Graduate School of Development Studies

Analysis on the Impacts of Field Bunds on Crop Yields in the Tigray Region of Ethiopia

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List of Acronyms

ANRBANR	Amhara National Regional Bureau of Agriculture and Natural Resources
EARO	Ethiopian Agricultural Research Organization
EB	Ethiopian Birr
EHRS	Ethiopian Highlands Reclamation Studies
EPTD	Environment and Production Technology Division
FAO	Food and Agriculture Organization
FB	Field Bunds
FFW	Food for Work
GDP	Gross Domestic Product
IFPRI	International Food Policy Research Institute
ILRI	International Livestock Research Institute
IV	Instrumental Variable
LPM	Linear Probability Model
MOA	Ministry of Agriculture
MU	Makelle University
OLS	Ordinary Least Squares
PACD	Plan of Actions to Combat Desertification
SAERT	Sustainable Agricultural and Environmental Rehabilitation in Tigray
TPLF	Tigray People's Liberation Front
2SLS	Two Stage Least Squares
UNCCD	United Nations Convention to Combat Desertification
UNCED	United Nations Conference on Environment and Development
UNCOD	United Nations Conference on Desertification
UNEP	United Nations Environmental Programme
WFP	World Food Programme

Abstract

In the Tigray region of the northern Ethiopia, adoption of field bunds has been promoted by the Ethiopian government and international organizations to cope with land degradation. However, it is not always clear to what extent field bunds have impact on crop yields. Using cross-sectional data from the IFPRI, we investigate factors affecting field bunds adoption, the impact of field bunds on crop yields, and the effect of interacting field bunds with fertilizers or seeds. We combine fixed effect and instrumental variable approaches to measure the impact of field bunds. We find that field bunds alone do not have impact on crop yields, but the interaction of field bunds with chemical fertilizers or improved seeds seems to increase the effectiveness of these inputs. Therefore, the promotion of field bunds should be accompanied by the promotion of these modern inputs to benefit famers with improved crop yields.

Relevance to Development Studies

Farmers are more likely to adopt land conservation measures on their plots if their action is rewarded with improved crop yields. Thus, understanding the impact of field bunds has important implications to sustainable development; and addressing this information needs is relevant to development studies.

Keywords

Ethiopia, Land degradation, Land conservation, Field bunds, Crop yields

Chapter 1
Introduction

1.1 Background

Land degradation is a serious problem that plagues many of the developing countries today. According to Blaikie and Brookfield (1987, p.1), land degradation is defined as a social problem involving environmental processes such as leaching and erosion occurred with or without human interference. Today, many people are affected by the problem of land degradation globally. Agenda 21 Chapter 12 states that desertification (land degradation in arid, semi-arid and sub-humid areas) "affects about one sixth of the world's population, 70 per cent of all drylands, amounting to 3.6 billion hectares, and one quarter of the total land area of the world." (UNCED 1992)

One of the most important consequences of land degradation is productivity decline. Pimentel et al. (1995) write that about 80% of the world's agricultural land experiences moderate to severe erosion today. According to the authors' estimates, about 75 billion metric tons of soil is removed from the land by wind and water erosion. Croplands are among these that are most vulnerable to erosion because of insufficient vegetation cover.

It is reported that direct causes of land degradation vary depending on the context and situation. According to Lal (1998), for example, land clearing and farming of marginal land is the major cause of land degradation in south and west Asia; conversion of shifting cultivation to intensive cropping, in west and central Africa; cultivation of steep lands without conservation measures, in Haiti and Dominican Republic. In sum, Eswaran et al. (2001) argue that land degradation is generally recognized as a multi-dimensional problem which involves many factors such as biophysical factors, socio-economic factors, and political factors.

International efforts to mitigate the negative consequences of land degradation have intensified since the 1970s responding to increasing public concerns about food security and environmental conservation. At the international level, the United Nations Conference on Desertification (UNCOD) adopted a Plan of Actions to Combat Desertification (PACD) in 1977, in which the international community promised to address land degradation problems through cooperative national, regional and international actions (Mabbutt 1987). However, the problem of land degradation only got worsened, as the United Nations Environmental Programme (UNEP) concluded in 1991 that the problem of land degradation on the whole remained severe worldwide (UNCCD 2010) despite these efforts. As a result, a new approach to the problem was initiated at the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in 1992, which emphasizes action to promote sustainable development at the community level (UNCCD 2010). This approach still serves as a basis for the action against land degradation today.

In this study, we focus on land conservation efforts in Ethiopia for two reasons. First, we focus on Ethiopia because this is the country that has been described as one of the most affected countries by soil-erosion-induced land degradation in the world (Blaikie and Brookfield 1987). Similarly, Bekele and Drake (2003) write that soil erosion by water poses threat to the nation's food security and development prospects. Second, we put emphasis on Ethiopia because it is among the countries which have been provided with extensive land conservation efforts by governments and international organizations. Therefore, we believe that a study on land conservation efforts in Ethiopia can offer interesting insights to help us achieve sustainable development in countries affected by land degradation.

1.2 Relevance and justification

This study has an important relevance in development studies. In this study, we have attempted to view land conservation efforts in the light of sustainable development. The term sustainable development is defined as "paths of progress which meet the needs and aspirations of the present generation without compromising the ability of the future generations to meet their need." (Brundtland 1985) Keeping this definition in mind, we recognize at least two linkages that land conservation efforts are related to sustainable development. First, land conservation efforts can improve environmental qualities and preserve the complexity of natural ecosystems and biodiversity. Second, land conservation efforts can increase crop yields by improving land quality, which in turn should increase food security and ultimately empower subsistent farmers.

In reality, however, there is no guarantee that land conservation efforts go hand in hand with sustainable development ideal described as such. Therefore, we need to critically evaluate the effectiveness of land conservation efforts to investigate to what extent they are in line with the objectives of sustainable development. To carry out this study, we have identified three areas that deserve investigation. First, we find it important to investigate factors affecting farmers' adoption of land conservation measures. Since land degradation and land conservation efforts are multi-dimensional processes where a variety of factors are involved, understanding the importance and effects of each factor is essential to provide information for formulating and implementing effective policies to solve land degradation and achieve sustainable development. Second, we find it critical to investigate the impact of land conservation measures on crop yields. Knowledge on the effectiveness of land conservation measures is indispensable to promote farmers with voluntary adoption of land conservation measures. Farmers are likely to adopt land conservation measures when they know they can make profits by doing so. Third, we find it essential to investigate whether there are any effects of interacting land conservation measures with certain fertilizers and seeds. This is important because land conservation measures may be effective only if they are used in combination of certain fertilizers or seeds.

The justification for this study is two-fold. First, despite increasing numbers of studies in the area of land conservation, there are a limited number of empirical assessments of the impact of and conservation measures with data from the sub-Saharan Africa (Byiringiro and Reardon 1996; Kassie, Stein Holden et al. 2009; Kassie, John Pender et al. 2009; Kaliba and Rabele 2003; Nyssen et al. 2006; Jan Nyssen et al. 2007; Pender and Gebremedhin 2006). Second, even if they do have the data, many of them suffer from serious methodological problems, which may cloud the accuracy of the estimates. Thus, reliable empirical assessments of land conservation measures are called for. Such assessments should take into account the complexity of the reality and use appropriate data which allow us to do so.

1.3 Research objective and questions

The overall objective of this study is to provide an empirical assessment on the effectiveness of land conservation measures in rural Ethiopia. In doing so, we focus on the effectiveness of field bunds, common land conservation measures in the Tigray region of Ethiopia[1].

The specific research questions dealt with in this study are:

- What are the factors associated with adoption of field bunds in rural Ethiopia?
- What is the impact of field bunds on crop yields?
- What is the effect of interacting field bunds with fertilizers or seeds?

1.4 Research methods

In this paper, we have adopted a three-step strategy in order to achieve our research objective. First, we specify the theoretical framework based on previous findings on land degradation and land conservation measures. Second, we outline the details for the study area based on the literature review. Third, we provide quantitative analysis on field bunds using econometric models. We draw on the secondary data from the International Food Policy Research Institute (IFPRI) to carry out quantitative analysis.

1.5 Research limitations

Several limitations should be mentioned concerning this study to avoid misinterpretation or misapplication about the findings. We have identified three limitations as follows.

[1] We provide details for field bunds and the Tigray region in Chapter 2 and Chapter 3, respectively.

First, in terms of land conservation measures dealt with in this study, we do not differentiate between stone bunds and soil bunds. Rather, we assume they are homogenous in the impact on crop yields; and therefore we use the term field bunds to describe them jointly. The rationale for this assumption is that the bulk of the plots in the sample have stone bunds; and therefore, introducing separate category does not yield much for analysis and unnecessary complicates matters. This assumption can be problematic if the impacts of stone bunds and soil bunds are dramatically different from each other. However, we do not believe this assumption would be too problematic because the basic function and configuration of stone bunds and soil bunds are generally identical, except for the materials comprising them.

Second, in terms of adoption of field bunds, we do not differentiate voluntary adoption and involuntary adoption. On one hand, voluntary adoption refers to a process in which farmers adopt field bunds taking their own initiatives. On the other hand involuntary adoption refers to a process in which farmers adopt field bunds spurred by public land conservation programmes. We acknowledge that failure to distinguish these two adoption processes is a limitation of this study because the factors affecting voluntary adoption and involuntary adoption may in principal be different from each other. Therefore, it is not possible in this study to pin down factors corresponding specifically to voluntary adoption or involuntary adoption. As such, our findings on field bunds adoption should be seen in this light. Therefore, we offer discussion on which factors are generally associated with adoption of field bunds regardless of adoption processes.

Third, we have not conducted a full cost-benefit analysis concerning the impact of field bunds on crop yields. We are unable to do so due to the lack of data associated with costs. Therefore, we focus only on the benefits side in our analysis. This is a limitation of this study because in principle we need to be able to compare the benefits with costs to make a final judgment on the effectiveness of land conservation measures. Despite this limitation, we believe that this study can offer important insights because it reveals whether or not land conservation measures have at least positive impact on crop yields. Thus, this study should be considered as a preliminary study which should provide a guidance to carry out a full cost-benefit analysis.

1.6 Organization of the research paper

The rest of the paper is organized as follows: Chapter 2 specifies the theoretical framework for theorizing land conservation measures in a rural agricultural economy in Ethiopia. Chapter 3 provides an overview on the study area of the Tigray region. Chapter 4 describes the data and provides descriptive statistics. Chapter 5 describes the models and empirical strategy that we have developed and applied. Chapter 6 presents results and discussion. Chapter 7 concludes the paper.

Chapter 2
Analytical Framework

In this chapter, we present the analytical framework that provides a basis for the analysis of this study. First, we outlined concepts related to land degradation and land conservation. Then, we proceed to present our analytical framework by connecting each concept together.

2.1 Land degradation

Land degradation is a major issue in rural areas of developing countries today. In many parts of the world, land degradation poses a threat to subsistent farmers who are predominantly dependent on resources from lands for obtaining income and livelihoods. Esser (2002) argues that soil erosion is one of the common causes of land degradation that deteriorates the physical and chemical properties of soils. The author claims that soil erosion is generally considered as a natural process, but the rate of soil erosion can be increased dramatically by human land use.

Today, Ethiopia is considered as a country which faces a high rate of land degradation. Previous studies show that Ethiopia is vulnerable to soil-erosion induced land degradation for two reasons. First, Ethiopia has geographical conditions that provide favourable grounds for soil erosion. In the highland regions[2] of Ethiopia, many of the areas are characterized by mountainous and hilly topography, torrential rainfall, and low degree of vegetational cover, which can be considered as ideal conditions for high soil erosion (Esser 2002). Second, inappropriate farming practice among farmers is considered to have accelerated the rate of soil erosion in Ethiopia. Shiferaw and Holden (1998) argue that intensification of cropping on sloping lands without sustainable amendments to replenish lost nutrients has led to wide-spread degradation of lands in rural areas, where lands are scarce due to increasing population pressure.

Land degradation is not a new phenomenon in Ethiopia. On the contrary, land degradation has been persistent for about 2,000 years (1977; cited in Esser 2002). Today, the extent of land degradation is evaluated by the Ethiopia Highlands Reclamation Studies (EHRS), which estimates half of the highland area (27 million hectare) is significantly eroded; 14 million hectares are seriously

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[2] In this study, we define highlands as areas located at more than 1,500 m in altitudes. Highlands consist of more than 43% of the country, 95% of the cultivated area, 75% of the livestock and host about 88% of the population (Gebremedhin and Swinton 2003).

eroded; and 2 million hectares suffer from irreversible erosion (Constable, 1985; cited in Beshah 2003, p.21). Similarly, Hurni (1988; cited in Gebremedhin and Swinton 2003) estimates that cropland lose 43 tons of soil per hectare annually, which exceeds the formation rate of the soil (3-7 tons per hectare). If these rates persist, the author warns that croplands in Ethiopia shall be deprived of all the fertile soil within 100-150 years.

The agricultural sector has been severely affected by land degradation for years in Ethiopia (Shiferaw and Holden 1998). The implications of land degradation to the agricultural sector deserve due attentions for two reasons. First, we should not make light of the implication of land degradation on agriculture because the Ethiopian economy is predominantly agrarian, where the agricultural sector accounts for the 50 percent of GDP and employs 85 percent of the population (Nega 2003). Therefore, it is important to prevent land degradation to improve the quality of lives of majority of the Ethiopian people who are likely to be affected in one way or another by land degradation. Second, we should not overlook the linkage between agriculture and land degradation to improve food security of the country. Food security is a very important concern for Ethiopia because the country was hit by severe famines in the past. For example, Lanz (1996) describes the famine of 1973 in the Tigray and Wollo regions took the lives of approximately 200,000 to 400,000 Ethiopian people. The author mentions that the disaster was brought by the combination of land degradation and draught. Severe famines are also reported in 1984 and 1991 (Keeley and Scoones 2000). There is no guarantee that another tragedy will not happen in Ethiopia if the problem of land degradation remain to be unsolved.

The situation is only getting worse as the linkage between land degradation and crop yields decline is documented by the FAO, which estimates the annual onsite productivity decreases by 2.2 percent in Ethiopia (1986; cited in Shiferaw and Holden 1998). Thus, implementing appropriate land conservation measures to prevent further land degradation is urgently needed. This sense of urgency is recognized by the Ethiopian government and international organizations, which have implemented public land conservation programmes for decades.

2.2 Land conservation measures in Ethiopia

The famine in the 1970s shook the Ethiopian government and called for public intervention programmes for promoting land conservation and food security. As a result, the Ethiopian government, often in collaboration with international organizations, has initiated environmental policies and carried out public land conservation programmes in degraded parts of Ethiopia. The Food for Work (FFW) incentives during the 1980s was one of the largest public land conservation programmes in the Ethiopian history in terms of extent and coverage (Hoben 1995). The program was implemented jointly by the Ethiopian government and the World Food Program (WFP) (Hoben 1995). The FFW incentives were, in a nutshell, intervention programmes in which subsistent farmers were mobilized to construct land conservation measures in exchange for foods. On the whole, farmers were willing to participate in the program as long as they were supplied with such benefits, and as a result, a large volume of land conservation measures were installed across regions in Ethiopia. Hoben (1995) writes;

> "Over the following five years (after 1985), peasants constructed more than one million kilometres of soil and stone bunds on agricultural land and built almost one-half million kilometres of hillside terrace. They also closed off more than 80,000 hectares of hillside to most form of use to foster regeneration of naturally occurring plant species, and planted 300,000 hectares of trees, much of it in community woodlots."

Despite the successful installation of massive land conservation measures, the FFW incentives-led land conservation measures met with several criticisms. First, the FFW incentives-led land conservation measures are often criticized for failure to induce farmers to adopt conservation measures voluntarily. Kassie et al (2009) argue that some land conservation measures only provide environmental (social) benefits but fail to provide enough private (economic) benefits to induce voluntary adoption. Second, the FFW incentives-led land conservation measures are criticized for a general lack of commitment and awareness among farmers concerning the maintenance of land conservation measures (Esser 2002). Shiferaw and Holden (1998) mention that many farmers were not motivated to provide maintenance work because conservation activities were often undertaken without the involvement of the land user. As a matter of fact, some farmers have been reported to have removed totally or partially land conservation measures constructed on their plots (Shiferaw and Holden 1998; Beshah 2003). The removal of the land conservation measures is indicative of the fact that there may be points in the criticisms in that farmers do not always appreciate the land conservation measures that have been promoted.

Of the two different criticisms described, we focus on the first criticism in this paper. Along with this line, we investigate whether land conservation measures provide private (economic) benefits in the form of improved crop yields. As far as the type of land conservation measures is concerned, we shed light on field bunds, which are common land conservation measures in the study area of the Tigray region of Ethiopia.

2.3 Field bunds

Field bunds are common land conservation measures in Ethiopia designed to prevent land degradation by reducing soil erosion and increase water infiltration (Nyssen et al. 2007). In terms of physical configuration, field bunds are considered as artificial structures with embankments constructed along the contour lines of the sloped fields, as shown in Figure 2.1. The most common materials comprising field bunds are stone and soil.

According to Nyssen et al (2006), field bunds are associated with short-run and long-run benefits. First, the short-run benefits include reduction in the quantity and eroding capacity of the overland flow by reducing the slope length and creation of small retention basins for run-off and sediment. Second, the long-run benefits include reducing the slope angle by forming bench terraces, fostering a vegetation cover on the bunds themselves, and inducing changes in land management practices to promote a more sustainable agriculture. As a result, well maintained field bunds are said to retain most of the soil eroded in between the structures.

However, the use of field bunds could be costly. First, it could be costly because construction and maintenance field bunds require a sum of labour and input materials that can be very high for the majority of the subsistent farmers in rural Ethiopia. For example, labour supply is often limited due to the conflict in demand between farm activities and off-farm activities in rural agricultural economy. Farmers may also lack in resources necessary to construct field bunds due to the lack of income. Second, the use of field bunds could be costly because the opportunity costs could be high. Herweg (1992; cited in Hoben 1995) claims that construction of field bunds on average reduces the arable land by 10 percent to 20 percent. Therefore, if farmers are to benefit from using field bunds, crop yields must not only increase but must increase by more than is lost by the reductions in arable land (Kassie, Stein Holden et al. 2009). Third, field bunds may increase the risk of production despite their positive association with land conservation. Many scholars mention that field bunds harbour rats and weeds that do harm on crops grown on the plots which discourage farmers to adopt field bunds (Hoben 1995; Beshah 2003; Nyssen et al. 2006).

Therefore, field bunds have both benefits and costs associated with adoption and use. However, we limit our analysis on investigating the benefits of field bunds in terms of crop yields as mentioned in Chapter 1. Future works should carry on to the full cost-benefit analysis based on the findings presented in this paper.

Figure 2.1 Typical view on plots with field bunds in Ethiopia

Source: Nyssen et al. (2007)

2.4 Adoption of field bunds

According to Bekele and Drake (2003), it is hard to generalize about the factors affecting adoption of field bunds in different parts of the world or even in different regions of a country, owing to the differences in agro-ecological and socio-economic settings under which farmers operate. The authors argue that while the utility maximizing objective of individual farmers might be the same for framers everywhere, the specific attributes influencing the utility of farmers and adoption decisions are not uniform. They also point out adoption of field bunds depends on these differences in attributes, many of which are specific to a particular plot, household, village, or region. Drawing from these points, we have chosen a number of factors that may be associated with adoption of field bunds from plot-level and household-level.

After reviewing previous studies on adoption of land conservation measures in Ethiopia (Bekele and Drake 2003; Gebremedhin and Swinton 2003; Shiferaw and Holden 1998; Pender and Gebremedhin 2006), we have selected plot-level factors and household-level factors to be analyzed and interpreted. For the plot-level factors, we have identified input use, farming practice, land characteristics, and land tenure as factors affecting adoption of field bunds. For the household-level factors, we have identified demographic characteristics, income strategy, and institutional factors. We have purposefully selected a large set of factors to minimize the likelihood of leaving out relevant factors that may affect adoption of field bunds. We provide more details on each factor in Chapter 4 and Chapter 5.

2.5 Impact of land conservation measures on crop yields

There are an increasing number of research works attempting to examine the impact of land conservation measures on crop yields. Previous studies indicate that whether land conservation measures provide positive benefits or not depend on the nature of the technology and the situation where the technology was applied. It seems also that the same type of land conservation measures does not always give rise to the same effect if it were applied to different locations. Furthermore, we should keep in mind that results may not be reliable if empirical strategies employed to measure the impact of land conservation measures are inappropriate.

In Rwanda, Byiringiro and Reardon (1996) show that farms with greater investment in soil conservation are associated with greater land productivity than farms without such investment. However, the authors rely on standard OLS to carry out their analysis, which may not be appropriate if adoption of land conservation measures is endogenous. Furthermore, they are not explicit about the type of land conservation measures in their study.

In the Philippines, Shively (1998) finds a statistically significant positive impact of contour hedgerows, common land conservation measures in his study area. The author shows that the contour hedgerows on average increase corn yields by 40 percentage points. He uses the endogenous switching regression model, which he derives from the Heckman's correction model, to estimate the impact. The advantage of this model is to correct for bias introduced when conservation-induced changes in productivity are accompanied by self-selection in the technology adoption process. However, one of the limitations of the model is to require a relatively strong distributional assumption in the error terms. Namely, the error terms need to be normally distributed jointly between adoption regression in the first stage and yields regression in the second stage. The regression results may not be reliable if this assumption breaks down.

In Ethiopia, Pender and Gebremedhin (2006) find that field bunds on average increase crop yields by 10 percentage point. The authors also explored the effect of interaction of field bunds with fertilizer and show that plots with filed bunds and input use have greater crop yields than plots absent of these factors. However, they failed to acknowledge that field bunds adoption is endogenous, and therefore, the regression results may be biased if unobservable factors are correlated with adoption of field bunds and/or crop yields. Similarly, Kassie and Pender et al (2007) also show a statistically significant positive impact of stone bunds on crop yields in the Tigray region but not in the Amhara region. The authors ascribe the different outcomes to the differences in the rainfall patterns between the regions. They claim that stone bunds are effective in the low-rainfall Tigray region because stone bunds have a greater impact in moisture conservation in low rainfall areas than in high rainfall areas. They use endogenous switching regression model and non-parametric regression of propensity score matching. Even though the results seem to be robust, the same type of limitation discussed earlier with Shively (1998) may hold true to this study as well.

Overall, previous studies show that land conservation measures have positive benefits in increasing crop yields. However, the accuracy of these results are in question because it is crucially dependent on how we could successfully control for unobserved factors that may be correlated with adoption of field bunds and/or crop yields. In this study, we have developed a new estimation strategy designed to control for unobserved plot-level factors and unobserved household-level factors. We will discuss more in Chapter 5.

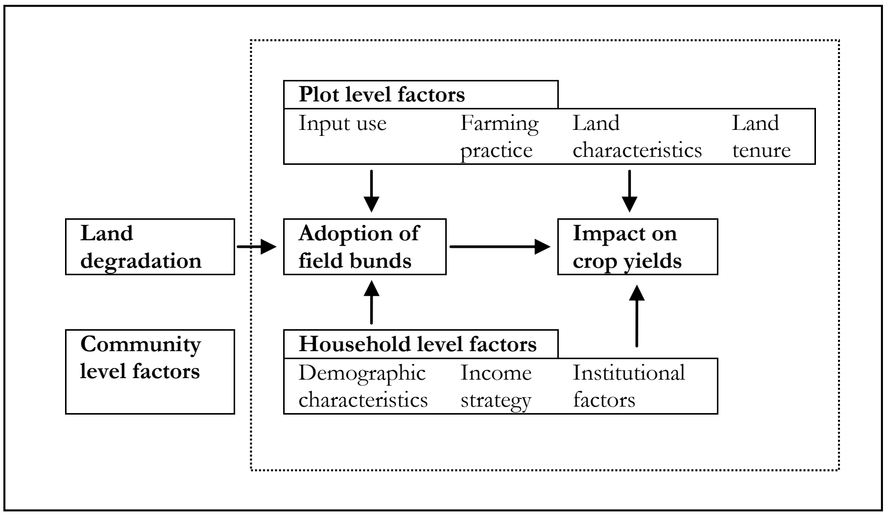
2.6 Analytical framework

Figure 2.2 presents the analytical framework in which the adoption of field bunds and impact of field bunds are described and analyzed. The focus of this study is indicated with the dotted rectangle in the figure. We first estimate factors affecting adoption of field bunds; we then estimate the impact of field bunds on crop yields. Furthermore, we estimate the effect of interacting field bunds with fertilizers or seeds.

In the analytical framework, we recognize a flow of events that consists of land degradation, adoption of field bunds, and impact of field bunds on crop yields. In this flow of events, we recognize that farmers may choose to adopt field bunds when they are faced with land degradation on their plots. Adoption of field bunds is then expected to increase crop yields, while all other factors affecting crop yields remain constant.

In investigating this process, we recognize the importance of factors affecting the adoption of field bunds and crop yields. We assume that most of the factors specified with adoption of field bunds also affect crop yields with a few exceptions[3]. We identify plot-level factors (input use, land characteristics, and land tenure) and household-level factors (demographic characteristics, income strategy, and institutional factors) in the analytical framework. In the analysis of adoption of field bunds, we provide interpretation of each factor as specified above. In the analysis of the impact of field bunds on crop yields, we provide interpretation of field bunds, fertilizers, and seeds. Finally, based on these analyses, we will draw a conclusion on the impact of field bunds and consider implications of the results for promoting sustainable agriculture in the Tigray region of Ethiopia.

Figure 2.2 Analytical Framework



Source: author

[3] Note that factors affecting only adoption of field bunds but not affecting crop yields play a crucial role in our analysis. A full discussion is given in Chapter 5.

Chapter 3
Study Area

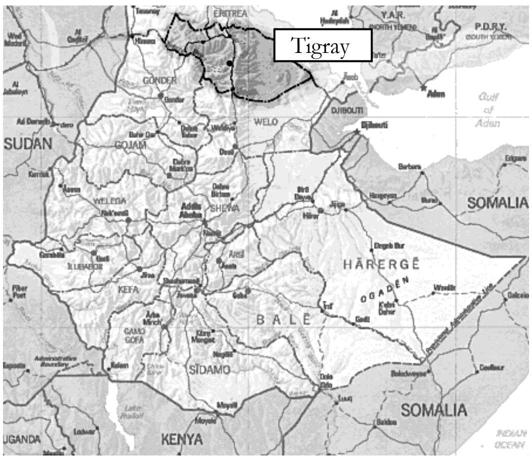
In this chapter, we provide information on the Tigray region of Ethiopia, the study area of this paper. A good grasp of knowledge on the study area is essential to carry out the analysis. We briefly discuss location, people, agriculture, and land conservation efforts in the Tigray region.

3.1 Location

The Tigray region of Ethiopia is located in the northern highlands, which vary in altitude from about 1,300 meters to over 3,000 meters. The region has an area of 50,078.64 km², which consists of about 4.5 percent of the Ethiopian territory. The region is characterized by dry climate and hilly topography. As a result, farmers in the Tigray region are predominantly prone to draught, as mentioned in Chamberlin et al. (2006). The region has an annual rainfall of less than 900 mm for the most of the areas. Recently, rainfall has been unpredictable, and thus some farmers have been forced to change their farming practices (Esser 2002). Sometimes, the pattern of rainfall is sporadic. The sporadic rainfall has brought negative consequences on agriculture in the region as it causes both water-logging and drought during one cropping season. (Esser 2002).

Due to such geographical conditions, land degradation is very severe in the Tigray region. Esser (2002) reports that virtually all topsoil, and in some places parts of the subsoil, has been removed from sloping land leaving stones or bare rock at the surface. Furthermore, the author argues that the speed of soil erosion has accelerated since more and more marginalized areas have been brought into cultivation recently.

Map 3.1 Map of Ethiopia with Tigray Region



Source: Esser (2002)

3.2 People

The population density in the Tigray region is relatively high. According to the 2007 population census, the Tigray region has a population of 4,314,456 as of 2007, increased from 3,136,267 in 1994 (Zekaria 2008). The population density is estimated at 86 people per square kilometre. The population growth rate in the period between 1994 and 2007 is estimated at 2.5%, roughly the same as the national average of the same period. The majority of the people in the Tigray region are subsistent farmers who live in rural areas. As of 2007, the rural population of the Tigray region is 3,471,733, which is about 80.5% of the total population (Zekaria 2008). The average rural household size is 4.6. Furthermore, the region is predominantly homogenous in Ethnicity, as Tigrayan consist of 97% of the population.

3.2 Agriculture

According to Esser (2002), wheat and barley are the two major crops in the highlands of the Tigray region. Maize had also been commonly grown before, but it is grown to a lesser extent nowadays due to the recent climate change characterized by unpredictable rains and frequent droughts. Similarly, the production of sorghum has also been reduced due to the late start of the rains and the spread of a parasitic weed. Teff is more commonly grown in the lowlands than in the highlands. Other miner crops grown in the area include millet, faba bean, chicken pea, grass pea, sesame, niger seed, lentil, among others.

Most of the farmers in the Tigray region use their own seeds for planting, but seeds are also bought from the local market or received from the local government when harvests are low (Esser 2002). Some farmers use improved seeds and chemical fertilizer to increase crop yields. For those farmers who do not have enough resources to obtain inputs and fertilizers, the Ethiopian ministry of agriculture (MOA) provide them with assistances by making loans and credits available to them to buy these inputs (Bekele and Drake 2003).

In terms of farming practices, Esser (2002) reports that mixed-cropping is commonly used by farmers in the Tigray region. One of the advantages of mixed cropping is its effect to reduce the risk of crop failure. Subsistent farmers in Ethiopia are generally considered as risk-averse and therefore likely to appreciate risk-reducing farming practices as mentioned by previous studies (Holden et al. 2004; Dercon and Christiaensen 2007). In addition, Esser (2002) mentions that ox-plough is also a common farming practice in the region; however, many of the farmers do not have oxen of their own and need to rent from other farmers. Therefore, planting times in the region are affected by the onset of rain and availability of oxen. Furthermore, the author writes that crop residues are commonly used as fodder for livestock while manure is burned for heating and cooking. However, these agricultural practices are not always considered appropriate because they could remove much of the organic litters from the soils (Esser 2002).

3.4 Land conservation efforts

An increasing awareness for land conservation has been seen in the Tigray region after the sever draught of 1973 (Lanz 1996). As a result, a large volume of land conservation measures were constructed in the region mainly through the FFW incentives. According to previous studies, 18,000 km of field bunds were constructed in the region in the period of five years between 1983 and 1988 (SAERT 1994; cited in Esser 2002). Moreover, land conservation has been one of the major policy focuses after 1991, when the regional government of Tigray undertook a new strategy for land conservation in that year. The strategy is called conservation-based agricultural-led industrialization and focuses on promoting conservation of natural resources and improvement of agricultural productivity and welfare through a broad public programmes. According to Pender and Gebremedhin (2006),

> "These efforts built on the philosophy of self-reliance and strategies of local democratic participation and community mobilization for local conservation and development efforts that were initiated during the struggle of the Tigray People's Liberation Front (TPLF) against the Derg regime and have been given high priority as a result of the recurrence famines in the region."

In sum, a fair amount of efforts has been provided to promote land conservation in the Tigray region for the last four decades. Field bunds have been the land conservation measures that have been actively promoted in the region as part of these efforts. However, the effectiveness of field bunds has not been always clear. In the following chapters, we attempt to address this information needs using quantitative analysis.

Chapter 4
Data and Descriptive Statistics

In this chapter, we first describe the data used for this study. Then we highlight plot holdings of sample households, adoption of field bunds at the plot and household levels. Next, we discuss the relationships of crop yields with field bunds, fertilizers, and seeds. Finally, we compare the mean differences by field bunds adoption on the relevant factors to our analysis.

4.1 Data

The data used in this paper is the Policies for Sustainable Land Management in the Ethiopian Highlands dataset. The data have been made available by the Environment and Production Technology Division (EPTD) of the International Food Policy Research Institute (IFPRI) in collaboration with the International Livestock Research Institute (ILRI), Mekelle University (MU), the Amhara National Regional Bureau of Agriculture and Natural Resources (ANRBANR), the Ethiopian Agricultural Research Organization (EARO), and the Agricultural University of Norway. The funding for the study was provided by the Governments of Norway and Switzerland.

The data is a primarily cross-sectional data collected in the highlands of the Tigray region in late 1998. It consists of a survey of 2,140 plots of 500 households in 100 villages in 50 communities. In selecting a sample, a random sample of communities was used, stratified by distance to the district town and whether irrigation project was present in the village. Two villages were randomly selected within each sample of community, and five households were randomly selected from each village. For each respondent household, information was collected on all plots owned or operated.

The data provide a wide range of information on rural agricultural livelihoods in Ethiopia. The plot-level survey provides information on plot-quality characteristics (soil type, slope, and size), land tenure, land investments, land management practices, input use (fertilizers, seeds, herbicides, insecticides), yields, and erosion indicators. The household-level survey includes information on household endowments of asset, land, labour, education, livestock; access to factors of production and credit, income sources, and livelihood strategies. The community-level survey covers topics on market access, population irrigation programs and organizations; local prices of crops, livestock and livestock products; community natural resource management, land use and land tenure.

In this study, we restricted our analysis to plots used for crop production. This restriction has led us to exclude pasture, woodlots, and fallow plots from the sample. After dropping these observations and missing observations, samples in the data were reduced to 1,841 plots of 491 households in 100 villages in 50 communities in the Tigray region.

4.2 Plot holdings

Rural households in the Tigray region vary in the number of plot holdings. As shown in Table 4.1, the plot holdings per households range from 1 to 12. The majority of the households (92 percent) have 6 plots or less. Not surprisingly, the number of plot holdings is positively correlated with the size of households, where the correlation coefficient between the two is estimated at 0.35. This correlation clearly indicates that larger households tend to have more plots than smaller households do.

Table 4.1 Number of plot holdings per household

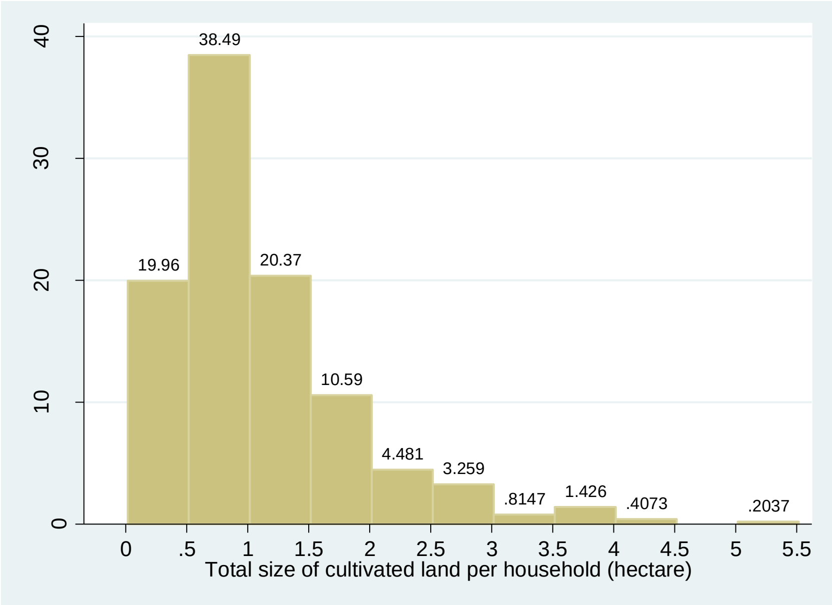
Number of plots	Frequency	Percentage	Cumulative percentage
1	46	9.37	9.37
2	90	18.33	27.70
3	107	21.79	49.49
4	101	20.57	70.06
5	65	13.24	83.30
6	44	8.96	92.26
7	18	3.67	95.93
8	12	2.44	98.37
9	3	0.61	98.98
10	4	0.81	99.80
12	1	0.20	100.00
Total	491	100.00	

Source: author

Furthermore, our data show evidences of plot fragmentation in the Tigray region. First, we find the average size of plot is as small as 0.3 hectare. Second, number of plot holdings per household and size of plot per household are negatively correlated with correlation coefficient estimated at -0.1729. These evidences are consistent with Shiferaw and Holden (1998), which report that an increasing number of farmers have pushed into marginalized areas in search of arable lands in rural Ethiopia. It is likely that plot fragmentation is caused by high population pressure in the region, as described in Chapter 3.

The variation in the total size of cultivated land across sample households also deserves attention. The distribution of the variation is shown in Figure 4.1. Notice that the distribution is skewed to the right, meaning that relatively few households are endowed with large cultivated lands while the majority of the households are endowed with small cultivated lands. We find that about 79 percent of households in the sample have plots with the size of 1.5 hectare or smaller. Therefore, these evidences suggest that there is no reservation to assume that the majority of the farmers in the Tigray region are small land holders.

Figure 4.1 Total size of cultivated land per household (hectare)



Source: author

4.3 Adoption of field bunds

Adoption of field bunds at the plot-level is summarized in Table 4.2. We find that 47 percent of the plots are conserved with field bunds while 53 percent of the plots are not. This proportion is suggestive that field bunds are indeed common land conservation measures in the Tigray region. In addition, we find 49 percent of the owned plots are conserved with field bunds while only 35 percent of operated plots are conserved with field bunds. Therefore, tenure security seems to be influential to farmers' adoption of field bunds.

Table 4.2 Plot-level adoption of field bunds by tenure security

Field bunds	**Tenure Security**		**Total**
	Operated	Owned	
Not adopted	179 (64.86%)	800 (51.12%)	979 (53.18%)
Adopted	97 (35.14%)	765 (48.88%)	862 (46.82%)
Total	276 (100%)	1,565(100%)	1,841(100%)

Source: author

Adoption of field bunds at the household-level is given in Table 4.3. We find that 81 percent of the households have at least one plot conserved with field bunds, while 19 percent of the household have none. Thus, the household-level adoption of field bunds reveals the popularity of field bunds in the Tigray region more evidently than the plot-level adoption does. This degree of popularity suggests that the technical aspects of the field bunds are well-known among farmers in the Tigray region. In fact, Nyssen et al (2006) mentions that farmers in the Tigray regions are knowledgeable about both advantages and disadvantages of field bunds.

Table 4.3 Household-level adoption of field bunds

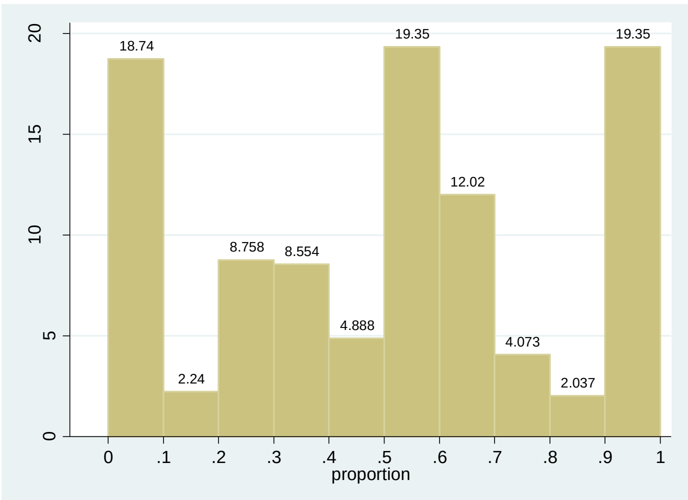
field bunds	Frequency (percent)
Not adopted	92 (18.74%)
Adopted	399 (81.26%)
Total	491 (100%)

Source: author

Furthermore, the proportion of the plots that are conserved with field bunds of all the plot holdings per household is given in Figure 4.2. The proportion is measured in the x-axis while the frequency of each range of proportion is measured in percentage in the y-axis. Notice that there are three peaks in the distribution. About 19 percent of the households have less than 10 percent of plots conserved with field bund; about 19 percent of the households have between 50 and 60 percent of plots conserved with field bunds; and about 19 percent of households have more than 90 percent of plots conserved with field bunds. These evidences clearly support the idea that adoption of field bunds is endogenous. Farmers are likely to decide whether or not to adopt field bunds strategically by taking into account various factors in this decision process.

In addition, these evidences suggest that there are groups of households that are unfavourable to the adoption of field bunds, favourable to the adoption of field bunds and somewhere in the middle. For those households which hardly adopt field bunds may be those that are too poor to construct them due to the lack of labour and input resources as discussed in Chapter 2. Or, they may oppose to use field bunds due to the side effects associated with field bunds such as harbouring rats and weeds that do harm on crops. In any case, the fact that a fair number of households do not adopt field bunds suggest that field bunds are not providing them with enough economic benefits in the form of increasing crop yields.

Figure 4.2 Proportion of the plots conserved with field bunds of all the plot holdings per household



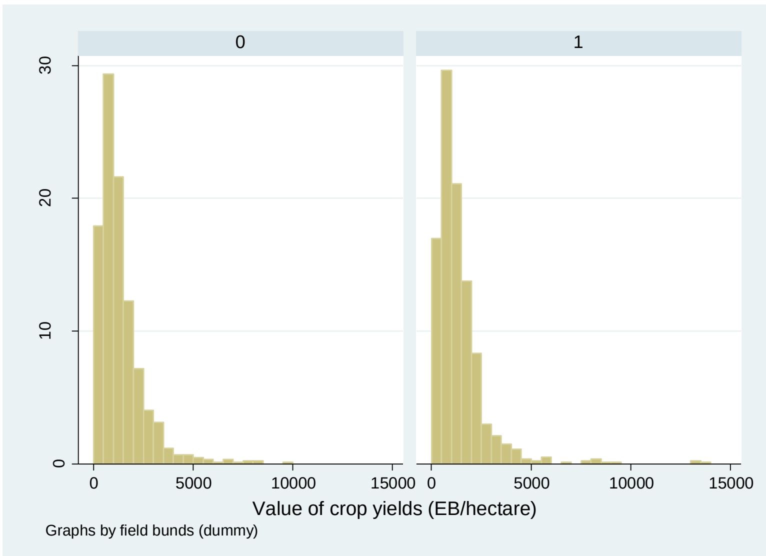
Source: author

4.4 Crop yields and field bunds

On average, sample plots have the value of crop yields of EB 1,377 (US$197[4]) per hectare[5]. In comparison, we find that plots with field bunds have a slightly higher value of crop yields than those without. The average crop yields of plots with field bunds is EB 1,408 (US$201) and those of plots without field bunds is EB 1,347 (US$192). This comparison seems to be consistent with the popular claim that field bunds are effective in reducing soil erosion; therefore they can improve crop yields.

The value of crop yields by field bunds adoption status is given in Figure 4.3. We find that both of the distributions are almost identical in shape and skewed to the right, which imply that only a handful plots are associated with higher value of crop yields. From the figure, we also find that the majority of the plots have the value of crop yields equal to EB 1,500 or less, regardless of the presence of field bunds. Therefore, comparing the distributions of the value of crop yields by the field bunds adoption does not provide much to infer the impact of field bunds on crop yields.

Figure 4.3 Value of crop yields (EB/hectare) by adoption status of field bunds



Note that the LHS figure shows the distribution of crop yields on plots without field bunds while the RHS figure shows the distribution of crop yields on plots with field bunds. Both of them have distriutions that are almost identical to each other.

Source: author

[4] The official exchange rate was about 7 EB per US dollar in 1998

[5] In this study, we use the monetary value of crop yields per hectare to measure the impact of field bunds. In calculating the value of crop yields, we used community level prices, instead of village level prices, because of many missing information on prices at the village level. Therefore, it should be noted that this study does not consider the local variation in the crop prices.

4.5 Crop yields, fertilizers, and seeds

The value of crop yields sorted by the type of input is given in Table 4.4. We have selected inputs—chemical fertilizers, improved seeds, organic fertilizers and local seeds—that have particular importance to crop production. We consider chemical fertilizers and improved seeds are modern inputs while organic fertilizers and local seeds are traditional inputs. We find that modern inputs are generally associated with higher value of crop yields than traditional inputs. In particular, improved seeds are associated with high crop yields. On average, value of crop yields of plots with application of improved seeds (EB 2,097/US$300) is significantly higher than those without application (EB 1,360/US$194).

Table 4.4 Value of crop yields by fertilizers and seeds

	Value of crop yields (EB/hectare)	
Type of inputs	N/A	Applicable
chemical fertilizers (dummy)	1351.09	1437.92
improved seeds (dummy)	1359.59	2096.58
organic fertilizers (dummy)	1370.77	1465.17
local seeds (dummy)	1433.48	1379.19

Source: author

4.6 Comparing the mean differences by field bunds adoption

In this section, we compare the mean differences of various factors associated with adoption of field bunds. In order to do so, we have divided our sample into two groups differentiated by field bunds adoption. We will provide analysis on mean differences of the factors at the plot and household levels in the following subsections.

Plot-level factors

As far as the plot-level factors are concerned, we find many significant differences in the mean values. The plot-level factors include input use, farming practices, land characteristics, and tenure security. Variable definitions and descriptive statistics are given in Table 4.5.

In general, plots conserved with field bunds receive more inputs than those without field bunds. For example, 39 percent of the plots with field bunds are treated with chemical fertilizer while only 30 percent of the plots without field bunds receive the treatment. Similarly, 4 percent of the plots with field bunds are supplied with improved seeds while only 2 percent of those without field bunds receive them. These evidences may suggest that farmers who have adopted field bunds are more motivated to provide efforts to increase crop yields than farmers who have not adopted them.

Furthermore, plots conserved with field bunds are likely to be treated with various types of farming practices. For example, 16 percent of the plots with field bunds are treated with burning to prepare fields. This is consistent with Pender and Gebremedhin (2006) who argue that farmers use burning to cope with weed problems associated with field bunds. Similarly, inter-cropping and mixed-cropping are more likely to be practiced on plots with field bunds. As mentioned before, these practices are considered to be effective in reducing the risk of crop failure. Thus, farmers may prefer using these farming practices on plots conserved with field bunds so as to reduce the risk of crop failure associated with field bunds including crop damages caused by rats and weeds.

In addition, land characteristics of plots conserved with field bunds are remarkably different from these of plots without field bunds. We find that the average size of the plot with field bunds is 0.34 hectare while that of plot without field bunds is 0.27 hectare. Thus, we find that plots with field bunds are on average larger in size than plots without field bunds. These differences in size are consistent with Beshah (2003) which claim that field bunds are suitable for the larger plots than the smaller plots because the field bunds should leave enough space on the plot to allow for contour-ploughing. Soil depth and slope gradients seem to be important consideration for adoption of field bunds. We find more field bunds on sloped plots and shallow-soil-depth plots, where severe soil erosion is suspected.

Lastly, plots conserved with field bunds are associated with stronger tenure security than plot without field bunds. 89 percent of the plots with field bunds are owned by the farmers while 82 percent of the plots without bunds are owned. Similarly, plots with field bunds are more likely to be associated with long-term tenure security than those without do.

In sum, these remarkable mean differences suggest that plots conserved with field bunds are systematically different from plots without field bunds. Plots conserved with field bunds tend to be provided with more care by farmers in terms of input use. Also, plots with field bunds tend to be situated where soil erosion is expected to be high. As such, we infer that plots with field bunds are those that are endowed with great agricultural potential but are threatened by high risk of soil erosion.

Table 4.5 Variable definitions and descriptive statistics: plot-level factors

Variable definitions	All plots		Plots w/o field bunds		Plots with field bunds	
	Mean	SD	Mean	SD	Mean	SD
value of crop yields (EB/hectare)	**1376.72**	1267.85	**1347.51**	1166.04	**1408.06**	1368.77
field bunds (dummy)	**0.47**	0.50	**n/a**	n/a	**n/a**	n/a
chemical fertilizer (dummy)	**0.34**	0.47	**0.30**	0.46	**0.39**	0.49
improved seeds(dummy)	**0.03**	0.17	**0.02**	0.15	**0.04**	0.19
organic fertilizer (dummy)	**0.11**	0.31	**0.07**	0.26	**0.15**	0.35
local seeds (dummy)	**0.96**	0.19	**0.95**	0.21	**0.97**	0.17
ox plough (oxen-	**24.44**	32.73	**24.00**	38.54	**24.93**	24.52

days/hectare)						
male labor input (person-days/hectare)	**81.62**	230.02	**89.44**	257.00	**72.82**	195.00
female labor input (person-days/hectare)	**36.36**	120.38	**39.33**	152.24	**33.03**	68.59
children labor input (person-days/hectare)	**15.31**	73.55	**16.94**	83.92	**13.47**	59.75
homestead (dummy)	**0.22**	0.42	**0.13**	0.33	**0.33**	0.47
rain-fed (dummy)	**0.72**	0.45	**0.79**	0.41	**0.65**	0.48
irrigated (dummy)	**0.05**	0.22	**0.08**	0.28	**0.02**	0.13
burning to prepare field (dummy)	**0.12**	0.33	**0.09**	0.28	**0.16**	0.37
Inter-cropping (dummy)	**0.02**	0.15	**0.01**	0.11	**0.04**	0.19
Mixed-cropping (dummy)	**0.11**	0.31	**0.08**	0.28	**0.14**	0.34
Contour-ploughing (dummy)	**0.93**	0.25	**0.91**	0.28	**0.95**	0.22
redued tillage (dummy)	**0.14**	0.34	**0.13**	0.34	**0.14**	0.35
altitude (masi)	**2138.49**	365.35	**2135.85**	383.95	**2141.05**	346.51
Size of plot (hectare)	**0.30**	0.24	**0.27**	0.24	**0.34**	0.24
No slope (dummy)	**0.62**	0.49	**0.70**	0.46	**0.52**	0.50
Gently sloped (dummy)	**0.30**	0.46	**0.24**	0.42	**0.37**	0.48
Steeply steep (dummy)	**0.08**	0.27	**0.06**	0.24	**0.11**	0.31
Deep soil depth (dummy)	**0.21**	0.40	**0.24**	0.43	**0.17**	0.37
Medium soil depth (dummy)	**0.37**	0.48	**0.37**	0.48	**0.37**	0.48
Shallow soil depth (dummy)	**0.43**	0.49	**0.39**	0.49	**0.47**	0.50
Distance between residence and plot (hour)	**0.37**	0.42	**0.44**	0.44	**0.29**	0.38
Gully (dummy)	**0.04**	0.20	**0.03**	0.18	**0.06**	0.23
Owned plot (dummy)	**0.85**	0.36	**0.82**	0.39	**0.89**	0.32
plot will be cultivated after 10 years (dummy)	**0.93**	0.26	**0.92**	0.27	**0.94**	0.24

Source: author

Household-level factors

In terms of the household-level factors, we do not find many significant differences in mean values the field bunds adoption. The household-level factors include demographic characteristics, income strategy, and institutional factors. Variable definitions and descriptive statistics are given in Table 4.5.

Some of the differences in the demographic characteristics are worth mentioning. We find that larger household size is associated with adoption of field bunds. On average, the household size is 5.6 for plots with field bunds and 5.2 for plots without field bunds. Consistent with previous studies (Shiferaw and Holden 1998), this may indicate that larger households are more advantageous in providing labour input necessary to construct and maintain field bunds than smaller households. On average, 19 percent of the households are female-headed for plots with field bunds while 28 percent for plots without field bunds. Therefore, female head of households are less associated with adoption of field bunds than male head of households. Educational attainment of the head of households does not show remarkable signs of influences on field bunds adoption, which is to the contrary to our expectation because education is expected to raise awareness for land conservation as well as to facilitate farmers to access resources and information necessary to construct and maintain field bunds. The mean values for income strategy and institutional factors are almost identical between the plots with field bunds and plots without field bunds, showing no signs of their influences on adoption of field bunds.

On the whole, many of the household level factors show similar values in the means. This is consistent with Bekele and Drake (2003) who argue that adoption of conservation measures for different plots depends on the specific circumstances of a plot and the importance of the plot to the household economy; thereby the plot-level analysis is more informative. Yet, we do not exclude household-level factors from our analysis because the omission of these factors may still introduce the bias of the estimates if they happen to have some influences.

Table 4.6 Variable definitions and descriptive statistics: household-level factors

Variable definitions	All plots		Plots w/o field bunds		Plots with field bunds	
	Mean	SD	Mean	SD	Mean	SD
household size (number)	**5.37**	2.21	**5.16**	2.17	**5.56**	2.23
Land-man ratio (cultivated area/household size)	**0.24**	0.19	**0.25**	0.20	**0.22**	0.18
female head of household (dummy)	**0.23**	0.42	**0.28**	0.45	**0.19**	0.39
age of household head	**46.45**	13.72	**45.05**	14.27	**47.69**	13.12
No education (dummy)	**0.79**	0.41	**0.80**	0.40	**0.78**	0.41
Grade 2 complete and less (dummy)	**0.15**	0.36	**0.15**	0.36	**0.15**	0.36
Grade 3-6 complete (dummy)	**0.04**	0.20	**0.04**	0.19	**0.05**	0.21
Grade 7 and above (dummy)	**0.01**	0.12	**0.01**	0.11	**0.02**	0.12
no secondary source of income (dummy)	**0.20**	0.40	**0.20**	0.40	**0.20**	0.40
saving (dummy)	**0.53**	0.50	**0.54**	0.50	**0.52**	0.50
loans received (dummy)	**0.59**	0.49	**0.58**	0.49	**0.60**	0.49
distance to all weather road (hours)	**1.97**	1.95	**1.90**	1.88	**2.03**	2.02
distance to market center (hours)	**2.91**	2.19	**2.88**	2.22	**2.93**	2.17

Source: author

Chapter 5
Model Specification and Empirical Strategy

In this section, we specify the models and empirical strategies used in this study. It is important that we provide sufficient explanations on them to assure the credibility of our results and discussions in the proceeding chapter. In the following sections, we present models to explain factors affecting field bunds adoption, impact of field bunds on crop yields, and effect of interacting field bunds with fertilizers or seeds. Then, we provide the rationale for the choice of variables in our models. Finally, we explain econometric concerns that should be taken note of to interpret our findings.

5.1 Adoption of field bunds

We have adopted linear probability model (LPM), modified LPM, and probit model to investigate factors affecting adoption of field bunds. We use these three models to assure the robustness of the estimates. First, we explain the LMP and modified LPM. Then, we discuss the probit model.

LPM and modified LPM

With LPM and modified LPM specifications, adoption of field bunds is modelled as

$$FB_{ij} = \alpha_0 + \alpha_1 P_{ij} + \alpha_2 H_{ij} + \varepsilon_{ij} \tag{1}$$

$$FB_{ij} = \alpha_0 + \alpha_1 P_{ij} + \mu_{ij} + \varepsilon_{ij} \tag{2}$$

Where equation (1) and (2) corresponds with the LPM and modified LPM, respectively. As far as the LPM is concerned, FB_{ij} shows whether a plot is conserved with field bunds; it denotes 1 if the plot is conserved with field bunds and 0 otherwise. The subscripts i and j stand for plot level and household level, respectively. P_{ij} is a vector of observable plot-level factors—input use, farming practices, land characteristics, and land tenure—that may influence field bunds adoption. H_{ij} is a vector of observable household-level factors—demographic characteristics, income strategies, and institutional factors—that may influence field bunds adoption. ε_{ij} captures unobservable factors. α_1 and α_2 are vectors of coefficients to be estimated.

Concerning the modified LPM specification in equation (2), variables are specified in the same way as in the LPM specification, except that the vector of observable household-level factors H_{ij} is replaced with household-fixed effect denoted by μ_{ij} . The household fixed effect captures the average effect of both observed and unobserved factors particular to each household. The household fixed effect is shown by a dummy variable assigned to each of the sample household. The modified LPM has advantage over the LPM in reducing bias in the estimates arose from the correlation between field bunds adoption and unobserved household-level factors such as household ability and motivation. Therefore, we believe that the estimates of modified LPM are more reliable than those of LPM[6].

However, the consequence of using the modified LPM is that we cannot estimate the effect of household-level factors on the adoption of field bunds. Therefore, we use the probit model to estimate the impact of household level factors. The probit is a non-linear model that is widely considered to outperform the LPM.

Probit model

With probit specification, adoption of field bunds is specified as

$$\mathrm{FB}_{ij}^{*} = \alpha_0 + \alpha_1 \mathrm{P}_{ij} + \alpha_2 \mathrm{H}_{ij} + \varepsilon_{ij} \tag{3}$$

$$\mathrm{FB}_{ij} = 1 \text{ if } \mathrm{FB}_{ij}^{*} > 0$$

$$\mathrm{FB}_{ij} = 0 \text{ if } \mathrm{FB}_{ij}^{*} \leq 0$$

Where equation (3) is the latent equation that we estimate with the probit model. Consider that FB_{ij}^{*} is the latent variable for unobservable utility gain associated with adoption of field bunds where field bunds adoption takes place if FB_{ij}^{*} is greater than 0; but it does not take place if FB_{ij}^{*} is less than or equal to zero. The specification of the rest of the variables follows those of the LPM in equation (1).

According to Gujarati (2003, pp.593-594), there are at least two features of probit model that make it advantageous over LPM in estimating the impact of factors affecting binary outcome. First, unlike LPMs, a probit model does not predict outcome variable that step outside 0-1 intervals as independent variables increase. Second, a probit model assumes non-linear relationship between outcome variable and independent variables where outcome variable approaches 0 at slower and slower rates as independent variables get small and approaches 1 at slower and slower rates as they get very large.

[6] However, we do not claim that the modified LPM is free from bias because adoption of field bunds may also be correlated with unobserved plot-level factors.

5.2 Impact of field bunds on crop yields

We have adopted ordinary least squares (OLS), modified OLS, and modified two stage least squares (2SLS) to investigate the impact of field bunds on crop yields. We use these three models to consider the direction of the bias associated with omitted household-level and plot-level factors. First, we explain the OLS and modified OLS. Then, we discuss the modified 2SLS model.

OLS and modified OLS

With OLS and modified OLS specifications, the impact of field bunds on crop yields can be given as

$$\mathrm{LnY_{ij}} = \beta_0 + \beta_1 \mathrm{FB_{ij}} + \beta_2 \mathrm{P_{ij}} + \beta_3 \mathrm{H_{ij}} + \varepsilon_{ij} \quad (4)$$

$$\mathrm{LnY_{ij}} = \beta_0 + \beta_1 \mathrm{FB_{ij}} + \beta_2 \mathrm{P_{ij}} + \mu_{ij} + \varepsilon_{ij} \quad (5)$$

Where equation (4) and (5) correspond with OLS and modified OLS, respectively. As far as the OLS model is concerned, $\mathrm{lnY_{ij}}$ denotes the logarithm of the value of crop yields (EB/hectare) of plot i of household j. Consistent with the regressions of field bunds adoption mentioned in the previous section, $\mathrm{FB_{ij}}$ shows whether a plot is conserved with field bunds; it denotes 1 if the plot is conserved with field bunds and 0 otherwise. $\mathrm{P_{ij}}$ is a vector of observable plot-level factors that may influence field bunds adoption. $\mathrm{H_{ij}}$ is a vector of observable household-level factors that may influence field bunds adoption. ε_{ij} captures unobservable factors. β_1 , β_2 , and β_3 are vectors of coefficients to be estimated. We focus on interpreting β_1 , which captures the impact of field bunds on crop yields.

Concerning the modified OLS specification in equation (5), variables are specified in the same way as they are specified in the OLS specification in equation (4) except that the vector of observable household-level factors $\mathrm{H_{ij}}$ is replaced with observable and unobservable household-fixed effect denoted by μ_{ij} . Similar to the modified LPM specification, μ_{ij} is estimated by a dummy variable assigned to each household. The modified OLS has advantage over the OLS in reducing bias in the estimates arose from the correlation between field bunds adoption and unobserved household-level factors. Due to this advantage, we believe that the estimates of modified OLS are more reliable than those of OLS.

However, estimates from modified OLS can still be biased if there are correlations between adoption of field bunds and unobserved plot-level factors. we have developed modified 2SLS model in order to address this issue. The advantage of the 2SLS is that it controls for both unobserved household-level factors and plot-level factors by incorporating fixed effect approach and instrumental variable approach simultaneously. The full discussion is provided in the following sub-section.

Modified 2SLS

With the modified 2SLS specification, the impact of field bunds on crop yields can be given as

$$\mathrm{LnY_{ij}} = \beta_0 + \beta_1 \widehat{\mathrm{FB}_{ij}} + \beta_2 \mathrm{P_{ij}} + \mu_{ij} + \varepsilon_{ij} \tag{6}$$

Notice that the basic specifications of modified 2SLS are the same as those of modified OLS, except that the variable on field bunds adoption $\mathrm{FB_{ij}}$ is replaced with the predicted value of field bunds adoption $\widehat{\mathrm{FB}_{ij}}$. This replacement of the variables is effective in removing the bias associated with the endogeniety of the field bunds adoption due to the correlation between field bunds adoption and unobserved plot-level factors. Two instrumental variables (IVs) are identified in the adoption regression of equation (2) in order to obtain the predicted value of field bunds adoption. The variables that we have identified as IVs are the distance between the residence and plot and whether a plot has gullies[7]. These variables are chosen on the basis of exclusion restriction, which states that we must use IVs that are correlated with field bunds adoption but not correlated with crop yields. We have performed several statistical tests[8] to ascertain these conditions. In addition to this 2SLS approach, we continue to use the household fixed effect approach in our modified 2SLS specification, which correct for bias introduced by omission of relevant household level factors. As such, we believe that the estimates of modified 2SLS specification are the most reliable of all the specifications concerning the impact of field bunds in that they have smaller bias.

5.3 Effect of interacting field bunds with fertilizers or seeds

In order to evaluate the effect of interacting field bunds with fertilizers and seeds, we have introduced interaction terms in the modified 2SLS specification. The interacting effect can be shown as

[7] Gullies are landform created by running water eroding sharply into soil, typically on a hillside.

[8] We have performed several tests to show the validity of these IVs. First, we performed F-test on the IVs. It confirmed that the IVs are jointly significance with F-statistics calculated at 4.93. Second, we performed the Sargan test on the IVs. The test result shows that the p-value is 0.56 and therefore we accepted the null hypothesis that all instruments are valid.

$$\text{LnY}_{ij} = \gamma_0 + \gamma_1 \widehat{\text{FB}_{ij}} + \gamma_2 \, (\widehat{\text{FB}_{ij} * \text{input}}) + \gamma_3 \, \text{input}_{ij} + \gamma_4 \, \text{P}_{ij} + \mu_{ij} + \varepsilon_{ij} \qquad (7)$$

Where input represents either fertilizers or seeds. The interaction effect is represented as $\widehat{\text{FB}_{ij} * \text{input}}$. The hat represent that this term is a predicted value of the interaction. We need to use the predicted value because field bunds adoption is endogenous by nature and therefore the interaction of it would also be endogenous. In order to obtain the predicted value of the interaction term, we have introduced a new IV for each input. The new IV is generated by interacting the variable on the distance between residence and plot with the variable on each input. The new IV should be valid because the distance variable and the interaction of distance variable with input variables are not perfectly collinear; they are correlated with field bunds adoption; and they are exogenous. Since the terms FB_{ij} , $\widehat{\text{FB}_{ij} * \text{input}}$, and input_{ij} are the variables of our interest, we focus on interpreting the coefficients of γ_1 , γ_2 , and γ_3 . In doing so, we focus on the joint significance to predict the effect of interacting field bunds with fertilizers or seeds.

5.4 Choice of variables

Analysis on land conservation measures involves a large variety of explanatory variables. In this study, we have specified plot-level variables and household-level variables that may influence the field bunds adoption and the impact of field bunds on crop yields. In the following, we present the rational for the choice of variables along with our expectations on their effect.

Plot-level variables

One of the factors that may affect adoption of field bunds is input use. On the theoretical grounds, Bekele and Drake (2003) argue that use of fertilizer may affect the adoption either positively or negatively. The authors claim that it may affect positively if a farmer using input is expecting to earn higher benefit and would invest in land conservation measures. On the other hand, the author argue that it may affect negatively if a farmer uses fertilizer as a substitute for land conservation measures which compensates for yield reduction due to soil erosion. With regards to the impact on crop yields, we expect that input use has a positive impact. Input use should by nature work as to improve the quality of soils and crops.

Another dimension that may affect adoption of field bunds relates to farming practices. Pender and Gebremedhin (2006) show a positive association between land conservation measures and inter-cropping. In our estimation, we make use of information on whether a plot adopted burning to prepare fields, inter-croping, mixed-cropping, contour-ploughing, and reduced-tillage to explore the effect of farming practices. Concerning the impact on crop yields, we expect that adoption of the listed farming practices should improve crop yields because many of these farming practices are meant to reduce soil erosion or to improve productivity.

Furthermore, land characteristics are considered to affect adoption of field bunds. We have identified altitude and plot size, slope gradients, soil depth, gully presence, and distance between residence and plot as major land characteristics that affect the adoption. For example, previous studies have shown that sloped plots are positively correlated with adoption of field bunds (Bekele and Drake 2003; Gebremedhin and Swinton 2003; Shiferaw and Holden 1998). The positive correlation with slope makes sense because field bunds are land conservation measures that specifically cater to sloped fields. In addition, plot size is expected to have a positive correlation with adoption of field bunds. Since field bunds occupy a fixed proportion of the plot, it would be more effective if they are installed on larger plots than smaller ones (Beshah 2003). Distance between residence and plot is expected to be negatively correlated with adoption of field bunds because it would be easier for farmers to provide maintenance on them if they are located close to their home than they are located in the distance. Gully presence is expected to have positively correlated with adoption of field bunds because they are physical indication of ongoing soil erosion on the plot. Note that the distance between residence to plot and gully presence on the plot are IVs used to estimate the impact of field bunds on crop yields. As such, these variables are not correlated with crop yields. Intuitively, this makes sense because the crop yields are largely influenced by the agricultural potential of the plot, which are by no means affected by the distance between the residence and the plot. Similarly, gully presence on the plot is considered irrelevant to crop yields because gullies can be present in any plots regardless of productivity.

Finally, there are reasons to believe that tenure security may affect adoption of field bunds. We have identified the present ownership of plot (whether a plot is owned or operated) and the long-run tenure security of plot (whether farmers believe the plot will be operated after 10 years). We expect that the stronger tenure security is associated with adoption of field bunds as farmers would feel more certain about their investment. For the same reason, we expect that tenure security is positively correlated with crop yields. Empirical evidences on the impact of tenure security are mixed, however. Gebremedhin and Swinton (2003) show that strong tenure security is associated with adoption of land conservation measures while Shiferaw and Holden (1998) do not confirm any impact of tenure security on field bunds adoption.

Household-level variables

First, we expect that various demographic characteristics of household are associated with adoption of field bunds. We have identified household size, land-man-ratio (area of land holdings per person), female head of household, age of household head, and educational attainment to capture the effect of demographic characteristics of household. Shiferaw and Holden (1998) find that a decrease in land-man ratio is negatively associated with adoption of field bunds.

The authors argue that this relationship is indicative of the neo-Malthusian scenario, which assumes a negative spiral with people pressuring on land without innovation but rather degradation. Gebremedhin and Swinton (2003) show a negative correlation between the adoption of field bunds and female head of households. This may be a reflection of gender inequality that exists in rural Ethiopia. Age of head of households is expected to be negatively correlated with adoption of field bunds as Shiferaw and Holden (1998) indicate that older farmers are more likely to reject conservation practices for their attachment to traditional agriculture. Educational attainment of the head of the household is hypothesized to be positively associated with adoption of field bunds following C. A. Ervin and D. E. Ervin (1982) in that educated farmers tend to have better knowledge and access to resources.

Second, income strategy may have an important influence on adoption of field bunds. We have selected variables on whether household have a secondary source of income, whether a household have a saving, and whether household received loans as proxies for household's income strategy. We expect that households without secondary source of income are more likely to adopt field bunds than those with secondary source of income following Holden et al. (2004), which find that access to non-farm income reduces farm household's incentives to invest in conservation and this leads to more overall soil erosion. The impact of savings is hard to predict a priori. On one hand, savings may have a positive impact on adoption of field bunds because households with savings are likely to be wealthier than those without savings; therefore they are more likely to be able to afford the cost of construction and maintenance. On the other hand, savings may have a negative impact on the adoption because households with savings may have preference in off-farm activities; therefore they may divert their resources away from land conservation investments to invest in off-farm activities. Households with loans received are expected to be associated with adoption of field bunds because such households are likely to have a good access to financial market to facilitate the finance of field bunds.

Lastly, institutional factors may have an impact on adoption of field bunds. We have included variables on the distance between residence to all-weather roads and the distance between residence and the nearest market centre. We expect that these factors are negatively correlated with adoption of field bunds because transaction costs associated with travelling to the market, transporting crop yields, searching for information, etc would be high if farmers live in a remote area.

5.5 Econometric concerns

Measuring the impact of field bunds on crop yields using cross-sectional data is a daunting task. This is largely due to the endogeneity problem associated with adoption of field bunds. The endogeniety problem can be addressed more confidently with panel data than with cross-sectional data. For example, we have more options available, such as fixed effect approach, random effect approach, generalized methods of moments approach, etc, to tackle the endogeneity problem if we had panel data. However, these options are not readily available for cross-sectional data. Despite this limitation, we have attempted to minimize the endogeneity bias of the estimate of the impact of field bunds on crop yields by incorporating household fixed effect approach and IV approach simultaneously. However, we acknowledge that there are at least two potential problems associated with our empirical strategy.

First, the modified 2SLS estimates of the impact of field bunds may be biased if instruments are weak. Weak instruments are known to have little reliability in removing the endogeneity bias. As a rule of thumb, Staiger and Stock (1997) suggest that the F-statistics of the IVs should be greater than 10 to ensure that the maximum bias in IV estimators to be less than 10%. According to the authors, even if we are willing to accept the maximum bias in IV estimators to be less than 20%, the F-statistics should be greater than 5. As far as the IVs used in this study are concerned, we calculate their F-statistics is 4.93, which is more or less equal to the lower threshold level. Therefore, we have to acknowledge the fact that the estimates from the modified 2SLS may still be biased to some extent due to the weak instrument problem. Second, we do not control for factors attributed to individual members of household that may affect the adoption or crop yields since such information is not covered by our data. This may introduce upward bias in the impact of field bunds on crop yields because unobserved ability and motivation of individual farmers are likely to be positively correlated with field bunds adoption and crop yields.

Chapter 6
Results and Discussion

In this chapter, the results of our estimations are presented. First, we provide the estimates of factors affecting adoption of field bunds. Then, we show the estimates of the impact of field bunds on crop yields. Finally, we discuss the estimates of the effect of interacting field bunds with fertilizers or seeds. We put emphasis on interpreting the estimates which show statistical significance.

6.1 Adoption of field bunds

The LPM, modified LPM, and probit results for adoption of field bunds are given in Table 6.1. Most of the regressors used in these models have sings that comply with our prior expectations. We find that farming practices, land characteristics, land tenure, household demographic characteristics, and income strategy have influences on adoption of field bunds. For the interpretation of the results, we resort to those of modified LPM and probit model for the plot-level factors while we use those of probit model for household-level factors for the reasons described in Chapter 5[9].

Plot-level factors

First, none of the coefficient estimates for input use in Table 6.1 shows a statistical significance on adoption of field bunds to the contrary to our expectation. The only exception is the use of chemical fertilizer, which is associated with a 7 percentage point increase in adoption of field bunds at 5 percent level of significance in the probit model; however, the statistical significance disappears in the modified LPM. This may be due to the correlation between use of chemical fertilizer and unobserved households' motivation that may also affect adoption of field bunds. Therefore, it is hard to avoid conclusion that a pattern of input use has no effect on field bunds adoption.

Second, farming practices show a statistically significant impact on adoption of field bunds. It is shown that rain-fed plots are on average associated with a 14 to 16 percentage point decrease in field bunds adoption in comparison to home-stead plots. This is perhaps because rain-fed plots are likely to correspond with highly marginalized and unproductive areas that are not considered to be worthwhile to be conserved with field bunds. Similarly, irrigated plots are on average associated with a 39 to 41 percentage point decrease in field bunds adoption. This may suggest that field bunds and irrigation may be substitutions.

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[9] Having said that, the regression results show that the LPM estimates are largely consistent with the modified LPM and probit estimates in signs and magnitudes.

Burning to prepare fields has a positive association with adoption of field bunds by 14 percentage point. This may probably be the result of farmers coping with weed problems associated with field bunds by burning them before the planting season.

Third, many of the land characteristics are strongly associated with field bunds adoption. We find that one hectare increase in plot size is associated with 25 to 33 percentage point increase in adoption of field bunds. This complies with our expectation that field bunds are more beneficial if they are installed in the larger plots than in the smaller plots. We find that a plot with gentle slope is more likely to be conserved with field bunds by 12 to 18 percentage point than a plot without slope. Similarly, a plot with steep slope is more likely to be conserved with field bunds by 17 to 25 percentage point than a plot without slope. Thus, farmers seem to understand that sloped fields are vulnerable to soil erosion and therefore try to conserve them with field bunds. We find that the distance between residence and plot is negatively correlated with adoption of field bunds by 13 to 18 percentage point. This is consistent with our expectation that field bunds are more likely to be adopted on the plots that are located close to home. Gully presence is also associated with a 12 to 13 percentage point increase in adoption of field bunds. This is also in line with our expectation that gullies are visible sign of soil erosion; therefore farmers response to it by adoption field bunds. Overall, these evidences seem to suggest that farmers have a good grasp of land characteristics and strategically decide on which plot to conserve.

Finally, we find that land tenure is positively correlated with field bunds adoption. Owned plots are associated with a 9 to 15 percentage point increase in adoption of field bunds in comparison to operated plots. This evidence suggest that tenure security is indeed important to encourage farmers making investments. The long-tem tenure security does not seem to matter so much concerning the adoption of field bunds as we did not find statistically significant impact of it.

Household-level factors

First, a small number of demographic characteristics are associated with adoption of field bunds. We find that female head of households are on average associated with a 8 percentage point decrease in adoption of field bunds in comparison to male head of household. Thus, female head of households might be disadvantaged in obtaining resources and information required for field bunds adoption. We find educational attainment of head of household is associated adoption of field bunds. On average, a head of household who has completed at least the basic level of education have a higher probability of adopting field bunds by 13 percentage point than those who have not received education. Land-man ratio does not show statistically significant impact on adoption of field bunds. Therefore, we do not find evidences for a neo-Malthusian scenario taking place in the Tigray region. Other variables including size of household and age of household head do not show statistically significant impact.

Second, one variable on household income strategy shows a statistically significant impact on adoption of field bunds. We find that household saving is associated with a 9 to 10 percentage point decline in adoption of field bunds. This implies that surplus household income does not necessarily give rise to field bunds investments. Thus, farmers with surplus resources may be more willing to invest in off-farm activities to generate higher returns to their investments, rather than investing in land conservation measures and remaining as subsistent farmers. We did not find a statistically significant impact of no secondary source of income or loans received on adoption of field bunds.

Third, we did not find a statistically significant impact of institutional factors on adoption of field bunds. Thus, the effect of transaction costs on adoption of field bunds is not clearly shown in this study.

Table 6.1 OLS, modified OLS, and probit estimates of factors affecting field bunds adoption

	OLS	**Modified OLS**	**Probit**
VARIABLES	**field bunds (dummy)**	**field bunds (dummy)**	**field bunds (dummy)**
Plot-level factors			
Input use			
chemical fertilizer (dummy)	0.0591**	-0.00492	0.0723**
	(0.0280)	(0.0378)	(0.0326)
Improved seed varieties (dummy)	0.0513	0.0959	0.0623
	(0.0908)	(0.104)	(0.104)
Organic fertilizer (dummy)	0.0296	0.0102	0.0355
	(0.0405)	(0.0531)	(0.0503)
Local seed varieties (dummy)	-0.0704	-0.0665	-0.0763
	(0.106)	(0.118)	(0.117)
Ox plough (oxen-days/ hectare)	-0.000146	-0.000131	-0.000191
	(0.000321)	(0.000380)	(0.000418)
Male labor input (person-days/hectare)	4.74e-05	3.55e-05	6.08e-05
	(5.21e-05)	(5.07e-05)	(6.16e-05)
Female labor input (person-days/ hectare)	-5.64e-05	0.000153	-5.88e-05
	(5.49e-05)	(0.000220)	(9.33e-05)
Child labor input (person-days/ hectare)	2.46e-05	4.00e-05	6.07e-05
	(0.000185)	(0.000228)	(0.000231)
Farming practice			
Rain-fed (dummy)	-0.136***	-0.146***	-0.159***
	(0.0372)	(0.0431)	(0.0413)
Irrigated (dummy)	-0.389***	-0.386***	-0.412***
	(0.0632)	(0.0803)	(0.0513)
Burning to prepare field (dummy)	0.119***	0.139**	0.139***
	(0.0396)	(0.0542)	(0.0448)
Inter-cropping (dummy)	0.142**	0.0269	0.202**

	(0.0699)	(0.0978)	(0.0912)
Mixed-cropping (dummy)	0.0648	0.0533	0.0745
	(0.0406)	(0.0590)	(0.0478)
Contour-plowing (dummy)	0.0748	0.0223	0.0989
	(0.0662)	(0.0816)	(0.0789)
Reduced-tillage (dummy)	0.0201	-0.0187	0.0216
	(0.0353)	(0.0506)	(0.0419)
Land characteristics			
Altitude (masi)	0.000116**	0.000181	0.000133**
	(4.60e-05)	(0.000160)	(5.29e-05)
Size of plot (hectare)	0.204***	0.334***	0.247***
	(0.0604)	(0.0774)	(0.0727)
Gently sloped (dummy)	0.162***	0.127***	0.183***
	(0.0284)	(0.0379)	(0.0314)
Steeply sloped (dummy)	0.221***	0.166**	0.247***
	(0.0467)	(0.0650)	(0.0480)
Deep soil depth (dummy)	-0.0871**	-0.0434	-0.107***
	(0.0357)	(0.0415)	(0.0408)
Medium soil depth (dummy)	-0.0480*	-0.0253	-0.0583*
	(0.0280)	(0.0342)	(0.0325)
Distance between residence and plot (hour)	-0.151***	-0.131***	-0.177***
	(0.0419)	(0.0505)	(0.0479)
Gully (dummy)	0.108*	0.120*	0.131**
	(0.0586)	(0.0629)	(0.0661)
Land tenure			
Owned plot (dummy)	0.133***	0.0900*	0.153***
	(0.0428)	(0.0529)	(0.0490)
Plot will be cultivated after 10 years (dummy)	-0.0637	0.0377	-0.0662
	(0.0587)	(0.0804)	(0.0673)
Household-level factors			
Demographic characteristics			
Size of household	0.00324		0.00453
	(0.00769)		(0.00883)
Land-man ratio (cultivated area/household size)	-0.0454		-0.0515
	(0.0873)		(0.0995)
Female head of household (dummy)	-0.0708*		-0.0811*
	(0.0400)		(0.0468)
Age of household head	0.00856		0.00953
	(0.00661)		(0.00771)
Age of household head squared	-7.52e-05		-8.37e-05
	(6.93e-05)		(8.08e-05)
Grade 2 complete and less (dummy)	0.109***		0.132***
	(0.0357)		(0.0404)
Grade 3-6 complete (dummy)	0.0648		0.0704
	(0.0590)		(0.0657)
Grade 7 and above (dummy)	0.143		0.141
	(0.110)		(0.120)
Income strategy			
No secondary source of income (dummy)	0.0208		0.0284
	(0.0344)		(0.0396)
Saving (dummy)	-0.0868***		-0.101***
	(0.0273)		(0.0319)

Loans received (dummy)	0.00623		0.0101
	(0.0287)		(0.0333)
Institutional factors			
Distance to all weather road (hour)	0.0131		0.0167
	(0.0111)		(0.0133)
Distance to market center (hour)	-0.00344		-0.00519
	(0.00950)		(0.0110)
Observations	1,460	1,468	1,460
R-squared	0.186	0.489	
Robust standard errors in parentheses			
***** p<0.01, ** p<0.05, * p<0.1**			

Source: author

6.2 Impact of field bunds on crop yields

The OLS, modified OLS, and modified 2SLS results for the impact of field bunds on crop yields are given in Table 6.2. The estimates of the field bunds are different across specifications. The differences in the estimates are likely to be resulting from the differences in the degree of correlation between adoption of field bunds and unobserved factors that may affect the adoption of field bunds.

We find that the coefficient on field bunds is positive and statistically significant with OLS and with modified OLS models. For the OLS result, field bunds are expected to increase crop yields by 8 percentage point. For the modified OLS result, the impact of field bunds is expected to be a 13 percentage point increase, which is greater than what the OLS results predict. Therefore, OLS results seem to underestimate the impact of field bunds in comparison to the modified OLS results, which take into account household fixed effect.

Initially, the underestimation of the impact of field bunds with the OLS specification had been taken as a surprise because we had expected that OLS result would overestimate the impact of field bunds rather than underestimate it. Overestimation of the OLS results were expected because we had the expectation that unobserved factors such as household ability and motivation should be positively correlated with adoption of field bunds; and therefore this correlation should lead to the overestimation of the impact if such an unobserved household motivation is not controlled for. However, the fact that we underestimate the impact of field bunds with OLS implies that there are factors that are negatively correlated with adoption of field bunds. After reviewing literatures, we have come to the hypothesis that households' sense of dependency on the government to construct field bunds may have caused the negative correlation with field bunds adoption. Beshah (2003, p.154) mentions that public intervention programmes for land conservation such as the FFW incentives have diminished the farmers' motivation for adoption of field buds. In his study, a farmer in the Wolaita region of Ethiopia claims that he left his land without field bunds for 17 years after the FFW incentives ended. The farmer is reported to have a strong belief that field bunds should be constructed under public incentive programmes where he is provided with food for his work. The author report that this is a common view held by many of the farmers in the Wolaita region. If farmers in the Tigray region in general have the similar view to those farmers in the Wolaita region, household motivation may be negatively correlated with field bunds adoption. Even though we cannot be completely sure about the validity of this hypothesis, the fact that we underestimate the impact of field bunds with the OLS specification in comparison to the modified OLS specification is suggestive of such a story.

When we use the modified 2SLS specification, the impact of field bunds has become statistically insignificant. Since we have controlled for both unobserved household and plot-level factors in this specification, we believe this result is more credible than the others. In addition to statistical insignificance, modified 2SLS estimates of field bunds have the smaller impact on crop yields in magnitudes. In comparison, the estimated coefficient of field bunds is 0.0524 (though statistically insignificant) with the modified 2SLS specification while that is 0.0794 with the OLS specification. This comparison implies that there are positive correlations between adoption of field bunds and unobserved plot-level factors, which the OLS specification does not consider. Therefore, we argue that the adoption of field bunds is likely to be correlated with the condition of plots that are favourable to crop production. In other worlds, it seems that farmers are likely to conserve plots with field bunds if such plots are endowed with great agricultural potential. This in turn suggest that the statistically significant impact of field bunds that we estimated with OLS and the modified OLS are illusions caused by the correlation between field bunds adoption and such unobserved plot-level factors. As such, it is hard to avoid the conclusion that the use of field bunds alone is not sufficient to improve crop yields.

Table 6.2 OLS, modified OLS and modified 2SLS estimates of the impact of field bunds on the crop yields

	OLS	**Modified OLS**	**Modified 2SLS**
VARIABLES	**Log of the value of crop yields (EB/hectare)**	**Log of the value of crop yields (EB/hectare)**	**Log of the value of crop yields (EB/hectare)**
bunds	0.0794*	0.128***	0.0524
	(0.0406)	(0.0439)	(0.394)
Plot-level factors			
Input use			
chemical fertilizer (dummy)	0.152***	0.127***	0.127***
	(0.0418)	(0.0483)	(0.0486)
Improved seed varieties (dummy)	0.398***	0.460***	0.466***
	(0.116)	(0.153)	(0.158)
Organic fertilizer (dummy)	0.217***	0.0907	0.0932

	(0.0528)	(0.0682)	(0.0694)
Local seed varieties (dummy)	0.372**	0.224	0.218
	(0.152)	(0.178)	(0.181)
Ox plough (oxen-days/ hectare)	0.00142	0.00189	0.00187
	(0.00131)	(0.00123)	(0.00125)
Male labor input (person-days/hectare)	0.000357***	0.000362***	0.000370***
	(0.000119)	(0.000107)	(0.000110)
Female labor input (person-days/ hectare)	5.37e-05	0.000794*	0.000808*
	(0.000379)	(0.000417)	(0.000426)
Child labor input (person-days/ hectare)	0.000493	5.99e-05	5.81e-05
	(0.000398)	(0.000341)	(0.000339)
Farming practice			
Rain-fed (dummy)	-0.0917*	-0.122**	-0.137
	(0.0485)	(0.0508)	(0.0937)
Irrigated (dummy)	-0.0468	-0.239*	-0.271
	(0.137)	(0.143)	(0.222)
Burning to prepare field (dummy)	-0.117**	-0.0190	-0.00595
	(0.0596)	(0.0822)	(0.102)
Inter-cropping (dummy)	0.0353	0.178*	0.178**
	(0.113)	(0.0908)	(0.0892)
Mixed-cropping (dummy)	0.0522	0.217***	0.219***
	(0.0539)	(0.0699)	(0.0707)
Contour-plowing (dummy)	0.133	0.0225	0.0233
	(0.0982)	(0.113)	(0.114)
Reduced-tillage (dummy)	-0.00319	0.0270	0.0259
	(0.0573)	(0.0700)	(0.0707)
Land characteristics			
Altitude (masl)	0.000195***	0.000378	0.000394
	(7.14e-05)	(0.000243)	(0.000262)
Size of plot (hectare)	-0.997***	-1.102***	-1.073***
	(0.0951)	(0.116)	(0.165)
Gently sloped (dummy)	-0.120***	-0.114**	-0.105
	(0.0429)	(0.0488)	(0.0702)
Steeply sloped (dummy)	-0.0880	-0.0613	-0.0496
	(0.0730)	(0.0842)	(0.101)
Deep soil depth (dummy)	0.298***	0.293***	0.293***
	(0.0505)	(0.0544)	(0.0547)
Medium soil depth (dummy)	0.199***	0.231***	0.231***
	(0.0425)	(0.0468)	(0.0465)
Land tenure			
Owned plot (dummy)	0.0880	0.109	0.111
	(0.0712)	(0.0747)	(0.0845)
Plot will be cultivated after 10 years (dummy)	0.100	0.194*	0.184*
	(0.0917)	(0.108)	(0.108)
Household-level factors			
Demographic characteristics			
Size of household	-0.000368		
	(0.0120)		
Land-man ratio (cultivated area/household size)	0.0266		
	(0.123)		
Female head of household (dummy)	-0.243***		

	(0.0675)		
Age of household head	-0.00678		
	(0.00925)		
Age of household head squared	7.87e-05		
	(9.81e-05)		
Grade 2 complete and less (dummy)	0.0603		
	(0.0528)		
Grade 3-6 complete (dummy)	-0.105		
	(0.0886)		
Grade 7 and above (dummy)	0.171		
	(0.115)		
Income strategy			
No secondary source of income (dummy)	-0.0610		
	(0.0519)		
Saving (dummy)	0.107**		
	(0.0418)		
Loans received (dummy)	0.0245		
	(0.0434)		
Institutional factors			
Distance to all weather road (hour)	0.0608***		
	(0.0164)		
Distance to market center (hour)	-0.0560***		
	(0.0134)		
Constant	6.105***	5.143***	5.163***
	(0.327)	(0.600)	(0.599)
Observations	1,410	1,418	1,416
R-squared	0.273	0.643	0.644
Robust standard errors in parentheses			
***** p<0.01, ** p<0.05, * p<0.1**			

Source: author

6.3 Effect of interacting field bunds with fertilizers or seeds

In this section, we provide the regression results for the effect of interacting field bunds with fertilizers and seeds. The results are summarized in Table 6.3. We use modified 2SLS specification to interpret the results. Before discussing the interaction effect of field bunds with these inputs, however, we first analyze the impact of each input on crop yields.

As shown in Table 6.2 in the previous section, modern inputs are associated with an increase in crop yields. According to the results from the 2SLS specification, chemical fertilizers on average increase crop yields by 13 percentage points while improved seeds, by 46 percentage points. On the other hand, traditional inputs such as organic fertilizers and local seeds do not show a statistically significant impact on crop yields. These results are very robust across all the specifications. Thus, these results are very supportive that modern inputs are effective in increasing crop yields.

In term of effect of interacting field bunds with fertilizers and seeds, we find that modern input has become more effective on the plots conserved with field bunds than on those without field bunds. We find the variables on bunds, input, and bunds*input are jointly significant for chemical fertilizers and improved seeds, even though individual coefficients may not necessarily be significant. We do not find the joint significance for organic fertilizers or local seeds. We predict that chemical fertilizers are associated with a 25 percentage point increase in crop yields when applied to a plot conserved with field bunds. This is significantly larger in effect than what we predict without the interaction, in which we have estimated the impact to be 13 percentage point. Similarly, we predict that improved seeds are associated with a 103 percentage point productivity increase when applied to a plot conserved with field bunds. This is also significantly larger in effect than what we predict without the interaction, in which we have estimated the impact to be a 46 percentage point increase.

This is consistent with Beshah (2003) who claims that field bunds improve effectiveness of chemical fertilizers as they retain moisture in the soil. These evidences seem to suggest that field bunds have a complementary role to boost the modern input effectiveness, and through this effect, they can increase crop yields. Therefore, the promotion of field bunds should be accompanied by the promotion of modern inputs. Such a strategy would prevent farmers from abandoning the field bunds in the long run. Thus, public land conservation programmes should not only concern about the installation of field bunds but should also concern about improving farmers' access to modern inputs. We expect that such programmes are in line with the objective of sustainable development in that they can prevent the problem of land degradation effectively and improve food security of the country.

Table 6.3 Modified 2SLS estimates of the effect of interacting field bunds with fertilizers or seeds

Inputs to be interacted	Chemical fertilizers	Improved seeds	Organic fertilizers	Local seeds
VARIABLES	**Log of the value of crop yields (EB/hectare)**	**Log of the value of crop yields (EB/hectare)**	**Log of the value of crop yields (EB/hectare)**	**Log of the value of crop yields (EB/hectare)**
bunds	-0.229	-0.00448	0.0701	0.642
	(0.476)	(0.387)	(0.390)	(2.709)
Input	-0.251	-0.136	-0.384	0.555
	(0.229)	(0.923)	(0.461)	(1.487)
Bunds*input	0.725*	1.168	0.678	-0.590
	(0.419)	(1.791)	(0.665)	(2.624)
Constant	5.245***	5.052***	5.123***	4.816***
	(0.601)	(0.653)	(0.605)	(1.645)
Observations	1,416	1,416	1,416	1,416
R-squared	0.610	0.631	0.642	0.643
Robust standard errors in parentheses				
***** p<0.01, ** p<0.05, * p<0.1**				

Note that other control variables not reported here include: variables on ox plough, male labour input, female labour input, child labour input, and those on farming practices, land characteristics, land tenure, demographic characteristics, income strategy, and institutional factors.

Source: author

Chapter 7
Conclusion

This paper provides empirical assessment of field bunds in the Tigray region of Ethiopia. In particular, we have examined factors affecting adoption of feild bunds, impact of field bunds on crop yields, and impact of interacting field bunds with fertilizers or seeds. Addressing these information needs has important relevance to the study of sustainable development and helps to formulate policies on this ground.

First, we have shown that various factors affecting the adoption of field bunds. We find that plot-level factors are in general more important than household-level factors in influencing the adoption of field bunds. Adoption of field bunds is likely to increase, among other things, with burning to prepare fields, large plot, steep slope, gully presence, plot ownership, educational attainment of the head of household. On the other hand, adoption is likely to be lower with rain-fed plots, irrigated plots, deep soil, increase in distance between residence and plot, female head of household, and household saving.

Second, we have shown that field bunds themselves do not have a statistically significant impact on crop yields. We have come to this conclusion by comparing the estimates of field bunds obtained from the different specifications. This comparison allows us to infer the direction the bias in the estimates arose from the omission of relevant unobserved factors. First, we have shown that the OLS specification underestimates the impact of field bunds compared to the modified OLS specification in which we control for unobserved household-level factors but not for plot-level factors. This finding is suggestive of the story that farmers may be somewhat dependent on public conservation programmes in adopting field bunds and this dependency may discourage them adopting field bunds voluntarily. Second, we have shown that the OLS specification overestimates the impact of field bunds compared to the modified 2SLS specification in which we control for both unobserved household-level factors and unobserved plot-level factors. This finding suggests that farmers adopt field bunds based on the plot conditions and they are likely to adopt field bunds on the plots endowed with great agricultural potential.

Third, we have shown that field bunds can boost the effectiveness of modern input. We have found that fertilizers and improved seeds become more effective when they are used on the plots conserved with field bunds. These evidences have led us to conclude that field bunds have a complementary role to these modern inputs. Therefore, public land conservation programmes should focus on providing farmers with improved access to modern inputs in addition to the promotion of field bunds. Such land conservation programmes are likely to be effective in motivating farmers to invest in land conservation and ultimately help Ethiopia to stay on the sustainable development path.

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