

**HOUSEHOLD TREE PLANTING IN TIGRAI, NORTHERN  
ETHIOPIA: TREE SPECIES, PURPOSES AND  
DETERMINANTS**

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# **HOUSEHOLD TREE PLANTING IN TIGRAI, NORTHERN ETHIOPIA: TREE SPECIES, PURPOSES AND DETERMINANTS**

## **Abstract**

Trees have multiple roles in rural Ethiopia where they provide significant economic and ecological benefits. Planting tree provide rural households with wood products for own consumption as well for sale and decrease soil degradation.

In this paper we used cross-sectional household level data to analyze the determinants of household tree planting and explore the most important tree attributes or purpose(s) that enhance the propensity to plant trees. A sample selection framework that simultaneously takes into account the two-step decision making of tree growers (first whether or not to plant tree, second intensity of tree planting) used to analyze the determinants of tree planting. On the other hand, logistic regression was performed to analyze the most important tree attributes contributing to households' tree planting decision. Land size, age, gender, tenure security, education, exogenous income and agro-ecology are found to increase both the propensity to plant trees and the level of tree planting, while increased livestock holding impact negatively both decisions. Our findings also suggest that households consider a number of attributes in making decision to plant trees. These results can be used by policy makers to promote tree planting in the study area by creating conducive tenure security and considering households' tree species selection attributes (criteria).

*Key words:* Tree planting; tree species; tree attributes/purposes; sample selection, Tigrai; Ethiopia.

*JEL classification:* Q2; Q23 ; Q28

## **1. Introduction**

Trees have multiple roles in rural livelihoods where they provide significant economic and ecological benefits (e.g., decrease soil degradation). Trees can augment household's

income through selling of wood products and can contribute to risk management through diversification of outputs and spreading risks during agricultural production failure. Some studies have indicated that *Eucalyptus* trees, which are relatively fast growing, are profitable. They found rates of return to farmers' investments in *Eucalyptus* to be often above 20 percent (Jagger and Pender, 2003). The economic benefits are greatest especially when community unproductive lands which are of low quality, are used for private tree planting. Similarly, the environmental benefits are substantial particularly when the trees are planted on degraded land.

Moreover, planting trees is currently seen as an alternative livelihood strategy, particularly in drier areas such as our study area where the drought is frequent, soils are very poor, and fertilizers and improved seeds use are risky and less profitable (Pender et al., 2006). Tree planting also has significant contribution to the production of Non-Timber Forest Products (NTFPs) such as honey and beeswax production. Harvesting honey and beeswax from forests has been a long and indigenous tradition in Ethiopia (Hartmann, 2004). Tree planting could substantially enhance the production of these NTFPs and the country's role in the export market Ethiopia ranks fourth in the world in beeswax exports, and tenth in honey (Fichtl and Adi, 1994). In addition to the above benefits, tree planting also provide farm equipments, food, construction materials for housing and making of household furniture, medicine, and fodder for animals.

Although there are some studies (e.g., Patel et al. 1995; Mekonnen, 1998; Amacher et al. 2004) that have analyzed the behavioral factors underlying tree planting decision and linking tree planting to fuel issues, there are limited studies to make detailed characterization about the extent of on-farm tree cultivation and management practices, the proportion of households in different regions who have adopted these practices, or their rationale for doing so (Deweese, 1995). Cooke et al. (2008) also emphasize that more careful empirical analysis, particularly at the household level, is essential especially for the choice and targeting of fuelwood related interventions.

In the present paper we address the questions: First, what factors affect the decision of whether or not to plant trees and second, how do such factors affect the intensity of tree planting once households have decided to plant trees? Third, What are the most important tree attributes or purposes for which households consider in deciding

to plant trees? The decision to plant trees and intensity of tree planting are estimated in a full information maximum likelihood (FIML) sample selection framework: first a selection (probit) equation explains the decision to plant trees and, second, a production function explains the intensity of tree planting. Logistic regression model on species by species applied to analyze most important tree attributes/purposes that contribute to the propensity of tree growing.

The paper is organized as follows. The next section presents literature review on tree planting, tree resources and rural livelihoods. Theoretical model is presented in section 3. In section 4, the empirical model is outlined. The empirical results are presented in section 5. The last section concludes and draw some policy implications of the study.

## **2. Tree Planting, Tree Resources and Rural Livelihoods: A Review**

Patel *et al.* (1995) analyze tree growing and tree planting decision of households. They find that farmers are responsive to incentives to plant trees, and tree planting is competitive with other production activities. They also attribute the differences among farm households in this regard to differences in factor costs owing to different factor endowments and poorly functioning factor markets. Mekonnen (1998) also analyzes tree growing and tree planting decisions of households in Ethiopia. He distinguishes between two broad categories of trees as all trees and *Eucalyptus* trees. He finds that family size, gender, education, and livestock holding are important factors influencing households tree planting behaviour. He also finds households with relatively more male labor, with relatively more income, and with higher share of off-farm income are more likely to plant trees. Amacher *et al.* (2004) examine tree planting in Tigray, Ethiopia. They distinguish between two groups of species, *Eucalyptus* and others, in the same way as Mekonnen, however with emphasis on two sites, i.e., tree planting on agricultural land versus microdam land. They find both distance and microdam to be important predictors of tree planting. They also find a strong substitution effect between tree planting and agricultural residues particularly on own land.

Hansen et al. (2005) investigate tree planting under customary tenure systems in Malawi. Specifically, they look at how gender specific variations in transferability of rights, as manifested in marriage and inheritance patterns, affect tree planting behavior. They find tree planting by married women is not necessarily promoted under matrilineal marriage patterns and tree planting by men might indeed be dissuaded by matrilineal marriage patterns. In fact, they argue that a high incidence of non-married women is associated with increased tree planting by women. Salam et al. (2000) analyzed why farmers plant trees in Bangladesh with emphasis in homestead agroforestry. They find that in tree planting efforts economic factors play a larger role than do ecological factors. They conclude that even fuelwood scarcity itself is not sufficient enough to induce tree planting decision, especially in circumstances where substitute fuels such as animal manure and agricultural residues can be used in place of wood. Based on historical analysis of impact of economic and institutional changes on tree planting on deforested farmlands of Sewu hills of Java, Indonesia, Nibbering (1999) argue that the government-launched tree planting campaign provided important incentives for establishing a critical mass of farmers adopting tree growing. But, Dewees (1995) argues that the government introduced tree planting bonus scheme in Malawi has been costly to administer and has had limited impact. Dewees also notes that household fuelwood demand and market prices for fuelwood, are most important in influencing subsistence farmers' decisions to plant trees.

Based on experience from Western Kenya, Scherr (1995) made three main generalizations: that agroforestry evolved historically in response to land-use intensification, that differing livelihood strategies and resource constraints implied differing choices of agroforestry practice on particular farms, and that associated risks affect farmers' adoption of agroforestry technologies particularly in the case of new technologies. Emtage and Suh (2004) investigate the socio-economic factors affecting smallholder tree planting and management intentions in four communities of Leyte province, Philippines. They find the primary purpose being to meet own household needs for timber, for house construction materials, and other household consumption. They argue that household circumstances rather than community circumstances are more

important influencing tree planting and management activities. However, their analysis was not species specific.

As regards the link between tree planting/ tree resources and rural livelihoods, timber, fuelwood, fodder and fruits directly satisfy household needs. Besides, while allowing for more efficient use of labor, tree planting provides households an alternative means to accumulate capital, added cash incomes, and diversified household economies/livelihoods (Nibbering, 1999). Nibbering argues that the combined benefit of tree growing outweighs the gains that would have been obtained from further expansion of annual crops production in the deforested farmlands of Sewu hills of Java, Indonesia. Some studies have suggested that *Eucalyptus* trees, which are relatively fast growing, are particularly profitable in northern Ethiopian context. They find rates of return to farmers' investments in *Eucalyptus* to be often above 20 percent (Jagger and Pender, 2003). Kidanu (2004) finds that planting *Eucalyptus* as field (plot) boundaries leads to stabilizing the livelihoods of resource poor farmers and would help smallholder farmers increase their income and achieve food security. Kidanu also suggests that short rotation of *Eucalyptus* based agroforestry system could be practiced in the seasonally waterlogged highland vertisols of Ethiopia to meet wood demand, without inducing significant nutrient depletion and crop yield loss.

Holden et al. (2003) analyze the potential of tree planting to improve household welfare in the less favored areas of Amhara region, using a bio-economic model. They consider particularly the potential of planting *Eucalyptus* trees as a strategy to reduce poverty in a less-favored area of the Ethiopian highlands. They find that planting *Eucalyptus* trees on private lands unsuitable for crop production can substantially contribute to poverty reduction in these areas. Salam et al. also link tree planting particularly homestead agroforestry to improvement of overall household income and alleviation of rural poverty. In fact, they contend that tree planting on homestead could increase overall household income by twofold, relative to that of arable crops. Arnold et al. (2006) argue that fuelwood production, selling/trading represents a significant part of their income for many whereas it could be their main source of income for some. They observe that, through commercial involvement with woodfuels, it provides supplemental, transitional or seasonal/occasional source of income for some and their main source of

income for others. In some cases it generates working capital for the start of new agricultural or other business. Besides generating income it is also related to livelihoods through meeting subsistence requirement of fuelwood.

The following conclusions can be drawn from the foregoing review: firstly, far too little is known about rural afforestation or tree planting to provide a good deal of information for sound policy making. That there exists inadequate understanding and inability to make detailed characterization about the extent of on-farm tree cultivation and management practices, the proportion of farmers/households in different regions who have adopted these practices, or their rationale for doing so. That more careful economic/empirical analysis, particularly at the household level, is essential especially for the choice as well as targeting of fuelwood related interventions. Secondly, whereas species considerations tend to be vital in terms of targeting forestry policy/interventions (Gebreegziabher, 2007), most of these earlier works on tree planting, for example, Patel *et al.* (1995) and Amacher *et al.* (2004), have looked either at tree planting in the aggregate or have distinguish only between two broad categories or groups of trees species as all trees vis-a-vis *Eucalyptus* trees or *Eucalyptus* vis-a-vis others and, hence, are not species specific. Thirdly, except for very few descriptive attempts that try to look at purposes/principal uses, empirical knowledge about the reasons why rural households plant trees, and what type of trees they prefer for particular type of purpose/attribute is extremely scanty. Fourthly, it has been obvious that trees have multiple roles in rural livelihoods and provide significant economic and ecological benefits for poor farmers. Tremendous opportunities also exist to increase family income and improve livelihoods particularly of rural poor through tree growing. Nonetheless, the livelihood dimension or aspects that the trees generate varies across species. All these issues call for a more careful and rigorous further scrutiny.

### **3. The Household Model**

In developing countries households face a number of constraints such as endogenous prices due to market imperfections, liquidity problems and non-profit motive labor allocation decisions. In this situation, the relevance of a separable household model is

often questioned (de Janvry et al., 1991). Therefore, the non-separable household model provides a suitable framework for analysing household micro-economic behaviour in a situation of market imperfection. This model considers that a market for some products does not exist or functions badly. This indicates that specification of the production and consumption of subsistence households in most developing countries is interdependent and non-separable. The joint production and consumption of various non-timber forest and agricultural products suggests the use of a non-separable household model, rather than a pure demand model (Singh et al., 1986).

The theoretical model to be constructed in this study is based on the on a conventional utility maximizing household, which derives the highest level of utility by consuming various goods. Specifically, consider a representative farm household that derive utility from consumption of goods and leisure. Let  $U$  be the utility of the household with respect to these goods.

$$(1) \quad U = U(c, F_c, T - L^S; \Phi),$$

where  $c$  is a composite good or commodity and represents all other goods consumed by the household,  $F_c$  is fuel consumption,  $T$  is total time endowment,  $L^S$  is labour supply of household or time allocated for labour activities, and  $\Phi$  stands for household demographic and other characteristics important to utility.  $U(.,.)$  is an increasing function and concave in all of its arguments.

In farm household settings like Ethiopia expenditure on food accounts for about 80 percent of the total household expenditure, with food grains constituting about half of the total household expenditure. Therefore, the composite good or commodity  $c$  can be regarded to be mainly food or agricultural staples.

If we designate  $H$  to be home time or leisure, then the household's time constraint can be specified as:

$$(2) \quad L^S = L_A + L_F + L_W \leq T - H,$$

where  $L_A$  is labor allocated for farm work producing agricultural staples,  $L_F$  is household labor allocation for production/ collection of fuel,  $L_W$  is labor allocated for wage-earning off-farm work.

The agricultural staples consumed by the household could be either own produced or market purchased so that:

$$(3) \quad Q - c < 0, > 0 \text{ or } 0$$

where  $Q$  is own produced and  $Q - c$  is market purchased or net marketed quantity of agricultural staples. Note that the net marketed quantity of agricultural staples could be negative, positive, or zero depending on whether the household is a net buyer, net seller, or self-sufficient in food.

The household's farm production of the agricultural staple is given by:

$$(4) \quad Q=Q(K_A, L_A, X_A, \Psi_A)$$

where  $K_A$  is fixed farm capital inputs including land and animals,  $L_A$  is labour inputs in production of agriculture staples as in above,  $X_A$  is other variable farm inputs other than labor such as seeds, and  $\Psi_A$  represents other variables that affect production, with  $Q(\cdot)$  a function relating the input levels to output and subscript A is as in above. The household's farm production function (4) is assumed to be increasing and concave in all its arguments.

Besides farm production of agricultural staples, households in the study area also collect fuels. Often households procure the fuels by themselves through collection from mainly two sources, from household own holdings and from village commons (and natural forests). Let the subscripts  $O$  and  $E$  stand for own holdings and village commons, respectively. Then, we can specify  $R_O$  and  $R_E$  to denote tree resource stocks at the two sites, respectively. Note that the two resource stocks are enhanced by tree planting efforts and are not necessarily equal. Hence, we can further represent that  $R_O = R(t_O, Z_O)$ , where  $t_O$  is planting effort on own holdings when household chooses to plant trees and  $Z_O$  is a vector of non-tree qualities of the resource stock. Therefore, it turns out quite straight away that  $\partial R_O / \partial t_O \geq 0$ .

Hence, in light of the foregoing discussion, we can now specify the household's fuel specific collection/production functions for fuelwood and dung as:

$$(5) \quad F^f = F^f(L_f, R_O, R_E, \Psi_F)$$

$$(6) \quad F^d = F^d(L_d, M, R_O, R_E, \Psi_F)$$

where  $F^f$  and  $F^d$  are quantities of fuel produced, with superscripts f and d standing for fuelwood and dung, respectively;  $L_i$  for  $i=f, d$ , stand for household time allocation to fuelwood and dung collection, respectively;  $\Psi_F$  represents other factors affecting fuel collection/production; and  $M$  is livestock holding of household in cattle equivalent with

$\partial F^d/\partial L_d > 0$ ,  $\partial F^d/\partial M < 0$ . The intuition is that it is needless to go for dung collection from village commons with increasing size of livestock holding. Equation (6) also suggests that the household's decision on whether or not to collect dung is dependent upon the relative scarcity of fuelwood from both sources.

However, we assumed market for fuelwood exists whereas the market for dung is missing. Therefore, the net marketed quantity of fuelwood can be specified as:

$$(7) \quad F^f - F_c^f > 0, < 0 \text{ or } = 0$$

depending on whether the farm household is a net seller, net buyer or self-sufficient in fuel wood. Where as in the case of fuel types like dung for which market is missing, consumption equals production, i.e.,  $F^d = F_c^d$ , for the household's optimum.

The household's choice problem is, therefore, to maximize (1) subject to resources/total time and income constraints. The cash constraint can be specified as:

$$(8) \quad p_A(Q-c) + p_f(F^f - F_c^f) + p_d(F^d - F_c^d) = wL_W + I$$

where  $p_i$  is price of  $i$ th good for  $i=A,f,d$  standing for agricultural staples, fuelwood and dung, respectively, and  $I$  is exogenous income from all non-wage, non-farm, and non-fuelwood sources.

Free collection accounts for the majority of the fuels consumed in the study area. The households considered use family labor in fuel collection. Though fuelwood is traded in the towns at the vicinity of the study sites, a lesser proportion of the households were involved in fuelwood buying.<sup>1</sup> Almost all of the sample households were not involved in buying dung. Moreover, hiring labor for fuel collection is not common practice. Hence, it was clear that hired labor and family labor are not perfect substitutes. Therefore, market wage rate can not be taken as an appropriate measure of the opportunity cost of family labor used in fuel collection. For this reason, the value of the marginal product (VMP), also known as 'virtual (shadow) wages', of household production activities is taken as a suitable measure of this opportunity cost, assuming that households are optimizers (Jacoby, 1993; Thornton, 1994; Mekonnen, 1999; Kohlin and Parks, 2001; Amacher et al., 2004). The intuition is that in the absence of hired labor a household attempts to equate the supply of and demand for its own labor. Virtual wage rate is a product of such an attempt and depends on household characteristics and resource endowments. This

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<sup>1</sup> See Table 3

virtual or shadow wage rate is assumed to be household and fuel specific. The VMPs are computed in two steps: first the fuel collection functions (5) and (6) are estimated, and then the marginal products specific to each fuel are computed.

On the other hand, as mentioned earlier, when market doesn't exist for a good, market prices may not reflect the true scarcity value of that good. Hence, there exists a need to look for some other measures of price, that is, shadow or virtual price. Cooke (1998) and Mekonnen (1999) have developed a procedure how to find the shadow or virtual prices. We applied this procedure in our case. These shadow or virtual prices represent the scarcity values of the respective fuels considered and, hence, are assumed to affect tree planting decisions.

After some manipulation of the above equations the optimal choices can be written as a function of all prices, income, resource stock, and production characteristics:

$$(9) \quad \Gamma^*(p_A, p_f, p_w, M, R_O, R_E, I, \Phi, \Psi_A, \Psi_F).$$

Note that in (9),  $\Gamma^*$  stand for a vector of optimal choices for labor in farm production of agricultural staples and fuel collection, labor in other activity, tree planting effort, and goods consumption decision.

## 4. Econometric Model

In this section we outline the econometric models employed in an answering our research questions.

### 4.1 Household tree planting determinants

Because tree planting is only observed for a subset of the sample population, the potential exists for the sample selection referred to as incidental truncation, i.e., households with tree planting observations are likely not to be a random sub-sample of the population. That is unobservable variables (e.g., risk, managerial or entrepreneurial ability, family background) may affects participation in tree planting. When this is the case, simply regressing the intensity of tree planting on exogenous factors will result in biased

parameters. To address this concern, we employ a sample selection model.<sup>2</sup> In the sample selection model, two equations are estimated simultaneously: (1) a probit equation (or selection equation) explaining the decision whether or not to plant tree, and (2) an equation explaining the intensity of tree planting (outcome equation). The empirical model corrects for possible sample selection bias by accounting for the joint normal distribution of between the errors of the selection equation and the outcome equation. Formally, the equations are specified as follow. Farmers' decision whether or not plant trees can be expressed with latent variable:

$$(10) \quad \begin{aligned} z_i^* &= \alpha' w_i + \mu_i, \text{ where } z_i = 1 \text{ if } z_i^* > 0, 0 \text{ otherwise;} \\ \text{Prob}(z_i = 1) &= \Phi(\alpha' w_i), \text{ Prob}(z_i = 0) = 1 - \Phi(\alpha' w_i), \end{aligned}$$

where  $w_i$  is a set of explanatory variables,  $\alpha$  is a coefficient vector and  $\mu_i$  is error term,  $\text{Prob}(\cdot)$  is a probability function and  $\Phi(\cdot)$  is the cumulative distribution function(CDF) of the standard normal distribution. In the next step, the intensity of tree planting( $y_i$ ) is defined as:

$$(11) \quad y_i = \beta' x_i + \varepsilon_i, \text{ observed only if } z_i = 1,$$

where  $x_i$  is a vector of explanatory variables,  $\beta$  is a coefficient vector and  $\varepsilon_i$  is error term. We assume that  $\rho = \text{corr}(\mu_i, \varepsilon_i)$  and thus the disturbance is  $(\mu_i, \varepsilon_i) \sim$  bivariate normal  $[0, 0, 1, \sigma_\varepsilon, \rho]$ . In order to account for the selection bias, we have to reformulate equation (2) as follow:

$$(12) \quad E[y_i | x_i, z_i = 1] = \beta' x_i + E[\varepsilon_i | z_i = 1] = \beta' x_i + \rho \sigma_\varepsilon M_i,$$

where  $M_i$  (inverse Mills ratio) =  $\frac{\phi(\alpha' w_i / \sigma_u)}{\Phi(\alpha' w_i / \sigma_u)}$ , and  $\phi(\cdot)$  and  $\Phi(\cdot)$  are the PDF and CDF, respectively, of the standard normal distribution. Equation (11) indicates that omitting  $M_i$  would lead to omitted variable bias in estimating  $\beta$ . To get consistent and

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<sup>2</sup> We chose not to employ the Tobit model due to its restriction that whether or not to plant trees and the extent of planting trees are determined by the same set of covariates, and that a variable that increases the probability of the decision to plant trees also increases the extent of tree planting. It also assumes the same variables have same magnitude impact on both decisions.

efficient estimates equations (10) and (11) will be estimated jointly by maximum likelihood estimation technique.

#### 4.2 *Tree species and purposes or attributes*

Farmers have different needs and preferences on planting different tree species. They consider different attributes as criteria when deciding to plant a specific tree species. These attributes or purposes include income contribution, food, fodder, fuel wood production, construction materials (for fencing, housing and making household utensil and farm implements), watershed benefits (e.g., soil conservation), and shelter for animals. Farm households will also plant tree species on the basis of specific attributes such as fast growth, ability to protect against winds, and so on. ,

We specify the following logistic regression model to identify the most important attribute(s)/purpose(s) of household tree growing:

$$(13) \quad \text{prob}(y = 1) = \frac{e^{G'\alpha_i}}{1 + e^{G'\alpha_i}}$$

where  $G$  is a vector of explanatory variables (i.e., in our case elicited tree planting attributes/purposes for a particular tree species) and  $\alpha_i$  vector parameters to be estimated.

## 5. Study Area and Data Description

Our data are from a survey of 200 rural households collected in 2000 in Tigray, northern Ethiopia. Two-stage sampling was used to select the sample households. First 50 *tabias* – the smallest administrative unit in the region – were randomly selected from a total of 600 available *tabias*, and then a random sample of 200 rural households was selected from these *tabias*. Both quantitative and qualitative data were collected on the household's tree planting, production (collection) and consumption of various biomass fuel types, and; household characteristics including age, gender family size and education of the household head. The dataset also include household physical assets such as total land area, cultivated area, livestock holdings, and information on tree planting such as number of trees grown by species, age of trees, and purpose(s) for which the

trees were grown. Village level factors, including agro-ecological conditions or altitude range and distance traveled (time spent) to collect different fuels were also collected. In addition to the above variables, the dataset include institutional variables such as household's perception of security of land tenure, i.e., whether the household feels secure about future use of current land holding. Table 1 provides summary statistics (means and standard deviation) of variables used in regression.

Table 2 presents detail characteristics of households involved in tree planting. Buying and adapting (transplanting) of naturally grown (self germinated) seedlings from the bush (forest) to the backyard/field constitute the main sources of seedlings in the area. There are also farmers who raise their own seedlings for this purpose. Government nurseries are the main sources of purchased seedlings. Most of the households were also found to be involved in sale of tree products, mainly poles.

Table 3 provides mode of fuel acquisition of sample households by fuel type. It is evident that free collection accounts for the majority of the fuels consumed in the study area. Though fuelwood is traded in the towns at the vicinity of the study sites, a lesser proportion of the households were involved in fuelwood buying. Own sources also account for a lesser proportion of fuel consumed by sample households, be it fuelwood or dung.

In rural settings, it is not uncommon to find diversity of tree species grown by farm households. In our dataset, we found a total of 112 tree species grown by sample households, of which seventeen species dominated, hence, were included them in the analysis. Twelve of them are indigenous, while the rest are exotic species. The detailed scientific and vernacular or local names of these seventeen tree species presented in Table A.1 in the Appendix.

## **6. Results and Discussion**

### *6.1 Household tree planting determinants*

The sample selection framework is applied to explore the factors that promote the propensity to involve in tree planting as well as the extent of tree growing. The full information maximum likelihood estimates of the sample selection model are shown in Table 4. Concerning the goodness of fit, likelihood ratio, LR test (see bottom row of Table 4),

suggests that we can not reject the alternative hypothesis that rho,  $\rho$ , is different from zero, implying that the two equations are not independent (or cannot be estimated independently) and Heckman selection model was the right procedure. This also justifies that we used an econometrically consistent framework estimating the two attributes of household tree growing, i.e., a household's decision to grow trees and the extent of tree growing.

The estimated coefficients in the upper panel of results table correspond to the outcome equation and the coefficient in the bottom half of the table 4 corresponds to the selection equation. The dependent variable for selection equation is equal to one if households plant tree and zero otherwise, while the number of trees grown by households formed the dependent variable in the outcome equation. The estimated correlation coefficient ( $\rho$ ) is statistically significant and the likelihood ratio (LR) test does reject independence of the two error terms. This supports the idea of joint estimation of both the selection and outcome equations. The LR test suggests that selection bias is a problem for the model estimated. We would like to acknowledge the model is estimated without exclusion restrictions, the same set of regressors appears in both equations. However, we have assumed identification of the model rely on the non-linearity of the inverse Mills ratio.

Although the level of significance and the magnitude of regressors vary both in selection and outcome equations, most of the variables are turned out to be statistically significant and positive in both equations. Land size, exogenous income, age, gender, and education all increased the propensity to plant tree and the extent of planting trees. Given the fact that the benefits from investing in trees accrue over time, this inter-temporal aspect implies that secure land access or tenure will impact tree planting decisions positively. Our results revealed that this particularly has a positive impact on the decision to plant trees and the extent of tree planting. This is line with Mekonnen (1998) finding for Amhara region of Ethiopia. Location and/or village agro-ecology variables have also significant positive impact. This may reflect the role that agro-ecology plays in promoting adoption of tree planting. Number of cattle turned out to be significant and negative, suggesting that households with relatively more cattle are less likely to be involved in tree planting. Shadow prices of fuel wood and dung, numbers of male adults and female adults were not found to have any significant impact in neither of

the equations. Moreover, model results or findings are also interesting in the sense it turns out that the same factors might not necessarily underlie the two aspects of tree planting, i.e., household's decision to plant trees and the extent/level of tree planting/growing.

## 6.2 Tree species and purposes

To identify the most important attributes and/or purposes for which the trees are grown, logistic regression was run on species-by-species basis for seventeen tree species considered in the study. Results are presented in Table 5. The description of the tree species considered in the study is presented in Appendix Table A.1.

Planting trees for fuelwood and shade were found to be the most important in the case of the species *Acacia ethbaica*. The purposes soil conservation, fuelwood and house construction material were found to be most important in the case of *Euclea shimperi* whereas farm implements was found to be the most important purpose in the case of *Olea europaea*. Although at a lower level of significance, making household utensils was found to be another important purpose for which *Olea europaea* is grown. Fuelwood was found to be the only most important purpose in the case of *Rhus natalensis* whereas market, fuelwood and farm implements were found to be the most important purposes in the case of *Eucalyptus* species.

Fuelwood and fencing were found to be the most important purposes in the case of *Acacia lihay*. In addition, however at a lower level of significance, house construction was found to be another important purpose of growing *Acacia lehay*. Farm implements, fencing and shade were found to be the most important purposes in the case of *Acacia seyal* whereas shade and farm implements were found to be the most important purposes in the case of *Balanites aegyptiaca*. Soil conservation, fencing and fuelwood were found to be the most important purposes in the case of *Mytenus senegalensis* whereas fodder and shade were the most important purposes in the case of *Faidherbia albida*. Shade and farm implements were found to be the most important purposes in the case of both *Melia Azedarach* and *Acacia saligna*.

House construction and fencing were found to be the most important purposes in the case of *Euphorbia candelabrum* where as house construction, farm implements, and

shade were found to be the most important purposes in the case of the species *Croton macrostachys*. Moreover, shade, house construction and fodder was found to be the single most important purpose in the case of *Shinus molle*, *Juniperus procera*, and *Ficus ingens*, respectively.

Generally, results are interesting in the sense they depict the multiple role of trees in rural livelihoods and the multiplicity of purposes involved in household tree planting. Most of the trees considered were found to involve diversity of purposes. For example, whereas the trees species such as *Rhus natalensis*, *Shinus molle*, *Juniperus procera*, and *Ficus ingens* can be designated as single purpose trees (SPTs), the rest of the tree species considered were found to be essentially multipurpose trees (MPTs).

## **7. Conclusions and Implications**

This paper analyses the determinants of household tree planting using datasets from sample cross-sections of 200 households in the highlands of Tigrai, northern Ethiopia. Key questions were: What factor(s) enhance the likelihood of involvement in tree planting as well as the extent of tree growing? What are the most important purposes for which households' plant trees? The following lessons or conclusions could be drawn.

As regards to factors underlying the households' decisions to plant trees and the extent of tree planting, both household characteristics, characteristics of the household head and village level factors were found to be the most important determinants. Our findings reveal a clear pattern, that exactly the same factors do not necessarily underlie the two aspects of tree growing. Moreover, our findings also suggest intra-household or sex-age patterns of resource endowments such as male versus female labor availability are irrelevant in the household's decision to grow trees as well as the extent of tree growing. Rather, institutional issues such as perception of tenure security tend to be more important in determining household tree planting.

In addition, concerning tree species and purposes, results depict the multiple roles of trees in rural livelihoods and the multiplicity of purposes involved in household tree planting. Most of the trees considered were found to involve diversity of purposes. More specifically, whereas the species *Rhus natalensis*, *Shinus molle*, *Juniperus procera*, and

*Ficus ingens* appear to be single purpose trees (SPTs), the rest of the tree species considered turned out to be essentially multipurpose trees (MPTs).

Results of the research are relevant in terms of drawing broader policy implications. That is, it brings in to light on which factors to focus/target as regards to enhancing household tree planting. For example, results suggest that policy measures/interventions that enhance the understanding/security of existing tenure and education of head would at the same time enhance household tree planting. Besides, results of this research are relevant in terms of sharpening (forestry) policy. Findings of the research pin point as to which species to pick up (i.e., which species might be more important to focus), for example, in light of the policy of addressing the fuelwood problem or depending on the policy objective.

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Table 1 Summary statistics of variables used in regression (n=200)

Variable	Mean	Std. Dev.	Min	Max
Family size	5	2	1	12
Adult males	1	1	0	5
Adult females	1	1	1	4
Exogenous income (Eth Birr/month)	0.35	2.86	0	25
Number of cattle	4	3	0	14
Land area (hectares)	0.834	0.496	0	2.5
Age of household head	48	13	23	85
Education of head (year of schooling)	0.92	1.47	0	7
Sex of head				
Female (in percent)	21.0			
Male (in percent)	79.0			
Involvement in tree planting				
Households involved (in percent)	93.0			
Households not involved (in percent)	7.0			
Total Number of trees (all trees)	74	172	0	1834

Table 2 Characteristics of households involved in tree planting (n=186)

Variable	Mean	Std. Dev.	Min	Max
Source of seedlings (in percent)				
Purchased	60.75			
Self raised	13.98			
Tree nursery for free	26.88			
Naturally grown	60.22			
Neighboring farmer for free	1.68			
Source of purchased seedlings				
Neighboring farmer (in percent)	1.61			
Government nursery (in percent)	51.61			
Community nursery (in percent)	2.69			
Both private and government nursery (in percent)	0.54			
Sex of head of head				
Female (in percent)	18.82			
Male (in percent)	81.18.0			
Involvement in sale of tree products				
Yes (in percent)	93.0			
No (in percent)	7.0			
Income from sale of tree products (poles) (Eth Birr/annum)	31.43	113.16	0	1050

Table 3 Distribution of sample households by mode/way fuel acquired (in %) (n=200)

Mode of acquisition	Fuel type	
	Fuelwood	Dung
Free collection	85.2	72.3
Buying	11.2	0.6
Own source (tree/cattle manure)	3.6	27.1
Total	100.0	100.0

Table 4 Results of full information maximum likelihood estimates of the sample selection model of determinants of tree planting (dependent variable total number of tree planted) and of the decision to plant trees

Explanatory Variable	Estimation results	
	Coefficient <sup>a</sup>	t-statistic
<b>Outcome equation</b>		
Adult males	-0.004	-0.04
Adult females	0.219	1.28
Land size (hectares)	0.482**	2.23
Number of cattle	-0.093*	-1.89
Exogenous income (Eth Birr/month) <sup>c</sup>	0.168	0.69
Age of head	0.055***	6.44
Education of head	0.186**	2.29
Sex of head <sup>d</sup>	1.129***	3.68
Tenure security	0.521**	2.34
Wood price/shadow	0.052	0.57
Dung price/shadow	0.011	0.81
Middle highland	0.720***	3.00
Upper highland	0.998***	3.12
Constant	-5.489***	-14.18
<b>Selection equation</b>		
Adult males	-0.001	-0.04
Adult females	0.040	1.28
Land size (hectare)	0.088**	2.25
Number of cattle	-0.017*	-1.90
Exogenous income (Eth Birr/month)	0.015***	2.49
Age of head	0.010***	7.17
Education of head	0.034**	2.33
Sex of head	0.205***	3.80
Tenure security	0.095**	2.37
Wood price/shadow	0.009	0.57
Dung price/shadow	0.002	0.81

**Table 4** Continued

Middle highland	0.131***	3.08
Upper highland	0.182***	3.20
<b>Statistic</b>		
$\rho$	1	7.39e-12 <sup>b</sup>
$\sigma$	0.182	0.013 <sup>b</sup>
$\lambda$	0.182	0.013 <sup>b</sup>
N	200	
Log likelihood	23.862	
Wald Chi2(13)	3008.01***	

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LR test of indep. eqns. (rho=0): chi2(1) = 50.81 Prob>chi2 = 0.000

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<sup>a</sup> \*\*\*, and \* indicate statistically significant at 1%, and 10% level , respectively.

<sup>b</sup> standard error rather than t-statistic.

<sup>c</sup> Birr is Ethiopian currency 1 USD was about 8.3044 Eth Birr during the survey period.

<sup>d</sup> Sex of head was capture as =1, if male, and 0, otherwise.

**Table 7 Logistic regression results (standard error in parenthesis) of purpose(s) of tree growing by tree species**

Explanatory variable	Tree Species <sup>a</sup>									
	1	2	3	4	5	6	7	8	9	
Market (=1; 0 otherwise)					8.143*** (1.038)					
Fuel wood (=1; 0 otherwise)	2.509*** (0.609)	5.570*** (0.8493)	0.782 (0.602)	4.956*** (1.214)	3.087*** (0.353)	2.610*** (0.7005)	0.532 (0.499)	0.771 (0.759)	2.222** (1.111)	
Soil conservation (=1; 0 otherwise)		6.079*** (1.8819)							6.562*** (1.734)	
House construction (=1; 0 otherwise)	0.939 (0.620)	-1.602** (0.715)	-1.040* (0.617)	-0.526 (0.842)		1.026* (0.604)	0.174 (0.545)	0.472 (0.879)		
Fodder (=1; 0 otherwise)		-2.441* (1.410)	-0.530 (0.674)			-0.769 (0.768)	0.287 (0.438)	0.574 (0.549)		
Farm implements (=1; 0 otherwise)	0.182 (0.684)	-1.128 (0.807)	5.012*** (0.770)	-0.206 (0.895)	1.324*** (0.376)	-0.225 (0.620)	2.541*** (0.496)	1.638** (0.780)	-1.129 (1.271)	
Fencing (=1; 0 otherwise)	-0.199 (1.089)					2.756*** (0.555)	2.540*** (0.505)	1.305 (0.930)	4.480*** (1.280)	
Shade (=1; 0 otherwise)	1.684** (0.726)					-0.572 (1.131)	1.575*** (0.599)	3.070*** (0.739)		
House utensils (=1; 0 otherwise)			4.304* (2.4107)							
Constant	-6.502***	-7.484***	-7.076***	-8.104***	-5.052***	-6.444***	-5.933***	-7.100***	-8.494***	

	(0.4299)	(0.7273)	(0.5844)	(1.000)	(0.215)	(0.417)	(0.323)	(0.569)	(1.096)
n	3568	3573	3573	3553	3573	3571	3571	3571	3573
Loglikelihood	-78.811	-54.055	-67.081	-36.074	-213.541	-88.297	-110.374	-45.486	-20.240
LR chi2(k) <sup>b</sup>	47.34	75.01	102.73	29.05	702.75	81.00	96.82	34.71	35.23
Prob>chi2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Pseudo R2	0.231	0.409	0.434	0.287	0.622	0.314	0.305	0.276	0.465

<sup>a</sup> \*\*\*, \*\*, and \* indicate statistically significant at 1%, 5% and 10% level (or better), respectively.

<sup>b</sup> k stands for the number of explanatory variables considered in each regression.

**Table 7. Continued**

Explanatory variable	Tree Species <sup>a</sup>							
	10	11	12	13	14	15	16	17
Market (=1; 0 otherwise)								
Fuel wood (=1; 0 otherwise)	-1.412 (0.944)	-0.618 (0.881)	-0.624 (0.883)	-0.506 (0.833)	0.347 (0.576)	0.150 (0.704)	0.096 (0.747)	0.397 (1.517)
Soil conservation (=1; 0 otherwise)								
House construction (=1; 0 otherwise)				3.932*** (0.983)	2.345*** (0.590)	1.345 (0.868)	4.541*** (0.919)	
Fodder (=1; 0 otherwise)	1.992*** (0.793)	0.973 (0.917)	0.946 (0.982)		1.146* (0.659)			4.343*** (1.520)
Farm implements (=1; 0 otherwise)	-0.382 (0.6882)	1.557** (0.9022)	1.547** (0.803)		1.325*** (0.544)			
Fencing (=1; 0 otherwise)			0.149 (1.397)	2.899*** (0.878)	-0.380 (1.112)			
Shade (=1; 0 otherwise)	5.636*** (0.633)	5.067*** (0.6632)	5.059*** (0.888)		1.633** (0.691)	5.747*** (0.708)		
House utensils (=1; 0 otherwise)								
Constant	-6.777*** (0.514)	-7.556*** (0.723)	-7.555*** (0.722)	-7.433*** (0.709)	-6.098*** (0.353)	-7.148*** (0.592)	-7.388*** (0.707)	-3.183*** (1.292)

N	3521	3571	3571	3391	3570	3417	3371	26
Loglikelihood	-55.390	-36.412	-36.406	-37.283	-100.490	-48.095	-47.313	-6.488
LR chi2(k) <sup>b</sup>	71.93	52.85	52.87	38.21	56.60	85.68	41.75	12.48
Prob>chi2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002
Pseudo R2	0.394	0.420	0.421	0.339	0.220	0.471	0.306	0.490

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<sup>a</sup> \*\*\*, \*\*, and \* indicate statistically significant at 1%, 5% and 10% level (or better), respectively.

### Appendix A.1 Description of Tree Species considered in the study

Tree Species	Scientific name	Local name	Key
1	<i>Acacia ethbaica</i>	Seraw	Indigenous
2	<i>Euclea shimperi</i>	Kliow	Indigenous
3	<i>Olea europaea</i>	Awlie	Indigenous
4	<i>Rhus natalensis</i>	Tetaelo	Indigenous
5	<i>Eucalyptus spp</i>	Kelanitos	Exotic
6	<i>Acacia lehay</i>	Lehay	Indigenous
7	<i>Acacia seyal</i>	Cha'a	Indigenous
8	<i>Balanites aegyptiaca</i>	Mekie	Indigenous
9	<i>Mytenus senegalensis</i>	Argudi	Indigenous
10	<i>Faidherbia albida</i>	Mommona	Indigenous
11	<i>Melia azedarach</i>	Nim	Exotic
12	<i>Acacia saligna</i>	Akacha	Exotic
13	<i>Euphorbia candelabrum</i>	Kolenkual	Indigenous
14	<i>Croton macrostachys</i>	Tambukh	Indigenous
15	<i>Shinus molle</i>	Tikur berbre	Exotic
16	<i>Juniperus procera</i>	Tsihdi Habesha	Indigenous
17	<i>Ficus ingens</i>	Shibakha	Exotic

### Appendix A.2 Modelling technology adoption/ tree planting

The adoption decision is modeled as the decision between planting trees and not planting trees. In making decisions about the adoption of tree planting, we assume that a farmer will evaluate the tree planting in terms of its expected incremental benefit. Letting  $(\pi)$  be expected incremental benefit or payoff, then, if the expected utility gains (benefit) of planting tree  $(\pi_1)$  is higher than the without planting trees  $(\pi_0)$ , the preference or utility for planting tree will be higher than the without planting tree. We assume that there is an unobserved or latent variable,  $y^*$ , that generates the observed variable  $y$ , which represents a farmer's decision to adopt tree planting or not. The latent variable  $y^*$  equals

$E[U(\pi_1)] - E[U(\pi_0)]$ , the net benefit or payoffs from adoption. The farmer will adopt tree planting if the expected utility gains with adoption is greater than the expected utility before or of non adoption. That is, when  $y^* > 0$ , the household adopts tree planting and  $y = 1$  is observed and when  $y^* \leq 0$ , the households do not adopt tree planting and  $y = 0$  is observed.

For farmer  $i$ , the latent variable  $y^*$  is related to observed farmer and other characteristics through a structural model as follows:

$$y_i^* = \beta' X_i + \varepsilon_i, (i = 1, \dots, N)$$

where  $X_i$  represent a set of explanatory variables, which influence adoption decision of the farmers,  $\beta'$  is a coefficient vector and  $\varepsilon_i$  is a random disturbances associated with the adoption and non-adoption of tree planting. Then  $y_i^*$  is linked to  $y_i$  as follows using indicator function:

$$y_i = 1[y_i^* > 0]$$

Farmer  $i$  adopts or involves in tree planting if  $y_i^* > 0$ . The probability that  $y_i = 1$  is then:

$$\Pr[y_i = 1] = \Pr[y_i^* > 0] = \Pr[\beta' X_i + \varepsilon_i > 0] = 1 - F(-\beta' X_i) = F(\beta' X_i),$$

where  $\Pr[.]$  is a probability function and  $F(.)$  is the cumulative distribution function. The function,  $F(\beta' X_i)$ , cannot be estimated directly without knowing the form of  $F$ . The exact distribution of  $F$  depends on the distribution of the random term  $\varepsilon$ . A probit model was used in this paper assuming the disturbance term is normally distributed with mean zero and variance one.