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1. INTRODUCTION

Many environmental problems such as soil degradation and forest depletion can be characterized as a result of incomplete, inconsistent, or non-enforced property rights (Bromely and Cernea 1989). It has been long observed that easily transferable and secure property rights have been identified as a key element to bring about higher levels of investment and access to credit, facilitate reallocation of production factors to maximize allocative efficiency in resource use, and allow economic diversification and growth (Deininger and Jin 2006; Place 2009).

More recently the importance of land tenure is given considerable attention. For instance, it has been mentioned as important in the Commission for Legal Empowerment of the Poor, Commission for Africa (2005), NEPADs Comprehensive African Agricultural Development, and the UN millennium Project (2005). It has also received attention in the Poverty Reduction Strategy Papers produced by many African countries. A number of African countries have passed legislation related to land reform. However, implementation of such legislation has been either very slow or non-existent in most of these countries. This makes it difficult for benefits from such legislation to be realized and potential benefits for the poor would be lost (Deininger et al. 2008b).

In Ethiopia to enhance tenure security and reduce land disputes in rural areas a low-cost land certification and registration was launched in four big regions since 1998/9 and is being carried out. This is the largest land certification program in the last decade in

Africa and possibly in the world (Deininger et al. 2008b). The cost of the land certification program is also considered to be an order of magnitude lower than what could be found elsewhere in the literature (Deininger et al. 2008b). The program started in Tigray region (one of our study areas) in 1998/99 while in the Amhara region (the other region covered in this study) the program began in 2003. There are limited studies on the impact of this new program on investment in land and agricultural productivity (Deininger et al. 2009; Holden et al. 2009). Holden et al. (2009) assessed the investment (tree and soil and water conservation) and crop productivity impact of land certification in Tigray region of Ethiopia using panel data. They found that the program has positive impact on investment and productivity. Similarly, Deininger et al. (2009) assessed soil and water conservation and productivity impact of this program in the Amhara region (our study area) and they also found positive impacts. The impact of land tenure (in)security depends on types of investments, available infrastructure, and the political setting of each region/country (Place 2009; Deininger and Jin 2006). Thus, results of empirical studies of impacts of land tenure insecurity or land titling are not uniform (Deininger and Feder 2009).

This paper is therefore expected to contribute to the growing but limited literature by focusing on impacts of land certification on the number of trees grown using household-plot level data in the Amhara and Tigray regions of Ethiopia. The specific objectives of the study are: To analyze the effect of land certification on tree growing behavior on private plots of rural households in the Amhara and Tigray regions of Ethiopia; and factors other than land certification that have significant effects on the number of trees planted on private plots of rural households. Unlike most other studies looking at impacts on tree growing we use household and plot panel data in the analysis.

We find that land certification has a positive impact on tree growing on private plots of rural households in both the Tigray and Amhara regions. We also find that other variables influence tree growing by rural households. The rest of the paper is structured as follows. Section 2 presents a brief review of related literature. The analytical framework and data used in the study are briefly described in section 3. Section 4 presents descriptive statistics while section 5 describes the methodology used. Section 6 presents results and discussion while section focusing on the effects of land certification on tree growing while section 7 concludes the paper.

2. BRIEF LITERATURE REVIEW

Increased tenure security could encourage farmers to invest in land and improve land productivity through its expected effects on possibilities of using land as collateral and on land transfer to those who use it more productively (Besley 1995). However, individual land titling may not always be appropriate for countries in Africa as it may be, among others, too costly and improper implementation may mean more confusion and conflict (Deininger et al. 2008b). On the other hand, there is demand in African countries to introduce some formal means that enable and encourage farmers to ensure proper land transactions take place and farm boundaries demarcated with some formal enforcement mechanism. For example, a recent study by Deininger et al. (2008a) in Uganda showed that more than 90% of households wanted to get a certificate, and 87% were willing to pay. Principles to be followed in addressing these issues include protection of women's rights and local level documentation of land rights which is less demanding and less costly than title but with possible external enforcement and improved state of certification in a future period. Examples of attempts to implement these principles in Africa include new land laws or policies in Tanzania (Sundet 2004), Malawi (Peters and Kambewa 2007), Mozambique (Tanner 2002), and Uganda (McAuslan 1998). Sikor and Muller (2009) argue that state-led land reforms encounter significant problems on the ground. Two main reasons for this are their reliance on ‘‘top-down” initiatives and bureaucratic implementation. They note empirical and conceptual insights suggest the benefits of a shift in emphasis from state to community in land reform.

Studies on the effect of land tenure insecurity (measured in different ways) on investment in land in Africa have found different results (Brasselle et al. 2002; Deininger and Jin 2006). A recent work by Place (2009) notes significant heterogeneity of findings of studies in Africa that examine the productivity effects of tenure systems and recommend the need to pay attention to local context and overarching macro and sectoral conditions. Deininger and Feder (2009) also note in a recent review of work on potential gains from land titles that existing evidence is not uniform. For example, a study in Madagascar suggests no effect of formal title on plot-specific investment (Jacoby and Minten 2007). On the other hand, in Uganda a shift from merely occupied plots by owner-cum-occupants to full ownership increased the likelihood of investment in trees fivefold and doubled that of soil conservation (Deininger and Ali 2008). In Ghana, Pande and Udry

(2005) find that tenure insecurity reduced investment in the form of fallowing leading to an estimated reduction in output by about one-third and very large losses in aggregate efficiency.

On Ethiopia, earlier studies have used measures of land tenure insecurity such as perceived insecurity by farmers or length of time the farmer has worked on the land. Some of these earlier studies have focused on soil and water conservation investments (e.g., Gebremedhin and Swinton 2003; Deininger and Jin 2006) while others have looked at tree growing (Holden and Yohannes 2002; Deininger and Jin 2006; Mekonnen 2009). Holden et al. (2003) found that there was a large potential for more tree planting on private land with good market access that was unsuitable for crop production due to steep slope and shallow soils in the Amhara region of Ethiopia. Stimulation of such investments could both reduce the pressure on communal lands and provide a good source of income for households without any significant negative impact on household food production.

Ethiopia’s recent implementation of a large scale and low-cost land certification program is an important example of attempts to formalize land rights with low cost while also addressing other related issues. Using community and household level data collected recently from the four major regions of Ethiopia, Deininger et al. (2008b) document such certification. As the study by Deininger et al. (2008b) is a first description of such a process, they recommend that such a study be complemented with more detailed evidence of certification impacts preferably using panel data.

Recently studies on Ethiopia have focused on the impact of land certification on investment and productivity in agriculture (Deininger et al. 2008b; Deininger et al. 2009; Holden et al. 2009). These studies were motivated by a large scale low-cost land certification program that has been undertaken in the four major regions of Ethiopia. Holden et al. (2009) use household and plot-level panel data collected from the Tigray region of Ethiopia to assess the investment and productivity impacts of the recent low-cost land certification. They find significant positive impacts including effects on the maintenance of soil conservation structures, investment in trees, and land productivity. Using panel data from the Amhara region of Ethiopia, Deininger et al. (2009) assess the effects of the low-cost land registration program in Ethiopia on soil and water investment. They find that despite policy constraints, the program increased soil and water -related investment.

In addition to land certification, other variables are also expected to influence tree growing. One such variable is access to and availability of wood from communal land or forests. A study by Heltberg et al. (2000) finds that rural Indian households substitute fuels from private sources for forest fuelwood in response to forest scarcity and increased fuelwood collection time. Similar results were found by Van't Veld et al. (2006) who find that when biomass availability from communal areas decreases, households would be more likely to use privately produced fuel instead of increasing the time they spend to collect fuel from communal sources. Linde-Rahr (2003) also finds that in Vietnam higher shadow prices of fuel wood collection from open-access leads to more collection from private plantations. Amacher et al. (1993) find that when fuelwood is sufficiently scarce on communal land, households eventually begin growing wood on their own private lands. Amacher et al. (2004) also find that in Tigray region of Ethiopia, distance to main fuelwood collection area positively affects decision to plant eucalyptus on own agricultural land and on microdam land. After a review of studies on household responses to fuel wood scarcity, Cooke et al. (2008) conclude that in the presence of sufficient scarcity, the empirical results generally reinforce the contention that households change their behavior in ways that are least costly to them.

This brief review suggests that more evidence is needed on the impacts of land certification on investment in land and agricultural productivity including tree growing behaviour.

3. ANALYTICAL FRAMEWORK AND DATA

The analytical approach for this research will draw from previous literature on the economics of farmers' participation in tree planting activities. Previous research on tree planting activities have modeled farmers' participation in tree planting as a function of a number of economic, social, demographic, institutional, plot variables, and other variables (e.g., agro-ecology indicator variables such as village dummy variables) (e.g., Holden et al., 2009; Deininger et al., 2009; Mekonnen 2009). In developing countries where input and product markets are imperfect, consumption and production decisions are non-separable. So, a non-separable farm household model will be used as our theoretical framework.

We use household and plot level panel data. The data used for the Amhara region was collected in 2002 and 2007 by the Environmental Economics Policy Forum for Ethiopia together with its partners. It included over 1700 households and covers 7 districts and 14 Kebeles in the Amhara region. The data from Tigray region includes 16 communities and is stratified by market access, population density, access to irrigation and agro-ecology. From each community, 25 households were selected with information from all plots surveyed in 1998, 2001, 2003 and 2006.

4. Descriptive statistics

4.1 Amhara Region

Table 1 presents mean and standard deviation of variables used in the analysis for the Amhara region.

Table 1. Descriptive statistics (Amhara region)

Variable	Mean	Std. Dev.
Dependent variable		
Planted trees (Number)	158.623	547.319
Explanatory variables		
Certification (1=yes)	0.405	0.491
Household age (year)	49.764	15.103

Family size (number)	5.328	2.131
Livestock (TLU)	5.579	39.758
Off-farm activity participation (1= yes)	0.125	0.331
Education (year)	3.211	4.198
Farm size (ha)	1.615	0.946
Distance to woreda town (minutes)	66.917	47.605
Distance to road(minutes)	35.084	35.009
Gender (1=male)	0.849	0.358
Extension contact(1=yes)	0.124	0.330
Credit access(1=yes)	0.364	0.481
Time spent to collect wood from communal land (in hours per round trip)	1.67	1.24
Time spent to collect wood from all sources (in hours per round trip)	1.66	1.23

The results show that on average a household grows 159 trees with a very wide variation across households as reflected by a standard deviation more than three times the mean. In terms of extent of certification, the data show that about 40 percent of the households have received land certificates.

4.2 Tigray region

Table 2 shows the average number of trees by type on plots with and without land certificates irrespective of year based on data from 1998, 2001 and 2006. For Young trees and tree seedlings we only had data from 2001 and 2006. Land certification took place in 1998-99. Plots that were on households' land certificates had significantly more trees than plots that were not included on households' land certificates. However, this does not say anything about the direction of causality between land certificates and planting of trees. Further econometric analysis is required for the inference of impacts from land certification. Basic variable description and statistics for the variables included in the econometric models are presented in Appendix Table A1.

Table 2. Descriptive statistics for tree variables (Tigray)

	Certificate			No certificate			
Variable	Mean	St.Error	N	Mean	St.Error	N	t-test
Eucalyptus trees	5.05	1.26	924	1.37	0.71	168	>***
Indigenous trees	15.78	4.20	939	1.99	0.59	169	>***
Young trees	5.97	1.19	928	0.95	0.40	168	>***
Tree seedlings	9.08	1.18	933	3.86	2.01	167	>**

5. Methodology

5.1. Amhara data analysis and estimation methods

The choice of method partly depends on the nature of the outcome variable. Our outcome variable has observations with both positive and zero values. Where a dependent variable contains both zero and positive values, a Tobit model and its variants could be used. In this paper random effect Tobit model is adopted.[1] We assumed household specific unobserved characteristics will not affect impact of certification as this intervention is exogenous to individual households and all households within a village are well aware that they will receive the certificate. However, the decision to adopt tree planting may be influenced by the gain from adoption. Estimation without controlling for this problem may lead to biased results. A Heckman self-selection correction approach is also tried to address this problem but the inverse Mills ratio was not significant. Thus, we report results only for probit and Tobit models. Both for the probit and Tobit models, to account for time varying variables we also used a correlated random effects model (Chamberlain-Mundlak approach) where average values of these variables are included as additional variables. Plot characteristics may affect household's decisions on tree planting, however, for the Amhara data the analysis is done at household level as the outcome variable is not collected at plot level during the 2007 round of data collection. We included district (Woreda) level fixed effects to address district level effects.

We also include two variables to examine the role of scarcity of wood. One is the time spent by households to collect wood from communal lands for which a positive correlation is expected with private tree planting. The second variable is time spent by households to collect wood from all sources including private sources which may be expected to have a positive correlation with private tree growing at least initially. But this

[1] Given the nature of the data, two years panel data, fixed effects and difference- in-difference (DID) methods could have been used. However, some households have one observation per year. A minimum of two points are required to implement fixed effects and DID methods. In addition to this, application of fixed effects on non-linear models is tricky because of incidental parameter problems (Wooldridge, 2002).

may be negative through time since those who planted private trees may spend less time on collection of wood.

5.2. Tigray data analysis and estimation methods

We applied a two-step approach to data analysis by first using non-parametric matching to ensure that we have a sample of plots with and without land certificates that satisfies the balancing and common support requirements. This facilitates elimination of selection bias due to observable plot and household characteristics. To assess the need for separation of planting of trees from how many trees to plant on a plot, we tested probit models versus tobit models and assessed the pattern of signs and significance levels for the two types of models. We found a remarkably similar pattern in the two types of models and decided that there is little reason to use two-stage models after matching and to worry about selection bias due to unobservables. We therefore used random effects Tobit models on the matched sample. Fixed effects models with limited dependent variables suffer from the incidental parameter problem, which leads to biased estimators (Greene 2003; Wooldridge 2002). The correlated random effects (Mundlak-Chamberlain model) was also tried but could not converge. This could be due to the problem that there were relatively few dependent variable observations with non-zero values. Models for farm-plot level investments in trees have the following specification for estimation of factors associated with plot level tree stocks and tree planting, including the certification impacts:

$$(4)\ I^{P}_{hpt} = \alpha_0 + \alpha_1 Q_{hpt} + \alpha_2 CY_{hpt} + \alpha_3 I^{F}_{hpt} + \alpha_4 I^{F}_{hpt} * CY_{hpt} + \alpha_5 DF_h + \alpha_6 CT_h + \alpha_7 Z_{ht} + \alpha_8 Z_v + \alpha_9 D_t + \zeta_h + e_{hpt}$$

where:

I^{P}_{hpt} is the log(number of trees +1) on plot p of household h in period t,

Q_{hpt} is a vector of plot level time-varying biophysical characteristics,

CY_{hpt} is the duration of ownership of land certificate for plots with certificate,

I^{F}_{hpt} is a public investment dummy on plot p of household h in period t,

DF_h is the distance to nearest communal forest area in 2003 (used as time-invariant variable),

CT_h is the time the household spent on collection of firewood per week in 2003 (time-invariant),

Z_{ht} is a vector of household characteristics,

Z_v represents zonal dummy variables

D_t represents time period dummy variables,

ζ_h is a household random effects error component,

e_{hpt} is the transitory error component.

The investment enhancement effect that may have accrued due to the land certification that has reduced plot level tenure insecurity is not likely to appear immediately after receiving land certificates and is likely to grow stronger over time. First the perceptions of stronger tenure security must sink in and then gradually they will start to affect plot level behavioral decisions. To capture this gradual effect, we used the time period (in years) that the individual households have possessed their land certificates. This also resembles a pipeline approach where variation in timing of allocation of certificates is utilized to identify the impacts. This variation in timing was caused primarily by administrative constraints. The land registration and certification took place all over the highlands of Tigray in a fairly short period of time in 1998-99 when more than 80% of the households received land certificates. Administrative errors caused some households or sections of communities to receive their certificates later than other households and sections of communities. It is this variation in timing of allocation of certificates that we utilize to identify the impacts.

The plot level characteristics include a dummy variable for homestead plots. We assume that tenure security is higher on homestead plots and that there are no restrictions on tree planting on homestead plots. Therefore we expect a positive sign for this variable. Another of the plot characteristics is the distance from the homestead to the plot. We assume that there is higher tenure insecurity on distant plots and also a larger risk that planted trees can be stolen or damaged due to the higher costs of monitoring and protecting investments on distant plots than on nearby plots. We also expect tree planting to be positively associated with sloping and shallow land.

We expect planting of trees to be negatively associated with public investments on the plot because of the prohibition of tree planting on land suitable for crop production (with the exception of homestead plots). In particular we expect such a negative relationship for eucalyptus for which restrictions on planting as most clear. It is possible therefore that land certification has not stimulated planting of eucalyptus even though certification may have reduced tenure insecurity. The restrictions are likely to be most efficient on plots that have been exposed to public conservation investment. We therefore test for the interaction between public investment and years with certificate and expect it to give a negative coefficient and particularly so in the eucalyptus model. However, there are also law restrictions against cutting down of indigenous trees and public investment on plots may be positively associated with the stock of indigenous trees on plots for that reason.

To assess the relationship between tree planting incentives on private land and availability of trees from communal land we have included two variables: the distance to nearest communal woodlot and the time the household spent per week on collection of firewood. We expect that tree planting incentives are stronger when the distance to the nearest communal woodlot is larger. Initially we also expect that households that spend a lot of time on collection of firewood would have stronger incentives to plant trees. Over time, however, it is possible that those who have planted more trees spend less time on collection of firewood (negative feedback effect). Since these two variables only are available for one year, 2003, in our data and we therefore use them as time-invariant variables, the expected sign for the collection time for firewood could be ambiguous due to the possible negative feedback effect.

6. Results and discussion: Effects of land certification on investment in trees

6.1. Amhara region

The distribution of the outcome variable (number of trees planted) is highly skewed, with a skewness of 8.52 and a kurtosis of 108.2. We therefore transform the outcome variable by taking logarithm. The natural logarithm of the outcome variable has a skewness of 0.67 and a kurtosis of 1.90. Estimation results are presented in tables 3 and 4. Bootstrapped standard errors are reported.

Results of the correlated random effects Tobit model[2] (Table 4) show that land certification has a positive and statistically significant effect on the number of trees

[2] We also run simple random effects Tobit and simple probit models but the results are similar. Results could be obtained from authors on request.

grown. Similarly, the effect of certification on the likelihood of tree growing in the correlated random effects probit model is positive (Table 3). This suggests tenure security is important given the fact that the benefits from long-term investments accrue over time.[3] Deininger et al. (2009) found similar results using the same data set but with soil conservation measures as the outcome variable.

On the other hand, the results of the Heckman correction approach suggest that the inverse Mills ratio is not significant. For this reason we report and discuss the probit results for analysis of the decision to plant trees (Table 4) while the analysis of number of trees grown is handled using the results for the correlated random effects Tobit presented in Table 3.

In addition to the certification variable, other variables also affect tree growing by rural households in our sample. Since the results differ across the different models used we use the results of correlated random effects Tobit (Table 4) to briefly present the effects of other variables. The results suggest that participation in off-farm activities, farm size, being a male head of household, and contact with extension agents were found to have a positive effect on number of trees grown. Households further away from roads planted less trees suggesting the role of market access. We also find that more educated households had less trees which is generally not expected. Households who spend more

3 We also tried propensity score matching (PSM) method and find same qualitative results as the Tobit model results. However, although the bias is substantially reduced, use of PSM did not completely eliminate the bias as some of the matching quality indicators such as the joint significance of covariates (the p-value of the likelihood value) are significant after matching.

time collecting fuelwood per trip from communal areas have more private trees.[4] However, time spent per trip to collect fuelwood from all sources is negatively associated with private tree growing, perhaps suggesting the role of access to private sources in reducing the time needed to collect fuelwood. The results from the correlated random effects Tobit model also suggest that there are significant differences across districts as these are jointly significant. We also find that time dummies and averages of time variant variables are jointly significant. Most of these results are similar in the probit as in the Tobit model.

Table 3. Tree investment decision: Results of the correlated random effect probit model

Variables	Coef.	Std. Err.
Certification (1=yes)	0.37***	0.12
Household head age	0.00	0.01
Family size	0.01	0.04
Livestock (in Tropical Livestock Units)	-0.01	0.01
Off-farm activity participation	0.31**	0.16
Education	-0.04**	0.02
Farm size	0.05	0.04
Distance to district (woreda) town	0.00*	0.00
Distance to road	0.00***	0.00
Gender of head (1=male)	0.26*	0.10
Extension contact	0.37**	0.16
Credit access	0.09	0.11
Time dummy	0.26***	0.14
Time spent to collect wood from communal sources	0.07***	0.01
Time spent to collect wood from all sources	-0.07***	0.02
Constant	-1.19	0.24
Joint significance of district dummies (chi2(6)	21.92***	

[4] It is important to note here that a majority of the households in the sample did not collect wood from communal lands. For these households we assigned the maximum amount of time in the data set for the variable assuming that the opportunity cost of collection from the commons for these households is very high.

Joint significance of average time varying variables(chi2(7)	28.53***
Likelihood-ratio test of rho=0: chibar2(01)	28.23***
Log likelihood	-1380.81
Wald chi2(28)	191.28***
Number of observations	3002

Note: * indicates p<0.10, ** indicates p<0.05, and ***indicates p<0.01

Table 4. Tree investment: Correlated random effects Tobit model (Chamberlain-Mundlak) approach

Variables	Coef.	Std. Err.
Certification (1=yes)	0.36**	0.17
Household head age	0.00	0.01
Family size	-0.02	0.06
Livestock (in Tropical Livestock Units)	0.00	0.00
Off-farm activity participation	0.49**	0.21
Education	-0.04*	0.02
Farm size	0.11**	0.06
Distance to district (woreda) town	0.00	0.00
Distance to road	-0.01***	0.00
Gender of head (1=male)	0.67***	0.16
Extension contact	0.58***	0.22
Credit access	0.17	0.14
Time dummy	1.14***	0.21
Time spent to collect wood from communal sources	0.11***	0.02
Time spent to collect wood from all sources	-0.09***	0.04
Constant	-0.41	0.38
Joint significance of district dummies (chi2(6)	69.26***	
Joint significance of average time varying variables(chi2(7)	45.22***	
Rho	0.327***	
Log likelihood	-6316.59	
Wald chi2(28)	672.48***	
Number of observations	3002	

Note: * indicates p<0.10, ** indicates p<0.05, ***indicates p<0.01

6.2 Tigray region

The restrictions on tree planting, especially eucalyptus trees, on arable land caused us to launch an alternative hypothesis for the effects of certification on tree planting, that land certification has not stimulated tree planting and particularly not planting of eucalyptus. However, eucalyptus may be the most profitable crop to grow for rural households in Ethiopia (Holden et al. 2003; Jagger and Pender 2000) and local norms and attitudes towards tree planting may differ from the rules stated by the law. We cannot therefore rule out that land certification has also stimulated eucalyptus planting.

The results from four household random effects panel Tobit investment models, including models with eucalyptus, indigenous trees, young trees (2–5 years old), and tree seedlings (< 2 years old) are presented in Table 6, using years that the household has held the land certificate as the variable for identification of the effect on land certification on investment in trees.

Table 5 shows that the years with certificate variable was significant at the 1% level and had a positive sign in the models with eucalyptus, young trees and tree seedlings while it was insignificant in the model with indigenous trees. There was a negative and significant correlation between public investments in conservation structures on plots and stocks of young trees and tree seedlings. This seems to indicate that the law restrictions on tree planting on arable land have an impact and more so on land that has been exposed to public conservation investments. Furthermore the interaction variable between public plot level investments and years with certificate was highly significant and with a negative sign. Assessing this effect jointly with the separate effects of the two interacted variables shows that land certification has stimulated the planting of eucalyptus but less so (the net effect is only about half of that on other plots) on land that has been exposed to public conservation investments. We also found that households with more educated household heads had more eucalyptus trees on their land. This is not likely to be because they are less aware of the restrictions on tree planting but rather that they are more aware of the advantages of eucalyptus.

We can therefore reject hypothesis that land certification has not stimulated tree planting. Land certification has stimulated tree planting, including planting of eucalyptus, even with the restrictions on tree planting on arable land.

Homestead plots had significantly more trees of all types, whereas the number of trees was significantly lower on distant plots, as indicated by the strongly significant and negative effect of distance to plots. This may be the result of lower land and tree tenure security on distant plots and the higher monitoring costs related to protection of trees on distant plots. None of the two variables indicating access to communal sources of wood were significant. This was where there was a difference for one of the probit models, the one for planting of tree seedlings (results not included in the paper but can be obtained from the authors). The variable for distance to woodlots had a positive coefficient and was significant at 5% level while the variable for time spent on collection of firewood had a negative coefficient and was significant at 5% level. While the first of these results is consistent with our expectations, the second result is a bit puzzling unless we assume that the feedback effect from tree planting on firewood collection time is dominating but this is hard to believe after so short time.

Table 5. Land certification on plot level investments in trees in Tigray (RE Tobit)

Variables	Eucalyptus trees	Indigenous trees	Young trees	Tree seedlings
Public investment in conservation on plot	0.064	-0.705	-1.886***	-2.354***
(dummy)	(0.660)	(0.550)	(0.703)	(0.782)
Years with certificate	0.647***	0.173	0.763***	0.803***
	(0.202)	(0.112)	(0.250)	(0.301)
Public investment*Years	-0.343**	0.211*	0.128	0.312
with certificate	(0.166)	(0.126)	(0.184)	(0.211)
Distance to communal	0.055	-0.100	0.098	0.012
Woodlot	(0.208)	(0.159)	(0.236)	(0.266)
Time used to collect	0.081	0.179	-0.182	-0.248
Firewood	(0.228)	(0.171)	(0.252)	(0.285)
Tree planting interest on	0.748	0.982	-0.272	-0.299
any plot in 2006 (dummy)	(1.098)	(0.920)	(1.001)	(1.150)
Perceived effect of land certificate on tree planting	-0.537	1.186*	-0.434	-0.592
(dummy)	(0.735)	(0.614)	(0.756)	(0.838)
Homestead plot (dummy)	1.893***	2.694***	2.828***	4.446***
	(0.528)	(0.445)	(0.517)	(0.620)
Sex of household head	-0.086	-0.259	0.354	-0.142
(dummy, 1=female)	(0.939)	(0.702)	(0.999)	(1.178)
Age of household head	0.024	0.009	0.012	0.025
(years)	(0.018)	(0.013)	(0.020)	(0.022)
Education of household	0.661**	0.276	0.488	0.279
head	(0.279)	(0.228)	(0.299)	(0.334)
Female labor force (log)	-0.648	-0.029	-0.477	-0.169
	(0.583)	(0.494)	(0.627)	(0.678)
Male labor force (log)	0.195	-0.621	0.908*	0.913
	(0.464)	(0.389)	(0.535)	(0.587)
Number of oxen/ha (log)	-0.818	-0.652	-0.691	-0.67
	(0.652)	(0.555)	(0.741)	(0.779)
Tropical livestock units/ha	0.489	0.074	0.072	0.983
(log)	(0.567)	(0.486)	(0.633)	(0.698)
Own farm size, tsimdi	0.14	0.113	0.092	0.139
	(0.090)	(0.074)	(0.099)	(0.112)
Plot size, tsimdi	-0.274	0.469***	-0.367	-0.198

	(0.270)	(0.144)	(0.263)	(0.265)
Soil depth (deep)	-1.275**	-1.230***	0.045	-1.141
	(0.610)	(0.449)	(0.601)	(0.705)
Soil depth (medium)	0.001	-1.566***	0.547	0.386
	(0.564)	(0.492)	(0.603)	(0.673)
Flat slope	-1.297	2.241	-0.789	-0.199
	(1.549)	(1.898)	(1.571)	(1.870)
Low hill	-0.757	2.98	0.521	0.684
	(1.572)	(1.896)	(1.582)	(1.871)
Mid hill	-0.355	5.438***	-2.414	-2.355
	(2.014)	(2.087)	(2.182)	(2.692)
Soil type Cambisol	-0.185	0.355	1.826***	0.235
	(0.594)	(0.470)	(0.619)	(0.677)
Soil type Vertisol	-0.563	-0.058	1.494**	-0.234
	(0.694)	(0.572)	(0.685)	(0.787)
Soil type Regosol	0.688	0.890*	0.339	0.937
	(0.664)	(0.512)	(0.733)	(0.757)
Distance to plot (minutes walk)	-0.142***	-0.048***	-0.078***	-0.098***
	(0.032)	(0.014)	(0.019)	(0.024)
Year dummies	Yes	Yes	Yes	Yes
Zonal dummies	Yes	Yes	Yes	Yes
Constant	-4.563	-6.657**	-6.764**	-11.877***
	(3.017)	(2.695)	(3.347)	(4.006)
Household panel variance	1.379***	0.000	2.054***	2.106***
	(0.436)	(1.688)	(0.427)	(0.465)
Residual variance	2.953***	3.027***	3.249***	3.935***
	(0.296)	(0.212)	(0.294)	(0.336)
Number of observations	958	975	963	964
Log likelihood	-363.906	-483.6435	-473.9615	-545.9238
Chi-square	99.22914	195.3426	103.4736	111.2366
P-value for model	2.46E-09	3.67E-26	5.21E-10	2.89E-11
Rho (Panel variance fraction)	0.179	1.14E-12	0.286	0.223

Note: Household random effects tobit models. * indicates p<0.10, ** indicates p<0.05, *** indicates p<0.01. Bootstrapped standard errors in parentheses, based on 500 replications, re-sampling households.

7. CONCLUSIONS

In this paper we attempted to examine the impact of land certification on tree growing on private plots of samples of rural households in the Amhara and Tigray regions of Ethiopia. The results show that land certification encourages tree growing as it is found that those who have certificates grow more trees. Tree growing was negatively associated with public investments on plots in Tigray and this may be related to the law restrictions on tree planting on arable land, especially for eucalyptus. Nevertheless, these restrictions have not been able to prevent the positive incentive effects of certification on tree planting. There is also a reason to question the rationale of restricting such tree planting on very marginal arable land where production of annual crops is likely to be less sustainable than growing of trees and where tree production is much more profitable than crop production. A stock of trees may also be more valuable to fall back on in case of drought to meet the immediate needs and food security of households. Gebregziabher and Holden (2011) found that collection of firewood and renting out of land for a low fixed rent was among the desperate coping strategies used by households after a severe shock. Allowing more tree planting on private land could therefore provide an alternative coping strategy that would reduce the pressure on communal lands. In the Amhara region we also find that households respond to scarcity of fuelwood from communal areas (reflected by time spent to collect wood from communal areas per trip) by planting trees on their plots. Involvement in off-farm activities is also positively associated with tree planting in the Amhara region suggesting the importance of such activities for increased private tree cover. Access to markets as reflected by distance to road also encourages tree growing.

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Appendix

Table A1. Variables used in the analysis in Tigray region

Variables	Obs	Mean	Std. Dev.	Min	Max
Number of eucalyptus trees	1048	4.671756	36.0918	0	650
Number of indigenous trees on plot	1065	14.25915	120.8971	0	2200
Number of young trees (2-5 years) on plot	1051	5.313987	34.14669	0	580
Number of tree seedligs (0-2 years) on plot	1053	8.292498	35.15054	0	400
Log of number of eucalyptus trees	1048	0.252643	0.892815	0	6.48
Log of number of indigenous trees on plot	1065	0.425352	1.207831	0	7.70
Log of number of young trees (2-5 years) on plot	1051	0.348412	1.036651	0	6.36
Log of number of tree seedligs (0-2 years) on plot	1053	0.467652	1.266248	0	5.99
Public investment in conservation on plot (dummy)	1726	0.349942	0.47709	0	1
Years with certificate	1726	3.9763	3.199153	0	8.92
Distance to communal woodlot	1719	4.638967	1.891153	0.69	9.21
Time used to collect firewood	1726	5.435084	1.767046	1.099	9.21
Tree planting interest on any plot in 2006 (dummy)	1641	0.912249	0.283019	0	1
Perceived effect of land certificate on tree planting (dummy)	1641	0.831201	0.374689	0	1
Homestead plot (dummy)	1726	0.293743	0.455608	0	1
Sex of household head (dummy, 1=female)	1726	0.169757	0.375528	0	1
Age of household head (years)	1726	54.26564	15.16672	0	100
Education of household head	1726	0.487833	0.762621	0	4
Female labor force (log)	1726	0.915345	0.531597	0	2.83
Male labor force (log)	1726	0.871548	0.623985	0	3.50
Number of oxen/ha (log)	1726	0.534374	0.566066	0	2.83
Tropical livestock units/ha (log)	1726	1.042118	0.785082	0	4.04
Own farm size, tsimdi	1726	4.513751	3.145199	0.25	19.5
Plot size, tsimdi	1726	1.123013	1.105606	0.0016	15
Soil depth (deep)	1726	0.393395	0.488645	0	1
Soil depth (medium)	1726	0.31518	0.464722	0	1
Flat slope	1726	0.714948	0.45157	0	1
Low hill	1726	0.192932	0.394714	0	1
Mid hill	1726	0.056199	0.230373	0	1
Soil type Cambisol	1726	0.279258	0.448765	0	1
Soil type Vertisol	1726	0.274044	0.446161	0	1
Soil type Regosol	1726	0.248552	0.432299	0	1
Distance to plot (minutes walk)	1702	24.02482	30.48366	0	360

Questions in 2007 Household Questionnaire in Tigray:

43	Are you interested in planting trees on any of your plots? 1=Yes, 0=No	Code	
44	Does having the land certificate increase your incentive to plant trees? 1=Yes, 0=No	Code	
45	Are there restrictions on tree planting in your community? 1=Yes, 0=No	Code	
46	If yes, what type of restrictions? 1=Not allowed to plant trees on land suitable for food crop production, 2=Not allowed to plant eucalyptus trees, 3=Eucalyptus trees are only allowed to be planted on homestead plots, 4=Other, specify:	Code More than one possible	
47	Would you have planted more eucalyptus trees if there were no restrictions on where they could be planted? 1=Yes, 0=No, 2=Don't know	Code	
48	If yes, where would you plant more eucalyptus trees? 1=On homestead plot, 2=On poor quality cropland, 3=On good quality cropland, 4=On communal land if it were divided to individuals, 5=Other, specify:	Code	
49	If yes, why? 1=Eucalyptus is profitable, good market, 2=Need it for construction purposes, 3=Need it for fuelwood, 4=Other, specify:	Code	
33	Do you believe that having a land certificate improves the tenure security of women? 1=Yes, 0=No, 2=Not sure	Code	