}$			-0.02***			
No. of observation			1441			

Notes: Likelihood ratio test of $\rho_{BC/M}$ ρ_{BF} $\rho_{FC/M}$ $=0$, $\chi^2(3)=16.44$, p- value < 0.0009. *;**;*** significant at 10%; 5%; and at 1%, respectively. B=Bunds, C/M=Compost/manure F=Fertilizer

4.4 Conclusions

Sustainable land management practices are important to increase productivity and improve food security in the highlands of Ethiopia. In this research, household and parcel level data were used to investigate farmers' perceptions about land quality, land fragmentation and tenure systems and their influences on SLM investments using a multivariate probit model. The study reveals that compost/manure and fertilizer are substituting each other (often not used together) in the farming system of the study areas. However, bunds have no substitution and/or complementary effect on compost/manure and fertilizer. This indicates the interdependence between the different SLM practices investment decisions. A single equation adoption model does not give information about this interdependence between SLM practices. Further local level research should generate this type of information, which is vital for extension personnel for disseminating SLM practices.

The results of the study on farmers' perceptions indicate that land certification has economic, environmental and social benefits. Thus the land certification process must be strengthened by cadastral surveys to define accurate dimensions and location of land parcels.

The results of the econometric analysis indicate that land quality is an important factor that affects the probability of investing in SLM practices. Thus, matching SLM practices with land quality is of paramount importance for facilitating the decision-making about and adoption of SLM investments. The study also reveals that the current level of farm fragmentation is very high and it affects SLM investments. Therefore policy measures are needed to stop the further fragmentation of cultivated land. On the other hand farmers prefer to some extent fragmented land, with different type of parcels, to minimize agricultural production risks. Thus, land consolidation/land amalgamation/land exchange policies should be backed up by a proper crop insurance scheme.

The study shows a significant difference in SLM investment among different tenure arrangements. The current land rental market (sharing and renting) is not supported by any institute except long term leasing. Thus, tenure arrangements, specifically sharing and renting, should have a legal backing to support long term SLM investments. Moreover, such arrangements have to have provisions that specify technically sound and environmentally safe long term soil management practices that have to be employed by the lessees or renters and also an associated investment security that should be offered by landowner.

To sum up, the overall results indicate that farm land attributes promote or hinder investments, and tenure systems regulate the decisions about investments. Thus, policy makers should pay much attention to these various land related factors in designing SLM policies and programmes.

Chapter 5

Investments in land management in the north-western highlands of Ethiopia: the role of social capital

This chapter is submitted as:

Teshome, A.[1,2], de Graaff, J.[1], and Kessler, A.[1]. Investments in sustainable land management in north-western highlands of Ethiopia: the role of social capital

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Investments in land management in the north-western highlands of Ethiopia: the role of social capital

Abstract

In the north-western highlands of Ethiopia investments in sustainable land management (LM) have not always been successful. The objectives of this study were to assess farmers' perceptions about implementation approaches of soil and water conservation (SWC) practices and to explore the relationship between the different dimensions (factors) of social capital and investments in LM practices. Simple descriptive statistics were applied to analyse the implementation approaches, while factor analysis was used to reduce the social capital variables to six non-correlated factors for subsequent analysis. The Seemingly Unrelated Regression (SUR) model was used to analyse the effects of social capital dimensions on investment in three LM practices: bunds, compost and fertilizer. The study showed that the majority of the farmers state that they prefer the mass mobilization approach (which embodies social capital) to implement SWC practices. But farmers also pointed out several shortcomings of the mass mobilization approach (e.g. inefficient in labour utilization, lack of benefit sharing mechanism). The SUR model shows that the different dimensions of social capital affect investments in the LM practices differently. In particular, cooperation and trustworthiness positively influence investments in bunds and fertilizer use, while the extent of participation in formal institutions has a positive effect on fertilizer use and compost. Understanding and making use of these relationships could help in designing and implementing LM policies, strategies and programmes.

Key words: Social capital, land management, soil and water conservation, mass mobilization, factor analysis, Ethiopia

5.1 Introduction

Agricultural development in Ethiopia is hampered by many factors, with land degradation being one of the key threats to the sustainability of agricultural production in the country (Anley et al. 2007; Girma 2001). Among the different land degradation processes in Ethiopia, soil erosion by water presents the most severe threat to food security, environmental sustainability and prospects for rural development. In response to the extensive degradation of its resource base, the Ethiopian government has implemented various measures to mitigate the problem of soil erosion and enhance the production potential of its agricultural land. Towards that end, integrated watershed management at community level and the construction of soil and water conservation structures through mass mobilization have been promoted as a strategy for improving and conserving the natural resources base (GTP 2010).

Land degradation problems are often characterized by strong interactions between up- and downstream parts of a landscape. This circumstance makes the integrated watershed management approach an appropriate option for effective and sustainable resource management (Bewket 2003). Furthermore, mobilization of the community for natural resource management (NRM) is a crucial issue for combatting degradation problems through community participation at watershed level.

In the north-western highlands of Ethiopia adoption rates of soil and water conservation (SWC) measures vary considerably and this is due to many different factors as shown in Teshome et al. (forthcoming). A detailed cost-benefit analysis indicates that SWC measures can be profitable in many situations (Teshome et al. 2013). This shows that farmers do often not adopt the SWC measures despite their financial profitability, and suggests that other factors beyond individual capabilities influence the investment/adoption behaviour of farmers. One of these factors could be the availability of social capital (Beekman and Bulte 2012; Adimassu et al. 2012; Shiferaw et al. 2009).

The major terms used in this paper are defined as follows: "SWC" and "LM" are used interchangeably, however SWC generally has a narrower meaning than LM. SWC refers to "bunds", including stone bunds, soil bunds and *Fanya juu* bunds (made by digging a trench and throwing the soil uphill to form an embankment); whereas LM, in addition to bunds, also includes compost, chemical fertilizer, etc. "Investments" in this paper refers to decisions made by smallholder farmers at household level to invest in LM practices.

SWC investments can yield public as well as private benefits. Conservation investments undertaken by one agent imply increased availability of water and less soil runoff for other agents in the watershed (Bouma et al. 2008). However, because there is strong physical interdependency between the upstream and downstream parts of a watershed and between adjacent farms with respect to hydrology and soil erosion (Teshome et al. forthcoming; Bewket 2003), effective and sustainable implementation of integrated watershed management requires strong collaboration between upstream and downstream households as well as between owners of adjacent farms. For example, conservation on one farm will have little impact when farm land in upstream areas or on adjacent farm plots is not conserved. This implies that, in order for the benefits of SWC investments to be realized, attention needs to be given to building cooperation in efforts to avert the problems of erosion. Such collaboration is influenced by the level and the type of social capital at the community and household level (Willy and Holm-Müller 2013). Similarly, structural social capital, especially in the form of connections beyond the village, is associated with more extensive adoption of innovations (e.g. organic fertilizer and compost). This form of social capital is creating access to knowledge, information and resources (van Rijn et al. 2012). Thus, different dimensions of social capital have different impacts on LM practices. On the other hand, when social capital is weak in a social system, natural resource degradation can easily be exacerbated. This failure of social capital calls for some kind of government intervention. One such intervention is collective action through mass mobilization (Taylor 1998).

The aforementioned studies indicate that social capital influences the household and community level investment behaviour of farmers. This is because social capital is a community and individual level attribute/an individual good and a collective good (Narayan 1997; Portes 1998; Putnam 2000; Ostrom and Ahn 2007). Despite the availability of different forms of social capital (e.g. networks, institutions and social norms) in rural Ethiopia, most investment or adoption studies in Ethiopia have not seriously investigated the role of social capital in LM investments (e.g., Tesfaye et al. 2013; Kassie et al. 2009; Bewket 2007). This paper focuses specifically on the role that social capital plays in decisions regarding LM practices.

The objectives of the study were to assess the farmers' perceptions about the implementation approaches of SWC management activities, to examine the level of social capital dimensions[1] among three watersheds, and to explore the relationship between the different dimensions of social capital and investments in LM practices.

5.2 Social capital and LM investments

Social capital is one of the institutional factors affecting socio-economic development (Narayan and Pritchett 1999; Woolcock and Narayan 2000). Social capital refers to the norms and networks that enable people to act collectively (Woolcock and Narayan 2000). Woolcock (2010) also explains social capital in simple terms as "not what you know, it's who you know". There are a variety of perspectives on the forms and features that constitute social capital within a population.

[1] *We used the terms 'dimension' and 'factor' interchangeably.*

According to Dasgupta (2000) and Uphoff (2000) there are two interrelated categorical forms of social capital: structural and cognitive. The structural form is associated with various configurations of social organization, rules, precedents and procedures as well as social networks that contribute to cooperation, such as formal and informal institutions. The cognitive form is derived from mental processes and resulting ideas, reinforced by culture and ideology, e.g., trust and adherence to norms.

Szreter and Woolcock (2004) however distinguish three dimensions of social capital - bonding, bridging and linking. Bonding social capital refers to trusting and cooperative relationships between members of a network who perceive themselves as being similar in terms of their shared social identity. Examples of bonding social capital include immediate family, close friends and neighbours. Bridging social capital, by contrast, comprises relations of respect and mutuality between people who know that they are not alike in some socio-demographic or social identity. This category includes loose friendships and workmates. Linking social capital refers to norms of respect and networks of trusting relationships between people who are interacting across explicit, formal or institutionalized powers or authority gradients in society (vertical networks).

Adding to this, Pretty (2003) posits that social capital has four important features: relations of trust; reciprocity and exchanges; common rules, norms, and sanctions; and connectedness in networks and groups.

Social capital is, therefore, an accumulation of various types of social, psychological, cultural, cognitive, institutional, and related assets that increase and improve mutually beneficial cooperative behaviour (Uphoff 2000).

The LM investment and adoption behaviour of farmers are shaped and fashioned by the level and type of social capital (Willy and Holm-Müller 2013; Nyangena 2008; Cramb 2005; Isham 2002). This is because social capital influences farmers' collaboration, preferences, transaction costs and information exchange (Grootaert et al. 2004; Grootaert and Bastelaer 2002). In particular, rural communities that are characterized by strong social capital have been found to have faster rates of technology diffusion and improved environmental management (Dessiea et al. 2012; Njuki et al. 2009; Cramb 2006). Social networks are especially important for small-scale farmers who have less access to formal institutions. These networks enable farmers to overcome economic constraints and thus facilitate adoption of technology (Di Falco and Bulte 2013; Wossen et al. 2013; Baumgart-Getz et al. 2012; Bandiera and Rasul 2006; Posthumus 2005). This is because social networks facilitate the exchange of information, relax labour and financial constraints of farmers, reduce transaction costs and increase farmers' bargaining power (Kassie et al. 2013). The concept of social networks refers to the interaction patterns in society. The social capital construct, however, is broader than that of social networks. Social capital goes beyond measuring who is interacting with whom to include the characteristics and consequences of that interaction. It is concerned with how interaction leads to trust and, ultimately, to effective collective action (Rohe, 2004).

Social capital is not the same across locations (Putnam, 1993). Some communities have stronger social capital than others, and some households have more social capital than others. This may be due to the difference in investments in social interactions as well as differences in endowments of social capital in the community where they live (La Ferrara, 2002).

Some LM activities can be undertaken by individual farmers (e.g. applying fertilizer or compost), but other investments, such as bunds, may benefit from a collective approach. Collective action (e.g. mass mobilization) is one of the means to increase social capital when social participation is weak in a social system (Tindall et al. 2012). Collaborative efforts influence the formation of new relationships and the structures of these relations (social networks), and these in turn influence success (Mandarano, 2009).

5.3 Materials and methods

5.3.1. Description of study areas

The study was undertaken in three watersheds in the East and West Gojam Zones of the Amhara region of Ethiopia, i.e., the Anjeni, Dijil and Debre-Mewi watersheds (Fig.1). The watersheds are part of the north-western highlands of Ethiopia and all three are situated at an altitude of around 2,400 m.a.s.l. These watersheds were selected because of their specific experience with LM activities and the availability of different formal and informal institutions. Moreover, the watersheds have diverse bio-physical and socio-economic characteristics (Table 5.1). The dominant farming system in the watersheds is characterized as crop-livestock mixed farming. Although situated in the same very large Nile river basin, the three watersheds are located quite far from each other and there are no clear interrelations.

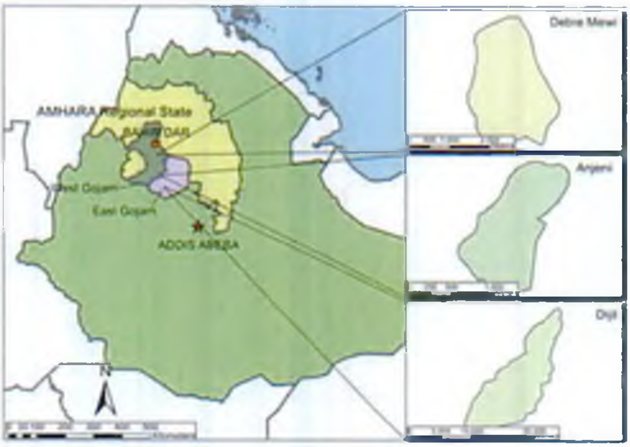

Figure 5.1. Map of study areas

Table 5.1. Socio-economic and physical characteristics of the study watersheds

Features	Anjeni	Dijil	Debre Mewi
Altitude (m.a.s.l)	2,450	2,480	2,300
Average annual rain fall	1,790 mm	1,300 mm	1,260 mm
Degradation	Degraded	Very degraded	Not heavily degraded
Dominant crop in farming systems	Barley	Oats	Tef
Productivity	Low	Low	High
All weather road	Poor	Good	Good
Distance to district town (Km)	20	8	12
Distance to regional capital (Km)	265	285	30
SWC projects	SCRP (long term)	SIDA and SLM-GIZ	No specific project

Anjeni Watershed

The Anjeni watershed is located in the Dembecha district of West Gojam Zone, 260 km south east of Bahir Dar. The watershed lies at 10.68°N and 37.53°E, covers an area of 113 ha and is home to 95 households. Anjeni is a high rainfall area, with an average annual rainfall of 1,790 mm (Table 5.1). The crops grown are barley, tef, maize, wheat, faba bean, potato, noug, field pea, lupine, and linseed. The major soil types in the watershed are Nitosols (red soil), Alisols, Regosols, and Leptisols. Soil and water conservation measures have a long history in this watershed. *Fanya juu*-soil conservation bunds were introduced as early as 1984 by the then Soil Conservation Research Project (SCRP) which was initiated by Bern University of Switzerland in collaboration with the Ethiopian Ministry of Agriculture.

Digil Watershed

The Digil watershed is found in the Gozamen district of East Gojam Zone at 10.24°N and 37.43°E. The watershed (which comprises the villages of Melit, Enerata, Yaya and Yedenigia) covers an area of 936 ha and has a total household number of 628. The major crops grown are oats, wheat, tef, barley, faba bean and potato. Red soils (Nitosols) are dominant in the watershed. The watershed is close to Debre Markos town (district and zonal capital). SWC activities were implemented specifically in the village of Melit in 1999 by the District Agriculture Office with financial support from the Swedish International Development Agency (SIDA) as part of its on-farm research program in the Amhara region. Currently, different NGOs are involved in SWC activities in the area, such as SLM-GIZ (The German Society for International Cooperation) and *Megibare Senay*.

Debre Mewi Watershed

The Debre Mewi watershed is located in the Yilmana Densa and Bahir Dar Zuria districts of West Gojam Zone. It is located at 11.34°N and 37.43°E, situated slightly lower than the other watersheds at an altitude of about 2,300 m.a.s.l and receives an average annual rainfall of about 1,260 mm. The total area of the watershed is estimated to be 523 ha and it is home to about 324 households. Major crops grown in the watershed are tef, maize, barley, finger millet, wheat, faba bean, potato, grass pea and niger seed. The dominant soil types are Nitosols (red), Vertisols (black) and Vertic Nitosols. Debre Mewi is a high crop production area. There is a SWC experimental site in the Debre-Mewi area which is handled by Adet Research Centre in collaboration with the SWHISA (Sustainable Water Harvesting and Institutional Strengthening in Amhara) project since 2008.

3.2. Sampling and data collection

The first stage of the sampling procedure involved the selection of three watersheds based on their specific experience with LM activities and diverse bio-physical and socio-economic characteristics (Table 5.1). In the second stage, farmers were selected randomly from lists of all households in each watershed. A total of 60, 125 and 115 farmers were selected from the Anjeni, Dijil and Debre Mewi watersheds, respectively. The sample size was based on heterogeneity of farm resources in the respective watersheds.

Primary data from these 300 farm households were collected from the three watersheds in 2011 using a general agro-socio-economic survey. This survey included a series of questions about the different dimensions of social capital. Through this survey, detailed information was collected about membership and extent of participation in various formal and informal institutions and social relationships (bonding, bridging and linking social capitals), as well as farmers' perceptions about cooperation among the community members. Moreover, data about sustainable land management was collected. A Participatory Rural Appraisal (PRA) with group and key informants interviews was used to gather supplementary data (e.g. perceptions of different stakeholders about SWC practices and approaches).

Additional, more specific, data on cooperation and disputes due to erosion and bunds and on farmers' perceptions of the advantages and shortcomings of implementation approaches were collected in 2012 from a sub-sample of 110 households (40 from Debre Mewi, 30 from Anjeni and 40 from Dijil).

5.3.3 Method of analysis

Descriptive analysis

The variables derived from the large survey and included in the detailed analysis were first analysed by simple descriptive analysis (e.g. means and standard deviations). The information on the perceptions of farmers about the implementation approaches of SWC activities, as obtained through the sub-sample survey, was also assessed by means of frequencies and percentages.

Factor analysis

Subsequently, factor analysis was applied to identify, characterize and categorize the type of social capital that exists and manifests itself at household and watershed level. Factor analysis is used to manage large sets of variables with unknown interdependencies by using correlations to group sets of variables where each group represents a single hidden factor. It also reduces the number of variables by combining two or more variables into a single factor (Field 2005). Thus, factor analysis is used to reduce the social capital variables into a smaller set of non-correlated factors.

A Varimax orthogonal rotation was used to produce a rotated component matrix that facilitates the interpretation of variables that compose each factor. It also helps for grouping similar variables into the same factor. In such a matrix the loading for each of the variables is given; and factors with eigenvalues greater than one are retained in the analysis. Additionally, only variables with factor loadings greater than 0.4 are used for the factor analysis. A high loading represents a variable that is influenced strongly by the factor. Next, each factor is given a label according to the set of variables (characteristics) of which it is composed.

Using the mean score of each construct (factor), a new data set representing each sample household was generated and then used to incorporate social capital dimensions as variables in subsequent analysis.

Eigenvalue was used to measure the total variance explained by each factor. Cronbach's alpha was also used to determine the internal consistency of multi-items in a survey instrument to gauge its reliability (for assessing the reliability of scales). Bartlett's test of sphericity was applied to examine whether the correlations between the variables were large enough for Principal Component Analysis (PCA). In addition, the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy tests was undertaken to measure the degree to which the variables are related.

3.3.3. Econometric analysis

Farmers are more likely to adopt a combination of practices to deal with a multitude of agricultural production constraints than adopting a single practice (Kassie et al. 2013). Thus, the system equation of the Seemingly Unrelated Regression (SUR) model was used to analyse the effects of social capital dimensions on interrelated LM practices (Bunds, Compost and Fertilizer). SUR allows the estimation of a set of equations with different dependent variables as a system by assuming that error terms are correlated across equations (Greene 2008). The general model can be specified according to Equation 3.2

$$y_i = X_i\beta_i + \varepsilon_i, \quad i = 1,......M \qquad [5.2]$$

Where:

y_i and ε_i are $N \times 1$ vectors,

X_i is a $N \times \sum_i K_i$ matrix and

β_i is a $\sum_i K_i \times 1$ vector.

If we stack these M vector equations on top of each other, the system will take form:

$$\begin{pmatrix} y_1 \\ y_2 \\ . \\ . \\ y_M \end{pmatrix} = \begin{bmatrix} X_1 & 0 & . & . & 0 \\ 0 & X_2 & . & . & . \\ . & . & . & . & . \\ . & . & . & . & . \\ 0 & . & . & 0 & X_M \end{bmatrix} \begin{pmatrix} \beta_1 \\ \beta_2 \\ . \\ . \\ \beta_M \end{pmatrix} + \begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \\ \\ \varepsilon_M \end{pmatrix} = X\beta + \varepsilon$$

The assumption of the model is that error terms have cross-equation contemporaneous correlations. Thus, the Breusch Pagan test was used to test the assumption that the errors across equations are correlated.

We considered three LM practices (dependent variables) in this study: bunds, compost and fertilizer. Following the adoption literature (Willy and Holm-Müller 2013; Kassie et al. 2013; Bandiera and Rasul 2006), the explanatory variables (social, human, financial and physical capital) were identified for SUR analysis. Next to several other explanatory variables a total of 22 social capital variables (reduced into six social capital factors by means of the previous factor analysis) were used in the econometric analysis. In this study, we put emphasis on the social capital variables. The effects of other variables on LM practices were already analysed in two previous studies (Teshome et al. 2014; Teshome et al. forthcoming).

Identical regressors were not used in the analysis. Some regressors were dropped from some equations in order to increase the efficiency of the system equation.

5.4 Results and discussion

5.4.1 Descriptive analysis results

Summary statistics of the variables

Definitions and summary statistics of the variables used in the econometric analysis are given in Table 5.2. On average sample households covered 47.4% of their farm area with bunds, and they applied 123 kg ha^{-1} of inorganic fertilizer (DAP and urea) and 0.70 t ha^{-1} of compost.

The means and standard deviations of social, human, financial and physical capital of the sample households were also calculated. The means of social capital variables of the sample households vary considerably. The average cultivated land size of the sample households is 1.03 ha. and the households have on average 5.35 tropical livestock units (TLU). The average total monthly off-income of the sample households is only about 57 Birr, but only 27 % of households do have off-farm income.

Table 5.2. Summary statistics of the variables for all households in the three watersheds

Variable	Type	Mean	St.Dev.
SLM Practices			
Total farm area covered in bunds	Percentage (%)	47.4	38.64
Total amount of compost	Continuous (t ha-^{1})	0.70	0.82
Total amount of fertilizer	Continuous (kg ha^{-1})	123.0	63.46
Social capital variables			
Extent of willingness of the people to help others	Scale (1=very low 5=very high)	3.01	0.81
Extent of cooperation between downstream and upstream households in flood control	Scale (1=very low 5=very high)	3.03	0.96
Extent of trust among people	Scale (1=very low 5=very high)	2.99	0.81
Extent of trust in lending and borrowing	Scale (1=very low 5=very high)	2.23	0.75
Extent of cooperation with adjacent farmer	Scale (1=very low 5=very high)	2.77	0.97
Proportion of the community contributing to solve the flood problem	Scale (1=very low 5=very high)	3.72	1.12
Spirit of the community to help others during unfortunate happenings	Scale (1=very low 5=very high)	3.41	0.82
Linkage with district administration	Scale (1=very low 5=very strong)	1.87	0.75
Linkage with district office of agriculture	Scale (1=very low 5=very strong)	1.94	0.85
Linkage with NGO	Scale (1=very low 5=very strong)	1.88	0.80
Extent of intimate friends	Scale (1=very low 5=very high)	2.42	1.30
Extent to which people provide money without interest	Scale (1=very low 5=very high)	2.44	1.28

Extent of relatives	Scale (1=very low 5=very high)	2.77	1.40
Extent to which people would be willing to assist during a long term emergency	Scale (1=very low 5=very high)	2.13	1.33
Extent people are willing to come to help during critical labour shortage time	Scale (1=very low 5=very high)	2.67	1.37
Level of participation in a development group	Scale (1=Not member 4=Executive member)	1.56	0.91
Level of participation in watershed group	Scale (1=Not member 4=Executive member)	1.50	0.88
Level of participation in *kebele*[1] government	Scale (1=Not member 4=Executive member)	1.57	0.91
Extent of abiding by norms and bylaws	Scale (1=very low 5=very strong)	3.39	0.74
Extent of sanction for those not participating in community activities	Scale (1=very low 5=very strong)	2.76	0.87
Level of participation in *Edir*[2]	Scale (1=Not member 4=Executive member)	2.75	0.66
Level of participation in *Mahiber*[3]	Scale (1=Not member 4=Executive member)	2.61	0.81
Human capital			
Education	Dummy (1=literate; 0=Illiterate)	0.54	0.50
Financial capital			
Off-farm income	Continuous (Monthly income in Birr[4])	56.72	147.29
Size of iron roof house (proxy variable for wealth)	Continuous (Number of iron sheets)	55.54	20.72
Physical capital			
Tools (e.g. shovel)	Dummy (1=yes; 0=no)	0.59	0.49
Cultivated land	Continuous (in ha)	1.03	0.50
Number of tropical livestock units (TLU)	Continuous (in TLU)	5.35	2.97
Watershed			
Debre Mewi (reference)	Debre Mewi watershed (1=yes; 0=no)	0.38	
Anjeni	Anjeni watershed (1=yes; 0=no)	0.20	
Dijil	Dijil watershed (1=yes; 0=no)	0.42	

[1] *Kebele* is the lowest administrative body in Ethiopia.
[2] *Edir* is risk reduction institution (cost of funerals)
[3] *Mahiber* is religious based institution: to commemorate the Saints.
[4] *Birr* is the unit of Ethiopian currency. It is equal to 0.059 Dollar

Degradation, cooperation and soil and water conservation technologies

Farmers' perceptions on the relation between degradation, cooperation and soil and water conservation technologies were collected from 110 households. Most farmers (98.2 %) stated that cooperation among the community members to avert land degradation before reaching a severe stage of degradation is very low. On the other hand, all farmers mentioned that cooperation among the community members to avert further land degradation once a severe stage of degradation has been reached is very high. This indicates that only in the end, when the problem of degradation reaches its climax stage, community cooperation intensifies. Additionally, institutions from outside the community are in a good position to communicate information on how to curb degradation for the sake of survival. This indicates that degradation of natural resources leads to cooperation among the community.

In addition, all farmers (100 %) mentioned that disputes among the community members due to erosion/flood problems before the implementation of SWC at watershed level are very common. This shows that disputes are a major barrier to implement SWC due to lack of cooperation. On the other hand, most farmers (97.3%) revealed that disputes among community members due to erosion/flood problems during and after the implementation of SWC at watershed level are not very common. This indicates the contribution that implementing SWC measures (together) can make to settle disputes or conflicts at the watershed and farm level.

SWC implementation approach

Different soil and water conservation approaches have been implemented in the north western highlands of Ethiopia during the last two decades. Between 2005 and 2010, an individual approach (individual level implementation) of SWC was advocated. Farmers were advised by development agents to implement SWC practices. In this approach, farmers were not forced to implement SWC measures.

Since 2010, the regional government of Amhara has intensively launched SWC activities through mass mobilization. Unlike the previous mass mobilization programmes of SWC (e.g., Food-For-Work and Productive Safety Net Program), the farmers are not offered any incentives for participation in SWC activities.

According to the Regional Government of Amhara, mass mobilization is the appropriate approach for implementation of SWC measures in the highlands of Ethiopia because of the large areas exposed to erosion due to the rugged topography, the adverse downstream effects and the lack of social capital. This shows the political-ecological interest of the state to combat land degradation.

The regional NRM (Natural Resources Management) approach being promoted by the government is community based integrated watershed development applying participatory methods and taking the watershed as a planning unit. In each watershed, agricultural offices along with local administrators organize 15-day-long farmers' conferences to create awareness about the problems of soil erosion and its causes. During the conference farmers prioritize their major natural resources' problems, causes and possible solutions. Eventually, they reach a consensus about the required collective action.

The recently launched mass mobilization approach has pluralistic institutional arrangements at different levels (regional, zonal, district and *kebele*). These arrangements are: the rural command post, the natural resource development protection and use process, development groups, "One to Five work teams" (one "contact farmer" (leader) and five "follower farmers" from the development group) and the watershed development committee. During group discussions, different stakeholders revealed that lack of commitment and leadership skills are major problems at the *kebele* and district levels of these institutional arrangements.

Perceptions of farmers about SWC implementation approach

Farmers have different preferences with regard to SWC approaches. Benefits and shortcomings of mass mobilization and individual approaches of SWC are discussed. The survey found that most farmers (80 out of 110, or 72.3 %) prefer the mass mobilization approach to implement SWC practices.

Perceptions of farmers about mass mobilization

The reasons for preferring mass mobilization are presented in Table 5.3. One of the main reasons for preferring the mass mobilization approach is that it solves the erosion problem at watershed level. Because the whole community implements SWC at the same time through collective action starting from the upstream areas of a watershed, the whole watershed is covered by the SWC measures.

Facilitation of social capital (e.g. cooperation) is another reason for preferring the mass mobilization approach by the sample households. During mass mobilization, the active labour force also constructs bunds for the elderly and physically disabled. Moreover, as a result of mass mobilization, the community starts to work together on their common problems and goals. It enhances team spirit within the community, and it solves conflicts with adjacent farmers. During mass mobilization SWC measures are constructed at watershed level in a holistic approach, thereby eliminating or avoiding disputes between adjacent farm owners due to erosion.

Furthermore, farmers prefer the mass mobilization approach since it allows a large amount of high quality SWC works to be constructed in a relatively short period of time. This is because a large number of labourers are mobilized to construct different structures at the same time, and because of the continuous supervision and technical backup from experts and a quality control team in every development group.

Existence of bylaws and enforcement might also contribute to the preference for the mass mobilization approach. Bylaws are formulated and endorsed by the *kebele* council to protect the SWC structures. However, during group discussions, farmers pointed out that things were often not implemented according to the agreements and therefore the bylaws will not ensure the sustainability of the watershed development program unless enforcement is strictly implemented.

The mass mobilization approach has increased the participation of all the community members in SWC activities. The whole active labour force (men, youth elders, women, and landless) participate in conservation activities, although there is a division of labour among the community. Women mostly involved in soil bund compaction and paving the waterways, and men are engaged in digging ditches, and the construction of stone terraces, waterways and cut off drains.

Table 5.3. Reasons for preferring mass mobilization approach and its shortcomings

Reasons for preferring mass mobilization approach (n=80)	**N**	**%**
To solve erosion problems at watershed level	79	98.8
To facilitate social capital (e.g. cooperation)	79	98.8
Large quantity SWC work is constructed in short period of time	78	97.5
To solve conflict with adjacent farmers	77	96.3
High quality SWC work is attained	76	95.0
Having bylaws and enforcement	68	85.0
To increase the participation of all the community members	64	80.0
To gain skills and knowledge	61	76.3
Availability of surveying materials and hand tools	46	57.5
Shortcomings of mass mobilization approach (n=110)		
Inefficient in labour utilization	63	65.6
Lack of benefit sharing mechanism	59	61.5
Overlapping with other agricultural activities	56	58.3
Quota system (passive participation of the community at planning and decision making)	43	44.8
Quality problem of SWC (e.g. inappropriate design)	28	29.2
Lack of SWC structures connectivity with water conveyance system	10	10.4
Lack of maintenance of SWC	8	8.3

Note: The number of responses (N) and percentages do not add up to 100% because of multiple responses.

Gaining skills and knowledge as well as the availability of hand tools are mentioned as important benefits of the mass mobilization approach. Farmers learn from development agents and fellow farmers about theoretical knowledge and practical skills for implementing SWC measures Moreover, hand tools are supplied by government and non-government organizations for the construction of SWC measures. Despite these positive aspects, farmers pointed out during group discussions that there is a critical shortage of hand tools at the community level.

Farmers in the sample also identified the main shortcomings of the mass mobilization approach (Table 5.3). Inefficiency in labour utilization is one of the main shortcomings of mass mobilization according to farmers. Some farmers arrive late and leave early during the implementation of SWC measures. Moreover, some farmers just come to fulfil the compulsory free labour requirement. This indicates that not all community members in a team are working equally.

Farmers also mentioned that the mass mobilization approach lacks a fair benefit sharing mechanism among active labour participants. Small farmers invest the same amount of time and labour as farmers with larger holdings. Moreover, landless and youth whose means of subsistence are non-farm activities also invest their time and labour for mass mobilization in SWC activities. But the idea of mass mobilization does not include a form or mechanism for benefit sharing, because it operates on the principle that the benefits will be diffuse and cannot be quantified for each farmer separately.

Another limitation of the mass mobilization approach is that it overlaps with other agricultural activities that demand more labour such as land preparation. Farmers underscored a need for an appropriate time schedule and synchronization of mass mobilization activities with other agricultural activities.

Passive participation of the community in the planning and decision making stages is another shortcoming identified by farmers. Key decisions are made at higher level and then endorsed and approved by farmers through continuous consultation during a conference at the grass roots level. During group discussions, most farmers complained about the duration and working hours of SWC works. Moreover, they complained about the restriction on free grazing of crop residues from farmland. This is a problem because crop residues are the major livestock feed, particularly in the dry seasons. Farmers recommend controlled grazing of crop residuals.

Perceptions of farmers about individual approaches

A minority of the sampled farmers (30 out of 110, or 27.3 %) prefers an individual approach for SWC activities. They pointed out the major advantages of the individual approach (Table 5.4). According to these farmers, higher quality SWC work is obtained through an individual approach because farmers feel a stronger sense of ownership when they construct bunds on their own farmland. Moreover, farmers can undertake SWC measures according to their own time planning, for instance after their main work. The individual approach is efficient in labour utilization because farmers work more seriously to use their time effectively. Also the individual approach allows each individual to harvest the benefits of his/her labour. Farmers do not end up working for others who have a larger farm size and may receive a relatively larger benefit.

Farmers also mentioned the major shortcomings of the individual approach (Table 5.4). One of the shortcomings of the individual approach of SWC is that erosion control is not achieved at the watershed level. Farmers implement SWC measures individually in a scattered manner and thereby the SWC measures do not control erosion at the watershed level.

A lack of skills and tools are also a major shortcoming of the individual approach. Development agents cannot provide technical backup to each individual farmer during SWC implementation. During the individual approach, farmers have also encountered a shortage of hand tools such as surveying materials and shovels.

A lack of quality SWC structures is another shortcoming of the individual approach of SWC. This is due to a lack of technical skills and the absence of continuous supervision from the development agents. Another drawback of the individual approach is labour shortage at household level.

Table 5.4. Reasons for preferring individual approach and its shortcomings

Reasons for preferring individual approach (n=30)	**N**	**%**
Quality SWC work is attained	30	100.0
Undertake SWC based on his/her time plan	28	93.3
Efficient in labour utilization	26	86.7
Benefit from his/her labour	26	86.7
Shortcomings of individual approach (n=110)		
Do not control erosion at watershed level (Not holistic approach)	86	86.9
Not all the community implement SWC voluntarily	78	78.8
Lack of skills	68	68.7
Lack of tools	62	62.6
Lack of quality work	53	53.5
Labour shortage encountered at household level	16	16.2

Note: The number of responses (N) and percentages do not add up to 100% because of multiple responses.

5.4.2 Factor analysis

Having looked at farmers' perceptions about SWC implementation approaches (mass mobilization and individual), we turn to the various dimensions (or forms) of social capital.

Following factor analysis the 22 social capital variables were reduced to six factors as shown in Table 5.5. The six factors are cooperation and trustworthiness (Factor 1), linking social capital (Factor 2), bonding and bridging social capital (Factor 3), participation in formal associations (Factor 4), enforcement (Factor 5) and participation in informal associations (Factor 6). Table 5.5 indicates the loadings of the 22 variables on the six factors extracted. The higher the absolute value of the loading, the more the variable contributes to the factor.

Table 5.5. Factor analysis of social capital variables

Variables	Component					
	Factor 1 Cooper.	**Factor 2** Linking	**Factor 3** Bonding	**Factor 4** Formal	**Factor 5** Enforce.	**Factor 6** Informal
Extent of willingness of the people to help others	.776					
Extent of cooperation between downstream and upstream HHS in flood control	.696					
Extent of trust among people	.685					
Extent of trust in lending and borrowing	.628					
Extent of cooperation with adjacent farmer	.585					
Proportion of the community contribute to solve the flood problem	.584					
Spirit of the community to help others during unfortunate happenings	.583					
Linkage with district administration		.881				
Linkage with district office of agriculture		.868				
Linkage with NGO		.803				
Extent of intimate friends			.734			
Extent of people provide money without interest			.699			

Extent of relatives			.671			
Extent of people would be willing to assist during a long term emergency			.665			
Extent of people willing to come to help during critical labour shortage time			588			
Level of participation in development group				.811		
Level of participation in *kebele* watershed group				.764		
Level of participation in *kebele* government				.673		
Extent of abiding by norms and bylaws					.796	
Extent of sanctions for those who do not participate in community activities					.767	
Level of participation in *Edir*						.800
Level of participation in *Mahiber*						.752
Explained variance (%)	14.39	12.02	11.87	9.69	7.29	7.24
Eigenvalues	2.88	2.40	2.37	1.94	1.46	1.45
Cumulative variance (%)	14.39	26.41	38.28	47.98	55.27	62.51
Cronbach's alpha	0.541	0.859	0.753	0.677	0.570	0.512
Bartlett's test	Chi Square=1724.185, degree of freedom =210 and P value-0.000					
KMO statistics	0.742					

Factor 1= Cooperation & trust, **Factor 2**= Linking social capital, **Factor 3**= Bonding and bridging social capital, **Factor 4**= Particpation in the formal association, **Factor 5**= Enforcement, **Factor 6**= Participation in informal association

Factor 1, "Cooperation & trustworthiness", encompasses variables related to cooperation and trustworthiness at the community level. Cooperation and trustworthiness lubricate interaction at the community level. Different variables that indicate cooperation and trustworthiness among the community have high loadings.

The second factor, "Linking social capital", consists of variables that represent the individual's ability to interact/engage with external institutions/organizations (in higher influential position). Variable loading in this factor includes linkage with the Office of Agriculture, District Administration and NGO's.

The third factor focuses on the blood and friendship ties and relations of an individual in the social system and, consequently, we call this latent variable "Bonding and bridging social capital". It is the combination of intra-group ties (bonding) and extra-group networks (bridging).

The fourth factor consists of the variables related to the extent of participation of an individual with formal associations at the community level such as development groups, watershed development groups and the *kebele* government.

The fifth latent variable of "Enforcement" is the aggregation of common rules, norms and sanctions. This factor encompasses the extent to which people abide by norms and bylaws, and the extent to which there are sanctions for those that do not participate in community activities.

The sixth factor is "Participation in informal associations". It comprises the variables related to how an individual participates in informal associations such as *Edir* (risk reduction institution: cost of funerals) and *Mahiber* (religious based institution: to commemorate the Saints as well as labour and animal power exchange).

Table 5.5 shows the results of the analysis using eigenvalues, Cronbach's alpha, Bartlett's test of sphercity and Kaiser-Meyer-Olkin (KMO) measure. The eigenvalue indicates the amount of variation explained by a factor. The eigenvalue associated with each factor represents the variance explained by that particular linear component. The percentage of variance explained by a particular factor is also presented (e.g. factor 1 explains 14% of the total variance) as well as the cumulative variance.

The analysis indicates that Cronbach's alpha coefficients range in value from 0.512 to 0.859. These values indicate that there exists an internal consistency among the test items.

A measure of appropriateness of the overall model is given by Bartlett's Sphercity test which indicates that the eigenvalues and consequently the principal components are different. The results of Bartlett's measure test ($p<0.001$) and the Kaiser-Meyer-Olkin (KMO) value (0.742) indicate that factor analysis is appropriate for these data.

5.4.3 The three watersheds and different aspects of social capital

The factor analysis (social capital factors) results are used to compare the level of social capital across the watersheds. The F-test analysis indicates that some factors of social capital differ across the watersheds (Table 5.6). The study shows that there are no significant differences in participation in formal and informal institutions among the three watersheds. But there are significant differences in cooperation and trustworthiness, linkage social capital, bonding and bridging social capital and enforcement.

The Anjeni watershed has a higher mean score for cooperation and trustworthiness, bonding and bridging social capital, and enforcement aspects of social capital. This indicates that Anjeni has relatively strong blood and social ties, mutual relationships and strong social cohesion. This could be due to long term (and probably appreciated) collective action in the watershed that may have contributed to strengthen social capital. The Anjeni watershed is a model site for SWC activities for the Amhara region and for the nation (Adgo et al. 2013).

However, the highest value for linking social capital is in the Dijil watershed. This implies that the farmers in the Dijil watershed have a strong link with outside institutions. This could be due to the fact that the Dijil watershed is very near to the district and zonal capital and also because a lot of NGOs are involved in the watershed in different development activities.

Table 5.6. Social capital dimension by watershed (on a 1-5 scale)

Social capital dimensions	Debre-Mewi	Anjeni	Dijil	F-test/P-value
Cooperation and trust	3.0	3.3	3.0	0.003***
Linkage social capital	1.5	1.8	2.3	0.000***
Bonding and bridging social capital	2.5	2.9	2.1	0.000***
Participation in formal institutions	1.6	1.7	1.5	0.707
Enforcement	2.9	3.2	3.1	0.071*
Participation in informal institutions	2.8	2.6	2.6	0.100

*; **; *** significant at 10%; 5%; and at 1%, respectively.

5.4.4 Econometric analysis

The social capital dimensions (factors) are used as variables in the econometric analysis. The econometric analysis indicates that the various aspects of social capital affect the intensity of LM practices differently (Table 5.7). The overall fitness of each regression model is also significant at the level of 0.01 (χ^2 -values for the area covered with bunds model, compost model and the fertilizer model are 259.11 ($p= 0.000$), 186.08 ($p=0.000$) and 41.46 ($p = 0.000$), respectively) despite the fact that the R2 values of the compost regression models are not high. The Breusch-Pagan test indicated that the residuals of three equations in the model are not significantly correlated (χ^2 =3.157, $p=0.3681$). In other words there are no potential efficiency gains obtained by estimating these equations as a system. Therefore, we could simply estimate the three equations by OLS (Ordinary Least Square method) separately.

Before running the SUR model, all the explanatory variables were checked for the existence of multi-collinearity problems. No serious problems of multi-collinearity were found.

Intensity of investments in SWC (area covered with bunds in percentage)

The results indicate that cooperation and trustworthiness aspects of social capital have a significant positive ($p<0.1$) effect on the intensity of investments in SWC, implying that a high level of cooperation and trustworthiness among the community members increases the intensity of investments in all kind of bunds. This suggests that SWC investments have a social dimension. It means that investing in bunds is a cooperation demanding technology. For hydrological and social reasons, cooperation and willingness of adjacent farmers as well as upstream and downstream households is required to make investment in bunds worthwhile. This result is consistent with findings of Beekman and Bulte (2012) in Burundi.

In addition, capacity factors like possession of tools (e.g. shovels) positively ($p<0.05$) affect the intensity of investment in bunds while off-farm activities (opportunity costs of labour) negatively ($p<0.01$) influence investments. This implies that possession of tools increases the intensity of investment in bunds, as tools for implementing conservation measures are one of the major inputs in SWC activities. On the other hand, involvement in off-farm activities tends to decrease the intensity of investment in bunds due to the fact that off-farm income represents a high opportunity cost of labour in agriculture. Thus, the households who are involved in off-farm activities appear to give less attention to labour-intensive activities.

Intensity of investment in bunds also varies by watershed. The positive coefficients for investment in bunds in the Anjeni and Dijil watersheds indicates that the intensity of investment in bunds increases when a household is located in these watersheds rather than in Debre Mewi (reference watershed). This is likely explained by the long term SWC interventions in these watersheds.

Table 5.7. Seemingly Unrelated Regression (SUR) results of SLM practices

Equation	Obs	Parameters	RMSE	"R-sq"	chi^2	P
Area covered with bunds (%)	243	11	26.56	0.5154	259.11	0.0000
Compost ($t\ ha^{-1}$)	243	12	7.48	0.1434	186.08	0.0000
Fertilizer ($kg\ ha^{-1}$)	243	11	49.27	0.4320	41.46	0.0000

	Option of SLM practices					
	Area covered with bunds (%)		Compost ($t\ ha^{-1}$)		Fertilizer ($kg\ ha^{-1}$)	
Variable	Coef	Std .Err	Coef	Std .Err	Coef	Std .Err
Constant	7.35	15.16	6.09	4.18	125.99***	27.43
Social capital						
Cooperation and trust	5.22*	2.99	0.63	0.82	13.16**	5.44
Linkage capital	4.84	3.07	-0.79	0.85	-6.39	5.59
Bonding and binding capital	-0.36	1.83	-0.62	0.52	-0.18	3.40
Formal institutions	1.39	2.37	1.44**	0.67	10.36**	4.38
Enforcement	-3.56	2.83	-	-	-	-
Informal institutions	0.10	3.00	-1.24	0.86	0.08	5.63
Human capital						
Education level	2.24	3.67	2.81***	1.03	10.41	6.80
Financial capital						
Off-farm income	-0.04***	0.02	0.00	0.00	0.14	0.02
Size of iron roof	-	-	0.00	0.03	0.26	0.17
Physical capital						
Tools (e.g. shovel)	8.86**	4.8	-	-	-	-
Cultivated land	-	-	-0.84***	0.28	-5.23***	1.84
TLU	-	-	0.66***	0.23	-	-
Watershed						
Anjeni	68.82***	5.22	2.04	1.42	-40.93***	9.23
Dijil	17.82***	4.94	2.26**	1.29	-84.70***	8.41

*; **; *** significant at 10%; 5%; and at 1%, respectively.

Intensity of compost utilization ($t\ ha^{-1}$)

The results of this study show that the extent of participation in formal institutions has a positive and significant ($p<0.05$) effect on the amount of compost used, indicating that the amount of compost used tends to rise with an increase in participation in formal institutions. Formal institutions (e.g. extension services) at the grass root level encourage and support rural farmers in the use of improved technologies such as compost.

The amount of compost used was found to be positively and significantly ($p<0.01$) influenced by the education status of the head of the households. This suggests that a change in the education status of the household head (from illiterate to literate) increases the amount of compost used per hectare. It is argued that literate farmers have the ability to obtain, process and use information related to compost technologies and also that they make more rational decisions. This is because education is usually the means to enhance the ability of farmers to acquire, synthesise and respond to innovations (Asfaw and Admassie, 2004).

The amount of Tropical Livestock Units (TLU's) is positively ($p<0.01$) related to the amount of compost used. This implies that each additional unit of livestock increases the amount of compost used per hectare. This is because animal manure is one of the major inputs for compost production. On the other hand, the cultivated land size has a significant negative ($p<0.01$) effect on the amount of compost used per area with each additional unit of cultivated land size tending to decrease the amount of compost utilization per ha. This could be explained by the limited availability of compost at the household level. The recommended rate of compost per hectare, 5 $t\ ha^{-1}$, is far beyond what farmers apply (Negassa et al. 2001).

The amount of compost used is positively related to the Dijil watershed compared to Debre Mewi. This may be explained by the presence of the relatively large number of livestock in Dijil watershed (Teshome et al. 2014).

Intensity of fertilizer use ($kg\ ha^{-1}$)

The cooperation and trustworthiness dimension of social capital is positively ($p<0.05$) related to the intensity of fertilizer use suggesting that a higher degree of cooperation and trustworthiness among the community members increases the intensity of fertilizer use. This may be because cooperation between adjacent farm owners and up and downstream households enhances the construction of bunds, which decreases erosion and thus prevents fertilizer from being washed away.

The intensity of fertilizer use is positively and significantly ($p<0.05$) influenced by the level of connectedness with formal institutions at the community level. This implies that the intensity of fertilizer use ($kg\ ha^{-1}$) tends to rise with a higher level of participation in formal institutions. An explanation for this is that, through such institutions, farmers may have access to credit and information about the optimal use of fertilizer. Availability of credit can relax farmers' economic and financial constraints, showing that social capital and economic capital are often closely linked.

Moreover, the intensity of fertilizer use is negatively and significantly affected by the area cultivated, with the intensity of the use of fertilizer tending to decline as area cultivated increases. Farmers with large amounts of arable land may encounter financial problems in trying to apply fertilizer in large quantities, particularly with the skyrocketing prices of fertilizer (e.g. DAP increased by 66%) (Teshome et al. 2014).

In addition, the intensity of fertilizer use is negatively related to Anjeni and Dijil watersheds compared to Debre Mewi. This may be explained by the fact that Anjeni and Dijil watersheds have a low crop productivity potential compared to Debre Mewi.

5.5 Conclusions

The objectives of the study were to assess the farmers' perceptions about the implementation approaches of SWC management activities, and to explore the relationship between the different dimensions of social capital and investments in LM practices. Most previous investment/adoption studies in Ethiopia and elsewhere have investigated social capital only in terms of participation in formal and informal institutions. By contrast, this research identified and used six social capital factors as variables in the analysis. The Seemingly Unrelated Regression (SUR) model was used to analyse the effects of this broader set of social capital factors on investments in three LM practices (bunds, compost and fertilizer).

The study showed the contribution of implementing SWC practices for settling disputes or conflicts among farmers at the watershed and farm level. This is because bunds are constructed at watershed level in a holistic approach during mass mobilization. The study also showed that the majority of the farmers in the north-western highlands of Ethiopia prefer the mass mobilization approach to implement SWC practices. Therefore, productive and protective measures need to be introduced through community participation to sustain the SWC activities. Nonetheless, farmers identified several shortcomings of the mass mobilization approach (e.g. inefficient in labour utilization, lack of mechanisms for benefit sharing). It is important to design a strategy to communicate and share the benefits from the watershed development programme with more of the participants (e.g. provide also benefits for landless). During collective action farmers work together and they interact and learn from each other as well as from extension personnel. This shows that mass mobilization enhances social capital. Such an approach has a synergic effect to tackle land degradation problems. Thus, there is a need to strengthen the mass mobilization approach through improving the capacity and the capability of different actors at different institutional levels (e.g. through training).

The results of the analysis show that some social capital factors differ across the watersheds due to socio-economic and institutional heterogeneity. In addition, we found that different aspects of social capital affect LM practices differently. Location of the households, physical capital (e.g. tools and size of cultivated land), human capital (e.g. education) are also very important factors for LM investments.

In particular, we found that cooperation and trustworthiness have a significant positive effect on the intensity of investment in bunds, indicating that such investment is a cooperation demanding technology. Thus SWC measures should be promoted through collective action at watershed level. In addition, the research shows that participation in formal institutions has a positive and significant effect on the amount of compost used, because compost is a knowledge demanding technology. Thus, investments in compost need technical know-how support from internal and external organizations. Therefore, there is a need to improve knowledge networks at the community level through capacity building and sharing knowledge of best practices. The intensity of fertilizer use was also found to be positively influenced by the level of participation in formal institutions at the community level, due to the need for cash and credit made available from formal institutions. Hence, increasing the participation of farmers in the formal institutions is of paramount importance to increase the intensity of both compost and fertilizer use. These findings provide insight in how to promote LM practices and community action in order to achieve desired results, and suggest that there is a need to strengthen social capital in order to facilitate the investment and adoption of LM practices (e.g. increasing the participation of farmers in formal institutions and encouraging collective action).

To conclude, LM practices are very important in the highlands of Ethiopia to avert land degradation problems. This study identified how particular factors of social capital affect LM investments and showed the strengths and shortcomings to implementation approaches of SWC. There is a need to pay more attention to social capital and how it operates in particular communities during the formulation and implementation of sustainable land management strategies, and take into account perceptions of farmers on the best way to tackle land degradation problems. Doing this will increase the participation in, and quality and effectiveness of LM practices in a sustainable way.

Chapter 6

Evaluation of soil and water conservation practices in the north-western Ethiopian highlands using multi criteria analysis

This chapter is re-submitted after review as:
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Evaluation of soil and water conservation practices in the north-western Ethiopian highlands using multi criteria analysis

Abstract

Investments by farmers in soil and water conservation (SWC) practices are influenced by the physical effectiveness, financial efficiency and social acceptability of these practices. The objective of this study is to evaluate different SWC practices in the north-western highlands of Ethiopia using various qualitative criteria and weights based on ecological, economic and social impacts using Multi-Criteria Analysis (MCA). The study reveals that MCA is a useful evaluation tool that takes into account non-monetary and less quantifiable effects of SWC practices. Farmers have a range of criteria to evaluate the performance of SWC practices. The relative importance of each criterion in their selection of SWC alternatives depends on slope categories. In steep sloping areas farmers give the highest score for criteria related to ecological impacts, and they prefer practices with stronger positive economic impacts in moderate and gentle sloping areas. Policy makers and development practitioners should pay more attention to farmers' preferences and slope specific circumstances in designing SWC strategies and programmes.

Key words: Multi-criteria analysis, soil and water conservation, farmer's preference, slope

6.1 Introduction

Agriculture is the major source of livelihood in Ethiopia. However, land degradation in the form of soil erosion has hampered agricultural productivity and economic growth of the nation (Haileslassie et al., 2005; Hengsdijk et al., 2005; Balana et al., 2010). Land degradation, low agricultural productivity and poverty are critical and closely related problems in the Ethiopian highlands (Pender and Gebremedhin, 2007; Yitbarek et al., 2012).

Investments[1] in soil and water conservation (SWC) practices enhance crop production, food security and household income (Adgo et al., 2013). Recognizing these connections, the government of Ethiopia is promoting SWC technologies for improving agricultural productivity, household food security and rural livelihoods. Particularly in the Ethiopian highlands, different SWC technologies have been promoted among farmers to control erosion. These technologies include stone bunds, soil bunds and *Fanya juu* bunds (made by digging a trench and throwing the soil uphill to form an embankment). The adoption rates of these SWC technologies vary considerably within the country (Tefera and Sterk, 2010; Kassie, et al., 2009; Tesfaye et al., 2013; Teshome et al., 2014). This is because investments by farmers in SWC are influenced by the ecological, economic and social impacts of the SWC technologies.

The impact of SWC measures in Ethiopia and elsewhere is mostly evaluated in monetary terms (cost-benefit analysis; CBA) (Teshome et al., 2013; Bizoza and de Graaff, 2012). However, SWC measures have also ecological and social impacts that cannot be easily quantified in monetary values (Tenge, 2005). Moreover, CBA is sometimes criticised for the limitation that it does not take into account the interactions between different impacts. Thus, more complete evaluation methods of SWC measures are of paramount importance to quantify the monetary and non-monetary values of SWC for better structuring the decision process of policy makers and development practitioners.

[1] Investments refers to any efforts (e.g. labour, knowledge and time) made by farmers to combat water erosion and enhance soil fertility.

Availability of several SWC alternatives, conflicting objectives and a range of evaluation criteria of farmers hamper decision making and adoption of SWC measures by farmers (Amsalu, 2006). Farmers' investment objectives about SWC measures may be very different from those of researchers and extension personnel. Farmers have other objectives in addition to reducing soil loss and maximizing financial benefits of SWC measures (Tenge, 2005). These objectives are often conflicting, which implies that there is no single SWC measure that can give best results for all farmers.

Therefore, there is a need to evaluate the objectives and criteria of farm households in decision making of SWC practices based on ecological, economic and social impacts. In order to identify and analyse multiple and conflicting objectives and goals, Multi-Criteria Analysis (MCA) is the best tool (Romero and Rehman, 2003). In addition, MCA methods are an appropriate modelling tool for combined economic-environmental evaluation issues (Mendoza and Martins, 2006; Munda et al., 1994).

The objective of this study is to evaluate different SWC practices using qualitative criteria by different stakeholders (farmers and experts) based on perceived ecological, economic and social impacts.

6.2 Multiple criteria analysis (MCA) for soil and water conservation evaluation

Most of the soil and water conservation investment activities are evaluated with the conventional cost-benefit analysis (CBA). CBA assumes that the complex of the soil and water objectives can somehow be converted into one basic objective of 'maximizing utility'. But usually the objective function consists of a single choice criterion. However, within SWC investments there are usually several objectives or goals instead of maximizing a single one (de Graaff and Kessler, 2011). Therefore discrete multi-criteria approaches (MCA) have been developed as a tool in decision making when different objectives have to be fulfilled. Recently, Fleskens et al. (2013) revealed that scenario assessments with integrated models can help determine location-specific financially viable technologies to combat land degradation problems effectively. They can also provide informative input to multilevel land management decision-making processes. Moreover, choice experiments, a stated preference valuation method, are also a tool to assign monetary values to environmental impact assessment (Vega and Alpízar, 2011).

MCA is a decision making tool applied to choice problems in the face of a number of different alternatives and several conflicting criteria (Hajkowicz, et al., 2000; de Graaff, 1996). Similarly CIFRO (1999) defined MCA as a decision-making tool developed for complex multi-criteria problems that include qualitative and/or quantitative aspects of the problem in the decision-making process. MCA is also defined as an evaluation method which ranks or scores the performance of decision options against multiple criteria (Hajkowicz, 2007). The multi-criteria model for evaluation has been developed based on the sustainable development economic theory, so that final results can have a clear meaning in terms of sustainability (Boggia and Cortina, 2010).

MCA has its own typical features or characteristics (Seo and Sakawa, 1988). The main characteristics of MCA are: multiplicity of objectives, heterogeneity of objectives and plurality of decision makers. MCA has its own advantages and disadvantages for evaluating SWC practices (de Graaff and Kessler, 2011) (Table 6.1). But MCA offers a great potential to address the shortcomings of other SWC evaluation methods.

For evaluation of SWC investments, CBA has the drawbacks that it normally compares only one 'with' case with one 'without case' (or 'before' and 'after' case), that all effects have to be valued in monetary values, and that it basically concentrates on the efficiency criterion. On the other hand, MCA has the disadvantages that it does not allow for an easy comparison of streams of costs and benefits over time, and that it basically relies on subjective weights attached to several criteria by the stakeholders concerned and represented (Table 6.1). An appropriate solution to evaluate SWC is the use of the results of the cost benefit analysis as one of the criteria (efficiency) to be used in the multi criteria analysis for evaluation of SWC measures (de Graaff and Kessler, 2011). Therefore, MCA is the best tool to evaluate soil and water conservation practices.

Table 6.1. Advantages and disadvantages of MCA for evaluating SWC

Advantages of MCA	Dis-advantages of MCA
Focus on several objectives and alternatives.	Non-comparability among objectives.
Considered the intangible effects of SWC.	Exposed to subjectivity problem: subjective weights attached to several criteria.
Use of both qualitative and quantitative effects.	Use of qualitative scales, where quantitative could be used.
Holistic approach: it can also incorporate CBA and other financial efficiency criteria.	Different methods give different results.
Increases the rationality of the decision process.	Difficult to incorporate the time dimension.
Shows clearly where gaps in knowledge are in SWC.	Pays little attention to uncertainty and to possible trade-offs among some of the objectives.
Interactive method	Different conflicting evaluation criteria are taken into consideration

6.3 Steps in Multi-Criteria Analysis (MCA) methods

MCA uses different steps to identify the best alternatives on the basis of relevant criteria (de Graaff and Kessler, 2011; Ananda and Herath, 2009; Hajkowicz and Higgins, 2008; Munda et al., 1994; Tenge, 2005; Voogd,1982). The major steps in the MCA are the following:

Step 1: Determination of objectives.

Step 2: Identification of alternatives/options, that contribute to achieve the objectives.

Step 3: Determination of the evaluation criteria, to assess the performance of the alternatives.

Step 4: Determination of the effects (score) on alternatives.

The effects of the alternatives are identified, measured (quantitative or qualitative) and determined according to the measurable criteria set, established in step 3.

Step 5: Standardization of the effects.

In this step, the effect of different dimension scoring of alternatives is eliminated by making the unit of scores comparable, on a scale between 0 and 1.

Step 6: Formulation of weights.

At this stage, weights are assigned to criteria by farmers, policymakers or other stakeholders to represent their relative importance for the respective group.

Step 7: Aggregation and ranking.

It involves combining the weighted scores for each alternative. Among the discrete MCA methods, the most important aggregation methods are the Additive Weighting and the Sequential Elimination methods.

6.4 Materials and Methods

6.4.1 The research areas

The study was undertaken in three watersheds in the East and West Gojam Zones of the Amhara region of Ethiopia, i.e., the Anjeni, Dijil and Debre-Mewi watersheds (Figure 6.1). The watersheds are part of the north-western highlands of Ethiopia. These watersheds were selected because of their specific experience with SWC activities. Moreover, the watersheds have diverse bio-physical and socio-economic characteristics (Table 6.2). The dominant farming system in the watersheds is characterized as crop-livestock mixed farming.

Table 6.2. Socio- and physical characteristics of the study watersheds

Features		Anjeni	Dijil	Debre Mewi
Size of watershed (ha)		113	936	523
Altitude (m.a.s.l)		2,450	2,480	2,300
Average annual rainfall (mm)		1,790	1,300	1,260
Dominant soil types		Alisols, Nitosols, Regosols, Leptisols	Nitosols	Vertic Nitosols, Nitosols and Vertisols
Degradation		Degraded	Very degraded	Not heavily degraded
Soil pH		5.7	4.3	6.7
Slope class	Flat to gentle (<10 %) (%)	30.5	13.9	19.7
	Medium (10-20%) (%)	28.6	41.4	41.9
	Steep (>20%) (%)	40.9	44.7	38.4
Dominant crop in farming systems		Barley	Oats	Tef
Productivity		Low	Low	High
Number of households		95	628	324
All weather road		Poor	Good	Good
Distance to district town (Km)		20	8	12

Sources: Liu et al., 2008; SCRP, 1991;Tesfaye, 2011; Zegeye, 2009.

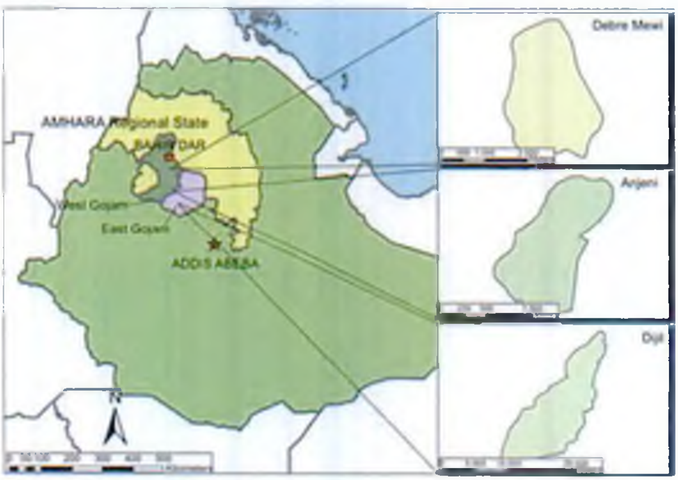

Figure 6.1. Map of study areas in Amhara regional state, Ethiopia

6.4.2 Data collection

Farmers and experts are the main stakeholders in SWC activities in Ethiopian highlands. Qualitative and quantitative data were collected from these stakeholders using group discussions and a formal survey in 2013. Two group discussions were undertaken in each watershed. The number of participants in each group ranged from 9-11 farmers. Group discussions were followed by an individual survey to cross-check the information. For this survey a total of 50 farm households (20 from Debre Mewi, 15 from Anjeni and 15 from Dijil) were carefully selected from an earlier much larger household survey[2]. In addition, 16 experts were interviewed from different levels of the Department of Agriculture (*kebele*[3], district, zone and region).

[2] These 50 farm households are part of large survey of households. This large survey included 60, 125 and 115 households from Anjeni, Dijil and Debre Mewi watersheds, respectively.

[3] *Kebele* is the lowest administrative body in Ethiopia. It is part of sub-district.

SWC alternatives and evaluation criteria were identified during the two previous surveys and group discussions (Teshome et al., 2014; Teshome et al., forthcoming). SWC alternatives and evaluation criteria were compiled and presented for discussions with farmers. During the group discussions, some SWC alternatives and criteria were dropped because these criteria were not very relevant, and the measures were not commonly practiced in the prevalent farming system (alternatives and criteria were fine-tuned during group discussions). For example, farmers in Anjeni dropped soil bunds since these were not important in their watershed. Then, weights were assigned through group consensus to the criteria dependent on different slope categories (steep, moderate, and gentle). This is because farmers mainly classify their parcels into three major categories, i.e., steep (*tedafat*), moderate (mekakelegna) and gentle (deledala/medama). A fixed point scoring technique is applied in this study (Hajkowicz et al., 2000). In this technique the decision maker is required to distribute a fixed number of points among the criteria. A higher point score indicates that the criterion has greater importance. Fixed point scoring is the most direct means of obtaining weighting information from the decision maker.

6.4.3 Soil and water conservation alternatives

SWC measures are part and the parcel of the farming system of the study areas. Almost all farmers perceived erosion problems and many of them also believed that SWC measures are profitable (Teshome et al., 2013). Thus, different SWC measures were introduced to avert erosion problems by government and non-government organizations in the study areas. Soil bunds, *Fanya juu* bunds and stone bunds are the major SWC measures that are widely implemented by farmers. Therefore, these three SWC measures and the "No measure" alternative were included in the evaluation.

Soil bunds

Soil bunds are embankments made from topsoil along a field's contour to control erosion (Figure 6.2). Soil bunds require less labour for construction compared to stone and *Fanya juu* bunds. This is because the excavated material from the ditch is thrown downhill rather than uphill, as is the case in the construction of *Fanya juu* bunds. However, soil bunds require more labour for maintenance than *Fanya juu* and stone bunds. The uphill ditches of the soil bund are much more affected by accumulated material (silt) and therefore require more labour to regularly excavate the ditches because farmers need to maintain the ditches for the evacuation of excess water. Grass is grown on the riser to stabilise the bunds. Soil bunds can be easily eroded by water during heavy rainfall in steep slope areas.

Fanya juu bunds

Fanya juu bunds are made by digging a trench and throwing the soil uphill to form an embankment (Figure 6.2). The *Fanya juu* bunds are more labour-intensive during construction since soil is moved uphill. It forms a terrace in a relatively short period of time. It also gives a chance to plant fodder or grass on the riser. But it has water logging problems.

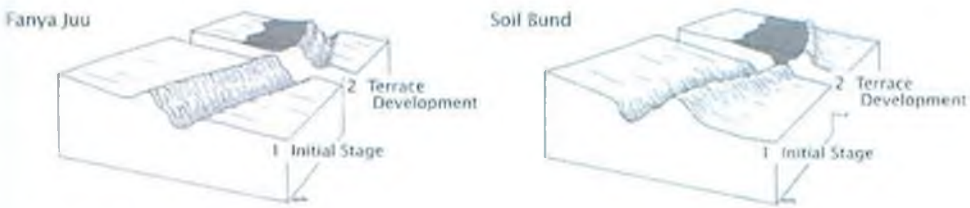

Figure 6.2. Different types of SWC measures. Left: Fanya juu, right: soil bund (Source: Haile et al. (2006))

Stone bunds

Stone bunds are usually constructed where stones are available on or near the field. Stone bunds are stable and durable measures. They also reduce runoff and soil erosion in the steep slope areas. Moreover, excess water can pass more easily through stone terraces. But it requires a large amount of labour for construction. It is also not convenient for ox-ploughing. Moreover, it can harbour rodents.

No measures

No measure is one of the options in the farmers' SWC investment decision making. This alternative would be preferred by farmers when SWC measures have minimal impacts (ecologically, economically and socially).

6.4.4 Data analysis

Data analysis included the ranking of the most important SWC alternatives and standardization of the effects. The average weight was taken in our analysis to accommodate the different views of the farmers and experts on the relative importance of each criterion. Farmers and experts evaluated SWC measures by giving scores to each criteria on the scale of 1 for worst and 4 for best (and 3 in case of Anjeni, where only three alternatives were considered). We used the mode (most typical value) to aggregate rankings of individual farmers and experts. Scoring of the alternatives were also calculated by averaging the scales to cross-check the results.

The Regime Analysis method was used to obtain the complete ranking and information on the relative importance between alternatives (Hinloopen and Nijkamp, 1990). The Regime Analysis method is one of the most common weighting methods, particularly in the case of qualitative data. This method is used to analyse ordinal and cardinal data. This method is based on pairwise comparison of two alternatives (i) according to criteria (j) (Hinloopen and Nijkamp, 1990).

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

$e_{ii'j}=1$ if $p_{ij}>p_{i'j}$ ....(1)

$e_{ii'j}=-1$ if $p_{ij}<p_{i'j}$ ....(2)

Where:

pij and pi'j are the ranks of alternatives i and i' according to criteria j. The regime vector (eii') for each pair of alternatives is then constructed by extending comparison of the alternatives i and i' to all criteria j = 1, 2, ... J as follows:

$e_{ii'}=(e_{ii',1}, e_{ii',2},...e_{ii',J})$ ....(3)

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:

$$p_{ii'}=\sum_{j=1}^{J} w_j * e_{ii',j} \qquad (4)$$

Where

wj =weight to criterion j

eii' =pairwise comparison of alternative i and i',

j=the criterion

6.5 Results

6.5.1 Major actors and their objectives

Soil erosion is one of the major agricultural constraints in the study areas. Erosion has adverse impacts on ecological, economic and social aspects of farming communities. Farmers evaluate these multiple effects of the problem in their SWC investment decisions. In our formal and informal surveys we found that the major objectives of farmers on SWC investments are ecological restoration (erosion control, enhance soil fertility and water retention), economic benefits (to increase production and decrease costs) and diminishing socially adverse effects of erosion and SWC measures. Similarly, the major objective of experts is to improve the livelihood of the farmers through comprehensive and integrated natural resource management and development.

6.5.2 Evaluation criteria and weights

Farmers and experts defined and used ten evaluation criteria to evaluate SWC measures (Table 6.3). These criteria are categorized into ecological criteria, economic criteria and social and other criteria.

Ecological criteria

Three criteria were identified for evaluating the ecological impacts of SWC alternatives. The criteria reveal that farmers would like SWC measures that are effective in erosion control, enhance soil fertility and improve water retention.

Economic criteria

Four criteria were mentioned to evaluate the economic impact of SWC alternatives. These evaluation criteria focus on the costs and benefits aspects of SWC alternatives.

Social and other criteria

Farmers in the study areas predominantly preferred SWC measures that have social benefits as well as measures that have no adverse effects on the farming system.

Table 6.3. Farmers'/experts' evaluation criteria of SWC measures

Objectives	Criteria	Unit of measurement
Ecological Impacts		
Erosion control **(C1)**	Minimize soil loss	Rank
Enhance soil fertility **(C2)**	Minimize nutrient loss	Rank
Water retention **(C3)**	Maximize water retention	Rank
Economic Impacts		
Crop yields **(C4)**	Maximize crop yields	Rank
Grass production **(C5)**	Maximize grass production	Rank
Labour requirements for establishment **(C6)**	Minimize labour for establishment	Rank
Maintenance costs **(C7)**	Minimize maintenance costs	Rank
Social and other Impacts		
Ox-ploughing convenience **(C8)**	Maximize ox-ploughing convenience	Rank
Risk of pest harbouring effect **(C9)**	Minimize risk of pest harbouring effect	Rank
Avoid dispute with adjacent farmers **(C10)**	Minimize dispute with adjacent farmers	Rank

Source: Own surveys

Farmers and experts gave weights for different evaluation criteria (Tables 6.4 and 6.5). The results show that farmers and experts gave different weights and that these vary by slope category. The ecological impact criteria were given the highest weights in the steep slope category. On the other hand, economic impact criteria got the highest weights in the gentle slope category. This illustrates that steeper slopes are more prone to erosion and that it is relatively more important to preserve them. The gentle plots, on the other hand, have generally a higher economic potential.

Farmers gave relatively high scores to the social and other impacts criteria of SWC measures compared to the experts. These criteria are: contributions of SWC measures to avoid disputes with adjacent farmers due to erosion, ox-ploughing convenience of the measures and the risk of pest harbouring effects of the measures. This shows that farmers pay more attention to everyday aspects of their lives while experts have larger scales than the field/farm, e.g. watershed level, in mind.

Anjeni farmers gave a higher weights for maximize crop yield, maximize ploughing convenience and minimize dispute with adjacent farmers as compared to other watersheds. This could be the long term soil and water conservation activities implemented during the watershed in the last three decades and thereby farmers perceived the benefits of conservation measures through time. Most of the *Fanya juu* bunds in Anjeni have stabilized into bench terraces. This results in a diminution of slope angles and increased topsoil depth behind the bunds, which has a positive effect on yields.

Table 6.4. Farmers' weight sets of evaluation criteria for each slope category in percentages.

Criteria	Steep Slope			Moderate slope			Gentle slope		
Watershed	D. Mewi	Anjeni	Dijil	D. Mewi	Anjeni	Dijil	D. Mewi	Anjeni	Dijil
Erosion control	30.0	31.0	30.0	20.0	18.0	22.5	7.7	5.0	5.5
Enhance fertility	16.6	14.0	16.0	12.3	9.0	12.5	7.0	6.0	13.5
Water retention	11.7	10.0	9.0	11.0	13.0	10.0	15.3	14.0	13.5
Crop yields	13.3	14.0	15.0	23.3	27.6	25.0	30.0	35.0	32.5
Grass production	7.7	6.6	7.5	5.3	3.8	3.5	3.3	3.2	2.5
Labour for establishment	3.0	3.1	2.25	8.0	5.8	5.0	13	10.1	7.5
Maintenance cost	2.7	3.3	2.75	5.0	5.8	4.0	8.7	8.7	7.5
Ploughing convenience	2.3	2.6	2.25	5.3	5.6	4.5	7.7	8.8	8.5
Pest harbouring effect	3.0	3.4	2.75	3.7	3.8	4.5	4.3	5.6	5.5
Dispute with adjacent farmers	9.7	12.0	12.5	6.0	7.6	8.5	3.0	3.6	3.5
Total (%)	100	100	100	100	100	100	100	100	100

Table 6.5. Experts' weight (%) sets of evaluation criteria for each slope category.

Criteria	Slope		
	Steep	Moderate	Gentle
Erosion control	30.4	21.4	10
Enhance fertility	15.7	14.1	9.9
Water retention	13.1	11.4	14.7
Crop yields	12.6	21.2	30.2
Grass production	9.5	8.1	5.5
Labour for establishment	3.5	7.1	10.9
Maintenance cost	3.9	6.1	7.5
Ploughing convenience	2.1	4.2	5.9
Pest harbouring effect	2.8	3.5	4.3
Dispute with adjacent farmers	5.9	2.9	1.1
Total (%)	100	100	100

6.5.3 *Farmers' and experts' multi-criteria ranking of the alternatives*

The results of farmers' and experts' ranking of SWC measures based on the evaluation criteria are presented in Tables 6.6, 6.7 and 6.8. The scores indicate the perceived level of importance of each SWC alternative with respect to the criteria defined.

Stone bunds are ranked first for erosion control in the steep slope category in the three watersheds by farmers and experts. In the moderate slope category, soil bunds are preferred by experts and farmers in Debre Mewi and Dijil watershed to control erosion. As mentioned earlier, soil bunds are not a common practice in Anjeni watershed. But farmers in Anjeni selected *Fanya juu* bunds to control erosion in the moderate slope category. In all watersheds, farmers gave priority to *Fanya juu* bunds to control erosion in gentle slope areas. In the same token, farmers' rankings of SWC alternatives for maximizing crop yield were highly correlated with degree of erosion control of the measures except for *Fanya juu* in Debre Mewi. Even though *Fanya juu* bunds were preferred to control erosion on gentle slopes, their contribution to increase yield was not ranked high probably due to the water logging effect of the measures in Debre Mewi.

Stone bunds were less preferred by farmers for their labour requirements for establishment, ploughing convenience and for minimizing the risk of pest harbouring effects across all watersheds and slope categories.

Soil bunds were next to "no measure" ranked first in minimizing labour requirements for establishment of SWC. On the other hand, it was ranked last in minimizing maintenance costs.

In general, farmers' preferences reflect their experiences, perceptions and attitudes about the merits and drawbacks of SWC alternatives under different situations.

Table 6.6. Farmers' ranking of SWC measures on the evaluation criteria for different slopes (4=Best, 1= Worst) : Debre Mewi and Dijil watersheds

Criteria	Slope	Watershed	Soil bund	*Fanya juu*	Stone bund	No measure
Minimize soil losses (erosion control)	Steep	Debre Mewi	3	2	4	1
		Dijil	3	2	4	1
	Moderate	Debre Mewi	4	2	3	1
		Dijil	4	3	2	1
	Gentle	Debre Mewi	3	4	2	1
		Dijil	3	4	2	1
Enhance soil fertility	Steep	Debre Mewi	3	2	4	1
		Dijil	3	2	4	1
	Moderate	Debre Mewi	4	3	2	1
		Dijil	3	4	2	1
	Gentle	Debre Mewi	3	4	2	1
		Dijil	3	4	2	1
Maximize water retention	Steep	Debre Mewi	4	3	2	1
		Dijil	4	2	3	1
	Moderate	D. Mewi	3	4	2	1
		Dijil	3	4	2	1
	Gentle	Debre Mewi	3	4	2	1
		Dijil	3	4	2	1
Maximize crop yields	Steep	Debre Mewi	3	2	4	1
		Dijil	3	2	4	1
	Moderate	Debre Mewi	4	3	2	1
		Dijil	3	4	2	1
	Gentle	D. Mewi	4	3	2	1
		Dijil	3	4	2	1
Maximize fodder (grass) production	Steep	Debre Mewi	3	4	1	1
		Dijil	3	4	1	1

	Moderate	Debre Mewi	3	4	1	1
		Dijil	3	4	1	1
	Gentle	Debre Mewi	3	4	1	1
		Dijil	3	4	1	1
Minimize labour requirement for establishment	Steep	Debre Mewi	3	2	1	4
		Dijil	3	2	1	4
	Moderate	Debre Mewi	3	2	1	4
		Dijil	3	2	1	4
	Gentle	Debre Mewi	3	2	1	4
		Dijil	3	2	1	4
Minimize maintenance costs	Steep	Debre Mewi	1	2	3	4
		Dijil	1	2	3	4
	Moderate	Debre Mewi	1	2	3	4
		Dijil	1	2	3	4
	Gentle	Debre Mewi	1	2	3	4
		Dijil	1	2	3	4
Maximize ox-ploughing convenience	Steep	Debre Mewi	3	2	1	4
		Dijil	3	2	1	4
	Moderate	Debre Mewi	3	2	1	4
		Dijil	3	2	1	4
	Gentle	Debre Mewi	3	2	1	4
		Dijil	3	2	1	4
Minimize risks of pest harbouring effect	Steep	Debre Mewi	2	3	1	4
		Dijil	3	2	1	4
	Moderate	Debre Mewi	2	3	1	4
		Dijil	3	2	1	4
	Gentle	Debre Mewi	2	3	1	4
		Dijil	3	2	1	4
Minimize dispute with adjacent farmers	Steep	Debre Mewi	3	2	4	1
		Dijil	3	2	4	1
	Moderate	Debre Mewi	4	3	3	1
		Dijil	4	3	2	1
	Gentle	Debre Mewi	4	3	2	1
		Dijil	3	4	2	1

Table 6.7. Farmers' ranking of SWC measures on the evaluation criteria for different slopes (3=Best, 1= Worst): Anjeni watershed

Criteria	Slope	*Fanya juu*	Stone bund	No measure
Minimize soil losses (erosion control)	Steep	2	3	1
	Moderate	3	2	1
	Gentle	3	2	1
Enhance soil fertility	Steep	2	3	1
	Moderate	3	2	1
	Gentle	3	2	1
Maximize water retention	Steep	3	2	1
	Moderate	3	2	1
	Gentle	3	2	1
Maximize crop yields	Steep	2	3	1
	Moderate	3	2	1
	Gentle	3	2	1
Maximize fodder (grass) production	Steep	3	1	1

	Moderate	3	1	1
	Gentle	3	1	1
Minimize labour requirement for establishment	Steep	2	1	3
	Moderate	2	1	3
	Gentle	2	1	3
Minimize maintenance costs	Steep	1	2	3
	Moderate	1	2	3
	Gentle	1	2	3
Maximize ox-ploughing convenience	Steep	2	1	3
	Moderate	2	1	3
	Gentle	2	1	3
Minimize risks of pest harbouring effect	Steep	2	1	3
	Moderate	2	1	3
	Gentle	2	1	3
Minimize dispute with adjacent farmers	Steep	2	3	1
	Moderate	3	2	1
	Gentle	3	2	1

Table 6.8. Experts' ranking of SWC measures on the evaluation criteria for different slopes (4=Best, 1= Worst)

Criteria	Slope	Soil bund	*Fanya juu*	Stone bund	No measure
Minimize soil losses (erosion control)	Steep	3	2	4	1
	Moderate	4	3	2	1
	Gentle	3	4	2	1
Enhance soil fertility	Steep	3	2	4	1
	Moderate	4	3	2	1
	Gentle	3	3	2	1
Maximize water retention	Steep	3	3	3	1
	Moderate	3	3	2	1
	Gentle	3	4	2	1
Maximize crop yields	Steep	3	2	4	1
	Moderate	4	3	2	1
	Gentle	3	4	2	1
Maximize fodder (grass) production	Steep	4	3	1	1
	Moderate	3	4	1	1
	Gentle	3	4	1	1
Minimize labour requirement for establishment	Steep	3	2	1	4
	Moderate	3	2	1	4
	Gentle	3	2	1	4
Minimize maintenance costs	Steep	2	2	3	4
	Moderate	2	2	3	4
	Gentle	2	2	3	4
Maximize ox-ploughing convenience	Steep	3	2	1	4
	Moderate	3	2	1	4
	Gentle	3	2	1	4
Minimize risks of pest harbouring effect	Steep	3	2	1	4
	Moderate	3	2	1	4
	Gentle	3	2	1	4
Minimize dispute with adjacent farmers	Steep	3	2	4	1
	Moderate	4	3	2	1
	Gentle	3	3	2	1

6.5.4 The evaluation matrix

The pairwise comparison of the SWC alternatives against the evaluation criteria is presented in Table 6.9. Pairwise comparisons refine a complex decision problem into a series of one-to-one judgments regarding the significance of each alternative relative to the criterion that it describes (Balana, et al., 2010). Each alternative under a criterion is compared with every other alternative under that criterion to evaluate its relative importance.

Table 6.9. Pairwise comparison of SWC measures based on evaluation criteria

Table 6.9a. In the Debre Mewi watershed

Regime	Steep slope										Moderate slope										Gentle slope									
vector	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
e-12	1	1	1	1	-1	1	-1	1	-1	1	1	1	-1	1	-1	1	-1	1	-1	1	-1	-1	-1	1	-1	1	-1	1	-1	1
e-13	-1	-1	1	-1	1	1	-1	1	1	-1	1	1	1	1	1	1	-1	1	1	1	1	1	1	1	1	1	-1	1	1	1
e-14	1	1	1	1	1	-1	-1	-1	-1	1	1	1	1	1	1	-1	-1	-1	-1	1	1	1	1	1	1	-1	-1	-1	-1	1
e-23	-1	-1	1	-1	1	1	-1	1	1	-1	-1	1	1	1	1	1	-1	1	1	0	1	1	1	1	1	1	-1	1	1	1
e-24	1	1	1	1	1	-1	-1	-1	-1	1	1	1	1	1	1	-1	-1	-1	-1	1	1	1	1	1	1	-1	-1	-1	-1	1
e-34	1	1	1	1	0	-1	-1	-1	-1	1	1	1	1	1	0	-1	-1	-1	-1	1	1	1	1	1	0	-1	-1	-1	-1	1

Table 6.9b. In the Anjeni watershed

Regime	Steep slope										Moderate slope										Gentle slope									
vector	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
e-12	-1	-1	1	-1	1	1	-1	1	1	-1	1	1	1	1	1	1	-1	1	1	1	1	1	1	1	1	1	-1	1	1	1
e-13	1	1	1	1	1	-1	-1	-1	-1	1	1	1	1	1	1	-1	-1	-1	-1	1	1	1	1	1	1	-1	-1	-1	-1	1
e-23	1	1	1	1	0	-1	-1	-1	-1	1	1	1	1	1	0	-1	-1	-1	-1	1	1	1	1	1	0	-1	-1	-1	-1	1

Table 6.9c. In the Dijil watershed

Regime	Steep slope										Moderate slope										Gentle slope									
vector	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
e-12	1	1	1	1	-1	1	-1	1	1	1	1	-1	-1	-1	-1	1	-1	1	1	1	-1	-1	-1	-1	-1	1	-1	1	1	-1
e-13	-1	-1	1	-1	1	1	-1	1	1	-1	1	1	1	1	1	1	-1	1	1	1	1	1	1	1	1	1	-1	1	1	1
e-14	1	1	1	1	1	-1	-1	-1	-1	1	1	1	1	1	1	-1	-1	-1	-1	1	1	1	1	1	1	-1	-1	-1	-1	1
e-23	-1	-1	-1	-1	1	1	-1	1	1	-1	1	1	1	1	1	1	-1	1	1	1	1	1	1	1	1	1	-1	1	1	1
e-24	1	1	1	1	1	-1	-1	-1	-1	1	1	1	1	1	1	-1	-1	-1	-1	1	1	1	1	1	1	-1	-1	-1	-1	1
e-34	1	1	1	1	0	-1	-1	-1	-1	1	1	1	1	1	0	-1	-1	-1	-1	1	1	1	1	1	0	-1	-1	-1	-1	1

Table 6.9d. By experts

Regime	Steep slope										Moderate slope										Gentle slope									
vector	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
e-12	1	1	0	-1	1	1	0	1	1	-1	1	1	0	1	-1	1	0	1	1	-1	-1	0	-1	-1	-1	1	0	1	1	0
e-13	-1	-1	0	1	-1	1	-1	1	1	1	1	1	1	1	1	1	-1	1	1	1	1	1	1	1	1	1	-1	1	1	1
e-14	1	1	1	1	1	-1	-1	-1	-1	1	1	1	1	1	1	-1	-1	-1	-1	1	1	1	1	1	1	-1	-1	-1	-1	1
e-23	-1	-1	0	1	-1	1	-1	1	1	1	1	1	1	1	1	1	-1	1	1	1	1	1	1	1	1	1	-1	1	1	1
e-24	1	1	1	1	1	-1	-1	-1	-1	1	1	1	1	1	1	-1	-1	-1	-1	1	1	1	1	1	1	-1	-1	-1	-1	1
e-34	1	1	1	1	0	-1	-1	-1	-1	1	1	1	1	1	0	-1	-1	-1	-1	1	1	1	1	1	0	-1	-1	-1	-1	1

6.5.5 Ranking of the alternatives

The weighted scores (p) of the pairwise comparisons and overall rank of the alternatives for each slope category are given in Tables 6.10 and 6.11. The higher the evaluation score is, the better is the performance of the SWC alternative. The evaluation score of each alternative pair in descending order gives the selection of the SWC measure from best to worst performing category.

Steep slope category

In steep slope areas, stone bunds are the best viable SWC alternative in all watershed areas and followed by soil bunds. Stone bunds are durable and stable to control high runoff in steep areas. Other measures are easily eroded by runoff. Stone bunds are also the first alternative for experts. Farmers and experts prefer *Fanya juu* as the least alternative next to "No measures" in steep slope areas. This is because high runoff easily breaks this structure. This shows that the main objective of farmers in steep areas is to control erosion. This is the reason farmers prefer the stone bund measure on steep slopes.

Moderate slope category

Soil bunds are the best alternative for farmers (Debre Mewi) and experts in moderate slope areas. But the *Fanya juu* alternative stands first in moderate slope areas for Dijil and Anjeni areas. Erosion problems are not very severe on moderate slopes and thereby it can be averted by soil embankments. Farmers' weight sets of evaluation criteria indicates that increasing yields is the main objective of farmers on moderate slopes (Table 6.4).

Gentle slope category

Fanya juu bunds come out to be the most preferred alternative on plots with gentle slopes in Dijil and Anjeni but not in Debre Mewi watershed. Similar to the moderate slope category, farmers invest on SWC in gentle slope areas to increase production and productivity and thus realise a higher profitability of the practice. Farmers of Debre Mewi preferred soil bunds for moderate and gentle slopes categories due to their long time experience with soil bunds.

Table 6.10. The weighted scores of the pairwise comparisons and overall rank (Rk) of the alternatives for each slope category, by watershed and for farmers and experts

	Ranking by farmers						Ranking by experts			Ranking by farmers		
	Debre Mewi watershed			Dijil watershed			All watersheds			Anjeni watershed		
R.S	S	M	G	S	M	G	S	M	G	S	M	G
p12	73.2	49.9	7.4	79.5	-10.0	-57.0	45.5	60.5	-39.3	**-48.6**	**88.4**	**82.6**
	-							87.8	85			
p13	44.6	89.9	82.6	-52.5	92.0	85.0	- 32.6			75.2	58.0	33.6
p14	78.0	55.9	32.6	80.0	64	42.0	74.9	58.2	42.8	68.6	54.2	30.4
	-							87.8	85			
p23	44.6	43.9	82.6	-70.5	70.5	70.5	- 32.6					
p24	78.0	55.9	32.6	80.0	64	42.0	74.9	58.2	42.8			
p34	70.3	50.6	29.3	72.5	60.5	39.5	65.4	50.1	37.3			
Rk	3>1>2>4	1>2>3>4	1>2>3>4	3>1>2>4	2>1>3>4	2>1>3>4	3>1>2>4	1>2>3>4	2>1>3>4	2>1>3	1>2>3	1>2>3

Table 6.11. MCA ranking of the SWC measures by farmers and experts

Watershed	Slope	Ranking
Ranking by farmers		
Debre Mewi	Steep	Stone bunds>Soil bunds >*Fanya juu*>No measure
	Moderate	Soil bunds>*Fanya juu*>Stone bunds> No measure
	Gentle	Soil bunds>*Fanya juu*>Stone bunds> No measure
Anjeni	Steep	Stone bunds>*Fanya juu*> No measure
	Moderate	*Fanya juu*> Stone bunds> No measure
	Gentle	*Fanya juu*> Stone bunds> No measure
Dijil	Steep	Stone bunds>Soil bunds>*Fanya juu*> No measure
	Moderate	*Fanya juu*>Soil bund>Stone bund> No measure
	Gentle	*Fanya juu*>Soil bund>Stone bund> No measure
Ranking by experts		
All watersheds	Steep	Stone bund>Soil bund >*Fanya juu*> No measure
	Moderate	Soil bund>*Fanya juu*>Stone bund> No measure
	Gentle	*Fanya juu*> Soil bund>Stone bund> No measure

6.6 Discussion

It is interesting to look at the differences between the weight sets of farmers and those of experts. While farmers in the three watersheds give social and other criteria on all three slope categories a weight of about 17 %, this is only 11 % among experts. The latter underestimate the issues of ease of ploughing, pest harbouring effects and disputes. The experts on the other hand attach higher weights to the three ecological criteria and to the earnings from the grass production, aspects which they focus on in their extension messages. This is in line with the finding of Tenge (2005). While farmers attach higher weights than experts to the crop production.

The results of the analysis also illustrate that farmers often stick to the practices that they are more familiar with. In Debre Mewi farmers on moderate and gentle slopes prefer soil bunds above *Fanya juu*, since they have become accustomed to soil bunds and not (yet) to *Fanya juu*. In Anjeni and (to a less extent) Digil farmers have already a long experience with *Fanya juu* and therefore prefer those on moderate and gentle slopes. It is interesting to note that among experts there is one favourite measure for each slope category: stone bunds for steep slopes, soil bunds for moderate slopes and *Fanya juu* for gentle slopes. But experts should still look at each particular situation and do not come up with rigid guidelines.

This study showed that farmers take into account ecological, economic, social and other impacts of the SWC when they select SWC practice to meet their multiple objectives. This shows that the adoption of SWC practices by farmers is not only based on economic or monetary values as usually demonstrated through cost-benefits analyses. This result is in line with the findings of Tenge (2005) and Amsalu (2006). This implies that SWC practices that fulfil both economic and other considerations of farmers can contribute to the continued adoption of SWC.

This study revealed that SWC practices have ecological, economic and social benefits. But SWC practices are mostly evaluated by CBA. These practices are sometimes not profitable from a private-economic point of view (Adimassu et al., 2012; Kassie et al., 2011). This is because the ecological and social benefits of SWC practices are not quantified in monetary values. Thus, holistic evaluation methods (e.g. MCA) are important to evaluate the overall benefits of SWC practices. Moreover, MCA accommodates diverse views, interests, preferences, and expertise of stakeholders (Balana et al., 2010).

As mentioned in Section 6.2, MCA with ordinal data does not incorporate the time dimension of costs and benefits, which is pertinent for SWC measures that need a long time for benefits to be realised.

The time dimension of SWC can be incorporated in MCA through the use of an efficiency criteria of CBA. The following describes an example.

In a cost-benefit analysis for a standard slope of 10 %, an assumed lifetime of the measures of 20 years and a 12.5 % discount rate, it was found that in Debre Mewi soil bunds (with grassed risers) and stone bunds had a Net Present Value (NPV) of 1819 and 1265 EtB ha^{-1} over 20 years respectively (1 EtB = 0.056 Dollar in 2013). Since *Fanya Juu* was only recently introduced in that watershed, it was not taken into account. In Anjeni watershed soil bunds (rare in this watershed), *Fanya juu* (both with grassed risers) and stone bunds scored a NPV of 1902, 2718 and 2217 EtB ha^{-1}, respectively (Teshome et al., 2013). Since these detailed calculations were only made for the most common slopes of 10%, these results can here only be used for the moderate slope category, and only for two watersheds and three alternatives. This information on financial efficiency (expressed by NPV) was subsequently used for the economic impact in the Regime Analysis (replacing the four separate cost and benefit criteria). The information on the other (ecological and social/other) evaluation criteria remained the same. The results of this analysis show the same ranking as in the previous analysis for the moderate slopes in the two watersheds: soil bunds better than stone bunds in Debre Mewi watershed and *Fanya juu* better than stone bunds in Anjeni watershed. The measures were in both cases better than no measure.

6.7 Conclusions

We evaluated different SWC practices in the north-western highlands of Ethiopia using MCA to assess their ecological, economic and social impacts. The study reveals that MCA is an effective evaluation tool that can take into account non- monetary and less quantifiable effects of SWC measures, which is not possible with Cost Benefit Analysis.

The results of the analysis indicate that farmers in the north-western highlands of Ethiopia have a range of criteria to evaluate the performance of SWC measures. The relative importance of each criterion in the selection of SWC alternatives depends to a large extent on slope categories. Farmers in the study areas give the highest score for criteria related to ecological impacts in steep slope areas, and they prefer the alternatives with stronger positive economic impacts in moderate and gentle sloping areas. In line with this, stone bunds are the best SWC alternative on steep slopes in all watersheds. *Fanya juu* bunds are the most preferred alternative on plots with gentle slopes in Dijil and Anjeni watersheds. This indicates that SWC alternatives must be promoted based on farmers' preferences and specific agro-ecological conditions such as slope. Thus in order to facilitate the adoption of SWC practices, a blanket recommendation approach must be avoided. The extension service should deliver a basket of choice of SWC alternatives for the needy farmers to pick appropriate alternatives depending on their preferences and plot situations. In addition, the Research-Extension-Famers linkage must be strengthened in order to identify and disseminate appropriate technologies based on farmers' needs and preferences. To conclude, policy makers and development practitioners should pay much attention to the farmers' preferences and particular circumstances (e.g. slope) in designing SWC strategies and programmes.

Chapter 7

Synthesis

Synthesis

7.1 Introduction

Economy, environment and society are the three major interconnected drivers of sustainable development (Giddings et al., 2002). Building harmony between them is of paramount importance in order to bring sustainable development, especially in the Ethiopian highlands.

Farmers in the highlands of Ethiopia need to produce more food in order to keep pace with the country's growing population. However, the Ethiopian highlands agricultural potential and the country's food security are threatened by land degradation. Soil erosion by water is the major bottleneck to agricultural development and food security. To alleviate these problems, different land management (LM) practices have been promoted by government and non-government organisations in the last four decades. Nonetheless, the adoption rate of these LM practices varies considerably within Ethiopia (Adgo et al., 2013; Tefera and Sterk, 2010, Bewket, 2007, Shiferaw and Holden, 1999) because investments in LM practices are influenced by various institutional, socio-economic and bio-physical factors (Adimassu et al., 2012; Shiferaw et al., 2009; Ervin and Ervin, 1982).

The main objective of this study was to explore the incentives and constraints of LM investments in the north-western Ethiopian highlands to enable the design of promising pro-poor interventions that could enhance the adoption and impacts of LM practices. The following research questions were addressed:

1. What are the main institutional, socio-economic and bio-physical drivers for the different stages of adoption of soil and water conservation (SWC[1]) practices?
2. What are the on-site costs of soil erosion and benefits of SWC practices?
3. What is the influence of land quality, land fragmentation and tenure systems on interrelated LM investments?
4. What is the relationship between the different dimensions of social capital and investments in LM practices?
5. What are the evaluation criteria of farmers and experts for different SWC alternatives?

To understand the complexity of LM adoption/investment decisions in the highlands of Ethiopia, a combination of institutional, socio-economic and bio-physical factors were analysed simultaneously. Some innovative approaches were used to answer some of the above-mentioned research questions:

- Analysis of the respective adoption phases rather than considering only the two categories, adoption and non-adoption;
- Comprehensive profitability analysis (soil loss estimation followed by perception of farmers about profitability of SWC practices, and then cost-benefit analysis);
- Examination of interrelated LM investment decisions rather than focusing on a single practice;
- Use of NPV as an efficiency criterion in MCA.

7.2 Brief answers to research questions

7.2.1 What are the drivers for the different stages of adoption of SWC practices?

Adoption of soil and water conservation (SWC) passes through four major phases: non-adoption/dis-adoption, initial adoption, actual adoption and final adoption. Some socio-economic and institutional factors have a different effect on the respective SWC adoption phases. Final adoption depends mostly on

[1] "SWC" and "LM" are used interchangeably, although SWC generally has a narrower meaning than LM. SWC is limited to line interventions such as stone bunds, soil bunds and Fanya juu bunds; whereas LM, in addition to bunds, also includes compost, chemical fertiliser, etc.

profitability, land-related factors, social capital and personal preferences. Specifically perceived erosion problems and profitability of SWC are important factors for the continued adoption of SWC. The next question would therefore concern the cost of soil erosion and the profitability of SWC practices.

7.2.2 What are the on-site costs of soil erosion and benefits of SWC investments?

SWC practices (Soil bunds, *Fanya juu* bunds and stone bunds) were effective in controlling soil erosion, though the profitability of these SWC methods was dependent on the site where they were used. *Fanya juu* and stone bunds are generally profitable under standard conditions (e.g. medium slope and average soil quality and labour costs). The next issue would then be where farmers invest in LM practices in relation to land-related factors.

7.2.3 What are the influences of land-related factors on interrelated LM investments?

Investments in LM practices are interdependent. For example, compost/manure and fertiliser are to a certain extent substitutions for each other (often not used together, or used interchangeably by farmers) in the farming system of the study areas. Land quality (e.g. slope and soil fertility status), land fragmentation (parcel size and distance of parcel from homestead) and tenure arrangements influence farmers' investments in LM practices. This leads to the question of how much farmers' investments are influenced by other factors, such as social capital.

7.2.4 What is the relationship between the different dimensions of social capital and investments in LM practices?

The different dimensions of social capital affect LM practices differently. In particular, the cooperation and trust dimensions of social capital are associated with the intensity of investment in SWC bunds and fertiliser use. The extent of participation in formal institutions has a positive effect on the use of fertiliser and compost. The next step would then be to identify farmers' evaluation criteria of SWC practices.

7.2.5 What are the evaluation criteria of farmers and experts for different SWC alternatives?

Farmers have a range of criteria to evaluate the performance of SWC practices. These criteria could be of an ecological, economic or social nature. However, the relative importance of each criterion in the selection of SWC alternatives depends a great deal on slope categories.

7.3 Emerging issues

7.3.1 Profitability and adoption of SWC

Economic factors either enhance or constrain farmers' investment in erosion control practices (Ervin and Ervin, 1982). In chapter 2, it was concluded that farmers' perceived erosion and the profitability of SWC are important factors for the continued adoption of SWC practices. Consequently, on-site costs of soil erosion and benefits of SWC practices were investigated (Chapter 3). Results from application of the Universal Soil Loss Equation (USLE) revealed that soil erosion rates on unprotected fields in Debre Mewi and Anjeni watersheds were 65 t ha^{-1} y^{-1} and 120 t ha^{-1} y^{-1}, respectively, indicating that both watersheds suffer considerably from soil erosion. A Cost-Benefit Analysis (CBA) shows that *Fanya juu* and stone bunds are generally profitable under standard conditions (e.g. medium slope and average soil quality and labour costs), but the profitability of soil and water conservation practices is very volatile. Different underlying assumptions change the CBA results considerably and consequently also change the conclusions regarding the circumstances under which SWC practices are or are not profitable. For example, when the assumption about the yield increases in the with-SWC case is increased from 10% to 20%, the NPV changes from 1276 to 4186 EtB ha^{-1} in the case of soil bunds in the Debre Mewi watershed. This shows that intensification of agricultural production can sharply increase profitability of SWC practices. In addition, profitability of soil bunds improves through grass planting (Chapter 3). Farmers also prefer the SWC alternatives with stronger positive economic impacts on moderate and gentle slopes (Chapter 6). The above findings underscore the fact that profitability of SWC practices is a central issue for continued adoption of SWC practices.

7.3.2 Influence of land-related factors on LM investments

Land quality is an important factor that affects investment in LM practices (Chapter 4). Specifically, the slope of the parcel is related to the decision in favour of bund investments and continued adoption of SWC practices (Chapters 2 and 4). Moreover, slope category is very important for farmers in selecting soil and water conservation alternatives (Chapter 6). Similarly, compost/manure is applied specifically to low and medium fertile soils to improve the soil fertility status (Chapter 4). This indicates that farmers select various LM practices based on the specific quality of their parcels.

The current level of farm fragmentation is very high and it affects LM investments (Chapter 4). Average parcel size influences the final adoption of SWC practices (Chapter 2). Parcel size particularly influences investments in bunds, compost and fertiliser (Chapter 4). Investments in compost/manure are inversely related to distance of parcels from farmers' homesteads. This indicates that the current level of farm fragmentation hinders sustainable intensification of smallholder agriculture. On the other hand, farmers prefer, to some extent, fragmented land, with different types of parcels, to minimise agricultural production risks. This shows that land fragmentation can be both a blessing and a curse for smallholder farmers in the highlands of Ethiopia.

In Chapter 4, we identified three main tenure arrangements: ownership, sharecropping and rental arrangements. Parcel ownership has a positive effect on the decision to invest in bunds and compost/manure. On the other hand, chemical fertiliser application is not negatively affected by sharecropping/renting tenure arrangements (Chapter 4). Moreover, tenure security is very important for the continued adoption of SWC practices (Chapter 2). On the other hand, a land certificate provides tenure security and thereby increases long-term LM (Chapter 4).

The results of the different chapters described above indicate that farm land attributes promote or hinder investments, while tenure systems regulate the decisions about investments in land management.

7.3.3 Social capital and SWC investment

Even though SWC practices are profitable, this does not guarantee their adoption, as other factors hinder farm households from investing in them (Posthumus, 2005). One of the factors is the availability of social capital. In Chapter 4, six major social capital dimensions were identified: cooperation and trust, linking social capital, bonding and bridging social capital, participation in formal association, enforcement, and participation in informal association. Some dimensions of this social capital differ across the watersheds and affect the LM practices differently. For example, cooperation and trust aspects of social capital influence investment in bunds and fertilisers (Chapter 5). Specifically, cooperation with adjacent farm owners is a key factor for the continued adoption of SWC (Chapter 2). This highlights the social components of SWC practices and the fact that investment in bunds is a cooperation-demanding technology. Furthermore, farmers prefer the mass mobilisation — embodying social capital — approach to implementing SWC practices, mainly due to its holistic effects for solving erosion problems at the watershed level. This mass mobilisation approach enhances social capital. Participation in formal institutions influences compost and fertiliser use (Chapter 5). Formal institutions (e.g. extension services) at the grass-roots level encourage and support rural farmers in the use of such improved technologies as compost. Similarly, farmers get access to credit and information about the optimal use of fertiliser from formal institutes. Overall, the LM investment has some social components.

7.3.4 Farmers' perceptions and preferences about SWC measures

For continued adoption of SWC practices, farmers need to perceive the economic significance of the erosion problems and the profitability of SWC. This finding was verified in Chapter 2. In addition, farmers take into account ecological, social and other impacts of the SWC practices when they select one of the existing SWC alternatives (Chapter 6). In line with this, farmers give the highest score for criteria related to ecological impacts in steep sloping areas, and they prefer the alternatives with stronger positive economic impacts on moderate and gentle slopes. As compared to the experts, farmers give relatively high scores to the social impacts criteria of SWC practices. The MCA shows that experts prefer stone bunds on steeper slopes, soil bunds on moderate slopes and *Fanya juu* on gentle slopes. Farmers agree to a large extent, but their preference also strongly depends on the extent to which they are already very familiar with the SWC measure. This shows that farmers need to perceive the ecological suitability, physical effectiveness, financial efficiency and social acceptability of the SWC practices for continued adoption of SWC practices.

7.3.5 Technical support and resource endowments and LM investments

One of the findings of this study concerns the positive impact of the programmes/projects on the continued adoption of SWC (Chapter 2). For example, almost all the farmers in Anjeni watershed are final adopters of SWC practices. This is thanks to the impact of the long-term soil and water conservation intervention in the area. In addition, the level of adoption of LM practices is also very high in the project intervention watersheds (Chapter 5). Moreover, training in SWC activities is very important for the final adoption phases of SWC (Chapter 2). For instance, the extent of participation in formal institutions has a positive effect on the amount of compost used, because compost is a knowledge-demanding technology (Chapter 5). Thus, investments in LM require technical know-how support from various organisations. Moreover, ownership of tools (e.g. shovels) and the amount of farm labour as a resource are very important for the final adoption phases of SWC (Chapters 2 and 5). Conservation tools are a prerequisite for construction and maintenance of SWC practices. Labour inputs constitute the largest cost factor for SWC line interventions (Chapter 3). This implies that technical support and resource endowments (tools and labour for SWC practices) are pertinent for farmers, to increase their investment capacity and know-how in order to facilitate the adoption process.

7.4 Reflections

7.4.1 Intensification of SWC practices

Studies confirm that profitability of SWC practices is one of the major factors for their adoption (Amsalu and de Graaff, 2007; Cary and Wilkinson, 1997). The construction of bunds does not per se increase output and net returns (Faltermeier and Abdulai, 2009). The construction of bunds takes land out of production, which is (often) not compensated by the increased productivity of the remaining area (Hengsdijk, et al., 2005). However, combining SWC measures with available nutrient inputs increases crop productivity and leads to higher economic benefits (Zougmore et al., 2004).

Some studies in the highlands of Ethiopia indicate that investments in SWC are not profitable. For example, soil bunds in central highlands of Ethiopia reduced annual runoffs by 28% and the annual soil loss by 47% on average. However, despite these positive effects for controlling soil erosion, the soil bunds were found to reduce crop yields by about 7% compared to the control plots. The reduction in crop productivity was attributed to reduction in cultivated area by about 8.6% because of the constructed soil bunds (Adimassu et al., 2012). Similarly, Kassie et al. (2011) investigated the impact of *Fanya juu* bunds on crop productivity and found a significantly negative effect. This shows that bunds need to be supplemented with biological and agronomic land management measures to increase productivity. The results in Chapter 3 indicates that SWC measures should be accompanied by an intensification of production on the remaining area and supplemented by planting additional high-value fodder crops on the bunds. Without these steps, SWC measures are unprofitable and the adoption rate and positive impacts of SWC are relatively low. However, because an intensification of production requires additional inputs such as improved seed and fertiliser (Abdoulaye and Lowenberg-DeBoer, 2000), there is a need to improve farmers' access to credit. It is therefore concluded that SWC can be profitable when production is intensified and supplemented with additional inputs. Policymakers and extension personnel should pay attention not only to the physical effectiveness for controlling erosion, but also to the financial viability of established bunds.

7.4.2 *Land fragmentation and tenure arrangements on LM investments*

Land-related factors play a major role in the decision of farmers of "where" to invest in LM practices (Chapters 2, 4, 5). Specifically, land fragmentation has a negative effect on LM investments (Sklenicka et al., 2014; Niroula and Thapa, 2005; Burton, 1988). This is because it increases the transaction cost for investments (Gebremedhin and Swinton, 2003). Consequently, land fragmentation has indirect effects on crop yields and land quality (Tan, 2005). In Chapter 4 we found that the current level of farm fragmentation is very high and that it affects LM investments, yet farmers prefer, to some extent, fragmented land in order to minimise risks. Particularly investment decisions involving bunds, compost/manure and fertiliser are influenced by parcel size. The distance of a parcel from home also has a negative effect on investment in compost and manure. This shows that "small" and "dispersed" parcels can be major constraints for LM investments. In addition, it is high time to think in advance about the challenges of land fragmentation for mechanised farming ("tractorisation") and agricultural transformation in the highlands of Ethiopia.

It is widely claimed that investments in productivity-enhancing and conservation techniques are influenced by land tenure arrangements (Abdulai et al., 2011). This is because farmers consider tenure implications when making investments (Place and Otsuka, 2002). Unenforceable, ill-defined and insecure use rights are linked with poor land use, which in turn leads to environmental degradation (Lapar and Pandey, 1999; Otsuka and Place, 2001). In particular, farmers who own land with secure tenure invest in long-term LM practices (e.g. tree planting, mulch, manure), but not necessarily in short-term measures like mineral fertiliser. Farmers on fixed-rent and sharecropping contracts were found to be less likely to attract investments in soil-improving measures (e.g. organic manure), but do invest in yield-increasing inputs such as mineral fertilisers (Abdulai et al., 2011). We confirmed these findings and found a significant positive effect of parcel ownership on bunds and on investment in compost and manure (Chapter 4). The current land rental market (sharing and renting) is not supported by any legal institution except long-term leasing. Thus, tenure arrangements, specifically sharing and renting, should have legal backing to support long-term LM investments. On the other hand, the existence of sharecropping and renting improves the efficiency of production factors, reduces inequality in land holdings, and shifts the income position of participating households (Teklu and Lemi, 2004).

In conclusion, land fragmentation and tenure arrangements influence farmers' decisions with regard to long-term land management practices. Investments in long-term practices yield public and intergenerational benefits. Thus, the issue of fragmentation and tenure arrangements should not only be seen from an individual farmer's point of view.

7.4.3 *Promoting collective action for SWC at watershed level*

The findings in Chapter 4 support the growing scientific consensus that social capital matters in SWC investment decisions. Chapters 2 and 4 revealed that construction of bunds is a cooperation-demanding technology. We thus conclude that collective action at watershed level is important to combat land degradation in the highlands of Ethiopia. This is because erosion problems in the highlands of Ethiopia are currently only addressed in the watershed context, since there is a strong physical interdependence between upstream and downstream areas (Bewket and Sterk, 2003). Moreover, collective action is a fundamental pillar of watershed-level natural resource management and it enhances farmer participation (Coleman, 1988; German and Taye, 2008). Social capital facilitates participation in collective action initiatives, which then influence individual soil conservation efforts (Willy and Holm-Müller, 2013). Our results indicate that farmers prefer the mass mobilisation approach (which embodies social capital) to implementing SWC practices, mainly due to its holistic effects for solving the erosion problem at watershed level. Excessive surface runoff and soil erosion in the upper Blue Nile Basin has enormous off-site impacts such as siltation of various water harvesting structures and lakes. It is also a big challenge for the newly constructed Grand Ethiopian Renaissance Dam. Thus combatting land degradation in the highlands of Ethiopia, through collective action at watershed level, is of paramount importance for food security, energy autarky and economic development. But there is a need to integrate SWC activities with the improvements of farmer livelihoods.

7.4.4 Understanding farmers/Farmer first/Working with farmers

From this thesis we learnt that farmers' perceptions and preferences about SWC practices are very important for the adoption of SWC measures. This is because a decision-making process could be enhanced or impeded partly by perceived characteristics of the technologies, such as observability, compatibility and relative advantage (Rogers, 1983). Farmers' participation in promotional activities of SWC programmes influences the adoption decision process of SWC (Mbaga-Semgalawe, 2000). But farmers only participate in SWC activities if their preferences are considered and the effects of SWC are perceived (Bewket, 2013).

We identified that farmers evaluate SWC practices in a holistic way by taking into account ecological, economic, and social and other benefits (Chapter 6). Enhancing the adoption and impacts of LM practices in the highlands of Ethiopia requires the promotion of farmer participation in order to capitalize on farmers' preferences. Thus the current mass mobilisation for the construction of SWC measures must take into consideration the preference of farmers.

7.4.5 Enhancing the capacity and capability of farmers

Technical support and resource endowments are among the most important factors that determine investments in land management (Chapters 2, 4 and 5). Furthermore, initial investments in some land management practices (e.g. soil/stone bunds) require relatively heavy investment costs beyond the capacity of farmers (Chapter 3; Shiferaw and Holden, 2001). Therefore, arranging continuous training, providing hand tools, and strengthening the different groups of mass mobilisation (development group and "One to Five work team") are important for enhancing the adoption and impacts of land management. Given farmers' resource limitations and lack of skill, and the high initial investment costs of LM practices, bringing tangible impact on LM by farmers is doubtful, unless more support is obtained from government and non-government organisations. Due to public as well as private benefits of SWC, it is also justifiable to provide technical and resource support for subsistence farmers. Therefore, government and non-government organisations should focus on how to improve farmers' capacity to invest in LM.

7.4.6 State-farmer relationship

The findings of this research and previous literature indicate that institutional, socio-economic and bio-physical factors affect farmers' investments in land management. The political-ecological interest of the state is also of paramount importance for investment in land management. The role of the state in land management is crucial in Ethiopia due to failure of social capital (low social capital), presence of externalities, and low awareness about the problem of land degradation. A committed state is needed in order to mobilise the community to avert land degradation. However, populist and neo-liberal approaches advocate an anti-state position in land management (Biot et al., 1995; Blaikie, 2000). In line with this, large parts of land in Ethiopia are covered with SWC due to the commitment of the state to natural resource management. In the last two years, through public mobilisation, more than 13.7 million hectares of land have been covered with SWC practices. In terms of money, this is estimated to be nearly ETB 10.2 billion — a huge mobilisation of resources. But the state needs to empower the community to move from participation to community responsibility. The state is viewed, therefore, as a "backseat driver".

7.5 Contributions to Science

We conceptualised the adoption/investment behaviour for LM as a decision-making process in different (adoption) phases which are influenced by institutional, socio-economic and bio-physical factors. The study showed that many factors at different spatial levels influence farmers' investment behaviour in LM practices. Final adoption depends mostly on profitability, land-related factors, social capital and personal preferences. Previous LM adoption studies (e.g. Tesfaye et al., 2013; Amsalu and de Graaff, 2007; Asfaw and Admassie, 2004; Bekele and Drake, 2003; Kassie et al., 2008) did not thoroughly investigate the connection between profitability, land fragmentation, land tenure arrangements, social capital and the adoption of LM practices.

7.5.1 *Adoption/investment analysis method of LM*

This scientific study contributes to the adoption literature by identifying four major adoption phases in the adoption process of the new technologies: non-adoption/dis-adoption, initial adoption, actual adoption and final adoption. Thus future adoption studies should not only focus on the classic comparison between adopter and non-adopter categories but rather investigate the adoption process of SWC measures at different phases of adoption.

The thesis also gives a new insight into the interdependence between different LM investment decisions. Previous LM adoption studies (e.g. Tesfaye et al., 2013; Kassie et al., 2008; Amsalu and de Graaff, 2007; Asfaw and Admassie, 2004; Bekele and Drake, 2003) mainly focus on analysing the adoption of one component or a single LM practice, which fails to consider complementary and/or substitution effects among different LM practices. In most cases, farmers adopt a combination of practices to cope with multiple agricultural production constraints.

7.5.2 *Evaluation method of SWC*

The findings of this thesis have brought to the fore that holistic evaluation methods for SWC measures are important for quantifying the monetary and non-monetary value of SWC. In this regard, we confirmed that MCA is a very helpful evaluation tool that takes into account non-monetary and less quantifiable effects of SWC measures. In this thesis, a cost-benefit analysis (CBA) is carried out to determine the profitability of the SWC practices under different conditions. Then the time dimension of SWC is incorporated in MCA through the use of an efficiency criterion of CBA (using NPV as an efficiency criterion in MCA).

One of the contributions of this thesis is to put forth a comprehensive method of profitability analysis for SWC. At the outset, the influence of perceived profitability of SWC on the continued adoption of SWC practices is analysed. This analysis is followed by a detailed Cost-Benefit Analysis. The thesis showed that farmers' perceived profitability of SWC practices can contribute to the continued adoption of SWC. The CBA also showed that SWC practices are generally profitable in the north-western highlands of Ethiopia.

We found that farmers use ecological suitability, physical effectiveness, financial efficiency and social acceptability as criteria to evaluate the performance of SWC measures. However, the relative importance of each criterion in the selection of SWC alternatives depends to a large extent on slope categories. Farmers prefer those SWC alternatives with higher economic impacts in moderate and gentle slopes areas.

7.5.3 *Land-related factors*

The thesis sheds light on the relationships between land quality (e.g. fertility and slope), land fragmentation, tenure arrangements and LM investments using multiple parcel-level observations. The thesis shows that land fragmentation can hinder farmers' investment decisions regarding LM practices. Three major types of land tenure arrangements are found in the highlands of Ethiopia: ownership, sharing and renting. However, previous studies (Teshome, 2014; Deininger et al., 2011; Holden et al., 2009) mostly studied the influence of tenure security and land certification on SWC adoption/investments. They did not give much attention to tenure arrangements. This thesis has attested that sharing and renting arrangements form major constraints to long term LM investments (Chapter 4).

7.5.4 *Importance of social capital*

The thesis has contributed to the way in which the social capital variables are analysed in adoption studies. Most previous investment/adoption studies in Ethiopia and elsewhere have investigated social capital only in terms of participation in formal and informal institutions. By contrast, this thesis identified and used six major social capital dimensions as variables in the analysis of adoption behaviour/decisions.

The thesis demonstrates the social components of LM practices and the relations between social capital and LM investments. Specifically, cooperation between adjacent farm owners can facilitate investment in bunds. The thesis also shows that the present mass mobilisation approach (which embodies social capital) is important to promote SWC practices in the highlands of Ethiopia to combat the erosion problem at watershed level.

This thesis has contributed to the relation between programme/projects and the continued adoption of LM practices. The thesis showed that project-assisted LM intervention can lead to continued adoption of LM practices. This is because farmers get technical support and resources from the project.

The thesis identified the role of technical support and resource endowments for LM investments. Specifically, training can accelerate the adoption rate of LM practices through creating awareness about the benefits of LM and delivering technical know-how about LM practices. In addition, we analysed the influence of resource endowments on LM investment decisions. Ownership of tools (e.g. shovels) and sufficient availability of (trained) farm labour can enhance the adoption and impacts of SWC practices. These resources are a prerequisite for construction and maintenance of SWC measures.

7.6 Limitations of the study

This section points out the limitations of this research. Investment/adoption behaviour of land management practices by farmers could probably have been explained more convincingly if more experimental economics methods had been used to supplement the survey data. Experimental/behavioural economics could have helped to model farmers' real decision-making behaviour, which the neo-classical economics decision theory fails to address. In addition, cross-sectional data sets were used to analyse the investment/adoption behaviour of farmers rather than panel data, which is used to analyse changes at the individual level (dynamics).

The analysis of different adoption phases would have benefited from a further distinction between non-adopters and dis-adopters (farmers who initially applied SWC measures but discontinued them at a later stage). However, there were not enough observations to enable us to treat these two groups separately. It is possible that the same institutional and socio-economic factors may not affect these two categories.

In the cost-benefit analysis an average slope of 10% is considered. It would have been interesting to take into account different slope categories; however, there is only limited research on the relationship between soil loss and crop yields for different slope categories for the study areas.

In this study the influence of land quality on land management investments was assessed from farmers' perspectives through interviews and field observations. Field measurements were undertaken with regard to slopes, but not with regard to soil fertility, etc. Farmers' perceptions of land quality could have been better cross-checked with sample analysis. In MCA, NPV as an economic criterion is used only for the moderate slope category and two watersheds, due to a lack of bio-physical data.

7.7 Recommendations for further research

Results from this thesis show that SWC practices are generally profitable in the highlands of Ethiopia. Future studies need to investigate the impact of land management practices on productivity, food security and poverty.

The profitability of SWC measures is investigated in this thesis from a private economic point of view. However, SWC provides both private and public benefits. Future studies need to investigate the costs and benefits of SWC practices by considering also off-site costs and benefits of land degradation and SWC investments. This can eventually help to increase awareness of the losses caused by soil erosion and the potential benefits of investments.

Huge investments in SWC, implemented through the present mass mobilisation approaches, have been undertaken at the national level in the last two years. However, no comprehensive assessment of these initiatives has taken place so far. Thus it is high time to monitor and evaluate the overall performance of the SWC activities that have been implemented by mass mobilisation.

Measurements of soil erosion and crop yields on the same fields (time series) for different slope categories are hardly available for the highlands of Ethiopia. Research institutes should collect more data of this kind and examine the relationship between soil erosion and agricultural productivity; this will improve the assessment of the potential benefits of SWC. Moreover, there is a need to undertake a suitability analysis for the SWC measures to identify the right niches (farming systems) for each practice.

Due to the soaring prices of fertiliser, farmers design their strategies to cope with such price increases (Chapter 4). Therefore, there is a need to examine the impacts of these strategies on productivity and household incomes.

7.8 Extension and policy recommendations

The findings of this research indicate that institutional, socio-economic and bio-physical factors functioning at different spatial levels affect farmers' investment behaviour in land management, but most of these factors are site- and situation-specific. Thus, the extension system needs to introduce appropriate land management practices based on farmers' preferences and specific agro-ecological situations. Farmer Research and Extension Groups (FREGs) should be established for land management practices to gear the research-extension continuum based on farmers' preferences. In addition, the Research-Extension-Farmer linkage must be strengthened in order to identify and disseminate appropriate technologies based on farmers' needs.

The results of the research show that SWC practices are generally financially viable and that intensification can sharply increase profitability of these practices. The viability of, and farmer preferences for, SWC practices vary according to the physical circumstances, and in particular to the slope of their parcels. Thus, the extension programme should not be based on a "one-size-fits-all" approach: rather, there should be different SWC recommendations for different slopes. As the recent spike in fertiliser prices is a major constraint for agricultural intensification, policymakers and extension personnel need to support resource-poor farmers by creating credit services for agricultural inputs.

The study confirms that land fragmentation affects the land management investment decisions of farmers. Therefore, policy measures are needed to stop the further fragmentation of cultivated land. Moreover, there is a need to reduce the pressure on land by creating job opportunities outside the agriculture sector (i.e. non-farm activities). In addition, land consolidation/land amalgamation/land exchange policies should be backed up by a proper crop insurance scheme in order to encourage farmers to exchange their lands.

The study shows that sharing and renting tenure arrangements are the major constraint to long-term land management investments. Thus, tenure arrangements, and specifically sharing and renting, should have legal backing to support long-term land management investments. Moreover, such arrangements must have provisions to specify technically sound and environmentally safe long-term soil management practices that have to be employed by the lessees or renters; as well, they should specify that an associated investment security should be offered by the landowner. In addition, the results of the analysis show that tenure security is an important factor for the continued adoption of SWC. Therefore, land policies should provide long-term and lasting tenure security to the farmers. In line with this, the land certification process must be strengthened by cadastral surveys to define accurate dimensions and locations of land parcels.

The study confirms that the current mass mobilisation approach (which embodies social capital) at watershed level is important for promoting SWC activities. Therefore, productive and protective measures (e.g. for free grazing) need to be introduced through community participation to sustain the SWC activities. It is also important to design a strategy to communicate and share the benefits from the watershed development programme with more of the participants (e.g. provide benefits also for the landless). In addition, there is a need to strengthen the mass mobilisation approach through improving the capacity and the capability of the different actors in the institutional mass mobilisation arrangements. Thus, policymakers should make available resources for training, and tools for enhancing the capacity and capability of farmers and extension personnel.

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Summary

Land degradation in the form of soil erosion and nutrient depletion is a major constraint to agricultural production in the highlands of Ethiopia. Over the last four decades, the government of Ethiopia and a consortium of donors have been promoting different land management (LM) practices to halt land degradation. However, the adoption rate of these practices has been minimal. This is because investments in LM practices are influenced by various institutional, socio-economic and bio-physical factors. The main objective of this research is to investigate the impact of these different factors on investments in LM in the northwestern Ethiopian highlands. It gives in particular emphasis on the drivers of the different stages of adoption, on profitability of LM practices, and on land quality, land fragmentation, tenure arrangements and social capital.

The introductory **Chapter 1** sets the scene, delineates the problem statement, objectives, research questions and conceptual framework and provides the outline of the thesis.

Chapter 2 examines the drivers of the different stages of adoption of soil and water conservation (SWC) practices using an ordered probit model. The results indicate that adoption of SWC passes through four major phases i.e., non-adoption/dis-adoption, initial adoption, actual adoption and final adoption. The results of the ordered probit model show that some institutional, socio-economic and bio-physical factors affect the adoption phases of SWC differently. Actual and final adoption depend on farm labour, parcel size, ownership of tools, training in SWC, presence of SWC program, social capital (e.g. cooperation with adjacent farm owners), and the perception of erosion problems. Final adoption is also much influenced by tenure security, cultivated land size, parcel slope and perception on SWC profitability. Policy makers should take into consideration these various institutional, socio-economic and bio-physical factors affecting the different stages of adoption in the design and implementation of SWC policies and programmes.

Chapter 3 investigates the effectiveness and profitability of three SWC practices (stone bunds, soil bunds and *Fanya juu* bunds) using the Universal Soil Loss Equation (USLE) and cost benefit analysis (CBA), respectively. The results show that SWC practices are effective in controlling soil erosion, but that the profitability of these SWC practices depends on the site where they are used. The results from USLE reveal that soil erosion rates on unprotected fields in Debre Mewi and Anjeni watersheds are 64.3 t ha^{-1} y^{-1} and 122.3 t ha^{-1} y^{-1}, respectively, indicating that both watersheds suffer considerably from soil erosion. Using the assumptions of a 12.5% discount rate and a life time of 20 years, CBA results shows that the net present values (NPV) of SWC measures for the standard cases are positive for all measures except soil bunds in Anjeni under the assumption of a 'without grass' scenario. And the internal rates of return (IRR) of the SWC practices are in all cases, except one, higher than the discount rate of 12.5% i.e. ranged from 17.0% to 21.9%. This indicates that SWC practices are generally, under average conditions, profitable in the North Western Highlands of Ethiopia. However, the study also shows that different underlying assumptions change the CBA results considerably and consequently also change the conclusions regarding circumstances under which SWC measures are or are not profitable.

Chapter 4 assesses farmers' perceptions about land quality, land fragmentation and tenure systems and their influence on interrelated LM (Bunds, Compost/Manure and Fertilizer) investments using a multivariate probit (MPV) model. The study is based on a detailed farm survey among 300 households and 1700 parcels in three watersheds. The study shows that on average sample households managed 4.54 parcels in different locations with an average parcel size of 0.26 ha. The MPV model analysis indicates that compost/manure and fertilizer do more or less substitute each other (often not used together) in the farming system of the study areas. However, bunds have no substitution and/or complementary effect on compost/manure and fertilizer. This indicates the interdependence between the different LM practices investment decisions. The results of the econometric analysis indicate that land quality is an important factor that affects the probability of investing in LM practices. Thus, matching LM practices with land

quality is of paramount importance for facilitating the decision-making about and adoption of LM investments. The study also reveals that the current level of farm fragmentation is very high and it affects LM investments. Therefore policy measures are needed to stop the further fragmentation of cultivated land. On the other hand farmers prefer to some extent fragmented land, with different type of parcels, to minimize agricultural production risks. The study identifies three major types of land tenure arrangements in the study areas i.e., ownership, sharing and renting. The study shows a significant difference in LM investment among different tenure arrangements. Specifically, sharing and renting arrangements form the major constraints to long term LM investments. To sum up, the overall results indicate that farm land attributes promote or hinder investments, and tenure systems regulate the decisions about investments.

Chapter 5 assesses the farmers' perceptions about the implementation approaches of SWC management activities, and explores the relationship between the different dimensions of social capital and investments in LM practices. Factor analysis is used to reduce the social capital variables to six non-correlated factors and these factors are used as variables in the subsequent analysis. The Seemingly Unrelated Regression (SUR) model is used to analyse the effects of social capital dimensions on investment in the three LM practices (Bunds, Compost and Fertilizer). The study shows that the most majority of the farmers in the northwestern highlands of Ethiopia prefer the present mass mobilization approach (which embodies social capital) to implement SWC practices. Nonetheless, farmers identify several shortcomings of the mass mobilization approach (e.g. inefficient in labour utilization, lack of mechanisms for benefit sharing). It is important to design a strategy to communicate and share the benefits from the watershed development programme with more of the participants (e.g. provide also benefits for landless). The SUR model shows that the different dimensions of social capital affect the LM practices differently. In particular, the cooperation and trust dimensions of social capital are associated with the intensity of investment in bunds, indicating that investment in bunds is a cooperation demanding technology. Thus bunds should be promoted through collective action at watershed level. In addition, the research shows that the extent of participation in formal institutions has a positive effect on the amount of compost used, because compost is a knowledge demanding technology. This shows that investments in compost need technical know-how support from internal and external organizations. The intensity of fertilizer use is also positively influenced by the level of participation in formal institutions at the community level, due to the need for cash and credit, which is made available by formal institutions. Hence, increasing the participation of farmers in the formal institutions is of paramount importance to increase the intensity of both compost and fertilizer use. Understanding and making use of these relationships could help in designing and implementing LM policies, strategies and programmes.

Chapter 6 evaluates different SWC practices in the northwestern highlands of Ethiopia using various qualitative criteria based on ecological, economic and social impacts using Multi-Criteria Analysis (MCA). The study reveals that MCA is a helpful evaluation tool that takes into account non- monetary and less quantifiable effects of SWC measures, which is not possible with CBA. In this study the time dimension of SWC is incorporated in MCA through the use of an efficiency criterion of CBA (using NPV as an efficiency criterion in MCA). The results of the analysis indicate that farmers have a range of criteria to evaluate the performance of SWC measures. The relative importance of each criterion in the selection of SWC alternatives depends to a large extent on slope categories. Farmers give the highest score for criteria related to ecological impacts in steep slope areas, and they prefer the alternatives with stronger positive economic impacts in moderate and gentle sloping areas. In line with this, stone bunds are the best SWC alternative on steep slopes in all watershed areas. *Fanya juu* bunds are the most preferred alternative on plots with gentle slopes in Dijil and Anjeni watersheds. The MCA shows that experts prefer stone bunds on steeper slopes, soil bunds on moderate slopes and *Fanya juu* on gentle slopes. Farmers give relatively high scores to the social impacts criteria of SWC measures compared to the experts. Policy makers and development practitioners should pay more attention to farmers' preferences and specific circumstances, such as slopes, in designing SWC strategies and programmes.

Chapter 7 provides a synthesis of the whole thesis. It briefly summarizes answers to the research questions, discusses key findings and scientific insights and provides suggestions for further research and policy making. The findings of this research indicate that final adoption depends mostly on profitability, land related factors, social capital and personal preferences.

For enhancing the adoption and impacts of land management, there is a need to increase knowledge about location specific viable LM practices, to promote collective action at watershed level, to pay more attention to farmers' preferences and to improve the capacity and capability of farmers.

Netherlands Research School for the
Socio-Economic and Natural Sciences of the Environment

C E R T I F I C A T E

The Netherlands Research School for the
Socio-Economic and Natural Sciences of the Environment
(SENSE), declares that

Akalu Teshome Firew

born on 10 April 1975 in Addis Ababa, Ethiopia

has successfully fulfilled all requirements of the
Educational Programme of SENSE.

Wageningen, 2 December 2014

the Chairman of the SENSE board

Prof.dr.ir. Huub Rijnaarts

the SENSE Director of Education

Dr. Ad van Dommelen

The SENSE Research School has been accredited by the Royal Netherlands Academy of Arts and Sciences (KNAW)

KONINKLIJKE NEDERLANDSE
AKADEMIE VAN WETENSCHAPPEN

The SENSE Research School declares that Mr. Akalu Teshome Firew has successfully fulfilled all requirements of the Educational PhD Programme of SENSE with a work load of 51 ECTS, including the following activities:

SENSE PhD Courses

- Environmental Research in Context (2010)
- Introduction to R for statistical analysis (2010)
- Research Context Activity: 'Policy Brief for local magazine: 'How to promote soil and water conservation activities in the North Western highlands of Ethiopia?' (2014)

Other PhD Courses

- Advance Econometrics (2010)
- Project and Time management (2010)
- Techniques for writing and presenting scientific papers (2010)
- Agricultural and Natural Resource Management: A Multi-Criteria Approach (2010)
- Introduction weekend of Product Ecology and Resource Conservation Graduate School (2010)
- Impact Assessment of Land and Water Management (2010)
- Physical aspects of land management (2010)
- Voice matters: Voice and presentation skills training (2014)

External training at a foreign Institute

- GIS for Agricultural Research Centres, ILRI, IWMI and ARARI (2011)
- Adoption and impact analysis, CIMMYT (2013)

Management and Didactic Skills Training

- MSc thesis supervision "Costs and Benefits of Soil and Water Conservation (SWC) Technologies in North-Western Ethiopia" (2011)

Selection of Oral Presentations

- Analysis of the institutional and socio-economic factors for adoption, and dis-adoption of SWC technologies. The 8th International Symposium Agro Environ, 1-4 May 2012, Wageningen, The Netherlands
- The Role of Social Capital and Mass Mobilization in Soil and Water Conservation Investments in North Western Highland of Ethiopia. International Conference on Cooperation or Conflict, May 29-31 2013, Wageningen, The Netherlands
- Investments in Sustainable Land Management in North Western Highlands of Ethiopia: the Role of Social Capital. 14th Annual Conference of Ethiopia Soil Science Society, 2-3 September 2013, Wageningen, The Netherlands

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Curriculum vitae and author's publications

Akalu Teshome Firew was born on April 10, 1975 in Addis Ababa, Ethiopia. He obtained his BSc degree in Agricultural Extension from Alemaya University in July 1998. In the same year, he was employed by East Gojam Cooperative Promotion Department as a cooperative promotion expert. He then joined the Amhara Agricultural Research Institute (ARARI) in October 1999 as junior researcher in the department of Socio-economics and Research-Extension, based at the Adet Agricultural Research Centre. In this capacity, he also served as department head and coordinator of USAID and SIDA support on-farm research programs.

Akalu joined Wageningen University in September 2003. He obtained a Master of Science (MSc) Degree in Development Economics in 2005. After completing the MSc programme, Akalu continued working for ARARI as a researcher and served the institute in different capacities including department head and acting director of the socio-economics and research-extension wing of the institute. As a researcher in socio-economics, he was responsible for the design and execution of different research projects. He has published peer reviewed articles, book chapters, policy briefs, proceedings, and he made a number of presentations at several national and international workshops, conferences and symposiums. Akalu also served as a general secretary for the research-extension-farmer advisory council of Amhara Region and the business process re-engineering (BPR) committee of Extension process of Rural Development and Agricultural Bureau of Amhara Region.

In April 2010, Akalu joined the Land Degradation and Development Group (currently named as Soil Physics and Land Management) of Wageningen University to pursue a PhD study. His PhD study was funded by NUFFIC. During his PhD study period, he also supervised a M.Sc. student and presented research results at both international and national conferences. At this moment, he is still working as a researcher at the Amhara Agricultural Research Institute, Ethiopia. His contact address is: akalu_firew@yahoo.com.

Scientific Publications

Peer reviewed international journals

Akalu Teshome, de Graaff J., Ritsema, C., Menale Kassie, 2014. Farmers' perceptions about influence of land quality, land fragmentation and tenure systems on sustainable land management in the North Western Ethiopian Highlands. Land Degradation and Development doi: 10.1002/ldr.2298

Akalu Teshome, 2014. Tenure security and soil conservation investment decisions: Empirical evidence from East Gojam, Ethiopia. Journal of Development and Agricultural Economics. 6(1): 22-32.

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Akalu Teshome, Jan de Graaff, Menale Kassie. Household level determinants of soil and water conservation adoption phases in the north-western Ethiopian highlands. Environmental Management (under review).

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Akalu Teshome, Jan de Graaff and Leo Stroosnijder. Evaluation of soil and water conservation practices in the north-western Ethiopian highlands using multi-criteria analysis. Frontiers in Environmental Science (under review).

Chapters in a book

Mati, B.M., Mulinge, W.M., Adgo, E.T., Kajiru, G.J., Nkuba, J.M., Akalu Teshome, 2011.Rainwater harvesting improves returns on investment in smallholder agriculture in Sub-Saharan Africa. In Suhas P.Wanie, J.Rockstrom and K.L. Sahrawat (ed.) Book of Integrated Watershed Management in Rainfed Agriculture. Taylor & Francis Group, London, UK.

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Proceedings

Akalu Teshome, Jan de Graaff, Menale Kassie, Leo Stroosnijder, 2012. Role of institutional and socio-economic factors on adoption, dis-adoption and non- adoption of soil and water conservation technologies: Empirical evidence from the North Western Ethiopia highlands. Agro Environ 2012. The 8th International Symposium Agro Environ 1-4 May 2012, Wageningen, The Netherlands. (http://www.agroenviron.com/)

Akalu Teshome, Andualem W., Anteneh A.,Dagninet A., Fentahun M., Kerealem E., Melaku W., Mihiret E., Minale L., Mulugeta A., Tatek D., Wolelaw E., Yirga A. 2010. Agricultural potentials, constraints and opportunities in Megech and Ribb rivers irrigation project areas in Lake Tana basin of Ethiopia. Amhara Region Agricultural Research Institute (ARARI) and Federal Democratic Republic of Ethiopia Ministry of Water Resources Ethiopian Nile Irrigation and Drainage Project

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