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A Household Plot-Level Analysis of the Roles of Poverty, Tenure Security, and Market Incentives

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Abstract

Land degradation is a major problem undermining land productivity in the highlands of Ethiopia. This study explores the factors that affect farm households' decisions at the plot level to invest in land conservation and how much to invest, focusing on the roles of poverty, land tenure security, and market access. Unlike most other studies, we used a double-hurdle model in the analysis with panel data collected in a household survey of 6,408 plots in the Amhara region of Ethiopia. The results suggest that the decisions to adopt land conservation investment and how much to invest appear to be explained by different processes. Poverty-related factors seem to have a mixed effect on both the adoption and intensity decisions. While a farmer's adoption decision is influenced by whether or not the plot is owner-operated (a measure of risk for the immediate period), intensity of conservation is determined by expectation of the certainty of cultivating the land for the next five years (a measure of risk for the longer term), farmer's belief of land ownership, and distance from plot to home.

Key Words: Ethiopia, land conservation, poverty, tenure security

JEL Classification: D1, Q12

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Introduction

A critical environmental issue facing governments of developing societies is land degradation, which is crucial to, among other things, 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) were 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.[1] Indeed, it is only recently that public intervention in land conservation has become an important priority in Ethiopia. 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

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[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 i the typical sloped areas of northern Ethiopia.

programs were adopted based on incorrect assumptions and little understanding of the incentives and constraints related to land conservation—which could be misleading and may even have exacerbated the degradation process.

Better knowledge about what criteria households use in their decisions to invest in land conservation and how these criteria are used will improve policymakers' ability to design effective programs that promote such land conservation investments. This study looks into factors affecting farm households' 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 a 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 (see, e.g., Hagos and Holden 2006; Gebremedhin and Swinton 2003; Clay et al. 2002; Holden and Shiferaw 2002; Holden et al. 1998; Godoy et al. 2001). 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 the possibility that poverty may positively influence land conservation investment. Similarly, there are studies that found or argued that more secure land tenure encourages land conservation investment (Feder et al. 1988; Alemu 1999; Gebremedhin and Swinton 2003; Joireman 2001; Rahmato 1992), 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. We used household plot-level panel data collected in household surveys in the years 2000, 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 (among others). 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 lets us analyze not only the determinants of adoption but also the level of investment in land conservation. Moreover, unlike most other studies,[2] and partly because of the availability of data on the level of investment, we also used Cragg's (1971) 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.

We found that the decision to adopt land conservation investment and the decision about how much to invest appear to be explained by different processes. 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 plot is owner-operated, the intensity of conservation is determined by expectation of the certainty that the farmer will cultivate the plot for a longer period,[3] 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 and is more important in intensifying land conservation investment. While access to extension services (which is often focused 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 in plots that are not well-conserved or plots with limited or no previous conservation structures.

The rest of the paper is structured as follows. The conceptual framework we use is presented in section 1. Section 2 presents the empirical strategy we follow. Data, results, and interpretation are presented in section 3, while section 4 summarizes and concludes.

1. Conceptual Framework

A farm household's expenditure on land conservation practices and input uses can consume a significant share of its overall expenditure. Land conservation and input uses, thus, imply that the household foregoes other consumption and/or investment opportunities, at least temporarily. Use of land conservation practices and inputs, therefore, are considered to be major investment decisions by farmers. For Clay et al. (2002), farmers are likely to pose two basic

[2] To our knowledge, the only exception is Gebremedhin and Swinton (2003).

[3] Households that feel certain that they will cultivate the plot for a longer period are associated with higher intensity of land conservation investment.

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” (including financial and physical) 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 the land conservation investment.

Ideally, financial or monetary incentive 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 (see, e.g., Gebremedhin and Swinton 2003; Clay et al. 2002.) 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 (e.g., perennials, such as coffee and bananas) versus more erosive crops (such as cereals and beans). We used site dummies to account for differences in prices across sites in this study. Moreover, in cases where much of the production is consumed by the household (a common situation in rural Ethiopia), we can assume (in our model) that farmers use criteria other than market prices to evaluate returns from land conservation and input investments. We can, therefore, model household conservation investment under imperfect factor markets because markets in developing countries (such as in our study sites) can often be missing, thin, or imperfect (Holden et al. 2001; Udry 1996). 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 (including asset, wealth, and endowments) and land tenure security, can play a critical role in influencing the decision and intensity of land conservation investments. Physical incentive factors can also affect profitability of investment in land conservation practices and inputs. (These include farm and plot characteristics, such as plot size, altitude, fragmentation, slope, fertility, irrigation access, and distance from plot to home.) 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. Such capacity factors are broadly called wealth (and in this study are referred as poverty-related factors) and constitute a major determinant of investments in land conservation and input uses.

Farmers also consider the risk of making land conservation investments and input uses, and this risk can alter their capacity to invest in land conservation practices and input uses. If, for instance, farmers are uncertain of recovering the full benefits of their investment in the land, then land investment will become riskier and incentives will wane. 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)[4] 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 right of use.

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:

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

This model (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 on the farm, the household budget, and the availability of labor. In terms of technology, the maximization is constrained by the 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).[5] The budget

[4] Volatile and unpredictable output prices can, for instance, be a source of farmers' risk by reducing incentives; farmers will be uncertain of their ability to recover their investment costs by selling surplus production.

[5] Here, it is assumed that the production function y is differentiable, increasing, and concave. It is not, however, assumed that the production function $y(.)$ is separable in inputs x

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 xji (the specific practice xj associated with the state of natural resource i) that depends on the prices (p) of output y; inputs x; labor La and Ln; the levels of other agricultural practices x(j) other than xj; farm capital or asset (k); and conditioning factors (z) related to economic infrastructure, natural characteristics, and the household's management knowledge and information.

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

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 the above analysis go beyond conventional accounting definition of "assets." In this model, the definition of capital assets (k, which gauges poverty) measures assets as physical and financial (including income, land, livestock, equipment, buildings, financial assets, and other inventories with marketable value (such as value of live trees). On the other hand, the value of people as a productive asset depends on their number (as measured by household size) and their quality (as measured by age and education) and is a key productive resource. Moreover, social capital is also an additional asset category worth consideration in the model. This is because social capital6 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

[6] In Ethiopia, *edir* and *ekub* are among the indigenous social capitals that may allow a community to impose social norms to individual behavior. *Edir* is mainly associated with funerals, and *ekub* is a rotating saving and credit association.

people in a community care about one another may ameliorate other conventional resource constraints, such as market access or credit limitations. In this study, the z variable can broadly account for institutional settings, such as market incentives and land tenure security.

2. 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 was also based on various related empirical works (e.g., Clay et al. 2002; Gebremedhin and Swinton 2003; Hagos and Holden 2006; and 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.

2.1 General Empirical Model

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

$$I_{tij} = \beta_0 + (Poverty_{t-1i})\beta_1 + (Tenure_{tij})\beta_2 + (Market_{ti})\beta_3 + (Plot_{tj})\beta_4 + (CV)\beta_5 + \varepsilon \quad (3)$$

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 per hectare over the last 12 months (i.e., over the t-time period); β_0 represents the constant term; and the vector $Poverty_{t-1i}$ 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 (see, e.g., 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. $\beta_1, \beta_2, \beta_3, \beta_4$, *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 or cluster of plots of a particular household), we attempted to correct the standard errors for clustering at the household level.

2.2 Issues in Model Selection

In principle, the decisions whether to adopt investment in land conservation and input practices, and how much to invest (level or 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 (see, e.g., 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 1993).

However, neither straightforward binary nor censored data models may help in a case where factors affecting each decision are different because such models assume that the process that results in non-adoption is the same as the one that determines the intensity of adoption (see, e.g., Moffatt 2003). An argument can be made here that if a given farm household's characteristic is known to have a positive effect on the extent of adoption, then a high value of this characteristic would inevitably lead to the prediction of adoption for such a farmer. There may be a proportion of the population of farmers who would, out of principle or because they will be negatively affected by adopting the land conservation practice or input, never adopt under any circumstances. In such a case, a model such as Tobit (see, e.g., Martinez-Espiñeira 2004) might be too restrictive because it allows one type of zero observation, namely a corner solution, since it is based on the implicit assumption that zeros arise only as a result of the respondent's economic circumstances. Even the p-Tobit model (a flexible version of the Tobit model in terms of considering the non-supporters of land conservation) fails to analyze the factors that will make a respondent more or less likely to be a supporter of land conservation (Martinez-Espiñeira 2004).

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 (using all observations) is followed by a truncated regression on the non-zero observations (Cragg 1971). Holding the argument that adoption and intensity of use decisions may not necessarily be made jointly, and that the factors affecting each decision may be different, leads to the use of the double-hurdle model, in which the event of a farmer being a potential adopter and the extent of adoption are treated separately.[7]

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 the double-hurdle model in their study on investment in soil conservation in northern Ethiopia.

2.3 The Double-Hurdle Model and Its Variants

In cases where the dependent variable with 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, even asymptotically. Simply omitting the zero observations and applying OLS also creates bias and would discard a great deal of valuable information (Long 1996). An alternative is to estimate the Tobit model,[8] which provides consistent estimates of the parameters. The Tobit model, which has been used in analysis of adoption, can be stated as:

$$y_i^* = x_i^{'}\beta + u_i \qquad i = 1,\ldots, n \tag{4}$$

[7] 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.

[8] The Tobit model was created by James Tobin (1958) in his analysis of household expenditure on durable goods and has since been applied to a large number of econometric models concerning censored data. Censoring occurs when there is an underlying continuous variable, but some subset of the range of values of the variable is coded to one number, thereby creating a mass point—zero value in our case.

$$u_i \sim N(0, \sigma^2) \quad ,$$

where y_i* is a latent variable representing household i's propensity to adopt, x_i is a vector of farm household and plot characteristics relevant in explaining the extent of adoption, β is corresponding vector of parameters to be estimated, and u_i is a homoskedastic and normally distributed error term.

Let y_i be the actual adoption (level of investment in land conservation and input). Since actual adoption cannot be negative, the relationship between y_i* and y_i is:

$$y_i = \max(y_i^*, 0) \quad . \tag{5}$$

Equation (5) gives rise to the standard censored regression (Tobit) model. The log-likelihood function for the Tobit model is:

$$LogL = \sum_0 \ln\left[1 - \Phi\left(\frac{x_i^{'}\beta}{\sigma}\right)\right] + \sum_+ \ln\left[\frac{1}{\sigma}\phi\left(\frac{y_i - x_i^{'}\beta}{\sigma}\right)\right] , \tag{6}$$

in which "0" indicates summation over the zero observations in the sample, while "+" indicates summation over positive observations, and $\Phi(.)$ and $\phi(.)$ are the standard normal cumulative distribution functions (CDF) and probability distribution functions (PDF), respectively.

The Tobit model has a number of potential shortcomings due to the restrictive assumptions it makes. First, it assumes that the same stochastic process determines both the value of continuous observations on the dependent variable and the discrete switch at zero (see, e.g., Blundell and Meghir 1987). Such assumption may not be appropriate to our study because the factors that affect whether or not a household adopts land conservation investment may be significantly different from the factors that affect how much to invest. Second, the Tobit model also assumes that all zero observations are, in fact, standard corner solutions and that households that do not adopt do so as a result of their economic circumstances. This is again incongruent to our study because it is possible that some farm households would never state a positive amount as a matter of principle[9] or because they consider land conservation investment or input use as a

[9] It may be that they do not believe it is their responsibility to take care of the land, 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.

bad. Moreover, maximum likelihood estimation for the Tobit model assumes that the errors are normal and homoskedastic, in the violation of which (each assumption) the maximum likelihood estimator is inconsistent (Maddala and Nelson 1975 and Arabmazar and Schmidt 1982, as cited in Long 1996). 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 by introducing 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 model's underlying assumption in our setting is that farm households make two decisions with regard to their investment in land conservation and use of inputs. Their first decision 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 (adoption equation and equation on level of adoption [Moffatt 2003]):

$$d_i^* = z_i^{'}\alpha + \varepsilon_i$$

$$y_i^{**} = x_i^{'}\beta + u_i \tag{7}$$

$$\begin{pmatrix} \varepsilon_i \\ u_i \end{pmatrix} \sim N\left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & 0 \\ 0 & \sigma^2 \end{pmatrix}\right]$$

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.

As shown in the last expression of equation (7), the two error terms (ε_i and u_i) are assumed to be normally and independently distributed. The first hurdle is then represented by:

$$d_i = 1 \quad if \quad d_i^* > 0 \tag{8}$$

$$d_i = 0 \quad if \quad d_i^* \leq 0\,;$$

the second hurdle is given by:

$$y_i^* = \max\left(y_i^{**}, 0\right)\,; \tag{9}$$

and the observed variable y_i is finally determined by equation (10):

$$y_i = d_i y_i^*\,. \tag{10}$$

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

$$LogL = \sum_0 \ln\left[1 - \Phi\left(z_i^{'}\alpha\right)\Phi\left(\frac{x_i^{'}\beta}{\sigma}\right)\right] + \sum_+ \ln\left[\Phi\left(z_i^{'}\alpha\right)\frac{1}{\sigma}\phi\left(\frac{y_i - x_i^{'}\beta}{\sigma}\right)\right] \tag{11}$$

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 (7), holds. Following Cragg (1971), the decision on adoption can be modeled as a probit regression (Gebremedhin and Swinton 2003):

$$f(y = 1 | X_1, X_2) = C(X_1^{'}\beta)\,, \tag{12}$$

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:

$$f(y | X_1, X_2) = (2\pi)^{-1/2}\sigma^{-1}\exp\left\{\frac{-(y - X_2^{'}\gamma)^2}{2\sigma^2}\right\} \times \frac{C(X_1^{'}\beta)}{C(X_2^{'}\gamma / \sigma)}\,. \tag{13}$$

For this paper, we estimated both the double-hurdle and standard Tobit models and select the appropriate model. We used the econometric software STATA, version 9.0.

2.4 Heteroskedasticity and Panel Effect

Given the panel nature of the data (multiple plot-level observations for each household), we attempted to control for the panel nature of the data, using clustering probit, Tobit, and truncated models available in STATA. The regressions were analyzed using robust estimators to account for clustering within households. For the Tobit model, the standard errors were adjusted for clustering on household identification by using interval estimation for Tobit with cluster.[10] In principle, the result from such estimation is comparable with the results using the Tobit command. Because the point estimates are the same and because all of the predictors are still significant with the robust standard errors, the interpretation will be the same as the Tobit model.[11]

2.5 Test for Model Appropriateness: Tobit versus Double-Hurdle Model

A test for the Tobit model against the double-hurdle model comes from the fact that the hurdle model log likelihood can always be written as the sum of the log likelihoods of the two separate models: a probit and a truncated model. As such the hurdle model likelihood function can always be maximized, without loss of information, by maximizing the two components separately (McDowell 2003).

Therefore, whether a Tobit or a double hurdle model is more appropriate can be determined by separately estimating the Tobit and the double hurdle models (the truncated regression model and the probit model) separately and then conducting a likelihood ratio test that

[10] As there is no robust option in the Stata Tobit command (in STATA, version 9.0, at least), a Tobit analysis with robust standard errors is addressed in this study by making use of interval estimation through the "intreg" command. To use this command, however, we reconfigured the dependent variable (level of investment in land conservation), so that it would work with intreg. The intreg command requires two values of the response variable for each observation. If we called these two values lX and uX, then for those cases in which the response is not censored both lX and uX are set to the same value. When a response is right-censored, uX is set to missing and when the response is left -censored, lX is set to missing. There are no right-censored responses in this analysis, thus the dependent variable is set to match the latter.

[11] See, for example, www.ats.ucla.edu/stat/stata/dae/tobit2.htm.

compares the Tobit with the sum of the log likelihood functions of the probit and truncated regression models.[12]

3. Data, Results, and Interpretation

The main source of data for this study was primary data collected from interviews with rural households in East Gojjam and South Wello zones of the Amhara region of Ethiopia with the general objective of studying household behavior regarding sustainable land use in the Ethiopian highlands. The data was collected 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. Households that were interviewed in the first round (year 2000) were re-interviewed in the second (year 2002) and third (year 2005) rounds. The necessary variables for this study were available in the second and third rounds of these surveys.

3.1 Data and Descriptive Statistics

A total of 1,520 households from 12 sites (villages or *kebeles*[13]), with a minimum of 120 households from each site, were interviewed in each of the two rounds. Two more sites (i.e., 240 households) and some new questions were included in the third round (year 2005). This made a total of 1,760 households in 14 sites interviewed in the third 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 first two rounds, so this study focused mainly on analyzing the data gathered in the third round and included poverty- and asset-related variables from the second round. The regression analysis in this study used

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[12] The likelihood ratio test statistics Γ can be computed (Greene 2000) as: $\Gamma = -2\left[\ln L_T - (\ln L_p + \ln L_{TR})\right] \sim \chi^2_k$, where L_T is the likelihood for the Tobit model; L_p is the likelihood for the probit model; L_{TR} is the likelihood for the truncated regressions model; and k is the number of independent variables in the equations. If the test hypothesis is written as:
$H_0 : \lambda = \frac{\beta}{\sigma}$ and $H_1 : \lambda \neq \frac{\beta}{\sigma}$, then H_0 will be rejected on a prespecified significance level, provided $\Gamma > X_k^2$, confirming the superiority of the double-hurdle specification over the Tobit model. In such a case, the decision to state a positive value for land conservation investment practices and input uses and the decision about how much to state will appear to be governed by different processes

[13] A *kebele* is the smallest administrative unit of local government in Ethiopia, similar to a ward or a neighborhood association.

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 (in the appendix) presents the definitions and observation level of the variables included in the analysis. The dependent variable in the first-stage probit model is the farm households' adoption of land conservation investment on specific plots, which takes a value of 1 if a plot receives land conservation investment (structure) and 0 otherwise. The level of land conservation or intensity of investment in land conservation was also used as another dependent variable in the second-stage truncated model. The rest of the variables listed in table 1 are explanatory variables. Following the conceptual framework and the hypothesis developed earlier in this paper, we classified the variables used in the analysis into six broad categories:[14] poverty-related factors,[15] risk or land tenure security,[16] market access, physical incentives, alternative input uses, and village dummies.

Table 2 (in the appendix) 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, which is used as the dependent variable for the probit, is undertaken on about 16% of the plots. The mean length of land conservation structure on a plot is 42.022 and 267.937 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). The rest of the variables in table 2 are explanatory variables.

[14] For simplicity, some variables were classified into a category that better (at least for this study) described them. For instance, access to credit could have been included in the market access category rather than with poverty-related factors.

[15] 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 sexes.

[16] 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. (The Simpson index is 0 when the farm consists of a single parcel and approaches 1 for farms split into numerous plots of equal size.) The simplex index portrays how fragmented farm plot holdings are, combining the number of plots by farm household and their relative size (see Bellon and Taylor 1993).

3.2 Model Appropriateness: Tobit versus Double-Hurdle Model

Noting that land conservation adoption and intensity of use decisions may not necessarily be made jointly, and that the factors affecting each decision may be different, we estimated both Tobit and double-hurdle models (probit and truncated regression models) separately, and then conducted a likelihood ratio test. (In the appendix, see table 4 for the probit and table 4.5 for the Tobit[17] and truncated regression model estimation results. Table 3 portrays the results of this likelihood ratio test.)

The results of the likelihood ratio test favor the use of the double-hurdle model. It shows that the likelihood ratio test statistics Γ is 707.62, which exceeds the critical value [$\chi^2(48) \approx 76.15$] at the 1%-level of significance. This confirms the superiority of the double-hurdle specification over the Tobit model; thus, the plot-level decision to state a positive value for land conservation investment and the decision about how much to state seem to be governed by different processes. This is also confirmed by the result of the Akaike's information criterion, which we included as an alternative model selection criterion. The less formal "test" of comparing the probit (table 4 in the appendix) and Tobit (table 5 in the appendix) estimated coefficients also confirmed the above test results. This is implied from the existence of several 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. The decision to adopt land conservation and the decision about how much to invest appear to be explained by different processes.

3.3 Determinants of Adoption of Land Conservation Investment

The results of the clustered-probit estimations for adoption decisions are presented in table 4 in the appendix.[18] The table reports the estimated coefficients, their robust standard errors (adjusted for clustering on household identification), and the marginal effects. The adjusted R-squared (the pseudo R-squared for probit) and 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.

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[17] Standard errors for the Tobit model were adjusted for clustering on household identification, using interval estimation for Tobit with cluster (see section 3.4).

[18] Gujarati (1995) states that multicollinearity may become a problem if the coefficient of the Pearson correlation exceeds 90%. Following this, a correlation matrix was created among the independent varibles, and none of the correlation coefficient exceeded 48%.

The pseudo R-squared shows that the regression explains 23% of the total variation in the dependent variable.

The probit regression estimates confirm that the probability of adopting land conservation investment is influenced by a wide range of factors. The results are discussed below with a focus on poverty-related factors, land tenure security, and market access.

Poverty-Related Factors

The role played by poverty-related factors in determining investment on land conservation and input uses has been emphasized in various research works. In particular, the negative relationship between poverty (in its different forms) and a household's decisions to invest on land conservation and with what intensity is substantiated in various studies (see, e.g., Hagos and Holden 2006, Gebremedhin and Swinton 2003, Clay et al. 2002, Holden and Shiferaw 2002, Holden et al. 1998, and Godoy et al. 2001).

Following is our result detailing poverty into income and asset variables. Cash-income (in all its forms), value of live trees, access to extension services, household belief of future life improvement, and household consumption expenditure are statistically significant poverty-related factors that explain farm households' investment decision in land conservation. Of the cash-income variables, the negative effect of non-crop income and employment income is in line with the argument that wages and 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.

The results indicate that cash-crop income is a statistically significant factor that reduces a household's probability of deciding to conserve the land. Theoretically, cash-crop income should encourage land conservation investment decisions by providing an incentive to farm households to improve land quality in the hope that the plot can provide more product (and, hence, more income) in the next crop season. While access to credit could mean better capacity to invest in land conservation, better access to credit is found to be associated with lower probability of adoption.

Except for the value of live trees, none of the non-liquid asset variables were found to affect the probability of plots receiving land conservation investment. Value of live trees is a statistically significant factor that increases households' probability of investing in land conservation. While this result for trees could be interpreted as a reflection of the wealth of the household in land conservation investment decisions, it can also be that the two are complements.

Except for household access to extension services, none of the human-capital variables were found to significantly affect decisions in land conservation investment. The results suggest that households with access to extension services are more likely to invest in land conservation. This shows the relative importance of extension services in encouraging decisions by farm households to invest in land conservation structures, perhaps through its effects on awareness and knowledge about such structures.

Households' social capital, as measured by a household's belief that life conditions will improve in the future, was found to be significant. In particular, the results suggest that households' probability of investing in land conservation is higher for households that are pessimistic about future life condition improvements. 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 (using household expenditure as an indicator) 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 sets a much smaller cut-off than the bare minimum requirement by the poor to address issues of resource degradation. That is, sizeable resources over and above bare subsistence consumption and production amounts are required by the poor to address issues of resource degradation.

Land Tenure Security

Except for the variable for land ownership type, all the land tenure [in]security variables were found to be statistically insignificant. This result suggests that plots that are owner-cultivated have a higher probability of receiving land conservation than plots either mortgaged (in/out) or rented (in/out). Specifically, a privately-owned plot increases the probability that farmers will invest in land conservation on it by 3%. Due to the usually short duration of tenure holding and other incentive problems associated with plots that are rented or mortgaged, such plots are less likely to receive land conservation investment than a plot that is owner-cultivated. This result is in line with the neo-classical economic theory that 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 Tekie (1999), Feder et al. (1988), Gebremedhin and Swinton (2003), and Rahmato (1992).

Market Access

A household's expectation of a return on land conservation investment (proxied by households' expectation of a long-term effect of fertilizer) turned out to be the only market access variable that affected a households' decision to adopt land conservation investment. A household which expected returns from land investment to increase productivity had 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 in influencing households' behavior toward investment in those measures.

Physical Incentives

Most of the indicators of physical incentives to invest in a plot, as reflected by plot-level variables, seem to have a role in a household's adoption decision. In particular, plot altitude negatively affects plot-level adoption probability. This may be explained by a tendency towards water-logging of vertisol soils,[19] which would discourage farm households from practices that would retain water on vertisol plots. A plot in the highlands (2,500 meters above sea level) decreases the probability that it will receive land conservation investment by 7%. Plots situated on steep (*dagetama*) slopes have a 5% probability of receiving land conservation investment. (Plots on steep slopes are associated with soil erosion and are often vulnerable to land degradation, and thus are likely to receive land conservation.)

There is a positive relationship between plot size and the probability of the plot receiving land conservation investment. On average, an increase in size of a plot by one hectare increases the probability that a plot will receive land conservation investment by 10%. This may be explained by the fact that farmers are likely to invest first and foremost in their largest parcel, often where their residences are also located. An alternative explanation for the positive relationship between plot size and adoption of land conservation may be that larger plots are expected to yield greater rewards and justify the costs of construction. Plots mainly used for tree planting have a lower probability (5%) of receiving land conservation investment than plots used

[19] These are black soils rich in clay content with an unstable structure. They have a low permeability for water (characterized by excess surface water) and form deep vertical cracks in dry seasons.

for annual crops and/or fallowing. Similarly, plots used for grazing have a lower probability (about 8%) of receiving land conservation investment.

Alternative Land Inputs

With respect to use of alternative land conservation practices, past land-conservation investment intensity and current natural fertilizer use were found to be statistically significant. The higher the intensity of previous land conservation investment on a plot, then the less likely it is that the plot will receive new land conservation investment. This shows the preference of farm households to invest first in plots that are not well conserved or plots with limited or no previous conservation structures. Natural fertilizer use is found to complement the probability of the plot to benefit from land conservation investment.

Village- or Site-Level Effects

The last set of explanatory variables in our analysis includes village/site or kebele dummies. The results indicate that almost half of the village dummies were found to be statistically significant—and the association is positive for some and negative for others, suggesting the importance of site-level fixed effects (or variations across sites).

3.4 Determinants of Intensity of Land Conservation Investment

About 1,005 (or 16%) of the plot-level observations have positive land-conservation investment intensity. This section presents the truncated regression estimation results. The Wald chi-square test results (presented at the bottom right of table 5 in the appendix) signify that the model in the overall is statistically significant, at least at the 1% 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.

Poverty-Related Factors

Similar to the results for adoption probability, cash-crop income has a negative and statistically significant relationship with the intensity of conservation. This result was not expected because an increase in cash income should have implied increased land-conservation investment through the greater capacity of the farm household. Access to credit, although significant in influencing adoption decision, turned out to be insignificant in the model for intensity of investment.

An increase of one hectare in total land holding increases plot-level conservation intensity by about 182 meters per hectare. This can be due to the nature of land conservation and input technologies involved because land conservation requires space. Moreover, the value of live trees turns out to have a positive influence on intensity: an additional ETB[20] 100 in the value of live trees is associated with an increase in the level of land conservation investment by about 2 meters per hectare. This is in line with the general expectation that assets, which indicate more wealth and capacity to conserve land, can increase the intensity of the investment.

The value of livestock, on the other hand, was found to be associated with lower intensity of land conservation investment. This result is contrary to the general expectation that livestock is an important indicator of wealth in rural Ethiopia and, hence, is expected to be positively associated with intensity of land conservation. However, it is possible that households with more livestock may use their plots for grazing, which often does not entail land conservation structures.

Two of the human capital variables have a statistically significant influence on the intensity of land conservation, namely, female adult per capital variable and access to soil conservation advice. Both variables have a positive association with land conservation intensity. An additional female adult in the household per hectare increases intensity by about 41 meters per hectare. Given the presence of poorly functioning labor markets in our study areas, this result suggests that more labor availability in the household encourages land conservation investment. 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 more important in intensifying land conservation investment.

Households' access to development agents' advice on soil conservation positively affects intensity. Compared to households that have never received advice about soil conservation, land-conservation intensity increased for those who were advised by about 220 meters per hectare. 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.

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[20] ETB = Ethiopian birr. As of February 2010, ETB 13.22 = US$ 1.

Land Tenure (In)Security

Households that feel certain that they will cultivate the plot for a longer period (five years after the survey) are associated with higher intensity of land conservation investment. Compared to those uncertain about cultivating the plot for the next five years, land conservation investment intensity was higher by about 182 meters per hectare for those feel certain. This result suggests that expectation for land tenure is important in influencing intensity of conservation investment. Compared to those households that believe the land belongs to the peasant association or to the government, land conservation investment intensity decreased by 169 meters per hectare among those who believe that land belongs to them—a result we find difficult to explain since one would have expected the reverse. Also, greater distance of plots from the homestead is associated with higher intensity: an increase of 10 walking minutes from home to the plot increases plot-level intensity by 140 meters per hectare.

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 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.

Market Access

Unlike the adoption model, distance of a residence from the market turned out to be statistically significant in influencing intensity: an increase of 10 walking minutes from the household's residence to the market place increases intensity by approximately 19 meters per hectare. 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. Return on investment is highly significant in both adoption and intensity models. Compared to households that expect the return from land investment will be increased productivity, intensity decreases by about 249 meters per hectare for 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 in influencing households' behavior toward such investments.

Physical Incentives

Among the physical incentives, plot soil fertility, plot area, and grazing plots were found to be significant in influencing investment intensity in land conservation. The positive effects of soil fertility suggest that fertile plots entail a higher return and hence receive a higher level of land conservation investment. On the other hand, the negative relationship between plot area and intensity is perhaps because intensity in our model is measured as meters per hectare. As in Gebremedhin and Swinton (2003) also argued, larger fields have fewer meters of conservation per hectare because of their indivisibility and diminishing marginal returns on conservation structures within a plot. Plots mainly used for grazing seem to be associated with a higher intensity than plots that are mainly used for farming and/or fallowing, a result we are not able to explain.

Alternative Land Conservation Practices and Site Dummies

None of the alternative land conservation practices were found to be statistically significant in influencing intensity of land conservation investment. Some of the site dummies were significant, suggesting that there are differences in intensity of land conservation across sites.

4. Summary and Conclusions

Land degradation is a major problem undermining land productivity in Ethiopia. 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 main source of data for this study was primary data collected from interviews of a sample of rural households in the Amhara region of Ethiopia. The regression analysis of the household-plot level data used a double-hurdle model. We used a large set of explanatory variables to explain farmers' plot-level decisions whether or not to invest in land conservation, as well as how much to invest.

The results in this study 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, policymakers will find that poverty-related factors, such as cash-income, value of livestock, access to extension services, and a household's belief in future life improvement; land ownership type (tenure [in]security factor); household's expectation of a return from land investment (market access factor); physical incentives, such as plot altitude, plot slope, plot area, major use of the plot (for tree planting, grazing); and alternative land conservation practices, such as previous land conservation intensity and intensity of natural fertilizer use are important in plot-level decision to adopt land conservation investment.

For the farm households who have already decided to invest in land conservation, poverty-related variables comprising cash-crop income, farm size, value of livestock, value of live trees, female adult per hectare, and access to advice on soil conservation; land tenure [in]security variables, including households' expectation of cultivating the plot for the next five years, belief of land ownership, and distance from plot to home; market access factors, including distance from residence to market and expectation on return from land conservation investment; and physical incentive factors, including plot soil fertility, plot size, and major use of plot (plots for grazing) are the key factors influencing plot-level intensity of investment in land conservation.

In general, 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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Appendix

Table 1. Definition and Observation Level of the Dependent and Explanatory Variables

Variables	Definition	Obs. level
Land conservation adoption (dependent variable)	Implemented new soil conservation works in the past 12 months: 1 if implemented; 0 if otherwise	Plot
Level of land conservation (dependent variable)	Length of land conservation investments in the last 12 months: in meters per hectare	Plot
Poverty-related factors		
Income		
Non-crop income	Sale of livestock and their products, energy, trees, and gift: ETB/year	Household
Employment income	Income from outside 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 ETB 200 per year: 1 if yes; 0 if no	Household
Non-liquid assets		
Farm size	Total land holding by the household in current year: in hectares	Household
No. of cattle	Number of cattle owned by the household	Household
No. of ruminants	Number of ruminants owned by the household	Household
Value of livestock	Monetary value of livestock owned if sold: in ETB/year	Household
Value of live trees	Monetary value of live trees owned if sold: in ETB/year	Household
Value of crop produced	Market value of crop output produced if sold: in ETB/year	Household
Human capital		
Male adults per hectare	Number of male adults between 12 and 65 years of age per hectare	Household
Female adults per hectare	Number of female adults between 12 and 65 years of age per hectare	Household
Dependent ratio	Ratio of non-working-age household members to working-age members (12–65 years)	Household
Age of household head	Age of head of the household: no. of years	Household
Sex of household head	Sex of head of the household: 1 if male; 0 if female	Household
Literacy of head	Literacy of head of the household: 1 if reading and writing; 0 otherwise	Household
Marital status of head	Marital status of head of the household: 1 if	Household

	married; 0 otherwise	
Access to extension services	Household access to extension services: 1 if has access; 0 if not	Household
Soil conservation advice	Development agents advised household on soil conservation: 1 if advised; 0 if not.	Household
Life improvements: Social capital	Household's belief that life condition will improve in the future: 1 = definitely possible; 2 = possible; 3 = not sure; 4 = impossible; 5 = completely impossible	Household
Household expenditure	Household expenditure per annum: in ETB	Household
Risk factors for land tenure security		
Cultivate plot for next 5 years	Plot owners feels certain will cultivate 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 or rent in/out)	Plot
Land ownership belief	Household believes that it owns land: 1 if yes; 0 otherwise*	Household
Plot-home distance	Distance of plot from residence: in 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-to-residence distance	Distance of household residence to nearest town: in walking minutes	Household
Road-to-residence distance	Distance of residence to nearest car road: in walking minutes	Household
Market-to-residence distance	Distance of residence to market where most products sold: in 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 2,500 meters; 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 hectares	Plot
Plot access to irrigation	Plot has access to irrigation: 1 if irrigated; 0 if not irrigated	Plot
*Major use of plot **		

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: in meters	Plot
Modern fertilizer use	Modern fertilizer used over the last 12 months: in kilograms	Plot
Natural fertilizer use	Natural fertilizer use over the last 12 months: in kilograms	Plot
Village dummy***		
Amanuel	1 if village is Amanuel; 0 otherwise	Prefecture
D. Elias	1 if village is D. Elias; 0 otherwise	Prefecture
Kebi	1 if village is Kebi; 0 otherwise	Prefecture
Telma	1 if village is Telma; 0 otherwise	Prefecture
Yamed	1 if village is Yamed; 0 otherwise	Prefecture
Wolkie	1 if village is Wolkie; 0 otherwise	Prefecture
Sekladebir	1 if village is Sekladebir; 0 otherwise	Prefecture

ETB = Ethiopian birr (currency)

* Zero is when household believes the land belongs to either the kebele (peasant association) or the government.

** The base group for the major use of plot dummy is "plot with major use for farming and/or fallowing."

*** The base group for the village dummies includes these villages: "Kete," "Godguadit," "Ambamariam," "Addismender," "Chorisa," "Indodber," and "Addisgulit."

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	0.157	0.364	1	0	0	0
Level of land conservation (m^2 per hectare)	42.022	146.5799	267.937	276.621	-	-
Poverty-related factors						
Income						
Non-crop income	511.630	593.447	478.186	518.165	517.851	606.259
Employment income	139.115	367.698	102.047	279.019	146.010	381.553
Cash-crop income	204.381	304.990	186.477	253.005	207.711	313.618
Access to credit	.192	.394	.178	.383	.195	.396
Non-liquid assets						
Farm size	1.607	1.224	1.492	1.116	1.628	1.243
No. of cattle	4.145	3.688	3.581	2.844	4.249	3.816
No. of ruminants	1.770	3.102	1.681	2.890	1.787	3.140
Value of livestock	1808.841	1568.159	1622.674	1342.553	1843.470	1604.362
Value of trees	2248.913	4404.926	2664.518	5092.195	2171.607	4260.956
Value of crop produced	893.176	1191.950	900.139	1308.161	891.881	1169.187
Human capital						
Male adults per hectare	2.161	1.910	2.222	1.992	2.149	1.990
Female adults per hectare	2.181	2.112	2.198	1.852	2.178	2.157
Ratio of dependents	.650	.545	.616	.483	.657	.556
Age of household head	50.059	14.466	49.781	14.890	50.111	14.387
Sex of household head	.882	.322	.876	.330	.883	.321
Literacy of household head	.514	.500	.488	.500	.519	.500
Marital status of household head	.881	.324	.852	.356	.886	.318
Access to extension advice	.506	.500	.586	.493	.492	.500
Soil conservation advice	.376	.485	.387	.487	.374	.484
Life improvements	2.473	.970	2.550	1.020	2.459	.961
Household expenditure	1399.221	1110.071	1237.133	888.093	1429.371	1144.170
Risk factors (land tenure security)						
Will cultivate plot for next 5 years	.695	.461	.752	.432	.684	.465

Land ownership type	.814	.389	.845	.362	.808	.394
Land ownership belief	.448	.497	.497	.500	.439	.496
Plot-to-residence distance	1.510	2.361	1.602	2.238	1.599	2.383
Simpson index	.782	.130	.773	.125	.783	.130
Plot age	18.837	9.549	18.767	9.702	18.850	9.521
Market access						
Town-to-residence distance	61.439	41.224	68.559	41.523	60.115	41.036
Residence-to-road distance	33.423	33.265	36.059	32.991	32.933	33.296
Market-to-residence distance	69.249	38.357	72.896	41.088	68.571	37.792
Return from investment	.380	.486	.308	.462	.394	.489
Physical incentives						
Plot characteristics						
Highland	.318	.466	.306	.461	.320	.467
Plot fertility	2.272	.723	2.293	.703	2.268	.727
Plot slope	.057	.232	.094	.291	.050	.219
Plot access	.216	.180	.217	.163	.216	.183
Access to irrigation	.044	.205	.047	.211	.044	.204
Major use of plot						
Tree planting	.048	.213	.041	.198	.049	.216
Grazing	.021	.144	.005	.070	.024	.154
Input						
Past land investment intensity	25.135	52.409	4.745	19.965	28.928	55.605
Modern fertilizer use	9.159	20.754	8.867	19.244	9.213	21.024
Natural fertilizer use	156.256	394.593	182.547	389.796	151.365	395.322

Note: Site dummies are included, but not reported here.

Table 3. Test for Comparison of Tobit with Double-Hurdle Model

	Tobit	Double-hurdle model	
		Probit, D	***Truncated regression, Y(Y>0)***
Wald χ^2	259.07	251.41	269.89
Prob > χ^2	0.0000***	0.000***	0.000***
LOG-L	-8832.3405	-2150.628	-6327.9011
AIC	1.39	0.342	0.995
Number of observations (N)	6408	6408	1005
χ^2-test: double hurdle vs. Tobit	$\Gamma = 707.62 > \chi^2(48) = 76.15$		

Note: *** Statistically significant at 1% level of significance.

Table 4. Probit Estimation: Determinants of Decision to Invest in Land Conservation

Variables	Robust coeff.	P-value	mfx[†]
Poverty-related factors			
Income			
Non-crop income	-.00017*	0.070	-0.000
Employment income	-.00020*	0.092	-0.000
Cash-crop income	-.00043**	0.020	-0.0001
Access to credit	-.196*	0.082	-0.027[††]
Non-liquid assets			
Farm size	-.030	0.676	-0.004
No. of cattle	-.019	0.391	-0.003
No. of ruminants	-.016	0.408	-0.002
Value of livestock	.00007	0.227	0.000
Value of trees	.00002**	0.040	0.000
Value of crop produced	.00007	0.214	0.000
Human capital			
Male adults per hectare	.017	0.506	0.003
Female adults per hectare	-.021	0.424	-0.003
Ratio of dependents	-.116	0.161	-0.017
Age of household head	-.001	0.793	-0.0002
Sex of household head	.128	0.474	0.018[††]
Literacy of household head	-.017	0.866	-0.003
Marital status of household head	-.147	0.402	-0.024[††]
Access to extension agent	.309**	0.017	0.046[††]
Soil conservation advice	-.063	0.631	-0.009
Life improvements	.112**	0.030	0.017
Household expenditure	-.00011**	0.022	-0.000
Risk factors (land tenure security)			
Will cultivate plot for next 5 years	.117	0.223	0.017[††]

Land ownership type	.204**	0.032	0.028††
Land ownership belief	.112	0.230	0.017
Plot-to-home distance	.016	0.141	0.002
Simpson index	.222	0.483	0.033
Plot age	-.002	0.619	-0.0003
Market access			
Town-to-residence distance	.002	0.116	0.0003
Residence-to-road distance	.001	0.467	0.0002
Market-to-residence distance	-.001	0.290	-0.0002
Return from investment	-.364***	< 0.001	-0.051††
Physical incentives			
Plot characteristics			
Highland	-.561***	0.001	-0.073††
Plot fertility	-.018	0.725	-0.003
Plot slope	.260*	0.066	0.045††
Plot access	.690***	< 0.001	0.102
Access to irrigation	.043	0.781	0.007††
Major use of plots			
Tree planting	-.442***	< 0.001	-0.049††
Grazing	-1.282***	< 0.001	-0.080††
Input			
Past land investment intensity	-.023***	< 0.001	-0.003
Modern fertilizer use	.001	0.400	0.0002
Natural fertilizer use	.0002***	0.001	0.0000
Constant	-.807**	0.034	-
Predicted probability at mean	0.16	-	-

Notes: Number of observations = 6,408. Log pseudo-likelihood = -2150.628. Wald chi2(48)/P-value = 251.41/0.0000. McFadden's R^2 = 0.23.

Standard errors are adjusted for clustering on household id.

*, **, and *** indicate statistical significance at the 10% level, 5% level, and 1% level, respectively.

Site dummies are included but not reported here.

† mfx represents marginal effect.

†† represents change in the probability of a decision to land conservation investment being made for a change in the respective explanatory variable from 0 to 1.

Table 5. Tobit and Truncation Estimations: Determinants of Level of Land Conservation Investment

Variables	Tobit				Truncated	
	Robust Coeff.	P-value	Marginal effect		Rob. coeff.	P-value
			mfx†	mfx††		
Poverty-related factors						
Income						
Non-crop income	-.065	0.106	-.006	-.011	-.065	0.393
Employment income	-.092*	0.061	-.008	-.015	-.067	0.564
Cash-crop income	-.190*	0.014	-.016	-.031	-.356*	0.099
Access to credit	-90.925*	0.055	-6.899	-14.102	88.052	0.310
Non-liquid assets						
Farm size	34.326	0.344	2.914	5.512	182.178***	< 0.001
No. of cattle	-3.222	0.753	-.274	-.517	34.510	0.109
No. of ruminants	-3.903	0.619	-.331	-.627	.242	0.985
Value of livestock	.0106	0.656	.001	.002	-.083*	0.076
Value of trees	.010**	0.029	.001	.002	.017***	0.008
Value of crop produced	.020	0.299	.002	.003	-.031	0.345
Human capital						
Male adults per hectare	10.950	0.322	.930	1.759	17.229	0.338
Female adults per hectare	-.927	0.933	-.079	-.149	40.623**	0.055
Ratio of dependents	-42.131	0.244	-3.576	-6.766	-2.977	0.968
Age of household head	-.604	0.727	-.0513	-.097	2.159	0.425
Sex of household head	39.194	0.560	3.129	6.176	34.205	0.792
Literacy of household head	-20.329	0.641	-1.728	-3.266	-49.684	0.587
Marital status of household head	-56.017	0.385	-5.194	-9.245	-168.634	0.187
Access to extension advice	104.314**	0.039	8.882	16.752	-122.539	0.238
Soil conservation advice	15.437	0.767	1.321	2.485	219.659**	0.031
Life improvements	51.703**	0.027	4.389	8.303	-48.730	0.302

Household expenditure	-.045**	0.035	-.004	-.007	.044	0.397
Risk factors (land tenure security)						
Will cultivate plot for next 5 years	64.183	0.118	5.185	10.148	181.647**	0.020
Land ownership type	71.912*	0.083	5.572	11.227	-53.803	0.551
Land ownership belief	20.550	0.596	1.753	3.305	-169.240**	0.029
Plot-to-residence distance	7.397*	0.097	.628	1.188	14.083**	0.039
Simpson index	67.849	0.620	5.759	10.895	-29.803	0.917
Plot age	-1.091	0.543	-.093	-.175	-.191	0.966
Market access						
Town-to-residence distance	.648	0.213	.055	.104	-1.519	0.206
Residence-to-road distance	.535	0.356	.045	.086	.647	0.598
Market-to-residence distance	-.193	0.684	-.016	-.031	1.877**	0.043
Return from investment	-181.891***	< 0.001	-14.363	-28.491	-249.305***	0.005
Physical incentives						
Plot characteristics						
Highland	-250.181***	0.003	-18.182	-38.123	-12.605	0.881
Plot fertility	5.187	0.809	.440	.833	87.922*	0.086
Plot slope	147.803**	0.030	16.436	25.857	77.540	0.419
Plot access	109.043*	0.084	9.256	17.511	-2838.395***	< 0.001
Access to irrigation	53.336	0.418	5.005	8.837	199.333	0.112
Major use of plot						
Tree planting	-159.084***	0.004	-10.092	-23.384	75.330	0.455
Grazing	-435.646***	0.001	-16.624	-54.875	670.176***	0.001
Input						
Past land investment intensity	-9.173***	< 0.001	-.777	-1.475	-.213	0.916
Modern fertilizer use	.583	0.356	.050	.094	1.512	0.390
Natural fertilizer use	.072***	0.005	.006	.012	.016	0.786

Constant	.583	0.356	-219.803	0.491
No. of observations	6,408 (uncensored = 1,005 and left-censored = 5,403		1,005 (5,403 truncated at 0)	
Log likelihood intercept only/fully	-9436.072/-8832.3405		----/-6327.9011	
Wald chi2(48)/P-value	259.07/0.0000		269.89/0.0000	
McFadden's R-squared	0.064			
σ[†††]/P-value	444.8358/0.000		342.05/0.000	

Notes: Standard errors are adjusted for clustering on household id in both the Tobit and truncated estimations.

Site dummies are included but not reported here.

[†] The marginal effects for the *unconditional expected value* of the dependent variable, E(y*), are "mfx compute, predict(ys(a,b))," where y* = max(a, min(y,b)); a (0 in our case) is the lower limit for left censoring; and b(**.** in our case) is the upper limit for right censoring.

[††] The marginal effects for the expected value of the dependent variable *conditional on being uncensored*, E(y|a<y<b), are "mfx compute, predict(e(a,b))."

[†††] σ represents the ancillary statistic/sigma and is the estimated standard error of the regression.