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Abstract

This study looked into tree-growing behavior of rural households in Ethiopia. With data collected at household and parcel levels from the four major regions of Ethiopia, we analyzed the decision to grow trees and the number of trees grown, using such econometric strategies as a zero-inflated negative binomial model, Heckman's two-step procedure, and panel data techniques. Our findings show the importance of analysis at the parcel level in addition to the more common household-level. Moreover, the empirical analysis indicates that the determinants of the decision to grow trees are not necessarily the same as those involved in deciding the number of trees grown. Land certification, as an indicator of tenure security, increases the likelihood that households will grow trees, but is not a significant determinant of the number of trees grown. Other variables, such as risk aversion, land size, adult male labor, and education of household head, also influence the number of trees grown. In general, the results suggest the need to use education and/or awareness of the role and importance of trees and point out the importance of household endowments and behavior, such as land, labor, and risk aversion, for tree growing. Finally, we observed that, while tree planting is practiced in all four regions covered, there are variations across regions.

Key Words: trees as assets, tree growing, Ethiopia

JEL Classification: Q15, Q23

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Introduction

Ethiopia's forest cover is estimated to be less than 4 percent of its total land area, which is a little over 1 million km^2, and its deforestation is estimated to be over 140,000 hectares per year (Mekonnen and Bluffstone 2008). Heavy dependence on woody biomass for fuel, increasing demand for grazing and agricultural land, and demand for wood for construction and furniture contribute to the severe deforestation and forest degradation. Deforestation and forest degradation in turn contribute to climate change.

While one possible solution to the problem of reduced availability of trees and tree products is finding substitutes, such as other sources of fuel and construction materials, this does not appear to be feasible for Ethiopia, at least in the near future. Other benefits from trees, such as carbon sequestration and ecological functions, may not have close substitutes. However, private tree growing is an alternative and farmers in Ethiopia are growing a significant number of trees relative to the land area they hold.

The role of private trees in households' livelihoods in Ethiopia is not yet well documented, and market and policy failures may influence tree-growing behavior of households. The extent and management of community forests and biomass availability may also have an influence on the decision of households to grow trees on farms (Bluffstone et al. 2008; Mekonnen and Bluffstone 2008). Variables such as property rights, risk and time preferences, social capital, economic status (poverty), asset holdings, access to credit, and other incentives (which may be influenced by government policies) can also be important in influencing households' tree growing behavior.

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A recent review by Cooke et al. (2008) noted that little empirical evidence analyzes the determinants of tree-growing behavior by taking various factors into account. The limited but growing empirical literature we are aware of looks only at household-level analysis of tree-growing behavior (e.g., Besley 1995), and most of these studies analyze only the decision to grow trees and not the magnitude of investment in or stock of trees. (Notable exceptions include Nepal et al. 2007; Bluffstone et al. 2008; Mekonnen and Bluffstone 2008; Mekonnen 2009; and Gebreegziabher et al. 2010). We are not aware of any empirical study that does such analysis at the parcel[1] level.

These studies also do not use information about forest cover and biomass availability, which is important in analyzing tree-growing behavior (e.g., Mekonnen 2009; Holden et al. 2009; Deininger et al. 2009). Additionally, while similar studies have looked into the role of variables (e.g., land certification), in influencing longer-term investment decisions like tree planting, such studies have not considered or controlled for other variables, such as households' risk and time preferences or economic status and asset ownership. Moreover, similar studies of Ethiopia used data collected before such recent changes as relatively high inflation, which could potentially influence household decisions to invest in land.

The objectives of this study are to describe the nature of tree-growing behavior of rural households in Ethiopia and look into the determinants of the decision to grow trees and how many trees to plant. This paper is different from previous papers for several reasons. We analyzed both parcel and household levels, unlike previous studies that focused only on household-level analysis. While previous studies in Ethiopia used data that typically covered only one region of the country (e.g., Holden et al. 2009; Mekonnen 2009; Deininger et al. 2009; Gebreegziabher et al. 2010), the data we use for this study covers the four major regions of the country.

In addition to using very recent data (unlike other studies), it also included information on tree growing at the parcel level and on the recent land certification program. More importantly, it also has spatial data on forest cover and biomass availability from satellite images supported with ground corroboration. We also used a number of other key variables in our analysis, some of which have not, to our knowledge, been used in similar studies. These include

[1] A parcel is a piece of land, which may consist of more than one plot, while a plot is an area planted with a particular crop.

measures of households' risk aversion based on risk preference experiments, measures of time preference based on households' responses to questions about their discount rates, indicators of social capital/social trust, access to credit, and indicators of economic status, such as asset holdings and income/expenditure measures.

Our results indicate the importance of analyzing tree-growing behavior at the parcel level, as well as at the household level. They also show the need to distinguish between the decision to grow trees and the number of trees grown. Using the relatively rich data set, we were also able to identify statistically significant variables from a number of variables that are expected to influence the decision to grow trees and the number of trees grown.

The rest of the paper is organized as follows. The following section briefly presents the theoretical framework and review of the empirical literature. Section 2 presents a description of the source of the data, and section 3 discusses and the econometric methods used for the analysis. The data used in the paper is described in section 4. Empirical results and discussion is presented in section 5, while section 6 concludes.

1. Theoretical Framework and Brief Review of the Empirical Literature

Different theoretical frameworks are used to analyze long-term, land-related investments, such as tree growing in rural areas of developing countries. Amacher et al. (1993) used a model to discuss farmer adoption of agroforestry technologies, while Besley (1995) analyzed investment incentives and property rights, using alternative theoretical explanations. Shively (1998; 1999) focused on the role of expected prices of trees as determinants of tree growing, using expected utility maximization framework. Gebremedhin and Swinton (2003) also used theoretical models to analyze determinants of long-term investments, such as physical soil conservation measures. Using a two-period model Deininger et al. (2003) discussed tenure security and land-related investment in Ethiopia.

A number of these studies note the importance of nonseparability in production and consumption decisions due to imperfection of product and input markets. This means that items, such as fuelwood, may be collected instead of being purchased and that collection depends on labor availability in the household due to imperfection in labor markets. Thus, decisions to produce (e.g. growing trees) and the number of trees grown may depend on availability of family labor, among other factors. Using these kinds of arguments, analyses of tree-growing behavior takes into account not only inputs into such activities (such as land size and property rights) but also resource endowments (such as labor availability and assets), which could substitute for lack of well-functioning credit markets. The empirical models used by the different studies mentioned above similarly end up estimating equations that analyze the determinants of the decision to invest in land or the intensity of investment.

There are a number of empirical studies that have looked into the determinants of investment in land in general and in tree growing in particular. (See, e.g., Gebreegziabher et al. 2010; and Mekonnen 2009 for a review.) A number of these focused on analyzing the decision to grow trees (Deininger and Jin 2006; Holden et al. 2009) or to undertake investment in soil conservation (Deininger et al. 2009). Others have also considered the intensity of tree growing (e.g., Bluffstone et al. 2008; Mekonnen and Bluffstone 2008; Mekonnen 2009; Gebreegziabher et al. 2010). However, these studies miss some potentially important variables as controls and/or were conducted using data collected before some of the significant changes that have been observed recently.

Variables, such as risk and time preferences of households, which are potentially important, are typically not included in such studies. It is noted in the literature that with imperfect rural credit markets, subjective discount rates are likely to be far greater than market interest rates and more accurately predict financial constraints (Pender 1996; Holden et al. 1998). Thus, given that most smallholder farmers in developing countries face credit constraints (Holden et al. 1998), it is important to examine and understand the effect of rate of time preference on tree-growing behavior of rural households, which is a relatively long-term investment. Theoretical studies of farmer behavior under risk indicate that, in the absence of a perfect market for insurance, resource-allocation behavior of risk-averse farmers differs from that of risk-neutral farmers. Under these circumstances, a variation in farm households' degree of risk aversion is often a major determinant of household investment decisions, such as tree growing (Andersson et al. 1977; Yesuf and Köhlin 2008).

In the case of Ethiopia, very few studies have looked at the possible effects of recent land-certification programs. (Notable exceptions include Deininger et al. 2009; and Holden et al. 2009). There are a number of earlier studies of how property rights to land influence investment in land in Ethiopia, but they are typically based on measures of tenure insecurity that either are subjective or are proxies (Mekonnen 2009; Gebreegziabher et al. 2010; Deininger and Jin 2006). A number of the studies that analyze tree-growing behavior in Ethiopia also rely on data collected only from one region of the country (e.g., Mekonnen 2009; Gebreegziabher et al. 2010; Holden et al. 2009; Deininger et al. 2009).

We drew several conclusions about the analysis of investment in land (focusing on trees) in the empirical literature. One is that most studies have focused on the decision to invest, but not the intensity of investment. The second is that the data used in the studies came from only one region of Ethiopia. Third, a number of these studies have not controlled for variables, such as risk and time preferences of households, which are potentially important. Fourth, most of the existing studies do not reflect recent changes in the economy, such as the relatively high rate of inflation. Inflation could change tree-growing behavior due to changes in relative prices, or have an effect on decisions for asset holdings. Fifth, while a number of studies addressed issues of property rights, using households' perception of tenure security, for example, very few studies have attempted to analyze the role of the recent land certification program in investment in land in Ethiopia. This paper attempts to contribute to the literature by addressing these gaps.

2. The Nature and Sources of the Data

The data we used was collected by the Environment for Development (EfD) Center in Ethiopia (the Environmental Economics Policy Forum for Ethiopia, based at the Ethiopian Development Research Institute) as part of a broader research project, "Household Forest Values under Varying Management Regimes in Rural Ethiopia," and financed by Sida. The survey covered 10 districts (*woredas*[2]) from four regions of the country—one district from the Tigray region and three districts each from Amhara, Oromiya, and SNNP (Southern Nations, Nationalities, and Peoples) regions. All 10 districts were selected from pilot watersheds of the current sustainable land management (SLM) program in the country run by the Ministry of Agriculture and Rural Development. In selecting the regions and woredas, we tried to capture variation in forest cover, agroecology, and local institutions.

Four *kebeles* (peasant associations) were selected from each woreda—two from within the watershed and two outside the watershed. From a total of 40 kebeles, we used systematic random sampling to select 15 households from each kebele. In addition to the household-level survey, community-level information was also collected. One of the unique features of this dataset, compared with others in similar studies, is the use of spatial data on forest cover and biomass availability from satellite images supported by ground corroboration by experts. This information is in addition to data on the risk preference of households (based on a survey), as

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[2] A *woreda* (district) is an administrative division, which consists of a number of *kebeles* (or peasant associations), the lowest adminstrative unit in Ethiopia.

well as measures of the time preference of households, which are typically not included in such types of studies. We also have data on land certification status and economic status of households, including asset holdings, expenditures, and off-farm income.

3. Empirical Strategies

In addition to description of tree-growing behavior of the sample households, we use several econometric techniques to identify the correlates of the decision to grow trees, as well as the number of trees grown—probit models in particular. We also take into account the fact that a substantial number of households or parcels do not have trees with zero-inflated negative binomial models, Heckman's two-step procedure, and panel data techniques for the analysis of parcel-level data. The empirical models are similar to those used by Gebreegziabher et al. (2010), Bluffstone et al. (2008), and Mekonnen (2009). While use of Tobit models is a possibility in such contexts, they do not distinguish between the determinants of the decision to grow trees and those of the number of trees grown, which can be different.

As explained above, we employed a discrete choice model to analyze the decision of households to grow trees at parcel and household levels. The common models are either probit or logit, depending on the distribution of the function chosen for the error term. We used the probit model, specified as:

$$y_i^* = x_i'\beta + \varepsilon_i, \qquad \varepsilon_i \sim NID(0,1),$$

where y_i^* is unobserved and is referred to as a latent variable

Thus, an individual *i* decides to plant trees at the household or parcel level when the utility difference of growing and not growing it exceeds a certain threshold, zero in this case, so that $y_i = 1$, if and only if $y_i^* \succ 0$; and $y_i = 0$, if $y_i^* \le 0$. So, the latent variable depends in the familiar way on *x*:

$$\Pr(y_i = 1/x_i) = \Pr(y_i^* \succ 0) = \Pr(u_i \succ -x_i'\beta) = 1 - F(-x_i'\beta) = F(x_i'\beta)$$

where $F(x_i'\beta)$ is a cumulative distribution function, associated with the assumed distribution of the error term. The choice of the cumulative normal distribution for $F(.)$ defines the model as a probit model.

The estimates of the parameters β are typically obtained using maximum likelihood, however, the magnitude of β is not especially meaningful except in special cases (Wooldridge

2002). Therefore, it is important to know how to interpret β in both continuous and discrete explanatory variables. When the parameters β are estimated, the marginal effect of a change in the i^{th} variable in X, X_j, is defined by:

$$\frac{\partial \Pr(Y_i = 1)}{\partial X_{ij}} = f'(X_i'\beta)\beta_j$$

The marginal effects thus depend on the value of X_i used. Typically, the overall mean value of X_i in the sample is used to calculate $f(\beta X_i)$. The signs and magnitude of the marginal effects indicate the effect of the variable X_j on the probability that the household will grow trees at the household or parcel level.

We analyzed the number of trees grown at the parcel and household levels with different models, such as ordinary least squares (OLS) and negative binomial. The negative binomial model is employed as a functional form that relaxes the equidispersion restriction of the Poisson model. Note that the negative binomial distribution is a continuous mixture of Poisson distributions, which allows the Poisson mean λ to be gamma distributed, and in this way model overdispersion. The models are specified as follows:

$$P(Y = y) = \frac{\Gamma(y+\tau)}{y!\,\Gamma(\tau)}\left(\frac{\tau}{\lambda+\tau}\right)^{\tau}\left(\frac{\lambda}{\lambda+\tau}\right)^{y},$$

$$y = 0, 1, 2, \ldots; \quad \lambda, \tau \succ 0$$

where λ and τ are the mean and the size parameters (that quantifies the amount of overdispersion), respectively. Y is the response variable of interest, and $\Gamma(.)$ is the gamma function. Clearly, the negative binomial distribution approaches a Poisson distribution, when τ tends to $+\infty$ (no overdispersion). In our case, we employed the zero-inflated negative binomial (ZINB) model. Because observed data will frequently display pronounced overdispersion, analysts typically seek alternatives to the Poisson model, such as the negative binomial model (Green 2008). Zero inflated count models provide a way of modeling the excess zeros in addition to allowing for overdispersion.

The ZINB distribution is a mixture distribution assigning a mass of p to "extra" zeroes and a mass of $(1 - p)$ to a negative binomial distribution, where $0 \le p \le 1$. Consequently, the probability function for a ZINB regression model is expressed as:

$$P(Y=y)=\begin{cases} p+(1-p)\left(1+\dfrac{\lambda}{\tau}\right)^{-\tau} & \textit{if} \quad y=0, \\ (1-p)\dfrac{\Gamma(y+\tau)}{y!\,\Gamma(\tau)}\left(1+\dfrac{\lambda}{\tau}\right)^{-\tau}\left(1+\dfrac{\tau}{\lambda}\right)^{-y} & \textit{if} \quad y\geq 1. \end{cases}$$

The mean and variance of the ZINB distribution are $E(Y)=(1-p)\lambda$ and $Var(Y)=(1-p)\lambda+(1-p)\left(p+\frac{1}{\tau}\right)\lambda^2$, respectively.

To compare the negative binomial and ZINB model, we use the Vuong statistic, defined as follows:

$$V=\frac{\overline{m}\sqrt{n}}{S_m}$$

where $\overline{m}$ is the mean, $m=log\left[f_1(.)/\ f_2(.)\right]$, with $f_1(.)$ being the density function of the ZINB distribution and $f_2(.)$is the density function of the parent-NB distribution. S and N are the standard deviation and sample size, respectively.

This statistic is a distributed standard normal; values larger than 1.96 favor the ZINB model; and values less than -1.96 favor the negative binomial. V lies between values 1.96 and -1.96, meaning that the test is indecisive. Therefore, both for the household-level and parcel-level analyses, we estimated ZINB models based on results of Vuong tests, which indicate that such models are better than standard negative binomial models. (z = 4.81 for parcel-level analysis, with p-value = 0.0000; and z = 1.65 for household-level analysis, with p-value = 0.049.)

In order to take advantage of panel-data econometric techniques, the parcel-level analysis includes random effects and fixed effects estimates, considering the fact that a household may have several parcels. The OLS is to compare results. For all three models used at the parcel level (i.e., OLS, random effects, and fixed effects), as well as OLS for the household-level analysis, we include the inverse Mills ratio as an additional explanatory variable to take into account the fact that households or parcels with no trees are left out of the analysis.

4. Data Description

In this section, we first present results about the nature and extent of tree growing by rural households in the study areas. Then we present descriptive statistics on the explanatory variables used in the study.

4.1 Description of Tree-Growing Behavior

In the survey, sample households were asked whether they have trees or bushes on their parcel. If they responded yes, they were also asked for more details, such as the most common types of trees and reasons for growing trees. About 44 percent of the parcels had trees and/or bushes on them (table 1). However, only on 28 percent of the parcels had sample households planted trees and bushes over the five-year period prior to the survey. This implies that for about half of the parcels with trees, the trees were older than 5 years. Excluding parcels where trees and bushes were not grown, the average number of trees on a parcel was about 571; including parcels without trees reduced the average number of trees to about 251 (table 1). When aggregated at the household level, the average number of trees grown is 861 with 86 percent of households growing trees (table 1).

Table 1. Descriptive Statistics

Variable	Obs.	Mean	Std. dev.	Min.	Max.
Household-level data					
Treeno	600	861.36	1816.61	0	12922
Grewtree	600	0.86	0.35	0	1
Corrugatedroof	599	0.41	0.49	0	1
Separatekitchen	598	0.59	0.49	0	1
Distancetotown	598	11.96	8.59	0.2	47
Distancetoroad	599	58.08	64.51	0	400
Totalexpenditure	600	3059.88	9640.56	116.38	227409.3
Certificate	569	0.85	0.36	0	1
Totalland	592	1.71	1.37	0	8
livestockinTLU	600	3.81	3.16	0	39.46
Genderofhead	599	0.90	0.29	0	1
Ageofhead	599	45.75	12.70	23	90
Yrsofschoolofhead	600	4.10	5.78	0	20
Familysize	600	6.53	2.39	1	15
Adultmales	600	0.36	0.80	0	6
Adultfemales	600	0.30	0.64	0	4
Offfarmincome	600	224.15	778.84	0	9600
Numberofshocks	600	0.55	1.58	0	10
Cprariskaver	590	0.67	1.09	0	3.87
Timepreference	595	0.25	0.28	0	2
Creditaccess	600	0.59	0.49	0	1

Lentmoney	599	0.32	0.47	0	1
Trustspeople	599	0.76	0.42	0	1
biomassperhousehold	592	25165.33	36076.13	0	124325.5
Parcel-level data					
Treeno	2062	250.64	862.90	0	10300
Grewtree	2062	0.44	0.50	0	1
pareceldistance	2049	23.56	28.43	0	300
parcelirrrigated	2046	0.05	0.22	0	1
parcelsoilwatercons	2038	0.37	0.48	0	1
Certificate	1964	0.83	0.37	0	1
Totalland	2012	0.61	0.85	0	8

The data on parcels with trees over the five-year period before the survey show that tree growing is considerable: an average of 380 trees are grown (only parcels with trees), which decreases to 101 for all parcels (includes those with no trees grown). Four different types of trees dominated over 88 percent of the parcels with trees: eucalyptus (31 percent of parcels with trees); followed by enset, or false banana (17 percent); coffee (12 percent); gesho, or hops (4.6 percent); and chat, a stimulant (2.9 percent). Eucalyptus, the most dominant,[3] averages 323 per parcel, when parcels without eucalyptus are excluded; and 207, when parcels with no eucalyptus are included.

There are also differences across the four regions in terms of tree planting. In particular, when we include all the sample households, the average number of trees planted by a household is largest in Oromia (1,420), followed by SNNP (1,215), Amhara (298), and Tigray (55). As expected, the average number of trees grown by a household rises when those not growing trees are excluded; however, the ranking of regions in terms of average number of trees remains the same. This ranking also holds for comparison of the average number of trees per parcel, when parcels without trees are excluded from the calculation, although the average number for SNNP exceeds that for Oromia when parcels without trees are included. There is also considerable variation in tree-growing behavior across the study sites.

The purposes of planting eucalyptus, the most dominant tree, in descending order of importance, are use as construction material (about 27 percent of parcels), source of food (26

[3] On parcels with trees, an average of 456 eucalyptus are grown, and 200 on all parcels (with and without trees), making it the most dominant tree type by a wide margin..

percent), source of fuel (25 percent), and source of income (14 percent). The Eucalyptus seedlings grown on 53 percent of the parcels came from own sources while purchase of seedlings was the second most important source for 21 percent of the parcels.

4.2 Description of Explanatory Variables

Table 2 presents a description of variables used in the analysis together with the variable names both for household- and parcel-level data. While most of the variables described may be clear, we need to explain two variables: "cprariskaver" and "timepreference." Cprariskaver represents, as described in table 2, constant partial risk-aversion coefficient. It is calculated from results of a hypothetical risk preference experiment based on responses of households to a choice between two equally probable events of bad and good weather with high and low returns, respectively. The value of the variable timepreference is a measure of the respondents' discount rate calculated from their responses to open-ended questions on the maximum amount they would pay back one year after borrowing ETB 100.[4]

Table 2. Description of Variables

Variable name	Variable description
Household-level data	
treeno	Number of trees and bushes grown
Grewtree	Household grew trees (1 if yes, 0 otherwise)
Corrugatedroof	House has corrugated roof (1 if yes, 0 otherwise)
Separatekitchen	Has separate kitchen (1 if yes, 0 otherwise)
Distancetotown	One way distance to nearest town by foot in km
Distancetoroad	Distance to nearest road in minutes
Totalexpenditure	Total monthly household expenditure in Birr
Certificate	Household holds certificate for use (or right) of land (1 if yes, 0 otherwise)
Totalland	Total land size per household in ha
livestockinTLU	Livestock in TLU per household
Genderofhead	Sex of household head
Ageofhead	Age of household head
Yrsofschoolofhead	Years of education of household head

[4] ETB = Ethiopian birr.

Familysize	Family size of household
Adultmales	Number of adult males in household
Adultfemales	Number of adult females in household
Offfarmincome	Off-farm income of household per year
Numberofshocks	Number of shocks experienced by household
Cprariskaver	Constant partial risk aversion coefficient
Timepreference	Stated time preference (interest rate per year)
Creditaccess	Access to credit (1 if yes, 0 otherwise)
Lentmoney	Has lent money (1 if yes, 0 otherwise)
Trustspeople	Trusts people in kebele (1 if yes, 0 otherwise)
biomassperhousehold	Biomass in kg per household at kebele level
Parcel-level data	
treeno	Number of trees and bushes on parcel
Grewtree	Grew trees on parcel (1 if yes, 0 otherwise)
pareceldistance	Walking distance of parcel from homestead in minutes
parcelirrrigated	Parcel irrigated (1 if yes, 0 otherwise)
parcelsoilwatercons	Soil and water cons. Structure on parcel (1 if yes, 0 otherwise)
Certificate	Household holds certificate for use (or right) of parcel (1 if yes, 0 otherwise)
Totalland	Total parcel size per household in hectares

Descriptive statistics on explanatory variables used in the analysis are presented in table 1. The first set of variables is household level, while the table, the last few rows are parcel level. A number of figures are self-explanatory, but we note a few of the descriptive statistics. About 85 percent of households and about 83 percent of parcels are certified, in the sense that the holders of the land have received a property certificate. At the household level, the average land holding is 1.71 hectares, and the average size of a parcel is 0.61 hectare. One of the most important assets of rural households in our study sites is a house; about 41 percent of the houses owned by households have corrugated-iron roofs, which is a sign of good quality housing.

Another important asset in our study sites is livestock. An average household owns 3.81 tropical livestock units (TLU). In addition to trees, these two assets (ownership of a house and livestock) are perhaps the most important assets to the households in our study areas. The results of the hypothetical risk preference experiment show that the households are generally risk averse. The average stated discount rate of households is 25 percent. This is perhaps a reflection that, if the benefits obtained from investments in the future are more uncertain compared with investments that offer short-term benefits, risk aversion behavior of households leads to a high rate of time preference.

While 59 percent of the households have access to credit when the need arises, about 76 percent of them reported that they trust people in their kebele. The estimated biomass per household is about 25,165 kg per kebele, with wide variation across sites. At the parcel level, about 5 percent are irrigated, and about 37 percent of parcels have soil and water conservation structures.

5. Empirical Results and Discussion

Correlates of tree-growing decision both at the household and parcel level are presented and discussed, followed by correlates of the number of trees grown. Please note that we conducted tests using variance inflation factor and correlation matrix to check for multicollinearity, since we have a number of variables included in the analysis, such as livestock, land area, and rates of time preference. The results suggest that multicollinearity is not a serious problem.

5.1 Correlates of Tree-Growing Decision

Tables 3 and 4 present the results of the probit analysis of the decision of households to grow trees at parcel and household levels, respectively. Measures of goodness of fit are indicated at the end of the tables; Wald chi-square test results show that the estimated models are statistically significant at the 1 percent level. Robust standard errors, which are adjusted for clusters at the kebele level, are used in the estimation.

Table 3. Probit Results for Decision to Grow Trees on Parcel

Variable	Probit result	Variable	Probit result
Pareceldistance	-0.009 (2.76)***	Yrsofschoolofhead	0.002 (0.36)
Parcelirrrigated	0.137 (0.56)	Familysize	-0.017 (0.93)
Parcelsoilwatercons	0.158 (1.68)*	Adultmales	0.063 (0.95)
Corrugatedroof	-0.442 (4.31)***	Adultfemales	0.002 (0.04)
Separatekitchen	0.288	Offfarmincome	0.000

	(3.33)***		(1.52)
Distancetotown	0.038 (5.48)***	Numberofshocks	0.013 (0.60)
Distancetoroad	-0.001 (0.79)	Cprariskaver	-0.053 (1.75)*
Totalexpenditure	0.000 (1.50)	Timepreference	0.017 (0.12)
Certificate	0.488 (4.23)***	Creditaccess	0.101 (1.20)
Totalland	0.327 (3.04)***	Lentmoney	-0.119 (1.16)
Livestockintlu	0.001 (0.06)	Trustspeople	0.065 (0.51)
Genderofhead	-0.040 (0.28)	Biomassperhousehold	0.000 (7.00)***
Ageofhead	-0.002 (0.69)	Constant	-1.014 (3.42)***
Observations	1826		
Wald chi2(25)	599.87***		
Pseudo R2	0.1978		

Notes: Robust z statistics are in parentheses (based on standard errors adjusted for kebele clusters).

* = significant at 10%; ** = significant at 5%; *** = significant at 1%.

Of five parcel-specific variables used, four were found to be statistically significant. In particular, whether or not the parcel is irrigated is not likely to have a statistically significant effect on the decision to plant a tree on a parcel. On the other hand, parcels farther away from the household were less likely to have trees on them. Households may prefer to plant trees on closer plots to ensure that they will look after them (especially the very young ones) and reduce the likelihood that mature trees will be stolen. In a number of places, farmers prefer to grow (most of) their trees in their backyard.

Most of the trees grown are eucalyptus, and farmers tend not to plant them on parcels with annual crops to avoid competition: eucalyptus appears to be a substitute instead of a complement. Thus, eucalyptus trees are likely to be planted with more concentration in particular parcels and closer to the homestead.

The results also show that parcels which have soil and water conservation structures are more likely to have trees on them, suggesting complementarity. The trees may be part of such conservation structures.

Land certification increases the likelihood that a parcel will have trees on it and that a household will decide to grow trees. This is in line with the expectation that a land certificate would make the holder more confident to invest in a parcel by growing trees. These results also confirm results of previous studies of the effect of land certification on investment on land in Ethiopia (Deininger et al. 2008; Holden et al. 2009). The results also show that larger parcels are more likely to have trees on them. However, this variable is not statistically significant for the likelihood that households will grow trees.

Table 4. Probit Results for Decision to Grow Trees at Household Level

Variable	Probit result	Variable	Probit result
Corrugatedroof	-0.682 (3.72)***	Adultmales	0.169 (1.65)*
Separatekitchen	0.420 (2.18)**	Adultfemales	0.185 (1.07)
Distancetotown	0.041 (3.10)***	Offfarmincome	0.000 (2.02)**
Distancetoroad	-0.002 (0.91)	Numberofshocks	0.102 (1.46)
Totalexpenditure	0.000 (1.14)	Cprariskaver	-0.084 (1.43)
Certificate	0.975 (5.76)***	Timepreference	-0.303 (1.27)
Totalland	0.032 (0.27)	Creditaccess	-0.032 (0.20)
livestockinTLU	0.102 (1.84)*	Lentmoney	-0.278 (1.93)*
Genderofhead	0.104 (0.33)	Trustspeople	0.099 (0.45)
Ageofhead	-0.003 (0.33)	Biomassperhousehold	0.000 (2.36)**
Yrsofschoolofhead	0.013 (0.80)	Constant	-0.931 (2.05)**
Familysize	0.050		

	(1.62)	
Observations	534	
Wald chi2(22)	336.06***	
Pseudo R2	0.2416	

Notes: Robust z statistics are in parentheses (based on standard errors adjusted for kebele clusters).

* = significant at 10%; ** = significant at 5%; *** = significant at 1%.

The results for household-level variables indicate that households, which lend money and own houses with corrugated roofs, are less likely to grow trees. Variables that increase the likelihood of households growing trees are households with a separate kitchen, farther away from towns, owning livestock, with more adult males, with higher off-farm income, and located in kebeles with more biomass available.

It is interesting to note that, while more biomass availability at the kebele level may reduce incentives of households to grow trees on private parcels, the results indicate the contrary. However, such a result is similar to Mekonnen and Bluffstone (2008) and Bluffstone et al. (2008), who found that in places where common-property forests are well managed (suggesting more biomass at the community level), households plant more trees. Carlsson et al. (2005) also found that households which have more access to community forests have a higher willingness to pay for the establishment of additional community forests.

We may also note that a number of variables, including measures of time preference, access to credit, social trust, household expenditure, gender, education, and age of household head, family size, and number of shocks experienced were not significant variables in affecting the likelihood of growing trees. Our measure of risk aversion was also not significant in influencing the decision to grow trees at the household level, although it is significant at the parcel level.

5.2 Correlates of the Number of Trees Grown

Tables 5 and 6 present results of correlates of the number of trees grown at the parcel and household levels, respectively. As noted above, results of several empirical models are presented. In particular, to take advantage of econometric techniques for panel data, the parcel-level analysis includes random effects and fixed effects estimates, considering the fact that a household holds several parcels. OLS is also used to compare results.

For all the three models used at the parcel level (i.e., OLS, random effects. and fixed effects), as well as OLS for the household-level analysis, we include an inverse Mills ratio as an additional explanatory variable to account for the fact that households or parcels with no trees are left out from the analysis. Due to this, the standard errors for these groups of models (OLS, random effects, and fixed effects) are bootstrapped with 200 replications, while they are also adjusted for kebele-level clusters.

Both for the household- and parcel-level analysis, we also estimate zero-inflated negative binomial models, based on results of Vuong tests, which indicate that such models are better than standard negative binomial models (z = 4.81 for parcel-level analysis with p-value = 0.0000'; and z = 1.65 for household-level analysis with p-value = 0.049). We may also note that the relevant goodness-of-fit measures are presented at the end of tables 5 and 6, which indicate the significance of the model estimates at 1 percent level.

Table 5. Regression Results for Number of Trees Grown at Parcel Level

Variable	OLS‡	Random effects‡	Fixed effects‡	Zero inflated neg. bin.
Pareceldistance	-2.583	-2.583	-1.403	-0.010
	(0.35)	(0.38)	(0.21)	(5.52)***
Parcelirrrigated	255.101	255.101	287.771	0.533
	(1.04)	(1.26)	(1.39)	(1.78)*
Parcelsoilwatercons	86.601	86.601	91.197	-0.058
	(0.43)	(0.49)	(0.45)	(0.39)
Corrugatedroof	23.192	23.192	34.960	0.285
	(0.06)	(0.07)	(0.10)	(1.70)*
Separatekitchen	127.990	127.990	69.604	0.139
	(0.47)	(0.55)	(0.24)	(0.87)
Distancetotown	4.641	4.641	3.477	-0.008
	(0.17)	(0.18)	(0.13)	(1.02)
Distancetoroad	-1.257	-1.257	-1.233	-0.003
	(1.10)	(1.32)	(0.96)	(2.73)***
Totalexpenditure	-0.001	-0.001	-0.001	-0.000
	(0.03)	(0.04)	(0.07)	(0.29)
Certificate	272.805	272.805	285.734	0.257
	(0.69)	(0.79)	(0.73)	(1.17)
Totalland	207.200	207.200	186.578	0.233
	(1.15)	(1.41)	(1.42)	(3.25)***

livestockinTLU	50.553	50.553	56.020	0.065
	(1.63)	(1.63)	(1.64)	(3.07)***
Genderofhead	-128.001	-128.001	-188.017	0.334
	(0.78)	(0.74)	(0.78)	(1.35)
Ageofhead	-1.098	-1.098	-2.229	0.004
	(0.24)	(0.24)	(0.44)	(0.88)
Yrsofschoolofhead	14.088	14.088	16.768	0.040
	(1.72)*	(1.56)	(1.97)**	(2.68)***
Familysize	-26.260	-26.260	-23.852	-0.005
	(1.02)	(1.13)	(0.84)	(0.19)
Adultmales	229.679	229.679	230.165	0.213
	(2.26)**	(2.57)**	(2.68)***	(2.81)***
Adultfemales	19.370	19.370	24.555	-0.013
	(0.18)	(0.17)	(0.31)	(0.13)
Offfarmincome	-0.009	-0.009	-0.008	0.000
	(0.10)	(0.11)	(0.08)	(0.99)
Numberofshocks	-24.569	-24.569	-24.360	-0.017
	(0.81)	(0.89)	(0.92)	(0.41)
Cprariskaver	-86.213	-86.213	-80.824	-0.116
	(1.57)	(1.69)*	(1.68)*	(1.83)*
Timepreference	241.475	241.475	185.818	0.488
	(1.23)	(1.34)	(1.34)	(2.20)**
Creditaccess	179.220	179.220	175.428	0.115
	(1.23)	(1.38)	(1.30)	(0.84)
Lentmoney	93.194	93.194	94.916	0.165
	(0.66)	(0.71)	(0.83)	(1.13)
Trustspeople	-56.750	-56.750	-56.257	-0.115
	(0.44)	(0.49)	(0.39)	(0.77)
Biomassperhousehold	0.008	0.008	0.008	0.000
	(0.84)	(0.93)	(.)	(5.86)***
Mills ratio	402.825	402.825	414.736	
	(0.33)	(0.38)	(0.38)	
Constant	-536.337	-536.337	-465.083	4.365
	(0.32)	(0.37)	(0.36)	(9.67)***
Observations	835	835	835	1826
Wald Chi2 (26)/LR chi2(25)	66.15***	71.1***		175.91***

* = significant at 10%; ** = significant at 5%; *** = significant at 1%.

‡ Bootstrapped standard errors (with 200 replications) and adjusted for kebele clusters.
Note: Z statistics are in parentheses;

When we look at the variables that are parcel specific, we find from the ZINB model that parcel distance from household has a negative association with the number of trees grown, while irrigated parcels and those with larger land size have a positive association with the number of trees grown. We note from the discussion above that, while the decision to grow trees on a parcel does not significantly depend on whether a parcel is irrigated, once the decision is made, the number of trees grown does depend on it. On the other hand, the results for parcel distance and land size are similar to those for the decision to grow trees. Land size also has a positive association with the number of trees grown at the household level.

We also find that whether or not a parcel is certified is not associated with the number of trees grown, although as noted above there is a positive association of land certification with the decision to grow trees. What this suggests is that certification status can influence the decision to grow trees, but not the magnitude of investment (i.e., the number of trees).

Table 6. Regression Results for Number of Trees Grown at Household Level

Variable	**OLS‡**	**Zero inflated neg. bin.**
Corrugatedroof	318.302	0.252
	(0.89)	(1.37)
Separatekitchen	134.226	0.095
	(0.48)	(0.53)
Distancetotown	-11.407	-0.008
	(0.62)	(1.10)
Distancetoroad	-0.734	-0.002
	(0.39)	(1.82)*
Totalexpenditure	-0.001	0.000
	(0.02)	(1.44)
Certificate	262.304	0.299
	(0.64)	(1.35)
Totalland	331.904	0.210
	(3.08)***	(3.61)***
livestockinTLU	52.741	0.034
	(0.95)	(1.32)
Genderofhead	-72.892	0.423
	(0.27)	(1.56)

Ageofhead	-1.732 (0.20)	0.004 (0.71)
Yrsofschoolofhead	24.013 (1.45)	0.039 (2.44)**
Familysize	-63.933 (1.36)	-0.013 (0.45)
Adultmales	343.281 (2.37)**	0.209 (2.55)**
Adultfemales	-99.733 (0.61)	-0.203 (1.78)*
Offfarmincome	-0.011 (0.07)	0.000 (1.16)
Numberofshocks	-79.023 (1.39)	-0.022 (0.50)
Cprariskaver	-84.928 (1.31)	-0.132 (1.85)*
Timepreference	437.961 (1.33)	0.313 (1.34)
Creditaccess	351.600 (1.80)*	0.166 (1.11)
Lentmoney	135.275 (0.54)	0.093 (0.57)
Trustspeople	-0.813 (0.00)	0.004 (0.03)
Biomassperhousehold	0.008 (1.06)	0.000 (5.36)***
Mills ratio	-429.985 (0.38)	
Constant	-55.513 (0.06)	4.622 (9.08)***
Observations	467	534
Wald Chi2 (23)/LR chi2(22)	69.07***	133.83***

* = significant at 10%; ** = significant at 5%; *** = significant at 1%.

‡ Bootstrapped standard errors (with 200 replications) and adjusted for kebele clusters.

Note: Z statistics are in parentheses.

Both for parcel and household level analyses, distance to road and risk aversion have negative association with the number of trees grown, while education of household head, number of adult males, and biomass availability have a positive association. These results suggest the importance of education and adult male labor for the intensity of trees grown. Moreover, similar to the results for the decision to grow trees, biomass availability at the kebele level seems to be associated with more tree growing by households on private parcels, in line with previous results.

There are also some variables that are statistically significant in the regression at the parcel level, but not at the household level, and vice versa. In particular, we find that the number of adult females is negatively associated with the number of trees grown at the household level, while credit access has a positive effect. On the other hand, the number of trees at the parcel level is positively associated with having a house with corrugated roof, livestock ownership, and high discount rates of households.

6. Conclusions

This study looked into tree-growing behavior of rural households in Ethiopia. The data comes from a sample of 600 households, selected from 40 peasant associations (kebeles) in 10 districts (woredas), plus data on tree growing collected at the parcel level. This study is different from previous studies that looked into tree growing by rural households in developing countries in general, and Ethiopia in particular, because it uses more comprehensive data from four regions of Ethiopia (Amhara; Oromia; Southern Nations, Nationalities and Peoples; and Tigray).

The fact that we also analyze the number of trees grown, and not just the decision to grow trees, and include a number of explanatory variables that are typically not found in a single study also distinguish it. (These include measures of risk aversion based on a hypothetical risk preference experiment; a measure of time preference of respondents; whether or not the parcel held is certified; and whether or not the household has access to credit; as well as indicators of economic status of the household. including livestock owned, land size, off-farm income, household expenditure, whether the house has corrugated roof, whether the household lent money, and whether the household had access to credit.)

As an indicator of social capital, we also used whether the household trusts most people in their peasant association (kebele). Another important variable used in this study, and typically not available in other data sets in similar studies, is a measure of availability of biomass based on satellite images supported by ground corroboration.

In addition to looking into the correlates of both the decision to grow trees and the number of trees grown, the study also separately examined these issues both at the parcel and household levels. One of the striking results from the descriptive statistics is that about 86 percent of the households grew trees on 44 percent of the parcels. The land size held by an average household is 1.71 hectares, and about 861 trees are grown by the average household. About 251 trees are grown on an average parcel.

The analysis shows a number of results with implications. First, it brings out the importance of doing the analysis at the parcel level, in addition to the more common approach of household level analysis. Analysis at the parcel level enabled us to note the importance of distance of parcels from the homestead, whether or not a parcel is irrigated, whether or not a parcel has soil and water conservation structures on it, what size the parcel is, and whether or not a household has received a certificate (for use of the land or right to the land) for the parcel.

Second, we find that the determinants of the decision to grow trees are not necessarily the same as those of the number of trees grown. One particular result worth mentioning is land certification, which increases the likelihood that households grow trees, but is not a significant determinant of the number of trees grown.

Third, we find that a number of variables, including risk aversion, land size, adult male labor availability, and education of the head of the household, are important in influencing the number of trees grown.

These results suggest the need to use education and/or awareness creation, as well as the importance of household endowments and behavior, such as land, labor and risk aversion, for tree growing. The study also finds that, while tree planting is practiced in all the four regions covered, there are variations across regions.

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