Investments in Land Conservation in the Ethiopian Highlands: A Household Plot-level Analysis of the Roles of Poverty, Tenure Security, and Market Incentives

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Received: March 13, 2012 Accepted: April 6, 2012 Published: June 1, 2012

doi:10.5539/ijef.v4n6p32 URL: http://dx.doi.org/10.5539/ijef.v4n6p32

The data used in this study is collected by the department of economics at Addis Ababa University (Ethiopia) and the University of Gothenburg (Sweden) with the support of Sida. The authors would like to acknowledge these institutions for allowing access to the data. We would like to most sincerely thank Peter Moffatt for his invaluable help with the programming of the econometric procedure used. The release time support from the University of Dubai to the corresponding author to work on this paper is greatly acknowledged.

Abstract

Land degradation is a major problem undermining land productivity in the highlands of Ethiopia. This paper analyses the decisions made by individual household to adopt and intensify land conservation investment. The paper used a Box-Cox Double Hurdle specification and offers the advantage of exploiting panel data collected in a household survey of 6,408 plots in Ethiopia. The results suggest that adoption and intensification decisions appear to be explained by different processes, justifying the use of Box-Cox double hurdle approach over more restrictive models. Poverty-related factors seem to have mixed effect on both adoption and intensification decisions. While farmer's adoption decision is affected by expectation of the certainty of cultivating the land for the next five years (risk for long term), intensification of land conservation investment is determined by whether or not the plot is owner-operated (risk for immediate period) and plot-home distance. A lesson for policymakers is that major changes in land conservation investments will require attention to many factors because no single factor can be used as a major policy leverage instrument. Some of these factors (such as land tenure security, plot size, and total farm holdings) can be directly influenced by government policies and programs.

Keywords: Ethiopia, land conservation, markets, poverty, tenure security, Box-Cox double hurdle model

JEL classification: D1, Q12

1. Introduction

A critical environmental issue facing governments of developing societies is land degradation, which is crucial, among other things, to the well-being of their people. Hurni, 1985, noted well over 20 years ago that Ethiopia was the most environmentally troubled country in the Sahel belt. Studies of land degradation in Ethiopia have confirmed that it undermines agricultural productivity primarily in the highlands, where most (88%) of the country's population lives, and accounts for more than 43 percent of the country's area, 95% of the cultivated land, and 75% of the livestock. Estimates of the extent of land degradation differ, but all indicate the importance of the problem. The Ethiopian Highland Reclamation Study (EHRS) estimated that by the mid-1980s about 50% of the highlands (27 million hectares) was significantly eroded, while more than one-fourth was seriously eroded (EHRS, 1986, cited in Gebremedhin and Swinton, 2003). Hurni, 1988, found that soil loss in cultivated areas averaged about 42 metric tons per hectare per year, far exceeding the soil formation rate of 3–7 metric tons per hectare per year. Stahl, 1990, estimated that the amount of land incapable of supporting cultivation would reach 10 million hectares by the year 2010.

The magnitude of land degradation (and deforestation) by far exceeds the conservation activities being carried out (Note 1). Indeed, it is only recently that public intervention in land conservation has become an important priority in

Ethiopia (Federal Democratic Republic of Ethiopia Rural Land Administration and Land Use Proclamation No. 456/2005). Land degradation was largely neglected by policymakers until the 1970s and national conservation programs introduced since then have been guided by little prior research (Shiferaw and Holden, 1999). Policies and programs were adopted based on incorrect assumptions and little understanding of the incentives and constraints related to land conservation - which could be misleading.

Better knowledge about what criteria households use in their decisions to invest in land conservation will improve policymakers' ability to design effective programs that promote such land conservation investments. This study looks into factors affecting farm households' private decisions to invest in land conservation and how much to invest by focusing on the roles of poverty-related factors, land tenure security, and market access.

The effects of these sets of variables on land conservation decision and level of conservation are not clear from the literature. For example, an inverse relationship between poverty (in its different forms) and a household's decision to invest in land conservation and at what intensity is substantiated in various studies (Holden, et al., 1998; Godoy, et al., 2001; Clay, et al., 2002; Holden and Shiferaw, 2002; Gebremedhin and Swinton, 2003; Hagos and Holden, 2006). On the other hand, it is also argued in the literature that risk aversion may enhance technology adoption if the technology reduces the risk to household income, suggesting that poverty may positively influence land conservation investment. Similarly, there are studies which argued that more secure land tenure encourages land conservation investment (Feder, et al., 1988; Rahmato, 1992; Alemu, 1999; Joireman, 2001; Gebremedhin and Swinton, 2003), while others found either weak or unclear effects of land tenure security on land conservation investment (Sjaastad and Bromley, 1997; Place and Migot-Adholla, 1998; Brasselle, et al., 2002; and Holden and Yohannes, 2002).

This study makes a number of contributions to the existing literature on land conservation. Its main contributions are related to the empirical application of a model of landowner decision-making to a panel dataset that enables investigation of several relevant aspects of the problem. In particular, using a panel of a vast data and the Box-Cox double hurdle model, together with extra explanatory variables is what this study offers in comparison with the previous literature. We used household plot-level panel data collected in household surveys in the years 2002 and 2005 from the Amhara region of Ethiopia. Unlike most other studies that have analyzed land conservation, the use of panel data enabled us to use lagged values of some of the explanatory variables, which helped resolve issues of endogeneity. At the same time, it gave us the chance to consider the effect of past values of variables on current decisions. The richness of the data on land conservation also allowed us analyze not only the determinants of adoption but also the level of investment in land conservation. Moreover, unlike most other studies (Note 2), and partly because of the availability of data on the level of investment, we also used Box-Cox double-hurdle model in our analysis, which helps identify whether the determinants of adoption are different from those of the level of investment in land conservation. Finally, compared with other studies on the topic, we incorporated a wider range of variables, including asset- and poverty-related factors as possible determinants of the decision to adopt and intensify land conservation investment.

The rest of the paper is structured as follows. The conceptual framework we use is presented in section 2. Section 3 presents the empirical strategy we follow. Data, results, and interpretation are presented in section 4, while section 5 summarizes and concludes.

2. Conceptual Framework

A farm household's expenditure on land conservation practices and input uses can consume a significant share of its overall expenditure. Use of land conservation practices and inputs, therefore, are considered to be major investment decisions by farmers as they forego other opportunities. For Clay, et al., 2002, farmers are likely to pose two basic questions before making land conservation investment and/or using land inputs: 1) will investment in land conservation and/or input use be profitable, and 2) can they afford it? Thus, factors that influence profitability can be thought of as the "incentives" to adopt land conservation practice and input uses. On the other hand, whether farmers can afford to invest in land conservation depends on their capacity to carry out land conservation investment.

Ideally, factors that affect profitability of investment in conservation practices and inputs include access to market, crop and input prices, cost of labor and materials used for conservation, prevailing wages for agricultural and non-agricultural activities, and yield effect of land conservation practices (Clay, et al., 2002; Gebremedhin and Swinton, 2003). In relation to access to market, output prices are expected to affect land investment through the incentive they can create to plant soil-conserving crops versus more erosive crops. We used site (i.e. 'Kebele' or Village) (Note 3) dummies to account for differences in prices across villages or sites. Moreover, as is common in rural Ethiopia, since much of the production is consumed by the household and markets are missing, thin or

imperfect, we can assume in our model that farmers also use criteria other than market prices to evaluate returns from land conservation investments. We can, therefore, model household conservation investment under imperfect factor markets (Udry, 1996; Holden, et al., 2001). This implies that households' production and investment decisions may not be dictated by profit considerations alone, but consumption choices as well.

In such settings where markets do not fully function or are entirely missing, other factors, such as household poverty-related characteristics and land tenure security, can play a critical role in influencing the decision and intensity of land conservation investments. Physical incentive factors (that include farm and plot characteristics) can also affect profitability of investment in land conservation practices and inputs. A farm household's capacity to carry out land conservation practices and inputs improves as the farmer gets richer, when financial capital increases and when levels of human and social capital are higher. Financial capital, which includes cash income and/or credit, and non-liquid assets, permits farmers to invest more, while human capital, such as education and labor input, enables farmers to use land conservation more efficiently.

Consideration of the risk of making land conservation investments and input uses by farmers can also alter their capacity to do so. For Feder, et al., 1985, these risks fell into two categories: risks affecting "confidence in the short term" (such as from price or rainfall instability), and risks affecting "confidence in the long term" (such as insecure land tenure). This study focuses on the latter. The effect of farmers' risk associated with *insecure land tenure* on their decision to make land conservation investment is relevant in Ethiopia where land is state-owned and the farmer has only use right .

Swinton and Quiroz, 2003, formally modeled the question as to which factors govern a household's choice to adopt and intensify a particular farming practice. For them, such a microeconomic decision emerged from the household's attempt to optimize its perceived welfare, subject to limitations imposed by the available economic and natural resources, as well as the parameters imposed by the larger economy. This household's problem can be modeled as:

$$\left.\begin{array}{ll} \underset{x}{Maximize} & U(c, y^c) \\ Subject\ to & y = y\ (L_a, x/k, z) \\ & P_c\, c \le p_y(y - y^c) - p_x x - p_{ah} L_{ah} + p_{\ln} L_n \\ & L = L_{af} + L_n \end{array}\right\} \quad (1)$$

Equation(1) states that "the farm household chooses the agricultural practices x that will maximize the household's utility from consuming marketed consumption-good c and home-produced good y in quantity y^c, subject to the technology for producing good y, household budget, and availability of labor. In terms of technology, the maximization is constrained by technology for producing good y on the farm, which depends on agricultural labor (L_a) and agricultural practices (x), and is conditioned by farm-level capital (k, in various forms) and other natural and external economic characteristics (z). The budget constraint states that no more of c can be purchased at price p_c than the household can afford with net income from sales of y after subtracting home consumption (y^c), the cost of production practices ($p_x x$), and the cost of hired farm labor ($p_{ah} L_{ah}$), plus income from non-farm employment ($p_{ln} L_n$). Finally, the labor available for own-farm production work (L_a) must either come from the family (L_{af}) or from hired labor (L_{ah}). And family labor may be devoted either to own-farm agricultural work (L_{af}) or to non-farm work (L_n).

The solution to this constrained optimization problem yields a reduced form input demand equation (equation (2)) for farming practices x_{ji} (the specific practice x_j associated with the state of natural resource (i)) that depends on the prices (p) of output y, inputs x, labor L_a and L_n; the levels of other agricultural practices $x_{(j)}$ other than x_j; farm capital or asset (k); and conditioning factors (z) related to economic infrastructure, natural characteristics, and the household's management knowledge and information".

$$x_{ji} = x_j(p,\ x_{(j)},\ k,\ z) \quad (2)$$

Equation (2) seeks to answer what matters in the choice of land conservation or farming practices. For instance, do poverty-related factors, such as asset levels, matter in determining the choice of farming practices? If so, which assets matter most - land, livestock, household labor, human capital (education), and/or social capital?

Following Reardon and Vosti, 1995, the categories of poverty or assets in our analysis go beyond the conventional accounting definition of "assets". In this model, the definition of capital assets (k) measures assets as physical and financial (including income, land, livestock, equipment, buildings, financial assets, and other inventories with

marketable value (such as the value of live trees)). On the other hand, the value of people as a key productive asset depends on their number (as measured by household size) and their quality (as measured by age and education). Social capital is also an additional asset category worth considering in the model. This is because social capital may allow a community to impose social norms to discourage individual behavior that undermines the long-term interests of the community as a whole. Moreover, the degree to which people in a community care about one another may ameliorate other conventional resource constraints, such as market access or credit limitations. The *z* variable can broadly account for institutional settings, such as market incentives and land tenure security.

3. Empirical Strategy

In this section, we present a general empirical model of farm investment on land conservation practices set in a way that reflects the conceptual framework summarized above. The selection of explanatory variables we used is based on various related empirical works (e.g., Clay, et al., 2002; Gebremedhin and Swinton, 2003; Hagos and Holden, 2006; Kabubo-Mariara, 2007) and theoretical literature on farm-level investment (e.g., Christensen, 1989; Feder, et al., 1992; and Feder, et al., 1985). In view of this, investment in land conservation is viewed as a function of six vectors of variables (poverty-related factors, land tenure security, market access, physical incentives or plot characteristics, alternative land conservation practices, and village dummies).

3.1 General Empirical Model

The general form of the empirical model we used is given by equation (3):

$$I_{tij} = \beta_0 + (\text{Poverty}_{t\text{-}1i})\beta_1 + (\text{Tenure}_{tij})\beta_2 + (\text{Market}_{ti})\beta_3 + (\text{Plot}_{tj})\beta_4 + (\text{CV})\beta_5 + \varepsilon, \quad (3)$$

where I_{tij} represents the level of land conservation investment made by the farm household *i* on plot *j*, as measured by the length of land conservation structure (Note 4) per hectare (Note 5) over the last 12 months (i.e., over the t-time period); β_0 represents the constant term; and the vector $Poverty_{t\text{-}1i}$ includes measures of income and asset levels of the farm household *i* over the year prior to the last 12 months (i.e., over the t-1 – time period). We assumed that initial poverty-related constraints would matter in the farm household's decision to invest in land conservation. Thus, we considered lagged values of the cash income and non-liquid asset variables. Such initial wealth conditions enable examination of the effect of time recursive causality of initial wealth characteristics on land conservation investments (Hagos and Holden, 2006). The vector $Tenure_{tij}$ represents variables measuring degree of tenure security by the farm household *i* on plot *j* over the t-time period. The vector $Market_{ti}$ is related to market access variables associated with farm household *i* over the t-time period. The vector $Plot_{tj}$ represents variables measuring physical characteristics pertinent to plot *j* of farm household *i* over the t-time period. β_1, β_2, β_3, β_4, *and* β_5 are each a vector of parameters corresponding to each vector of variables$_j$. We also included other control variables (CV). These consist of intensity of alternative land conservation practices and village dummies. ε represents the error term.

As highlighted above, we modeled adoption and intensity of land conservation investment at the plot rather than at the household level. Thus, the model design takes into account that land conservation adoption and intensity decisions are not made uniformly for the entire farm of the household. Unlike most other studies that analyze land conservation, we used a broader set of variables needed to understand the farm management and household strategy seen in such investments. Due to the panel nature of the data used in this study (associated with multiple plot-level observations for each household), we attempted to correct the standard errors for clustering at the household level.

3.2 Issues in Model Selection

In principle, the decisions whether to adopt investment in land conservation and input practices, and how much to invest (intensity of investment), can be made jointly or separately. It can be argued that adoption and intensity of use decisions are not necessarily made jointly (Gebremedhin and Swinton, 2003). The decision to adopt may precede the decision on the intensity of use, and the factors affecting each decision may be different. Had it been the case that the two decisions were made jointly (see Sureshwaran, et al., 1996; Pender and Kerr, 1998) and that these decisions were affected by the same set of factors, then the Tobit model would be appropriate for analyzing the factors affecting the joint decision (Greene, 2000).

However, neither straightforward binary nor censored data models may help in a case where factors affecting each decision are different (Moffatt, 2005).

In the case where the decision whether to adopt the land conservation investment and the decision about how much of it to adopt are not jointly made, it is more suitable to apply a "double-hurdle" model, in which a probit regression on adoption is followed by a truncated regression on the non-zero observations (Cragg, 1971) (Note 6).

The double-hurdle model has rarely been used in the area of adoption and intensity of land conservation investments and input uses. An exception we know of is Gebremedhin and Swinton, 2003, who applied it to examine northern Ethiopian farmers' reasons (focusing on land tenure security and public programs) for adopting and intensifying soil

conservation measures (stone terraces and soil bunds). The double-hurdle specification, however, assumes that the error terms are normally and independently distributed, and in case the normality assumption does not hold estimates will be inconsistent. A solution to this problem is to use a Box-Cox double hurdle specification.

3.3 The Hurdle Model and Its Variants

In cases where the dependent variable takes only positive values and a large proportion of zeroes (which is the case in this study where 84% of observations have zero values), ordinary least squares (OLS) econometric techniques are biased (Long, et al., 2006). An alternative is to estimate the Tobit model, which also has a number of potential shortcomings due to the restrictive assumptions it makes (Blundell and Meghir, 1987). In particular, it assumes that all zero observations are, in fact, standard corner solutions and those households who do not adopt do so as a result of their economic circumstances. This is incongruent to our study because it is possible that some farm households would never state a positive amount as a matter of principle (Note 7) or because they consider land conservation investment or input use as a bad. The p-Tobit model has also been proposed as an alternative, but this is generalized by the use of the double-hurdle model.

The double-hurdle model is a parametric generalization of the Tobit model (Martínez-Espiñeira, 2006) that introduces an additional hurdle which must be passed for positive observations to be observed. As the name "double-hurdle" suggests, farm households must scale two hurdles in order to invest in land conservation. There may be farmers who do not adopt, and hence fall at the first hurdle, and others who pass the first hurdle. The first decision or hurdle for farm households in our setting is whether they will make any land conservation investment at all, while their second decision is the level of land conservation investment, conditional on their first decision.

In the double-hurdle model, both hurdles have equations associated with them, incorporating the effects of adopter characteristics and circumstances. An explanatory variable may appear in both equations or in either of them, and a variable appearing in both equations may have opposite effects in the two equations. The double-hurdle model contains two equations - the adoption equation and the equation on level of adoption (Moffatt, 2005):

$$\begin{aligned} d_i^* &= z_i'\alpha + \varepsilon_i \\ y_i^{**} &= x_i'\beta + u_i \\ \begin{pmatrix} \varepsilon_i \\ u_i \end{pmatrix} &\sim N\left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & 0 \\ 0 & \sigma^2 \end{pmatrix}\right] \end{aligned} \tag{4}$$

where d^* is a latent adoption variable that takes the value 1 if the household adopted land conservation investment, and 0 otherwise; z is a vector of explanatory variables; and α is a vector of parameters. y represents intensity of adoption and x is a vector of explanatory variables, and β is a vector of parameters.

The first hurdle is then represented by:

$$\begin{aligned} d_i &= 1 \quad if \quad d_i^* > 0 \\ d_i &= 0 \quad if \quad d_i^* \le 0 \quad . \end{aligned} \tag{5}$$

The second hurdle is given by:

$$y_i^* = \max\left(y_i^{**}, 0\right) \quad . \tag{6}$$

And the observed variable, y_i, is finally determined by equation (7):

$$y_i = d_i y_i^* \quad . \tag{7}$$

The log-likelihood function for the double hurdle model is:

$$LogL = \sum_0 \ln\left[1 - \Phi\left(z_i'\alpha\right)\Phi\left(\frac{x_i'\beta}{\sigma}\right)\right] + \sum_+ \ln\left[\Phi\left(z_i'\alpha\right)\frac{1}{\sigma}\phi\left(\frac{y_i - x_i'\beta}{\sigma}\right)\right] \tag{8}$$

The double-hurdle model (as originally proposed by Cragg, 1971) is equivalent to a combination of a truncated regression model and a univariate probit model, provided the assumption of independence between the error terms ε_i and u_i, stated in equation (4), holds. Following Cragg, 1971, the decision on adoption can be modeled as a probit regression (Gebremedhin and Swinton, 2003):

$$f(y = 1 | X_1, X_2) = C(X_1'\beta), \tag{9}$$

where C(.) is the normal cumulative distribution function, and X_1 and X_2 are vectors of independent variables, not necessarily distinct. The decision on the intensity of use can be modeled as a regression truncated at zero:

$$f(y | X_1, X_2) = (2\pi)^{-1/2}\sigma^{-1}\exp\left\{\frac{-(y - X_2'\gamma)^2}{2\sigma^2}\right\} \times \frac{C(X_1'\beta)}{C(X_2'\gamma/\sigma)} \tag{10}$$

3.4 Box-Cox Double Hurdle Model

As shown in the last expression of equation (4), the two error terms (ε_i and u_i) in the double hurdle specification are assumed to be normally and independently (Note 8) distributed. In case the normality assumption does not hold the maximum likelihood estimate will be inconsistent. A solution to this problem is to transform the dependent and latent variable. This can be done by manipulating the dependent variable, Y, using a Box-Cox transformation (Jones and Yen, 2000; Moffatt, 2005; Martínez-Espiñeira, 2006):

$$y^T = \frac{y^\lambda - 1}{\lambda}, \quad 0 < \lambda \le 1 \tag{11}$$

where $\lambda = 1$ and $\lambda \to 0$ represent special cases of straightforward linear transformation and the logarithmic transformation respectively. Normally, λ would be expected to be somewhere between these two extremes. The Box-Cox double hurdle is obtained by applying the transformation on the dependent variable in the double hurdle model (equations 6 and 7), and defining the hurdles as (Moffatt, 2005):

First hurdle:

$$\begin{aligned} d_i &= 1 \quad if \quad d_i^* > 0 \\ d_i &= 0 \quad if \quad d_i^* \le 0 \end{aligned} \tag{12}$$

Second hurdle:

$$y_i^{*T} = \max(y_i^{**T}, -\frac{1}{\lambda}) \tag{13}$$

Observed variable, y^T, is finally determined by:

$$\begin{aligned} y_i^T &= y_i^{*T} \quad if\ d_i = 1 \\ y_i^T &= -\frac{1}{\lambda} \quad if\ d_i = 0 \end{aligned} \tag{14}$$

The log-likelihood function for the Box-Cox double hurdle model is:

$$LogL = \sum_0 \ln\left[1 - \Phi\left(z_i'\alpha\right)\Phi\left(\frac{x_i'\beta + 1/\lambda}{\sigma}\right)\right] + \sum_+ \ln\left[\Phi\left(z_i'\alpha\right) y_i^{\lambda-1} \frac{1}{\sigma}\phi\left(\frac{y_i^T - x_i'\beta}{\sigma}\right)\right] \tag{15}$$

which is similar to equation (8) except that in equation (15) y^T is used instead of y which requires a Jacobian term $y^{\lambda-1}$ to be included.

In this study, we estimated both the Box-Cox double-hurdle and Box-Cox tobit models and select the appropriate one (see section 4.2). We used the econometric software STATA (version 11).

3.5 Heteroskedasticity and Panel Effect

We attempted to control for the panel nature of the data (multiple plot-level observations for each household) using clustering in STATA. The regressions were analyzed using robust estimators to account for clustering within households.

3.6 Exogeneity of RHS Variables

Some of the exogenous variables seem to be jointly determined with the land conservation decision and may appear endogenous. Thus, we considered lagged values of the suspected variables such as poverty and wealth related

variables. This enables examination of the effect of time recursive causality of initial characteristics on land conservation investments.

3.7 Test for Model Appropriateness: Box-Cox Tobit versus Box-Cox Double-Hurdle Model

Whether a Box-Cox tobit or a Box-Cox double hurdle model is more appropriate can be determined by separately estimating the Box-Cox tobit and the Box-Cox double hurdle models and then conducting a likelihood ratio test that compares their log likelihood functions. The likelihood ratio test statistics is computed and decisions are made (see section 4.2) following the literature (Greene, 2000).

4. Data, Results, and Interpretation

The main data source for this study was rural household survey collected in East Gojjam and South Wello zones of the Amhara region of Ethiopia. We use panel data that was collected in 2002 and 2005 as part of a collaborative research project by the economics departments at Addis Ababa University, Ethiopia, and University of Gothenburg, Sweden, with financial support from Sida/SAREC.

4.1 Data and Descriptive Statistics

A total of 1,520 households from 12 sites (villages or *kebeles*), with a minimum of 120 households from each site, were interviewed in the 2002 round of the survey. Two more sites (i.e., 240 households) and some new questions were included in the 2005 round. This made a total of 1,760 households in 14 sites interviewed in the 2005 round. The selection of the sites was deliberate to ensure variation in the characteristics of the sites, including agro-ecology and vegetative cover. Households from each site were then selected using simple random sampling.

Some of the variables of interest to this study were not included in the 2002 round, so this study focused mainly on analyzing the data gathered in the 2005 round and included poverty- and asset-related variables from the 2002 round. The regression analysis in this study used 6,408 household plots, after dropping the remaining plots due to missing values. The data gathered a host of household-related variables, as well as plot-level data, including land conservation practices and inputs, and questions pertaining to household poverty, land tenure security, and market incentives.

Table 1 presents the definitions and observation level of the variables included in the analysis. The dependent variable in the first hurdle is the farm households' adoption decision of land conservation investment on specific plots. The level of land conservation or intensity of investment in land conservation is also used as another dependent variable in the second hurdle. The rest of the variables listed in table 1 are explanatory variables. Following the conceptual framework and the related discussion earlier in this paper, we classified the variables used in the analysis into six broad categories (Note 9): poverty-related factors (Note 10), risk or land tenure security (Note 11), market access, physical incentives, alternative input uses, and village dummies.

Table 1. Definition and observation level of the dependent and explanatory variables

Variables			Definition	Obs. Level
Land conservation adoption (Dependent variable /DV/)			Implemented new soil conservation works in the past12 months: 1 if implemented; 0 if otherwise	Plot
Level of land conservation (DV)			Length of land conservation investments in the last 12 months: Meter/Hectare	Plot
Poverty-related factors	Income	Non-crop income	Sale of livestock and its products, energy, trees, and gift: ETB/year	Household
		Employment income	Income from non-own agricultural employment: ETB / year	Household
		Cash crop income	Income from sale of production: ETB / year	Household
		Access to credit*	Household had access to credit over 200 ETB per year: 1 if yes; 0 if no	Household
	Non-liquid asset	Farm size	Total land holding by the household in current year : Hectare	Household
		Number of cattle	Number of cattle owned by the household	Household
		Number of ruminants	Number of ruminants owned by the household	Household
		Value of livestock	Monetary value of livestock owned if sold: ETB / year	Household
		Value of live trees	Monetary value of live trees owned if sold: ETB / year	Household
		Value of crop produced	Market value of crop output produced if sold: ETB / year	Household
	Human-capital	Male adults per hectare	Number of male adults of age between 12 and 65 per Hectare	Household
		Female adults per hectare	Number of female adults of age between 12 and 65 per Hectare	Household
		Dependent ratio	Ratio of number of non-working to working age-members of age 12 -65	Household
		Age of household head	Age of head of the household: number of years	Household
		Male head of household	Gender of head of the household: 1 if male and 0 if female	Household
		Literacy of head	Literacy of head of the household: 1 if read /write; 0 otherwise	Household
		Marital status of head	Marital status of head of the household: 1 if married; 0 otherwise	Household
		Access to extension	Household access to extension services: 1 if has access; 0 if no	Household
		Soil conservation advise	Development agents advised household on soil conservation: 1 if advised; 0 if not.	Household
	Life improvements: Social capital		Household's belief in life condition improvement in the future: 1=definitely possible, 2=possible, 3=not sure, 4=impossible, 5=completely impossible	Household
	Household expenditure		Household expenditure per annum: ETB	Household
Land tenure security – risk factor	Cultivate plot in 5 years		Plot owners feels certain to cultivate the plot 5 years from now:1 if certain; 0 if not	Plot
	Land ownership type		Type of land ownership: 1 if owner-operated; 0 if otherwise (mortgage/rent –in or out)	Plot
	Land ownership belief		Household believes that land belongs to itself 1; 0 otherwise[i]	Household
	Plot-home distance		Distance of plot from residence: walking minutes	Plot
	Simpson Index: Index of land fragmentation		1 minus the ratio of the sum of squared plot areas to the squared area of the total farm size of the household: plot fragmentation index	Household
	Plot age		Number of years since land was held by the household	Plot
Market access	Town-residence distance		Distance of household residence to nearest town: walking minutes	Household
	Road-residence distance		Distance of residence to nearest car road: walking minutes	Household
	Market-residence distance		Distance of residence to market most products sold: walking minutes	Household
	Return from investment		Proxy by household expectation of long term effect of fertilizer: 1 if decreases or no change to productivity; 0 if increases productivity	Household
Physical incentives	Highland		Plot altitude from sea level: 1 if above 2500m; 0 otherwise	Plot
	Soil fertility		Fertility of the plot's soil: 3 if fertile, 2 if medium, 1 if low fertility	Plot
	Plot slope		Slope of the plot: 1if steep uphill /'dagetama'; 0 otherwise	Plot
	Plot area		Plot area in Hectare	Plot
	Plot access to irrigation		Plot has access to irrigation: 1 if irrigated; 0 if not irrigated	Plot
	Major use of plot[ii]	Tree plant	Major use of the plot is for tree planting: 1 if yes; 0 otherwise	Plot
		Grazing	Major use of the plot is for grazing : 1 if yes; 0 otherwise	Plot
Input	Past land investment intensity		Length of land conservation investments before the last 12 months: Meter	Plot
	Modern fertilizer use		Modern fertilizer used over the last 12 months: Kilogram	Plot
	Natural fertilizer use		Natural fertilizer use over the last 12 months: Kilogram	Plot
Village Dummy[iii]	Amanuel D.Elias		1 if village is Amanuel; 0 otherwise 1 if village is D.Elias; 0 otherwise	Prefecture
	Kebi Telma		1 if village is Kebi; 0 otherwise 1 if village is Telma; 0 otherwise	Prefecture
	Yamed Wolkie		1 if village is Yamed; 0 otherwise 1 if village is Wolkie; 0 otherwise	Prefecture
	Sekladebir		1 if village is Sekladebir; 0 otherwise	Prefecture

*In this study, credit access is considered as part of household's cash income. Assessment of the data resulted in 200 ETB as a cut-off point for access to credit

.[i]Zero is when household believes the land belongs to either the peasant association or the government. [ii] The base group for the major use of plot dummy is 'plot with major use for farming and/or fallowing'. [iii] The base group for the village dummies include villages named 'Kete', 'Godguadit', 'Ambamariam', 'Addismender', 'Chorisa', 'Indodber', and 'Addisgulit'

Table 2 provides summary statistics for all the dependent and explanatory variables used in our analysis for the full sample, non-adopters, and adopters of land conservation investment. Land conservation adoption is undertaken on about 16 percent of the plots. The mean length of land conservation structure on a plot is 42 and 268 meters per hectare for the full sample and the adopting plots, respectively. This is far less than the average requirement of 700 meters per hectare of stone terraces or soil bunds to conserve a hectare of land and reduce soil erosion effectively on typical sloped areas in northern Ethiopia as estimated by Gebremedhin and Swinton, 2003.

Table 2. Summary statistics for full sample, adopters and non-adopters of land conservation investment

Variables			Full sample (N = 6408)		Adopting (N = 1005)		Non-adopting (N = 5403)	
			Mean	**Std.Dev**	**Mean**	**Std.Dev**	**Mean**	**Std.Dev**
Land conservation adoption			0.16	0.36	1	0	**0**	**0**
Level of land conservation (m per ha.)			42	147	268	277	-	-
Poverty-related factors	Income	Non-crop income	512	594	478	518	518	606
		Employment income	139	368	102	279	146	382
		Cash crop income	204	305	187	253	208	314
		Access to credit	.19	.39	.18	.38	.20	.40
	Non-liquid asset	Farm size	1.61	1.22	1.49	1.12	1.63	1.24
		Number of cattle	4.15	3.69	3.58	2.84	4.25	3.82
		Number of ruminants	1.77	3.10	1.68	2.89	1.79	3.14
		Value of livestock	1809	1568	1623	1343	1844	1604
		Value of live trees	2249	4405	2665	5092	2172	4261
		Value of crop produced	893	1192	900	1308	892	1169
	Human-capital	Male adults per hectare	2.16	1.91	2.22	2	2.15	2
		Female adults per ha.	2.18	2.11	2.0	1.85	2.18	2.16
		Dependent ratio	.65	.55	.62	.48	.66	.56
		Age of household head	50	15	50	15	50	14.39
		Male head of household	.88	.32	.88	.33	.88	.32
		Literacy of head	.51	.50	.45	.50	.52	.50
		Marital status of head	.88	.32	.85	.36	.89	.32
		Access to extension	.51	.50	.59	.49	.49	.50
		Soil conservation advise	.38	.49	.39	.49	.37	.48
	Life improvements		2.47	.97	2.55	1.02	2.46	.96
	Household expenditure		1399	1110	1237	888	1429	1144
Land tenure security – risk factor	Cultivate plot in 5 years		.67	.46	.75	.43	.68	.47
	Land ownership type		.81	.39	.85	.36	.81	.39
	Land ownership belief		.458	.50	.50	.50	.44	.5
	Plot-home distance		1.51	2.36	1.60	2.24	1.60	2.38
	Simpson Index		.78	.13	.77	.13	.78	.13
	Plot age		18.84	9.55	18.77	9.70	18.85	9.52
Market access	Town-residence distance		61.44	41.22	68.56	41.52	60.12	41.04
	Road-residence distance		33.42	33.27	36.06	33.00	32.93	33.30
	Market-residence distance		69.25	38.36	73	41.10	68.57	37.79
	Return from investment		.38	.49	.31	.46	.39	.49
Physical incentives	Highland		.32	.47	.31	.46	.32	.47
	Soil fertility		2.27	.72	2.29	.70	2.27	.73
	Plot slope		.06	.23	.09	.29	.05	.22
	Plot area		.22	.18	.22	.16	.22	.18
	Plot access to irrigation		.04	.21	.05	.21	.04	.20
	Major use of plot	Tree plant	.05	.21	.04	.20	.05	.22
		Grazing	.02	.14	.01	.07	.02	.15
Input	Past land investment intensity		25.14	52.41	4.75	19.97	28.93	55.61
	Modern fertilizer use		9.16	20.75	8.87	19.24	9.21	21.02
	Natural fertilizer use		156	395	183	390	151	395

Remark: Site dummies are included but not reported here.

4.2 Model Appropriateness: Box-Cox Tobit versus Box-Cox Double Hurdle Models

Model appropriateness was determined by examining the normality of the error terms. To give a feel for the distribution of the dependent variable over the 1005 adopters, a histogram is shown in Figure 1. The dependent variable shows a strong positive skewness, bringing us into doubt the validity of the normality assumption in the

error terms. Hence, we used the Box-Cox transformation (equation 11) and proceed with the Box-Cox estimation procedures.

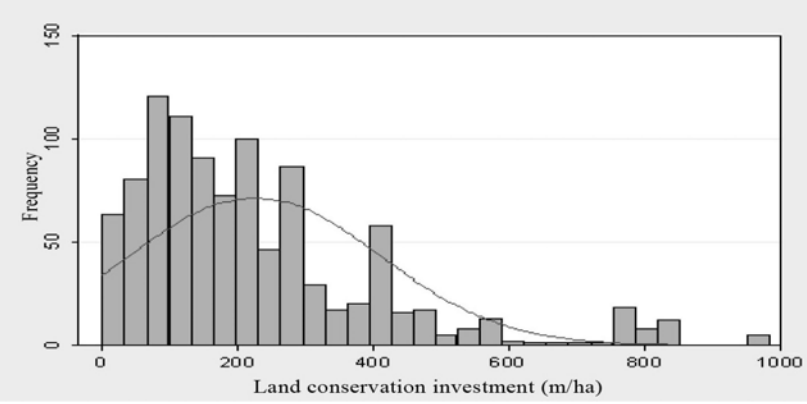

Figure 1. A histogram of land conservation investment

We estimated both Box-Cox tobit and Box-Cox double-hurdle models separately (see table 3 for estimation results (Note 12)), and then conducted a likelihood ratio test.

When testing the Box-Cox tobit model as a restricted version: likelihood ratio statistics, Γ , is 2(8823.38-8579.75)=487.26, which, when compared to the $\chi^2(48)$ [≈ 73.68, at the 1 percent-level of significance] distribution is seen to represent overwhelming evidence of the importance of the first hurdle. This confirms the superiority of the Box-Cox double-hurdle specification, implying that the plot-level decision to adopt land conservation and the decision about how much to invest appear to be governed by different processes. This is also confirmed by the result of the Akaike's information criterion (AIC), which is included at the foot of table 3. This is a model selection criterion which adjusts for the number of parameters and the model with the lowest AIC is preferred. The less formal "test" of comparing the Box-Cox tobit and Box-Cox double-hurdle models estimated coefficients also confirmed the above test results. This is implied from the existence of variables that significantly affect adoption decision without being significant factors for the intensity decision, and vice versa. Even among those that affect both adoption and intensity, the direction of effect for some is different. Furthermore, the estimated coefficients in the simpler Box-Cox tobit model are overestimated when compared to the corresponding estimates in the Box-Cox double hurdle model. This bias arises as a result of the invalid treatment of both hurdles as a single process in the former model.

Table 3. MLEs for Box-Cox tobit and Box-Cox double hurdle models (Dependent variable: Level of land conservation (m per ha.))

			Box-Cox tobit		Box-Cox double hurdle	
First hurdle			Coef.	Robust std. errors	Coef.	Robust std. errors
Constant					-136.96	123.24
Poverty-related factors	Income	Non-crop income			-0.05**	0.02
		Employment income			-0.04	0.03
		Cash crop income			-0.03	0.08
		Access to credit			11.45	22.86
	Non-liquid asset	Farm size			38.99**	18.86
		Number of cattle			0.18	6.52
		Number of ruminants			9.47	10.00
		Value of livestock			-0.01	0.02
		Value of live trees			0.01*	0.003
		Value of crop produced			0.01	0.01
	Human-capital	Male adults per hectare			4.40	7.91
		Female adults per hectare			15.48	12.40
		Dependent ratio			-33.72*	20.98
		Age of household head			0.022	1.13
		Male head of household			103.43	81.57
		Literacy of head			-23.74	30.24
		Marital status of head			-78.74	55.44
		Access to extension			82.63*	55.85
		Soil conservation advise			-51.87	35.67
	Life improvements: Social capital				24.80	23.21
	Household expenditure				-0.04**	0.02
Land tenure security – risk factor	Cultivate plot in 5 years				93.45*	60.80
	Land ownership type				-6.84	22.45
	Land ownership believe				15.49	39.50
	Plot-home distance				-3.67	3.54
	Simpson Index				149.75	162.38
	Plot age				-1.13	1.11
Market access	Town-residence distance				-0.32	0.36
	Road-residence distance				-0.98**	0.51
	Market-residence distance				0.25	0.34
	Return from investment				-55.36*	32.52
Physical incentives	Highland				-45.83	59.06
	Soil fertility				-18.96	15.93
	Plot slope				82.26**	35.11
	Plot area				-94.28*	39.98
	Plot access to irrigation				41.34	47.63
	Major use of plot for tree planting				-30.84	63.88
	Major use of plot for grazing				121.16	162.72
Input	Past land investment intensity				-3.08***	0.99
	Modern fertilizer use				0.32	0.29
	Natural fertilizer use				0.004	0.02
Village Dummy	Amanuel				-288.84**	134.47
	D.Elias				-371.24***	88.56
	Kebi				-216.22***	63.78
	Telma				-99.40	74.63
	Yamed				99.57	71.99
	Wolkie				-37.62	71.99
	Sekladebir				68.09	62.93

Table 4. continued (for the second hurdle).

Second hurdle			***Box-Cox tobit***		***Box-Cox double hurdle***	
			Coef.	*Robust std. errors*	*Coef.*	*Robust std. errors*
Constant			-253.97**	116.21	0.83	3.60
Poverty-related factors	Income	Non-crop income	-0.04*	0.02	0.0002	0.001
		Employment income	-0.06*	0.03	-0.0003	0.0004
		Cash crop income	-0.12**	0.05	-0.002*	0.001
		Access to credit	-54.36*	30.59	-0.88***	0.34
	Non-liquid asset	Farm size	18.55	22.64	-0.20	0.17
		Number of cattle	-2.23	6.15	-0.05	0.06
		Number of ruminants	-2.54	4.73	-0.18	0.23
		Value of livestock	0.01	0.01	0.0002	0.001
		Value of live trees	0.01**	0.00	0.0001	0.001
		Value of crop produced	0.01	0.01	0.000	0.000
	Human-capital	Male adults per hectare	6.34	6.72	0.04	0.11
		Female adults per hectare	-0.92	6.71	-0.21**	0.11
		Dependent ratio	-26.47	22.22	0.31	0.28
		Age of household head	-0.34	1.05	-0.002	0.03
		Male head of household	24.26	40.84	-1.46	1.69
		Literacy of head	-10.99	26.21	0.16	0.43
		Marital status of head	-35.22	39.79	0.94	1.15
		Access to extension	63.86**	31.52	-0.58	0.95
		Soil conservation advise	7.58	31.78	0.76*	0.52
	Life improvements: Social capital		31.09**	15.60	-0.15	0.54
	Household expenditure		-0.03**	0.01	0.001*	0.0004
Land tenure security – risk factor	Cultivate plot in 5 years		38.14	24.70	-1.19	1.16
	Land ownership type		44.50***	27.01	0.99**	0.53
	Land ownership believe		13.67	23.71	-0.14	0.58
	Plot-home distance		4.53*	2.85	0.21***	0.07
	Simpson Index		42.19	83.00	-2.22	2.46
	Plot age		-0.71	1.12	0.01	0.02
Market access	Town-residence distance		0.40	0.33	0.01	0.01
	Road-residence distance		0.32	0.35	0.03***	0.01
	Market-residence distance		-0.13	0.29	-0.01	0.01
	Return from investment		-109.32***	31.99	-0.68**	0.35
Physical incentives	Highland		-148.82***	51.87	-0.87	0.79
	Soil fertility		2.71	13.10	0.34	0.22
	Plot slope		87.36**	44.26	-0.35	0.72
	Plot area		71.39*	38.15	4.94***	1.82
	Plot access to irrigation		31.06	40.13	-0.31	0.62
	Major use of plot for tree plant		-96.96***	35.42	-0.65	0.59
	Major use of plot for grazing		-271.00***	92.83	-3.86***	0.77
Input	Past land investment intensity		-5.60***	1.41	-0.02***	0.01
	Modern fertilizer use		0.34	0.39	0.002	0.01
	Natural fertilizer use		0.04***	0.02	0.001***	0.001
Village Dummy	Amanuel		-274.02***	73.05	2.23	14.61
	D.Elias		-356.75***	85.63	4.46	3.73
	Kebi		-253.58***	75.12	-0.12	0.94
	Telma		100.75*	51.96	4.05***	1.53
	Yamed		164.41	56.60	1.35*	0.76
	Wolkie		-70.46	74.16	-1.17*	0.64
	Sekladebir		-12.52	58.15	-1.002	0.85
σ			269.49***	42.10	181.21***	38.39
λ			0.906***	0.029	0.88***	0.03

ISSN 1916-971X E-ISSN 1916-9728

Sample size (n)	6408	6408
Log L	-8823.38	-8579.75
Wald chi2 (48)	64.66	69.05
Prob > chi2	0.0545	0.025
AIC = (- LogL + k), where k is number of parameters	1.39, where k=51	1.35, where k=99

Standard errors are adjusted for clustering on household id in both the Box-Cox tobit and Box-Cox double hurdle estimations.

*P<0.10, **<0.05, ***<0.01.

4.3 Determinants of Adoption of Land Conservation Investment

The results of the Box-Cox double hurdle estimations for the first hurdle (i.e. adoption decisions) are presented in table 3. The table reports the estimated coefficients and their robust standard errors (adjusted for clustering on household identification). The chi-square test results are presented at the bottom of the table. The estimated likelihood ratio test shows that the model is a good fit overall. The results are discussed below with a focus on the role of poverty-related factors, land tenure security, and market access.

4.3.1 Poverty-related Factors

The negative relationship between poverty (in its different forms) and a household's decisions to invest on land conservation and the level of intensity is substantiated in various studies (Hagos and Holden, 2006; Gebremedhin and Swinton, 2003; Clay, et al., 2002; Holden and Shiferaw, 2002; Godoy, et al., 2001; Holden, et al., 1998).

We present our results for poverty-related factors by classifying them into income and asset variables. Cash-income (in the form of non-crop income), farm size, value of live trees, dependent ratio, access to extension services, and household consumption expenditure are statistically significant factors that explain farm households' investment decision in land conservation. The negative effect of non-crop income is in line with the argument that incomes from competing non-farm opportunities can discourage farmers' probability of investing in land conservation. This suggests that better returns from non-owned farms will compete for both labor and investment capital that could be used in agriculture.

Except for farm size and value of live trees, none of the non-liquid asset variables were found to affect the probability of plots receiving land conservation investment. Both of these are statistically significant factors that increase households' probability of investing in land conservation. The positive effect of farm size can be due to that land conservation requires size. While the result for the value of live trees could be interpreted as a reflection of the importance of wealth of the household, it can also be that the two are complements.

Except for the dependent ratio and household access to extension services, none of the human-capital variables were found to significantly affect decisions in land conservation investment. The result for the dependent ratio suggests that more dependents (such as children) in the family implies less time availability (for land conservation) for the non-dependents as the later have to spend more time taking care of their dependents than farming. The result for access to extension services suggests that households with access to extension services are more likely to invest in land conservation indicating the importance of such services perhaps through its effects on awareness and knowledge about such structures.

Household consumption expenditure is found to decrease the probability of a household's decision to invest in land conservation. This is similar to the results for measures of cash income reported above and it suggests that richer households are less likely to invest in land conservation.

The above result confirms that defining poverty in specific measurement units (such as cash-income, non-liquid asset, human and social capital assets) is important in land conservation studies. Given that assets often matter in natural resource management, defining poverty in accordance with income and/or expenditure alone may be restrictive. Sizeable resources over and above bare subsistence consumption and production amounts are required by the poor to address issues of resource degradation.

4.3.2 Land Tenure Security

Except for the variable for 'cultivate plot in 5 years', all the land tenure [in]security variables were found to be statistically insignificant. Households that feel certain that they will cultivate the plot for a longer period (five years after the survey) are associated with higher probability of investing on land conservation suggesting the importance of expectation about land tenure.

4.3.3 Market Access

Distance of a residence from nearest car road is found to be statistically significant in influencing adoption decision. Increase in walking minutes from the household's residence to the nearest car road decreases household's probability to adopt land conservation investment. This can be due to the expected less benefit from investing on plots with less transportation access. This is further amplified by the result for the variable: return on land conservation. A household's expectation of a return on land conservation investment positively affects (note how this variable is specified in table 1) the households' decision to adopt land conservation investment. A household which expected returns from land investment to increase productivity has a higher probability of investing in land conservation. This may be due to the importance of perceived positive marginal benefits received from undertaking land investment in terms of land quality improvements and increased yield.

4.3.4 Physical Incentives

Most of the indicators of physical incentives to invest in a plot, as reflected by plot-level variables, seem to have no role in a household's adoption decision. Plot slope and plot area are turned out to be the only physical incentive variables that affect the households' decision to adopt land conservation investment. Plots situated on steep ('*dagetama'*) slopes have a higher probability of receiving land conservation investment, which suggests that plots on steep slopes are associated with soil erosion and are often vulnerable to land degradation. There is a negative relationship between plot size and the probability of the plot receiving land conservation investment. An increase in size of a plot decreases the probability that the plot will receive land conservation investment. This may be explained by the fact that farmers are likely to invest first and foremost in their smaller parcel perhaps to increase productivity per hectare.

4.3.5 Alternative Land Inputs

With respect to use of alternative land conservation practices, past land-conservation investment intensity is found to be statistically significant. The higher the intensity of previous land conservation investment on a plot, the less likely that the plot will receive new land conservation investment. This shows the preference of farm households to invest primarily on plots that are not well conserved or plots with limited or no previous conservation structures.

4.3.6 Village -or Site- Level Effects

The last set of explanatory variables in our analysis includes village/site dummies. The results indicate that almost half of the village dummies were found to be statistically significant, suggesting the importance of site-level fixed effects. Though not directly implied from our study, village-level fixed variables or community and secteur level factors (including presence of community-led-investments such as Food for Work projects – learning by example) might have a stimulating role in the decision to invest in land conservation measures.

4.4 Determinants of Intensity of Land Conservation Investment

About 1,005 (or 16 percent) of the plot-level observations have positive land-conservation investment intensity. This section presents the results of the Box-Cox double hurdle estimations for the second hurdle (i.e. intensity of land conservation investment) as presented in the second half of table 3. The Wald chi-square test results (presented at the bottom right of table 3) indicate that all the variables in the model are jointly and significantly different from zero, at least at the 5 percent level. The first point to be noted from the results is that many of the determinants of level of land conservation have effects contrary to those of the determinants of adoption.

4.4.1 Poverty-related Factors

Similar to the results for adoption probability, cash-income (in the form of cash-crop income and credit access) appears to be important in the second hurdle. Cash crop income has a negative and statistically significant relationship with the intensity of conservation, a result not in line with expectations. Access to credit, although insignificant in influencing adoption decision, turned out to be strongly significant in explaining investment intensity. While access to credit could mean better capacity to invest in land conservation, better access to credit is found to be associated with lower levels of land conservation investment.

Unlike the first hurdle decision, none of the non-liquid variables are significant in the second hurdle. Among the human capital variables, however, number of female adults in the household and access to soil conservation advice play important role in the second hurdle. An additional female adult in the household is associated with lower levels of land conservation. We do not have a good explanation as to why female adult labor is significant and not male adult labor. However, the result seems to amplify the gender-specific nature of labor division in Ethiopia, suggesting that female labor availability represents a different asset type and is less important in intensifying land conservation investment. Compared to households that have never received advice about soil conservation, land-conservation

intensity increased for those who were advised. It is also interesting to note that, while access to extension services (which often focuses on general issues related to agriculture) affects adoption, access to advice on soil conservation affects intensity. This suggests that once the household passes the first hurdle of the adoption decision, advice on specific soil conservation issues is more important in order for the household to intensify land conservation investment. Unlike its effect on the first hurdle, household consumption expenditure appears important in the second hurdle, with household expenditures being associated with higher land conservation intensity. This is in line with our expectation that richer households are more likely to intensify land conservation.

4.4.2 Land Tenure [In] Security

Plots that are owner-cultivated are associated with higher intensity of receiving land conservation than plots either mortgaged (in/out) or rented (in/out). Due to the usually short duration of tenure holding and other incentive problems associated with plots that are rented or mortgaged, such a plot receives less land conservation investment than a plot that is owner-cultivated. This result is in line with neo-classical economic theory which suggests, all things being equal, that reduced risk and longer planning horizons should enhance expected returns and encourage investment. It also supports earlier works, such as Alemu, 1999; Feder, et al., 1988; Gebremedhin and Swinton, 2003; Rahmato, 1992.

We also find that greater distance of plots from the homestead is associated with higher intensity. At first glance, this result seemed contrary to our prior expectations that plots not remote from the homestead would receive more land conservation investment, due to not only to the lesser transaction cost involved but also the stronger degree of security attached to homestead farms (or farms closer to the homestead), where land redistribution is infrequent. The result, however, makes more sense when one examines the rural land policy of Ethiopia. According to the Rural Land Administration and Land Use Proclamation of Ethiopia, "a holder of rural land shall have the obligation, among others, to use and protect his land. And when the land gets damaged, the land user should lose his right." Plots at far distances from the homestead are where frequent land redistribution often occurs. Thus, a possible explanation is that households are perhaps conserving first a plot at remote distance from their residences in an attempt to have greater security over the plot.

4.4.3 Market Access

Unlike the adoption decision model, distance of a residence from the nearest car road turned out to be statistically and positively significant in influencing intensity: increase in walking minutes from the household's residence to the nearest car road increases land conservation intensity. This is perhaps because the limited (or absent) alternative off-farm employment opportunities (during the dry season, in particular) and the prevalence of lower wages in distant places reduce the opportunity cost of family labor and the cost of hiring labor, and thus lower the opportunity cost of labor-intensive investments in land conservation. Expectation of return on investment is significant in both adoption and intensity models. Similar to its effect in the first hurdle, return on investment has positive effect in the second hurdle. In particular, intensity decreases among the households that expect returns from land investment to decrease or at least not change productivity. This suggests the importance of perceived positive marginal benefits received from undertaking investment in terms of land quality improvements and increased yield.

4.4.4 Physical Incentives

Among the physical incentives, plot area and grazing plots were found to be significant in influencing investment intensity in land conservation. Given that intensity in our model is measured as meters per hectare, the positive relationship between plot area and intensity is in contrary to prior research results. As argued by Gebremedhin and Swinton, 2003, for instance, larger fields have fewer meters of conservation per hectare because of their indivisibility and diminishing marginal returns on conservation structures within a plot. Regarding major use of the plot, the result suggests that plots mainly used for grazing are associated with a higher intensity than plots that are mainly used for farming and/or fallowing.

4.4.5 Alternative Land Conservation Practices and Site Dummies

Similar to its effect on probability of adoption, past land investment intensity has a significantly negative effect on land conservation intensity. The more a plot received land conservation investment in the past, the less it will receive new land conservation investment in the current year. This shows the preference of farm households to invest primarily on plots that are not well conserved or plots with limited or no previous conservation structures. Natural fertilizer use is found to complement intensity of land conservation investment. Some of the site dummies were significant, suggesting that there are differences in intensity of land conservation across sites.

5. Summary and Conclusions

Using panel data from Ethiopia and the Box-Cox double-hurdle model, this study explores the factors affecting farm households' decision to invest in land conservation and their decision on how much to invest at the plot level, focusing on the roles of poverty, land tenure [in]security, and market access.

The results demonstrate that the decision to adopt land conservation investment and the decision about how much to invest appear to be explained by different processes. The relevant policy and program tools for encouraging land conservation investment depend on whether or not farm households are already convinced of the need to adopt land conservation investments.

In general, poverty-related factors seem to have a mixed effect on adoption as well as intensity decisions. While a farmer's adoption decision is influenced by whether or not the farmer is certain to cultivate the plot for a longer period (in 5 years time), the intensity of land conservation is determined by farmer's belief of land ownership, and plot-home distance. Our results amplified the gender-specific nature of labor division in Ethiopia, suggesting that female labor availability represents a different asset type in intensifying land conservation investment. While access to extension services (which is often focuses on general issues related to agriculture) affects adoption, access to advice on soil conservation affects intensity. Furthermore, our results show a preference of farm households to invest first and foremost on plots that are not well-conserved or plots with limited or no previous conservation structures.

All in all, our study confirms the complexity of land-conservation investment decisions. This is highlighted by the large number of statistically significant variables in the models, each marginally contributing to the overall decision to invest or not, as well as to the decision on how much to invest. A lesson for policymakers is that major changes in land conservation investments will require attention to all these factors because no single factor can be used as a major policy leverage instrument. Some of these factors (such as land tenure security, plot size, and total farm holdings) can be directly influenced by government policies and programs.

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Notes

Note 1. Gebremedhin and Swinton, 2003, for instance showed that land conservation structures were less than the average requirement of 700 meters per hectare of stone terraces or soil bunds to conserve one hectare of land and effectively reduce soil erosion in the typical sloped areas of northern Ethiopia.

Note 2. To our knowledge, the only exception is Gebremedhin and Swinton, 2003.

Note 3. A 'Kebele' is the smallest administrative unit of local government in Ethiopia, similar to a ward or a neighborhood association.

Note 4. This study focused on total household-plot level conservation investment instead of disaggregating them into different types. In such an approach in addition to stone terraces and soil bunds we also include the efforts of farmers that invest on other land conservation measures such as ditch-digging, 'Kitir' works, and other types including grass-cover, counter-farming and forestation.

Note 5. Because of its role in reducing soil erosion effectively, we consider density of land conservation (m/ha) as a more appropriate measure than total length per household-plot.

Note 6. Moreover, as underscored in Feder, et al., 1992, it is necessary to go beyond the typical binary dependent variable methods applied to cross-sectional surveys on technology adoption.

Note 7. It may be that they do not believe that taking care of the land is their responsibility, which is possible in Ethiopia where land is not privately owned, or it may be that they do not adopt because of their belief that their adoption will unlikely make any real difference.

Note 8. The independent assumption is a common practice in these kinds of models (see Jensen and Yen, 1996; Newman et al., 2003).

Note 9. For simplicity, some variables were classified into a category that better described them. For instance, access to credit could have been included in the market access category rather than with poverty-related factors.

Note 10. Because of the gender specific nature of the division of labor in most rural areas of Ethiopia, we made a distinction in the availability of labor between the two genders.

Note 11. Farm fragmentation can be expressed by three measures: the number of plots; the average distance to the parcels in each farm; and the Simpson index, which can be calculated as 1 minus the ratio of the sum of squared parcel areas to the squared area of the total farm (it takes the value between 0 and 1) (see Bellon and Taylor, 1993).

Note 12. Gujarati, 1995, states that multicollinearity may become a problem if the Pearson correlation coefficient exceeds 90%. Our results from a correlation matrix for the independent variables suggest that none of the correlation coefficients exceeded 48%.