Incentives to Plant Trees in Tigray Ethiopia: Interactions of Public Microdams and Health

Amy C. Osorio

Thesis submitted to the faculty of the
Virginia Polytechnic Institute and State University
College of Natural Resources
Department of Forestry
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE
IN
FORESTRY

Approved:
Dr. Gregory S. Amacher, Chairperson
Dr. B. Jay Sullivan
Dr A.L. Hammett

May 20, 2002
Blacksburg, Virginia

Keywords: tree planting, public health

ABSTRACT

Governments of developing countries face the dual tasks of increasing agricultural productivity and ensuring sustainability of resources. The government of Ethiopia initiated a major rural development program in Tigray, Ethiopia ten years ago, called SAERT (Sustainable Agricultural and Environmental Rehabilitation), to change the decline in agricultural productivity and reverse local forest degradation. SAERT targets water resource development through the construction of regional public microdams, intended to bring irrigated agriculture to surrounding villages and improve household income. Through SAERT, villagers can choose to plant trees on public microdam sites, protected and monitored by the surrounding villages. Unfortunately, microdams may cause potentially serious side effects to human populations through water-borne illnesses such as malaria and schistosomiasis. This paper examines incentives for villagers in Tigray to plant trees for private use, in both villages with and without access to regional public microdams. In addition, we investigate the importance of health factors on the household decision to plant trees on household and public land.

ACKNOWLEDGEMENTS

I would like to thank my advisor, Dr. Gregory S. Amacher, for his support during my Masters program. He continually provided me with assurance and support, and politely responded to my never-ending stream of emails.

I would also like to thank my committee members. Dr. Jay Sullivan was there to answer my questions if Greg had a meeting with his bike. Dr. Tom Hammett offered advice and patiently dealt with last minute changes to my thesis and defense.

Thanks also to Melinda Vokoun for struggling with me through it all, and for being a constant lunch companion. I wish her all the best in her doctoral program!

Finally, a special thank you to Hylton Haynes. You helped me become both more diligent in my studies and more relaxed in my time off. Thanks for encouraging me through this endeavor! I only hope I can be as supportive of you in your doctoral program, as you were of me through my masters.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER 1: INTRODUCTION

Governments of developing countries face the dual tasks of increasing agricultural productivity and ensuring sustainability of resources. This is usually achieved through public investments with financial supports from government agencies or NGOs. Investments most typically take the form of incentives to adopt improved technologies or information dissemination for technologies themselves (Eicher 1994). Technologies in many cases involve financial assistance for the planting of trees, or adoption of agroforestry practices, which reduce the need to visit local forests for fuel or protect crops in arid regions subject to soil loss.

The northern Tigray region of Ethiopia provides a perfect example. Tigray is thought of as the most land-degraded state of Ethiopia. As a semi arid to arid region consisting of subsistence households, it has forest stocks which have come under intense pressure from in-migration caused by the many recent civil wars (Hurni 1993). The government of Ethiopia initiated a major rural development program there ten years ago, called SAERT (Sustainable Agricultural and Environmental Rehabilitation), to correct the decline in agricultural productivity and reverse local forest degradation. SAERT targets water resource development through the construction of regional public microdams, intended to bring irrigated agriculture to surrounding villages and improve household income. Villagers can choose to plant trees on public microdam sites, protected and monitored by the surrounding villages. Availability of irrigation water from these dams is also expected to encourage planting of trees on land households lease from the government. By and large the economically important tree species for the region is eucalyptus, which provides wood for fuel and construction.[1]

Land tenure within Ethiopia has allowed for both the quick construction of microdams and for the unique relationship between local villages and microdam sites. The government owns all land within Ethiopia. Individuals may lease land from the government for their personal use, such as a homesite or an agricultural field. However, leases are not strictly regulated and are granted for extended periods of time. This land tenure arrangement essentially allows for the

---

[1] Other species, such as Neem trees, are also planted around households, because it is believed that Neem provides resistance to malaria transmission.

individual to own the land they inhabit without concern that the government will withdraw their leasing privileges.

Microdams were constructed within the Tigray region of Ethiopia for several reasons. The SAERT development program was initiated after an Ethiopian government election. While the primary goals of the SAERT were development based, secondary motives were political. The newly empowered government focused development into the region they had inhabited, in this case Tigray. The microdams were created by diverting water from the Nile river into small dams.

Unfortunately, microdams are not without potentially serious side-effects to the human population. Tigray has historically had little prevalence of water-borne disease during dry months. The World Health Organization and the Tigray Health Bureau now fear that standing water provided by microdams, and the resulting irrigation ditches, could increase water-borne disease across the region, specifically malaria and schistosomiasis (Lampietti 1999). Both diseases are debilitating and, if contracted, will affect a person's work productivity and their allocation of labor, either because they are too sick to work effectively or they must spend time and money caring for sick household members. The consequences of diseases will increase home fuel needs, and have deleterious impacts on private and public microdam tree planting. In the end, microdams may do little to protect remaining forest stocks.

The purpose of this thesis is to examine incentives for villagers in Tigray to plant trees for private use, in both villages with and without access to regional public microdams. Planting on household private land includes two locations: interspersed among agricultural crops and planted on homestead (non-agricultural) property. In addition, given that microdams are managed cooperatively by surrounding villages, we also consider how the incentive to plant trees on the government dam sites differs. As noted above, health will obviously play a role in the income and resources available to the household, and thus the importance of disease to household tree planting decisions will also be investigated.

Our objectives for this thesis are: (1) determine if households view planting on village common-protected microdam sites as substitutes for private land planting, (2) determine the most important factors that affect incentives to plant trees in Tigray, (3) evaluate how the level of planting and the decision to plant depend on health and on the presence of microdams, and (4) explore the potential complementarities of water projects and tree planting by asking: does the presence of microdams provide additional incentive to establish alternative fuelwood sources, through greater water use opportunity, or are they impeding this through their impacts on health and income? Because tree planting reduces pressures on remaining government open access forests, the spillover effects of health and microdams on private tree planting is an unknown and important issue with our study.

These questions have not been studied elsewhere to our knowledge. Yet they are extremely important when targeting policies to reduce pressure on primary forest, and evaluating government water development projects. When studying the effect of human interactions with ground conditions, such as through agricultural practices and forestry regimes, Mann found that changes from indigenous farming techniques to farming techniques which incorporate western equipment and planting and harvesting cycles can influence local weather (Mann 1990). For instance, it is thought that a change in agricultural and forestry practices in Africa, from farming for self-use to farming for export and large-scale markets, has played a role in lengthening drought conditions.

Tree planting has been an important piece of forest development work. Caviglia and Kahn (2001) studied tree planting with a focus on individual households using a utility-based model within Rondônia, Brazil, with the goal of determining methods of decreasing the number of farmers that participate in slash-and-burn agriculture. Although their use of a Tobit type II model is similar to ours, their sample size was relatively small, planting on public and private land was not contrasted, and neither health nor microdams were important elements of their data. Shivey (1998) examined fluctuations in agricultural prices in the Philippines determines tree-planting levels. Using a dynamic stochastic household model based on production functions, he found that perceived risk was important to incentives to plant. Amacher et al. (1993) and Amacher et al. (1994) examine tree-planting incentives within a household production framework for Pakistan and Nepal. In Nepal, the authors show differences between fuelwood collection on both private (tree planted) and public land, while in Pakistan tree planting is shown to be related to price and output risk. However, health and microdams used for irrigation do not factor into their analysis, nor was the intensity of planting considered.

Finally, there is much literature focused on tree planting as a means of alleviating deforestation. Dewees argues that household fuelwood demand and market prices for fuelwood are most important in affecting subsistence farmers' desires to plant trees (Dewees 1992), while Salam et al. (2000) argues that economic factors play a larger role in tree-planting effort than ecological factors. They contend that fuelwood availability itself is not a large enough factor to greatly influence planting, especially in situations where alternative forms of fuel, such as animal manure and agricultural residue, can be used in place of wood (Salam et al. 2000). These studies have established that aside from fuelwood demand and availability, the importance of hired labor availability is critical to the means to plant trees, by freeing up family labor for activities other than fuelwood collection. However, Amacher et al. (1996) show it is important to differentiate households for these purposes into those that collect fuelwood for own consumption and those that are net purchasers of fuels.

Other studies on tree planting have focused on participation levels. Sommer et al. (1994) found that programs which encourage active participation had a greater resident satisfaction level than those which used efforts from 'outsiders' to plant trees. Others have noted that local population's need to be encouraged to plant trees using cash incentives and lessened restrictions, coercion and trust (Ahlback 1995). Similarly, Nibbering (1999) researched slash-and-burn agriculture and tree-planting adoption, and found that studying the local populations historical perspective on tree planting and providing people free planting material and cash incentives were an important aspect of determining success rates of government incentive programs. These all establish the importance of preferences and utility to any tree planting decision for a representative household.

We follow this work, but extend it considerably by examining private and common property planting, and by considering the intensity of planting. Perhaps our biggest contribution, and the major difference between our work and others, is identifying for the first time a link between health, water development projects, and incentives to plant trees. In accommodating this link, we will approach tree planting in a different more complete manner than previous work. For example, we will develop an econometric specification that addresses the incentive to plant trees from the underlying household utility maximization problem. This specification will have as its basis a correction for the endogeneity associated with household time allocation decisions. Endogeneity is derived from the fact that the time household members spend caring for the sick is a family activity, so a market wage rate is not observed. Instead, the opportunity cost of this activity is proxied for using a 'shadow wage' following the literature. Use of a shadow wage will illustrate how household preferences, activities involving time caring for sick family members, and the resulting loss of production by diverting labor to health care, all affect the decision to plant trees and relieve pressure on primary forests. These issues have not been investigated in other studies, which specify tree planting as a function of only output prices, incomes, and village characteristics. This omits important variables that drive the incentive to establish trees and reduce forest degradation in settings where poor health is endemic. Our more complete focus will therefore allow better targeting of policies and a clearer understanding of the decision behind forest development in countries with water borne disease and water development projects.

There is also very little work that investigates the link between disease and natural resources in general. This is surprising given the interest in bringing irrigated agriculture to arid developing country regions. Grossman (1972a, b) first established a connection between health and economic decisions, showing that individuals invest in health production until the marginal cost of health production equaled the marginal benefits of improved health status. Since Grossman, several others (Pohlmeier and Ulrich 1995; Johansson and Lofgren 1995; Gerdtham and Johansson 1997) have carried out empirical studies on the demand-for-health, but most of this work relied on wage-earning individuals in the developed countries. There is no work we are aware of that establishes how health is important to household activities in developing countries. The one exception is Audilert (1986), who investigated the effect of health status on the productivity of agricultural workers, particularly non-wage-earning rice-growing peasants in Cameroon. He showed that a worker's health status significantly influenced paddy output through a production function analysis.

CHAPTER 2: A HOUSEHOLD PRODUCTION-CONSISTENT FRAMEWORK

In this section we derive the basic components behind the decision of a representative household to plant trees, in a setting where microdams may be present and can impact both health and water availability. The incentive to plant trees will be couched within a household production framework, which makes clear the allocation of household time to various productive activities, and to unproductive (income-reducing) activities such as caring for sick family members.

Representative households (decision-makers) derive utility from consuming goods and leisure time,

$$U(x, T - L; H, \Omega) \quad (1)$$

where x represents a composite variable and includes fuelwood and other goods consumed by the household. Utility of decision-makers is affected by the health of household individuals, measured by a general health index H, as well as other household characteristics, Ω. The variable H will heretofore be measured as time sick for household members. The variable T – L is leisure time, and L is a vector of labor activities for members of the household, i.e.,

$$L = L_F + L_H + L_A + L_o \quad . \quad (2)$$

L_F is household labor allocated to fuelwood collection, L_H is labor allocated to taking care of sick family members, L_A is labor allocated for work in the household's own fields, and L_o is labor allocated to off farm wage-earning work.[2]

Households collect fuelwood and agricultural residues, and produce crops. Production functions for crops and fuel collection depend on labor, health, the availability of water from microdams and other household characteristics,

$$Q = Q(L_A, D, H; \Psi_A) \quad (3)$$

$$F = F(L_F, R, D, H; \Psi_F) \quad (4)$$

where Q represents agricultural production, F represents fuelwood collection, R represents the tree resource stock, D represents a vector of microdam characteristics that affect production (such as irrigation opportunities, distance, planted forest stocks, etc), and Y_A and Y_F represent characteristics of the market or household that affect production. The presence of microdams affects production in (3)-(4) through its impact on health, fuel availability from planted trees at the dam site, and water availability. Notice that labor caring for the sick, L_H, reduces time spent in production activities from (2); it will therefore decrease overall household production. Also, note we abstract from capital in (4) – (5) to reduce notation, although we shall include these measures in our econometric estimation. Indeed, planted trees represent a form of capital for

[2] Labor variables could be reinterpreted as vectors of the labor time for members in the household. These variables and the fuel variables will be disaggregated later in the empirical analyses.

fuelwood collection, and this choice will be made explicit later. For now, we can simply assume that trees contribute to the size of the resource stock, R.

The household cash budget constraint is a function of production, labor and time decisions**,**

$$px + wL_{hd} = M + wL_0 + p_A(Q_c - Q) + p_F(F_C - F) \quad (5)$$

where p is the vector price of goods purchased, L_{hd} is hired labor, and w is the market wage rate for hired/off farm labor. M is exogenous income from source other than household fuel and crop production activities, p_A is the market price of agricultural products, Q is agricultural production by the household while Q_c is household own consumption of agricultural products, F is a vector of fuel collection, F_c is fuel consumed by the household, and p_f is the market price vector for fuel components. Implicit in the budget constraint is household production of goods for sale or for home consumption.

Labor markets are well-defined in Tigray for all activities except home health care, which is undertaken only by family members.[3] For non-home health care activities, the appropriate opportunity cost of household labor is therefore the market wage rate, w in (5). However, for home health care, households face an opportunity cost that is an implicit function of household preferences. This is the classic shadow price problem in household models (e.g. Jacoby 1993, Amacher et al. 1999). We will denote the shadow wage of home health care as $\hat{w}$ from here on. Using this wage, we could write the budget constraint in 'implicit form' recognizing all opportunity costs faced by the household for its activities, as

$$px + wL_F + wL_A + \hat{w}L_H + wL_{hd} = M + wL_0 + p_A(Q_c - Q) + p_F(F_C - F) \quad (6)$$

Specific means to find an instrumental variable or proxy for $\hat{w}$, following the literature, will be discussed in the econometric specification below.

The last matter to address is a function explaining time sick for household members. Water borne-diseases such as malaria and schistosomiasis are debilitating, making work difficult and reducing productivity while working. Without loss we can define the health function H as time sick. Time sick is *exogenous* and is not a household choice variable, i.e., one cannot choose

---

[3] The use of a single wage for hired and off farm labor reflects this well-defined labor market, which has been our experience for the Tigray region and specifically the villages sampled. All households reported a wage rate for these activities, and most hire labor and engaged in off farm work.

either to be sick or to be healthy. It should depend on such variables as access to health care, labor allocated to caring for the sick, expenditures on health care, and other family and domicile characteristics. Indirectly it should also depend on the presence of microdams, because these positively affect disease prevalence through their increase in standing water. Thus we have,

$$H = H(L_H, D; \Psi_H), \qquad (7)$$

where all non-labor and non-microdam effects are combined into Y_H for simplicity in notation. Elements of Y_H include the number of household members, quality of house and toilet, access to health care facilities, expenditures on medicines, planting of certain species of trees believed to reduce the malarial threat, and possession of improved heating and stoves, among other things. Household health care labor, L_H, obviously reduces time sick.

Econometric Model of Tree Planting

The presence of the shadow wage implies the model in (1) – (7) is *not separable*. Nonseparability implies that tree planting decisions will depend on the shadow wage, health and health care variables, traditional income and consumption variables (output prices, market wages), indicators of the resource stock (R, D), and household preferences (ψ, Ω) (e.g., Amacher et al. 1998,1999). As a result, time sick and the implicit wage of household labor spent caring for the sick, will affect tree planting decisions[4]. A model, which specifies these decisions without accounting for this nonseparability, will not be correctly specified.

There are two forms of planting in Tigray. Tigranian households can plant on their own private agricultural land, or they can choose to contribute to planting on public microdam sites that are maintained by the villages surrounding the dams. Planting on private land includes dispersion of trees on cropland, as well as planting on non-crop land. Therefore, we need to examine each decision in our econometric model.

We can find an estimable form for the tree planting choice by first constructing an indirect utility function of a household under tree planting and no tree planting scenarios – the comparison then reveals the incentive to plant. An indirect utility function represents the maximum utility a household receives, conditioned on the choices it makes. To construct one,

---

[4] In a separable model, tree planting decisions would depend only on output prices and input prices, because it would be undertaken only to maximize profits associated with fuelwood production and sale.

we first consider that the household maximizes (1) subject to (2)-(6) by choosing labor in all activities, fuelwood collection and agricultural production, and fuelwood, agricultural and other goods consumption. The specific choices are not important. What is important is to represent the vector of optimal choices as a function of prices, wages, household characteristics, income, and health,

$$\Gamma^{*}(p, p_f, p_A, w, \hat{w}, D, R, M, H, \Omega, \Psi_H, \Psi_F, \Psi_A) \qquad (8)$$

The implicit wage $\hat{w}$ for home health care labor is now included in (8), although it is unobserved and must be instrumented appropriately in our estimation below.

The indirect utility function is now obtained by substituting the vector of choices in (8) into the utility function (1) to define maximum utility households receive once their decisions are made optimally,

$$V = U(\Gamma^{*}(p, p_f, p_A, w, \hat{w}, D, R, M, H, \Omega, \Psi_H, \Psi_F, \Psi_A)) = U(x^{*}, T - L^{*}; \hat{H}, \Omega) \qquad (9)$$

Trees are a form of capital and represent an enhancement to households resource stock. Thus, we can define an indirect utility function under tree planting as $\hat{V} = U(\hat{\Gamma}^{*}) = V(p, p_f, p_A, w, \hat{w}, D, \hat{R}, M, H, \Omega, \Psi_H, \Psi_F, \Psi_A)$. Households will plant trees in any location only if they are better off with the enhanced resource stock, i.e., if and only if

$$\hat{V} - V > 0 \qquad (10)$$

Note that this decision is dependent on prices, resource stocks, microdams, health, wages, and implicit (unobserved) wages because of its foundation in the utility maximization problem described earlier.

Any variable causing (10) to become more positive makes it more likely a household will plant trees. In the appendix we detail how changes in health and microdams affect the decision. Here we specifically examine how improvement in the resource stock, that follows from planting trees, affects (10),[5]

$$\frac{\partial \hat{V}}{\partial \hat{R}} = l_F \, p_F \frac{\partial F(.)}{\partial \hat{R}} + \frac{\partial \hat{V}}{\partial \hat{w}} \frac{\partial \hat{w}}{\partial \hat{R}} \qquad (11)$$

---

[5] This derivative makes use of the envelope theorem, which accounts for the fact that household decisions other than tree planting are set at their optimal levels given the definition of the indirect utility function (Varian 1992).

The first term on the right-hand side describes the direct effect of planting on household production, while the second term describes the indirect impact of planting on the implicit wage. Recall that, unlike observed market wages, this wage is not taken as given by the household; it will therefore be linked to the tree planting decision as an endogenous variable.

Both terms in (11) can be used to represent tree planting on either public or private land, in that this planting improves the tree stock. However, planting at the two locations does so to different degrees. For example, microdam sites may improve the growth rates of trees through their abundant water source, but the trees are managed as common property. We leave the specific comparisons to the empirical results.

Econometric Specification

An econometric form for (10) follows from rewriting it using a random utility function for V(.), and restating the decision in terms of probabilities,

$$\begin{aligned} &\mathbf{Pr}[\hat{V}] \quad > \quad \mathbf{Pr}[V] \\ &\Leftrightarrow \hat{V} + h_{\hat{R}} > V + h_R \\ &\Leftrightarrow \Phi(p, p_f, p_A, w, \hat{w}, D, \hat{R}, M, H, \Omega, \Psi_H, \Psi_F, \Psi_A) + h^* > 0 \end{aligned} \tag{12}$$

where $h^* = h_R - h_{\hat{R}}$ is an error term that has an extreme value distribution (e.g., see Madalla 1986). Equation (12) shows the decision to plant as a discrete stochastic choice. However, once households choose to plant, they then must choose the intensity of planting (i.e., how many trees to plant). This comes from choosing the planting stock that maximizes the stochastic form of $\hat{V}$, conditional on other choices being set at their optimal levels,

$$\underset{\hat{R}}{Max}\, \hat{V}(p, p_f, p_A, w, \hat{w}, D, \hat{R}, M, H, \Omega, \Psi_H, \Psi_F, \Psi_A; e) \tag{13}$$

where ε is an error term representing the continuous choice of resource stock improvements. Equation (13) has a Tobit interpretation, while equation (12) has a probit interpretation. The strategy for estimating (12) and (13) is through a Tobit type II model, where the error terms ε and η* are potentially correlated (Greene 1997).

A complicating factor in this estimation is finding an instrument for the endogenous shadow wage. This variable is potentially correlated with ε and η^*.[6] Following the literature, a suitable instrument is the lost marginal products incurred by diverting household labor to caring for the sick at home. We can recover this marginal product by first estimating a production function, and then use the estimated male and female labor marginal product times the labor hours males and females choose to stay at home and care for the sick. Because females in Tigray are primarily responsible for fuel collection, except for time spent caring for the sick, we make use of the fuelwood collection production function.

Following this approach we will proceed in two stages. First, we will estimate a Cobb-Douglas production function for fuelwood collection. We will then recover the marginal product lost from time females and males spent caring for sick family members using the following relationship,

$$\hat{w} = (\frac{\hat{F}}{L_F}) \tag{14}$$

where $\hat{F}$ is predicted fuelwood collection from the fuelwood collection production function. This instrument will then be used in place of $\hat{w}$ and then equations (12) and (13) will be estimated. At this second stage, all regressors in (12) and (13) will be exogenous, and the resulting estimates will be consistent and unbiased. This is because, after insertion of (14) into the estimation model, other prices and wages are exogenously taken as given by the household. Notice also that by definition the time sick variable is exogenous in the estimated equations; recall that the time sick variable measures the amount of time someone suffers from disease. This distinguishes the time sick variable from our implicit wage for home health care time, which is in fact a household choice that may be correlated with errors in the choice to plant and levels of planting.

CHAPTER 3: DATA COLLECTION AND SURVEY DESIGN

---

[6] See Thorton (1994) and Jacoby (1993) for the early literature on implicit prices in nonseparable models, and Amacher et. al (1996) for a fuelwood example.

Our data come from a World Health Organization (WHO) sponsored project undertaken with cooperation of the Mekelle University of Dryland Agriculture in Tigray, Ethiopia, and the Tigray Health Bureau. A survey of 800 households was enumerated during the 1996-97 harvesting season, with recall based on weeding, planting, and harvesting phases. The survey was questionnaire-based and administered by enumerators trained and accompanied by Dr. Gregory S. Amacher and Dr. Lire Ersado over a period of 2-3 months. Prior to sampling a pretest was conducted in the winter of 1995-96. Enumerators and their survey location were chosen through an interview process conducted in cooperation with Mekelle College University. Surveys were conducted on household heads/decision makers and contained a detailed list of questions on health, number of days a household member was sick, household production, household consumption, and natural resource and fuel use, as well as demographic information and other characteristics important to decisions and preferences. All households approached agreed to participate in the survey.

Random sampling was conducted on households in villages. Villages were located both close to and far away from irrigation microdams to increase variation in the data. Villages near the microdams were considered to be 'intervention' sites because of the impact of microdams on household production and health, while villages far away from microdams were considered to be 'control' villages. Village selection relied on cooperation with the Tigray Health Bureau to maximize variation in the effect of microdam–related malaria proliferation or availability of irrigation water for villages. Out of 34 villages in the sample, 19 were intervention sites and 15 were control sites. A random sample of 20 to 25 households was selected from each village, resulting in the total sample of 800. After discarding missing data for the variables of interest, our complete sample represented 524 observations.

CHAPTER 4: DEFINITION OF VARIABLES AND DESCRIPTIVE STATISTICS

Definitions of Variables

The variable abbreviations used for the actual modeling, were not included in the results tables due to difficulty in interpreting the meaning of the abbreviations. However, to allow for a comparison between the output files and tables presented, the variable abbreviates, subsequent variable definitions and units used are clarified (Table 1).

Some variables were transformed to create a better understanding of the relationship between health and tree planting effort. Dummy variables include: the incidence of malaria among males (mhhalskm) and the use of an improved stove (impstove). The individual variables measuring levels of sickness; number of days males spent sick (mhhalsck), days females spent sick (fhhalsck) and the days children spent sick (chldsck); were combined into one sickness variable which measured the total number of days everyone in the household was sick (totsick).

Other variables were also combined for ease of comparison. A variable was created which described the total number of animals owned by each household. The totals from individual animal count variables; number of oxen (oxenno), horses (horseno), donkey (donkeyno), mules (mulesno), camels (camelsno) and the number of cows (cowsno); were combined into one variable (animalno) and weighted according to their relative importance. Two variables were also created to add the number of acres owned and rented by individual households. The first of these combined landownership variables; cereal land owned (olandcer), vegetable land owned (olandveg) and other land owned (olandoth); to create a single total land ownership variable (landtot). The second variable combined rented land variables; cereal land rented (rlandcer), vegetable land rented (rlandveg) and other rented land (rlandoth); to create a single total rented land variable (rentland).

Although the government owns all land within Ethiopia, for the purpose of this thesis we do classify land as private and public. Within the results sections, any land referred to as privately owned is indeed leased from the government. We classified private land as being either used for agricultural purposes (agricultural land) or homesite uses (household land). We classified government land as only land immediately surrounding, and including, the microdam (also termed microdam land).

Descriptive Statistics

When presenting the descriptive statistics of select variables in our sample, the data are presented for the entire sample (Table 2) and are separated by control and intervention villages (Table 3 and Table 4). The discussion of the descriptive statistics is then divided into the categories of:

general household and microdam characteristics, tree planting characteristics and household health. For the descriptive statistics, the mean and standard deviation are reported for every variable tested through our model.

General Household and Microdam Characteristics

The average household sampled was located 3.7 km from a microdam, with household closest to microdams an average of 1.9 km away and those furthest an average of 5.5 km from the nearest microdam. Households in intervention areas (those impacted by microdams through the presence of irrigation) are three times more likely to engage in irrigation technologies, and to adopt other technologies such as improved stoves, compared to households in control villages (those areas which do not have irrigation from microdams). Households in intervention areas on average own the same amount of land as households in control areas; however, intervention households rent an average of twice the amount of land rented by households in control areas. Intervention household also hire an average of three times the amount of labor as used in control areas, an explanation for this is given within the health section of the descriptive statistics.

The average age of microdams is 5 years, although microdam ages range from 1 year to 15 years old. Microdams appear to be located where access to health centers is higher, as the distance to health centers is on average two km closer for intervention villages. Also the distance to a fuelwood collection site is an average of 2.5km closer for intervention areas then for control areas; this could suggest that households are using the microdams as an additional source of fuelwood.

Fuelwood collection appears twice as high in control areas. Similarly, households within control areas spend twice as much time collecting fuelwood as those in the intervention areas. Regardless of the area, women spend more time collecting fuelwood then men on average, as was expected. Perhaps fuelwood collection is highest in control areas because the opportunity cost of shifting labor away from crop production is lower there, household members are healthier, or the decreased time the females spend caring for sick family members frees them to engage in greater fuel collection and cooking, their primary responsibilities.

Tree Planting Characteristics

Households in intervention areas have a larger tree stock on their private land than households located in the control regions, with an average of 28 percent more trees. Interestingly, households in intervention sites collect less fuelwood than households on control sites. Similarly, households in control areas hire an average of twice the amount of male labor and a third more female labor to collect fuelwood; possible reasons for this are explained within the health section of the descriptive statistics.

Tree planting was analyzed through the amount and location of eucalyptus and other tree species planted. Since eucalyptus was determined to be the most important species planted, its level of planting was measured independently of the general category given for all other tree species found. Few neem trees were found so they are not included in the discussion of the results. Due to the notion that neem can help cure malaria, we thought it would have been present in large amounts on the land, however only small amounts of neem were planted when compared with the number of eucalyptus and other tree species recorded. This can be explained though, by the general usefulness of eucalyptus. If the household must decide between neem and eucalyptus, it was found to most likely favor eucalyptus because it can meet a larger array of household needs (such as construction material and fuelwood) whereas the primary importance of neem is in combating malaria. For simplification, tree planting will be first compared by the location where the trees where found; three such categories identified through the surveys were: agricultural land, household land and government microdam land.

In general, more trees were planted on household land than on government land and agricultural land. Household land contained twice as many trees, eucalyptus and other trees combined, as government land and three times as many trees as agricultural land. Eucalyptus was the most common tree species found on household land, with almost twice as much eucalyptus as other trees. Control areas had more trees planted on household property than intervention areas. The household land category with the most trees was for the category of eucalyptus planted within control areas; the fewest trees were found on intervention areas planted with other trees.

Agricultural land contained the fewest number of trees when compared to tree planting on household and government lands. On agricultural land, there were more trees planted in control areas. Regardless of household location with relation to a microdam, other tree species were more prevalent on agricultural land than eucalyptus; twice as many other trees were found on agricultural lands. The agricultural region with the most trees found was land within control areas planted with other trees; the fewest trees were found on intervention areas planted with eucalyptus.

On the government land studied, other trees were planted more often than eucalyptus trees with almost five times as many other trees found than eucalyptus. This could be explained by the relative expensiveness of eucalyptus seedlings. People planting on microdam sites, especially younger sites, may be concerned with the potential for theft of any eucalyptus trees planted on government land. Older microdam sites have more established plantings and community involvement in theft deterrence. However, government land located in control areas had a high rate of other trees planted, an average of 41 trees. This was the second highest average of trees found on any land classification; the highest average, 53 trees, was for eucalyptus planted on household land within control areas. Also, the two lowest average numbers of trees planted were recorded for eucalyptus trees planted on government land within control areas, an average of 4 trees, and eucalyptus planted on government land within intervention areas, an average of 7 trees.

Regardless of location with respect to a microdam, or land type classification, there were slightly more other trees found than eucalyptus (an average of 126 and 113 trees, respectively). Also, there were twice as many trees found within the control areas as found within intervention areas. This could support our theory that health does impact tree-planting effort. Control villages do not have irrigation channels and thus have less standing water and a lower prevalence of water borne illnesses, whereas intervention villages have a greater occurrence of such illnesses. On all of the control land studied there were more other trees found than eucalyptus trees, and within all of the intervention areas studied, more eucalyptus trees were found.

<u>Household Health</u>

One word about the health/sickness variables is now in order. In our data we have two measures of disease, a personal assessment of each person as to number of days they suffered due to disease, and an assessment of whether they were suffering from malaria or schistosomiasis.

Given that people may not know what disease they have, the total time sick is a more reliable variable for establishing a link between productivity and health.

With this in mind, the prevalence of disease appears to indeed be higher in intervention villages, but more so for male laborers who are likely to be working in the irrigated agricultural fields where exposure to schistosomiasis and malaria is greater. Not surprisingly, the time females spend staying home and taking care of sick family members is two times higher in microdam areas than in control villages (medical expenses are also twice as high in these locations). This time allocation has interesting effects on other household decisions, as our theory demonstrated. For example, increased time females spend caring for the sick has the effect of increasing hired labor and goods purchasing, but production nonetheless remains higher for microdam-impacted villages. This is perhaps because these villages make use of crop irrigation, which substitutes for labor in the fields.

CHAPTER 5: ESTIMATION RESULTS

We now turn to the estimation of the Tobit type II selection models outlined earlier. The first stage analyzes the probability that local people undertake tree planting, while the second stage analyzes the number of trees planted for those households that choose to plant (i.e. the extent of the adoption of tree planting). This Tobit type II model was selected for the estimation results over a two-stage Heckman, primarily because Heckman models are best suited for situations where the same variables are not expected to determine the probability of adoption and the level of adoption.

For ease of comparison, the estimation results were grouped and analyzed based on the location of the tree planting: agricultural land (Table 5), household land (Table 6) and government land (microdam sites) (Table 7). Planting on microdam sites is similar to the household choosing to donate trees to the community, in return for the security that the village will manage and protect the community woodlot.

Agricultural Land

The decision to plant eucalyptus on agricultural land depends on several key variables (Table 5).

The more days family members spend sick, the greater is the probability they will adopt planting of eucalyptus on their agricultural fields; the variable total days spent sick is significant at the one per cent level. Also as agricultural residue prices increase, households are more likely to start planting eucalyptus on agricultural fields, significant at the 5 per cent level. Since agricultural residue is a substitute source of fuel, as the price of substitutes increases the household may plant trees so they can sell their residue and use wood as their primary source of fuel; in addition, as prices of agricultural residues increase, the household will be less able to afford the residue and would become more dependent on substitute sources of fuel, such as eucalyptus wood.

The distance between the household and the fuelwood collection area and the shadow wage rate for males both positively influences adoption of eucalyptus tree planting on agricultural land, as we would expect; significance levels are ten and five per cent, respectively. If the distance to a fuelwood collection site is long and the household has to decide between collection of fuelwood and other activities, they are more likely to want to adopt tree planting as a substitute for time spent traveling to collection areas; tree planting would decrease the time spent pursuing fuelwood and would create more time for other household labor activities, such as agricultural production. Likewise, as the shadow wage rate for males increases, the probability of adoption of tree planting increases. This makes sense as the shadow wage measures the opportunity cost of male household labor.

Adoption of eucalyptus planting is negatively influenced by increases in the distance to the nearest healthcare center, the number of days males spend sick with malaria and the female hired labor wage rate. The variable of greatest significance is the female hired labor wage rate. This suggests that as the hired labor rate for females increases, and more females work away from their homesite, the probability of tree adoption decreases. This could be because females working outside of their homesite would have less time to tend to trees, and would therefore pick agricultural activities which could provide an immediate return on investment over tree planting. Moreover, eucalyptus is a high valued tree and expensive to purchase, thus, sick households may have fewer resources to spend planting this species.

Some signs for the probit model for eucalyptus trees planted on agricultural land are not what were expected. For example, according to our model, as the price of cereal increases, households are more likely to adopt tree planting. However, the opposite should be true. As the price of cereal increases, landowners should be encouraged to plant more cereal because they will receive a more favorable market price for their product. However, this could be measuring an income effect, i.e., as cereal becomes relatively more valuable, households have more resources to spend on eucalyptus trees.

The extent of eucalyptus planting on agricultural land is determined solely by the age of the nearest microdam to the household, significant at the 10 per cent level. Households located closest to older microdams are more likely to plant a greater number of eucalyptus trees than those located nearest to young microdams. These households are likely to have more developed irrigation possibilities, and irrigation is complementary to tree planting.

The decision to plant other tree species on agricultural land is positively influenced by the total number of animals owned, the total days spent sick, the distance to market and the market prices of vegetables. This is similar to what was found for eucalyptus on agricultural land; however, significant differences also exist. For example, with eucalyptus trees we found that the distance to the market had a negative sign – although it was not found to be significant - whereas with other trees distance to market has a positive sign and is significant at the 1 per cent level. The total number of animals owned was positively correlated with household adoption of other tree planting on agricultural land, with significance at the 5 per cent level. This could be because animals and trees can be complimentary on agricultural land, in an agroforestry setting, or that animals are not prolifically found on agricultural land in this region so the variable is not of importance.

The decision to plant other species on agricultural land is negatively influenced by the age of the nearest microdam, the distance to the nearest healthcare center and the price of cereal. As microdams age, they become of a greater use to the households closest to them since the tree species planted will have matured and will be able to provide a greater amount of fuelwood. There is less of a need to plant additional trees, because the household is able to use those planted in the past. Therefore, according to our results, as microdams age households are less likely to adopt tree planting. Also, as the distance to the nearest healthcare center increases, households are less likely to plant other trees on their own agricultural land. A reason for this could be that as household members spend more time traveling to the healthcare center, they have less time to devote to other activities and therefore their labor-leisure trade off is influenced, and households are more likely to favor activities that produce a steady and immediate income (such as agricultural activities).

Also, according to our results, as males spend more days sick from malaria, the probability of them planting trees increases. If males are sick for long periods of time, then they are unable to work in agricultural fields at a level necessary to sustain agricultural activities. Tree planting and trending of trees requires less physical effort than crop production, and trees are needed in caring for the sick through their fuelwood use, and so households with a high sick rate will be more willing to plant trees rather than increase their crop production.

In this model there were also several trends that were not expected. According to our results, as the price of vegetables increases, households are more likely to plant other trees on agricultural land. It would seem that under these circumstances, household would favor vegetable production over tree planting efforts; it should be noted that for the vegetable variable under the probit model was significant at the 5 per cent level, while the extent of planting due to this variable was found to be negative and not significant. One reason could be that vegetable planting largely occurs in gardens around private homes, so that tree planting on agricultural land does not directly compete with vegetable planting.

The extent of planting other trees on agricultural land was affected by the age of the nearest microdam, the total number of animals owned and the market prices for cereal and agricultural residue. As the price of agricultural crops increases, households favor planting more crops on their land, and would plant any trees on other, nonagricultural, land. Interestingly, the probability of adoption was found to be negative and significant at the 1 per cent level for the variable microdam age; however, the extent of adoption for the same variable was found to be positive and significant at the 1 per cent level. An explanation is that few households, near older microdams, would choose to plant other trees on their agricultural land; however, for those households that do choose to plant other trees, the extent of their planting is high. If households are located near older microdams, than there is a chance that the inhabitants could be suffering from malaria, unable to tend to crops, and more willing to plant trees on their agricultural land. Perhaps the households are more willing to have trees on their agricultural land because their proximity to the microdam provides them with a ready source of irrigation; the agricultural fields that they do have are likely to be more productive than if they were not near a source of water, and the household would be able to plant trees on their agricultural land without having a loss in crop production.

Household Land

The decision to plant eucalyptus on household land depends on the distance of the household to the nearest healthcare center, the distance to the nearest fuelwood collection area and the price of cereal (Table 6).

The decision to plant is negatively impacted by distance to market, distance to a microdam, and the days males spend sick with malaria. As the distance to market increases, households spend more time gathering produce and other goods. The desire to plant eucalyptus on their household land decreases, although the probability that the landowner will plant other tree species on their household land increases and is significant at the 1 per cent level. Other tree species, such as fruit trees or those that provide animal fodder, may be more useful to a landowner located far from a market. An explanation for the sign for distance to microdam, which is significant at the 5 per cent level, is a bit more confusing. According to the model, as the distance to the nearest microdam increases, the household is less likely to want to plant eucalyptus on their household land. The same was found for other trees planted on household land, although the significance level in this case was 1 per cent. Perhaps household land space is so minimal that decision makers would favor having the trees on their agricultural land, unless other conditions restricted that, and that distance from the nearest microdam alone is not enough of a determinant to plant on household land; the extent of adoption in both cases was found to be insignificant.

The extent of eucalyptus tree planting on household land depends upon the days males were sick with malaria, the female hired labor wage rate and the price of cereal. For the variable cereal price, the probability of adoption was positive and significant at the 5 per cent level and the extent of adoption was positive and significant at the 10 per cent level. Therefore, as the market price for cereal crops increases, landowners are more likely to plant eucalyptus trees on their household land; a reason could be that the increase in value of cereal causes the agricultural land to gain value, so rather than plant on agricultural land, inhabitants would plant on their homesites. The decision to plant eucalyptus on household land was found to be negative and significant at the 10 per cent level for the variable measuring the number of days males were sick with malaria, the extent of planting was determined to be positive and significant at the 5 per cent level. This could suggest that as male sickness rates increase, the household is less likely to plant trees on their household, but those which do plant are likely to plant a large number of eucalyptus trees on their household lands.

Interestingly, the variables significant to the decision of whether to plant other trees on household land were different than those found for eucalyptus trees on household land. Total days spent sick, distance to market and price of vegetables were found to positively influence the decision to plant other trees. Distance to market was the most significant variable for this decision, with significance at the 1 per cent level. The extent of adoption for this variable was also positive and had a significance level of 5 per cent. Total days spent sick was significant at the 5 per cent level, although the extent of adoption was found to be positive and insignificant. Price of vegetables was significant at the 10 per cent level, and the extent of adoption is negative and insignificant.

Several decision-making variables negatively influence the decision to plant other trees on household land. An increase in the distance to the nearest healthcare center, nearest microdam and nearest fuelwood collection area all cause a decrease in the probability to plant other trees, all are significant at the 1 per cent level. The extent of planting based upon the distance to the nearest healthcare center was also negative and significant at the 5 per cent level.

Government Land

The decision to plant eucalyptus on government land was positively influenced by the age of the nearest microdam, the distance to the nearest healthcare center, the distance to the nearest fuelwood collection area and the price of agricultural residues (Table 7). According to this model, as microdam age increases households are more likely to decide to plant trees on the microdam site. Microdam age was significant at the 1 per cent level. Perhaps older microdams have a better anti-theft enforcement system and households close to them feel their trees are safe from theft on the microdam sites. This is different than was found for the decision to plant eucalyptus on agricultural and household land, both of which had positive coefficient signs but were not significant. This suggests that households closest to old microdams will choose to plant eucalyptus trees on the microdam sites over planting eucalyptus on agricultural or household land. The agricultural land, which being close to the microdam will have a ready source of irrigation, can therefore be reserved for either other tree species, such as fruit trees, or used for crop production.

Distance to the nearest healthcare center was positive and significant at the 1 per cent level. It was also the only variable, for eucalyptus planting on government land, which had a positive, significant value for the extent of the planting. As the distance to the nearest healthcare center increases, it is more probable that the household will decide to plant eucalyptus trees on government land. Households that decide to plant eucalyptus trees on government land will tend to plant a large number of eucalyptus trees.

The decision to plant eucalyptus on government land was discouraged by price of fuelwood and cereal, significant at the 1 percent level, distance to the nearest microdam and market, significant at the 1 percent level, and the days males spent sick with malaria, significant at the 10 per cent level. The sign for the price of fuelwood and cereal variables was not expected. It was thought that if prices for agricultural goods increased, households would be encouraged to plant trees on land other than their agricultural fields. However, according to our model, this occurs only if the price for agricultural residue increases; and even in this case the extent of planting is positive but not significant.

As the distance to the nearest microdam increases, it is less probable that households will plant eucalyptus trees on the microdam sites. Since the trees are being planted so that households can use the wood products, this makes intuitive sense. The investment of time needed to collect tree products if the microdam is located far away, would not be worth the effort it would take to plant the trees there. The landowner would be better off planting trees on either their agricultural land or on their homesite.

The decision to plant other tree species on government land is positively influenced by the distance to the market and the price of agricultural residue; both of these variables are significant at a 1 per cent level. As the distance to the nearest market increases, the probability that households will plant other trees on government land increases and the extent to which these trees are planted also increases. As the price of agricultural residue increases, the probability that the landowner will plant other trees on government land increases, however the extent of planting was found to be positive but was not significant.

Several decision-making variables were found to discourage the planting of other trees on government land; these include the price of cereal and the price of fuelwood, both significant at the 1 per cent level, the distance to the nearest healthcare center and microdam, both significant at the 1 per cent level, and the use of improved stoves, significant at the 10 per cent level. As discussed prior, it was thought that an increase in agricultural prices would cause an incentive for households to plant trees in areas other than their agricultural land, so these signs are not expected.

An increase in distance traveled to the healthcare center or microdam decreases the probability that the household will plant other trees on government land. This could occur for several reasons. First, if the distance to the healthcare center is high, and the household has sick members and therefore spends time traveling to the healthcare center, then they will obviously have less time to spend planting trees and going to trees on government land. These households may be more likely to plant trees on their agricultural or household land, where there would be a shorter distance to travel to the trees. Also, if the household is located in an area far from a microdam, they would be less likely to invest the time needed to get to the microdam to plant trees and then later to collect wood products. In this case also, the household would most likely prefer to plant trees closer to their home site.

The extent to which other tree species were planted on microdam land was influenced by the gender of the decision maker, the amount of land planted in cereal, the total amount of land owned, the distance to the market, the days males spent sick with malaria, all of which were significant at the 1 per cent level, and the female hired labor wage rate, which was significant at the 5 per cent level.

CHAPTER 6: HYPOTHESIS TESTING

Groups of variables were dropped from the probit models in order to determine the level of importance of select variable groups. For the purpose of this paper two hypotheses were tested. The first hypothesis focused on the role of human sickness on the decision to plant trees. The variables for number of days males spent sick, females spent sick and children spent sick and the number of days males were sick with malaria were dropped from the original probit model. The number of days males, women and children spent sick were first combined into a general total days spent sick variable, which was then omitted from the new model. The second hypotheses tested the effect of a microdam on the presence and level of tree planting. The variables microdam age and distance to the nearest microdam were omitted from the original probit model. For all hypotheses tested, the null hypothesis was that the models would not change due to the level of human sickness or the location or presence of a microdam; therefore, we hypothesized that the restricted probit test, those where the variables were removed, would have solutions similar to those of the unrestricted probit test.

The results of the likelihood ratio tests conducted on health and microdam variables are discussed within the text and are presented in a table (Table 8). Likelihood ratios were computed. These were used, along with the degrees of freedom in each scenario, to determine the chi-squared value. Results with high chi-squared values suggest that those variables are most important to the decision maker. For the discussion of these results, each group will be discussed based on the location of planting, agricultural land, household land and government land.

Agricultural Land

Eucalyptus and other tree planting on agricultural land yielded opposite results through the hypothesis tests. When eucalyptus was planted on agricultural land, sickness variables are the most important to the decision to plant; the chi-squared value of 10.14 was significant at the one per cent level. Since eucalyptus trees provide for a greater number of opportunities; sale of firewood, private consumption of firewood, use of wood for building materials; then most other tree species, the results of these tests could be explained through a labor-leisure tradeoff. In households with greater levels of sickness; were members must spread their labor between paid work, non-paid work and caring for the sick, less time can be dedicated to planting and tending trees because more is allocated to tending to sick family members. And, perhaps regardless of the distance the agricultural land is to the nearest microdam and the age of the microdam, eucalyptus will be favored over other species if the household is healthy.

However, if other trees are planted on agricultural land, then microdam age and location are the most important variables to the decision maker; the chi-squared value of 13.195 was significant at the one per cent level. Through the estimation results, we determined that as microdams age households are less likely to plant other species on their agricultural lands. Older microdams are more likely to have well enforced timber theft deterrents in place. Therefore, households are more comfortable planting trees at older microdam sites then planting at younger sites.

Household Land

Decision makers that plant eucalyptus on their household land are influenced by both microdam and sickness variables. In this case, the sickness hypothesis test had a chi-squared value of 3.95 and was significant at the 15 per cent level, while the microdam hypothesis test had a chi-squared value of 6.53 and was significant at the ten per cent level.

Microdam variables are most important to decision makers who plant other tree species on their household land. The microdam hypothesis test results of 16.17 were significant at the one per cent level. In the estimation results, we found that an increase in the distance a household is from a microdam causes the landowner to be less likely to plant other tree species on their household land.

Government Land

Microdam variables were found to be the most important in making the decision to plant eucalyptus on government land; the chi-squared value of 28.28 was significant at the one per cent level. This follows closely to the estimation results, which suggest that decision makers are more likely to plant eucalyptus tress on microdam sites that are older and on microdams that are a close distance from the decision maker. Microdam variables were also the most important to the decision maker when deciding to plant other tree species on government land; the chi-squared value of 56.26 was significant at the one per cent level.

A general trend among the hypothesis testing results was that regardless of where other tree species were planted, microdam variables were found to be the most important to the decision to plant other trees. The hypothesis testing results for eucalyptus tree plantings were mixed. If eucalyptus was planted on agricultural land, health variables were the most important, if it was planted on household land, neither set of variables were important and if eucalyptus was planted on government land, microdam variables were the most important.

CHAPTER 7: CONCLUSIONS AND POLICY IMPLICATIONS

The research was conducted after the SAERT program was initiated by the government of Ethiopia, prompting the construction of public microdams, and raising concern among various organizations about a possible increase in water-borne illnesses due to increased standing water within the microdams and subsequent irrigation channels. Although the purpose of this thesis was not to determine the effectiveness of the SAERT program, this thesis does allow for some determination of the level of tree planting on the government microdam lands studied and for a preliminary estimation on the effect of health on tree planting effort. This thesis examined the presence and extent of tree planting by villagers in Tigray, Ethiopia who lived either in villages with irrigation from regional public microdams or in villages without access to irrigation from regional public microdams. Surveys were conducted which collected information on general demographics, household production and consumption, household health and tree planting efforts. For the purpose of this research, we included health variables within the model to take into consideration the effect human sickness has on tree planting effort on household, agricultural and government lands. In addition, the model incorporated shadow wage rates for females and males who tended to sick household members to provide a more realistic impact of the time spent caring for sick family members on a household decision making framework.

Variables affecting tree planting differed based on the type of trees planted and the location of planting. A head of the household was more likely to plant eucalyptus on agricultural land if the days a household member spent sick increased. They were more likely to plant other trees on agricultural land if the distance to the nearest market was great, there was an increase in the number of days they were sick, or if the market price for vegetables increased.

Of particular interest to this research was determining the variables that influence tree planting on government microdam land. The decision to plant eucalyptus on government land was affected by microdam age, the distance to the nearest healthcare center and the price of agricultural residues. The decision to plant other species on government land was affected by the distance to the nearest market and the price of agricultural residue. Households were less likely to plant trees on government land if the distance to the microdam was great, the price of cereal increased, or the price of fuelwood increased. The extent of planting eucalyptus on government land was largely determined by the distance to the nearest healthcare center; with an increased distance being related an increase in number of trees planted. The amount of planting of other trees on government land was positively affected by the total amount of land owned by the household, the amount of land rented to grow cereal, the distance to the nearest market, and the number of days males spent sick with malaria. The extent of planting other tree species on government land decreased as the distance to the nearest healthcare center increased.

The government of Ethiopia initiated the SAERT program with the desire to increase agricultural productivity and reverse forest degradation by encouraging tree planting on microdam sites. Based on the research we conducted, tree planting should be packaged with health incentives. For instance, we found that as males spent more days sick with malaria, their household was less likely to accept eucalyptus planting on government land. Perhaps access to anti-malarial drugs would not only serve to increase agricultural productivity, but also increase the acceptance of tree planting on government land. Such effort could be targeted to villages with irrigation from microdams – which we have identified as having a higher risk for malaria and schistosomiasis and a greater potential for increased agricultural productivity due to the irrigation.

Future research should be conducted which also links health and tree planting effort. Such research could focus on additional health concerns in developing countries, such as HIV, AIDS and malnutrition or could focus on other tree planting variables, such as access to extension facilities and use of improved seedlings. Research could also access the impact of health on the effectiveness of seedling planting; do households with a high number of days spent sick have lower seedling survival rates.

As developing countries desire to both increase productivity and decrease deforestation, amid such detrimental factors as high sickness rates, research should be undertaken that continues to examine the dynamic relationship between health and tree planting effort.

REFERENCES

Ahlback, Arnold J. (1995). Mobilizing Rural People in Tanzania to Tree Planting: Why and How. Ambio. Vol. 24, No. 5, pp. 304-310.

Amacher, G., W. Hyde, and K. Kanel. (1999). Nepali Fuelwood Production and Consumption: Regional and household distinctions, substitution, and successful intervention. Journal of Development Studies 35(4):138-163.

Amacher, Gregory S., Hyde, W. and Kanel K. (1996). Household Fuelwood Demand and Supply in Nepal's Tarai and Mid-Hills: Choice Between Cash Outlays and Labor Opportunity. World Development, Vol. 24, No. 11, pp. 1725-1736.

Amacher, G., W. Hyde, and M. Rafik. 1993. "Local adoption of new forestry technologies: An example from Pakistan's Northwest Frontier Province." *World Development*, 21(3): 445-453.
Audilert (1986)

Caviglia, Jill L. and Kahn, J. (2000). Diffusion of Sustainable Agriculture in the Brazilian Tropical Rain Forest: A Discrete Choice Analysis. Economic Development and Cultural Change, Vol. 49, No. 2, pp. 311-333.

Cline-Cole, R.A., Main, H.A.C. and Nichol, J.E. (1990). On Fuelwood Consumption, Population Dynamics and Deforestation in Africa. World Development. Vol. 18, No. 4, pp. 513-527.

Culyer, A. J. and Wagstaff, A. (1993). Equity and Equality in Health and Healthcare. Journal of Health Economics. Vol.12, No. 4, pp. 431-458.

Dewees, P.A. (1992). Social and Economic Incentives for Smallholder Tree Growing: A Case Study from Muranga District, Kenya. Community Forestry Case Study Series. No. 5. FAO, Rome. Italy.

Doorslaer, Evan, Wagstaff, A, et al. (1997). Income-Related Inequities in Health: Some International Comparisons. Journal of Health Economics. Vol. 16, No. 1, (20 pages).

Gerdtham U-G., Johansson M., Lundberg L. (1997). The Demand For Health: Results From New Measures of Health Capital. European Journal of Political Economy. Vol. 15, No. 3.

Ginsberg, Paul. (2000). Afforestation in Israel: A Source of Social Goods and Services. Journal of Forestry. Vol. 98, No. 3, pp. 32-36.

Grossman, Michael. (1972a). The Demand for Health: a Theoretical and Empirical Investigation. Occasional Paper: National Bureau of Economic Research. No. 119.

Hurni, Hans (1993). Famine in Somalia: Fate or Failure? Journal of Soil and Water Conservation. Vol. 48, No. 1, pp. 20-33.

Hocking, Drake, Hocking, A. and Islam, K. (1996). Trees on Farms in Bangladesh: 3. Farmers' species preferences for homestead trees, survival of new tree planting, and main causes of tree death. Agroforestry Systems. Vol. 33, pp. 231-247.

Hosier, Richard H. (1989). The Economics of Smallholder Agroforestry: Two Case Studies. World Development. Vol. 17, No. 11, pp. 1827-1839.

Jacoby, H.(1993). Shadow wages and peasant family labour supply. Review of Economic Studies. Vol. 60, No. 4, pp. 903-921.

Johansson, P-O; Lofgren, K-G. (1995). Wealth From Optimal Health. Journal of Health Economics. Vol. 14, No. 1,

Knapp, Keith C. and Sadorsky, Perry A. (2000). Economics of Agroforestry Production in Irrigated Agriculture. Journal of Agricultural and Resource Economics. Vol. 25, No. 1, pp. 286-306.

Lampiette, (1999). Do Husbands and Wives Make the Same Choices: Evidence from Northern Ethiopia. Economic Letters. Vol. 62, No. 2.

Madalla, .(1986).

Mann, R.D. (1990). Time Running Out: The Urgent Need for Tree Planting in Africa. The Ecologist. Vol. 20, No. 2, pp. 48-53.

Nibbering, J.W. (1999). Tree Planting on Deforested Farmlands, Sew Hills, Java Indonesia: Impact of Economic and Institutional Changes. Agroforestry Systems. Vol. 46, pp. 65-82.

Pohlmeier, Winfried and Ulrich, Volker. (1995). An Econometric Model of the Two-Part Decision Process in the Demand for Health. The Journal of Human Resources. Vol. 30, No. 2,

Price, L. and Campbell, B. (1998). Household Tree Holdings: A Case Study in Mutoko Communal Area, Zimbabwe. Agroforestry Systems. Vol. 39, pp. 205-210.

Salam, M.A., Noguchi, T and Koike, M. (2000). Understanding Why Farmers Plant Trees in the Homestead Agroforestry in Bangladesh. Agroforestry Systems. Vol. 50, pp. 77-93.

Shively, Gerald E. (1998). Economic Policies and the Environment: The Case of Tree Planting on Low-Income Farms in the Philippines. Environment and Development Economics. Vol. 3, pp. 83-104.

Sommer, Robert, et al (1994). The Social Benefits of Resident Involvement in Tree Planting. Journal of Arboriculture. Vol. 20, No. 3, pp. 170-175.

TABLES

Table 1. Abbreviated variable names and descriptions of the variables used in the survey and the Limdep input and output formulation, for a tree planting study conducted in Tigray, Ethiopia during the 1996 major crop season.

Abbreviation	Definition of Variable	Units
Hhage	Combined age of household members	Years
Hhsex	Gender of head of household	Male or Female
Hheduc	Number of years of education	Years
Mcrdmage	Age of the microdam	Years
Hhsize	Number of household members	Total people
Olandcer	Land owned and used for cereal	Timads
Olandveg	Land owned and used for vegetables	Timads
Olandoth	Land owned and used for other uses	Timads
Rlandcer	Land rented and used for cereal	Timads
Rlandveg	Land rented and used for vegetables	Timads
Rlandoth	Land rented and used for other uses	Timads
Rentfee	The rental land fee	Ethiopian Birr
Hseucalp	Eucalyptus planted on household land	Number of trees
Aleucalp	Eucalyptus planted on agriculture land	Number of trees
Goveuca	Eucalyptus planted on microdam land	Number of trees
Hsneem	Neem planted on household land	Number of trees
Alneem	Neem planted on agriculture land	Number of trees
Govneem	Neem planted on microdam land	Number of trees
Hsothtre	Other tree species planted on household land	Number of trees
Alothtre	Other tree species planted on agriculture land	Number of trees
Govothtr	Other tree specie planted on microdam land	Number of trees
Oxenno	Oxen owned by household	Number of ox
Horseno	Horses owned by household	Number of horses
Donkeyno	Donkey owned by household	Number of donkey

Abbreviation	Definition of Variable	Units
Mulesno	Mules owned by household	Number of mules
Camlesno	Camels owned by household	Number of camels
Cows	Cows owned by household	Number of cows
Sheep	Sheep owned by the household	Number of sheep
Goat	Goat owned by the household	Number of goat
Mhrdlcer	Male labor for cereal production	Man day (8hrs/work day)
Mhrdlveg	Male labor for vegetable production	Man day (8hrs/work day)
Mhrdlfwc	Male labor for fuelwood collection	Man day (8hrs/work day)
Mhrdlr	Male off-farm labor rate	Birr per man day
Mhrdlsk	Male time spent caring for the sick	Man day (8hrs/work day)
Mhrdlwgt	Male hired labor wage rate	Birr per man day
Fhrdlcer	Female labor for cereal production	Man day (8hrs/work day)
Fhrdlveg	Female labor for vegetable production	Man day (8hrs/work day)
Fhrdlfwc	Female labor for fuelwood collection	Man day (8hrs/work day)
Fhrdlr	Female off-farm labor rate	Birr per man day
Fhrdlsk	Female time spent caring for the sick	Man day (8hrs/work day)
Fhrdlwgt	Female hired labor wage rate	Birr per man day
Mhhalsck	Male labor time spent sick	Days Sick
Mhhalskm	Male sick with malaria	Days Sick
Fhhalsk	Female labor time spent sick	Days sick
Chldlsck	Child time spent sick	Days sick
Housesiz	Size of the house	
housecon	Income of the household	Ethiopian Birr
Impstove	Use of improved stove	Yes/No
Dmarket	Distance to nearest market	Kilometers
Dhealthc	Distance to nearest healthcare center	Kilometers
Dmcrodam	Distance to nearest microdam	Kilometers
Dfwcarea	Distance to fuelwood collection area	Kilometers

Abbreviation	Definition of Variable	Units
Cerprice	Harvest time cereal price	Birr per kilogram
Vegprice	Harvest time vegetable price	Birr per kilogram
Fwprice	Fuelwood price	Birr per donkey load
Arprice	Agricultural Residue price	Birr per 30 kilo sack

Table 2. Descriptive statistics of select variables collected in Tigray, Ethiopia during the 1996 major crop season.

Variable	Mean	Standard Deviation	Number of Cases
Household Age (years)	162.227	406.753	679
Household Sex	15.921	68.330	680
Household Education (years)	1.029	2.297	679
Microdam Age (years)	5.149	3.082	680
Household Size (number)	4.999	2.263	679
Cereal Land Area (timads)	1.210	2.818	730
Vegetable Land Area (timads)	0.114	0.483	730
Rented Land Fee (Birr)	23.641	53.720	721
Male Sick Days	10.255	25.828	730
Female Sick Days	15.270	34.672	730
Child Sick Days	3.032	11.871	729
Improved Stove (yes/no)	0.144	0.351	730
Distance to Market (km)	7.912	4.416	732
Distance to Health Center (km)	7.577	4.683	731
Distance to Microdam (km)	1.709	2.393	730
Distance to Fuelwood (km)	11.812	18.849	730
Cereal Price (Birr/kilo)	1.737	0.416	731
Vegetable Price (Birr/kilo)	2.216	0.525	698
Fuelwood Price (Birr/donkey load)	13.884	5.393	722
Agricultural Residue Price (Birr/30 kilo)	14.664	5.841	635
Male Sick Days with Malaria (yes/no)	0.204	0.404	729

Table 3. Descriptive statistics of select variables collected in Tigray, Ethiopia during the 1996 major crop season, delineated by control and intervention villages.

	Control Villages		Intervention Villages	
Variable	Mean	Standard Deviation	Mean	Standard Deviation
Microdam Age (years)			5.075	3.219
Household Size	5.255	2.231	5.093	2.248
Household Total Income (Birr)	1047	708.684	1080.72	854.916
Medical Health Expenses (Birr)	13.68	46.686	23.097	55.233
Total Cereal Produced (kilo)	452.9	283.992	503.763	421.631
Total Vegetable Produced (kilo)	17.46	32.64	25.113	63.218
Total Fuelwood Collected (donkey loads)	16.46	14.492	11.229	15.222
Total Own Landholding (timads)	4.605	3.298	4.727	2.474
Total Rental Landholding (timads)	0.842	1.888	1.604	3.428
Forest Stock Level (timads)	46.76	175.283	65.231	148.387
Animal Units (total owned)	3.698	2.762	3.644	3.632
No. of Oxen Owned	1.462	1.103	1.308	1.13
Male Labor Wage Rate (Birr)	9.343	2.564	9.041	2.545
Female Labor Wage Rate (birr)	6.735	1.648	6.632	2.207
Male Labor for Cereal Produced (man days)	38.15	33.076	38.28	45.032
For Vegetables Produced	0.89	5.402	1.682	8.89
For Fuelwood Collected	11.83	24.518	6.157	12.599
Male Off-Farm Wage Labor (man days)	16.31	30.472	5.627	22.287
Male Labor Taking Care of Sick (man days)	0.171	1.253	0.983	7.919
Male Labor Time Spent Sick (man days)	6.085	13.83	11.847	28.344
Female Labor for Cereal Produced (man days)	17.73	23.788	17.633	26.588
For Vegetables Produced	0.385	2.75	0.398	3.777
For Fuelwood Collected	12.38	23.536	8.107	21.385
Female Off-Farm Wage Labor (man days)	7.271	15.194	1.549	11.006
Female Labor Taking Care of Sick (man day)	0.704	4.601	1.158	7.288
Female Labor Time Spent Sick (man days)	9.741	19.11	16.696	36.845
Malaria Incidence Dummy (0,1)	0.194	0.396	0.319	0.467
Ownership of Improved Stove (0,1)	0.073	0.26	0.179	0.384
Irrigation Dummy (0,1)	0.049	0.215	0.157	0.365
Distance to Market/Health Center (km)	9.63	4.453	7.033	4.136
Distance to Agricultural Land (km)	2.247	2.66	2.117	2.962
Distance to Microdam (km)	5.524	1.871	1.86	1.081
Distance to Fuelwood Collection Area (km)	10.19	8.8829	7.741	8.977
Harvest Time Cereal Price (Birr/kilo)	1.676	0.373	1.77	0.433
Harvest Time Vegetable Price (Birr/kilo)	2.16	0.466	2.228	0.536
Fuelwood Price (Birr/donkey load)	13.33	4.091	14.202	5.891
Agricultural Residue Price (Birr/ 30 kilo sack)	15	5.724	15.172	5.417

Table 4. Descriptive statistics of select variables collected in Tigray, Ethiopia during the 1996 major crop season, delineate by control and intervention villages, continued.

	Control Villages		Intervention Villages	
Variable	Mean	Standard Deviation	Mean	Standard Deviation
Eucalyptus on Household Land (no.)	53.90	154.519	30.99	151.406
Other Trees on Household Land (no.)	34.87	212.276	14.13	83.906
Eucalyptus on Agricultural Land (no.)	10.10	45.776	7.45	27.308
Other Trees on Agricultural Land (no.)	15.02	125.732	9.68	86.148
Eucalyptus on Government Land (no.)	4.32	14.490	6.97	17.250
Other Trees on Government Land (no.)	41.19	182.342	11.55	75.669
N: Number of Observations	247		483	

Table 5. Tobit results for Eucalyptus and other tree species planted on agricultural land within Tigray, Ethiopia during the major crop season in 1996.

	Eucalyptus Trees		Other Tree Species	
Variable	Planting Decision	Planting Extent	Planting Decision	Planting Extent
NONCONTROL	2.34E-04 (0.001)	3.01E+00 (0.117)	-0.2286 (-1.279)	-17.1273 (-0.261)
Microdam Age	-8.63E-03 (-0.315)	8.563* (1.886)	-1.46E-1*** (-3.217)	9.57E+1*** (3.452)
Rented Land for Cereal	2.46E-02 (1.031)	5.88E-02 (0.017)	1.37E-02 (0.529)	-9.39E+00 (-1.335)
Rented Land for Vegetables	5.03E-02 (0.379)	2.45E+01 (1.28)	4.93E-02 (0.355)	-1.17E+2** (-1.989)
Total No. of Animals	-1.49E-02 (-0.667)	-2.54E+00 (-0.604)	4.91E-02** (2.025)	2.39E+01** (2.347)
Total Land	-1.38E-02 (-0.494)	1.65E+00 (0.324)	4.90E-02* (1.662)	1.21E+1 (1.388)
Total Days Spent Sick	3.93E-03*** (2.619)	0.1675 (0.396)	3.74E-03** (2.214)	-9.04E-01 (-1.338)
Improved Stove Use	1.03E-01 (0.475)	-4.75E+1 (-1.352)	1.70E-01 (0.644)	4.17E+00 (0.046)
Distance to Market	-4.05E-02 (-0.828)	5.93E+00 (0.697)	0.1777*** (3.423)	-2.20E+01 (-1.02)
Distance to Health Center	-8.68E-02* (-1.929)	2.00E+00 (0.175)	-2.49E-1*** (-5.358)	1.71E+01 (0.534)
Distance to Microdam	1.83E-02 (0.438)	-6.74E+0 (-0.992)	5.10E-02 (0.888)	-25.2343 (-1.022)
Distance to Fuelwood Collection	7.91E-03* (1.952)	-6.37E-02 (-0.088)	-2.58E-03 (-0.534)	-2.17E+00 (-1.08)
Price of Cereal	2.4E-01 (1.398)	-2.41E+1 (-0.802)	-9.46E-1*** (-4.569)	2.57E+02* (1.8)
Price of Vegetables	-9.26E-02 (-0.736)	2.98E+00 (0.108)	0.2437** (1.978)	-3.17E+1 (-0.74)
Price of Fuelwood	2.88E-03 (0.145)	2.07E+00 (0.703)	5.84E-03 (0.224)	-1.48E+1 (-1.456)
Price of Agricultural Residue	3.73E-02** (2.357)	1.81E+00 (0.467)	1.43E-03 (0.071)	13.4071* (1.809)
Male Days Sick with Malaria	-4.27E-01** (-2.026)	50.0718 (0.865)	3.28E-01* (1.648)	-70.1878 (-0.881)
Female Hired Wage Labor Rate	-1.53E-01*** (-4.065)	24.2548 (1.159)	5.64E-02 (1.298)	1.78E+00 (0.111)
Shadow Wage for Males	3.01E-02** (2.069)	-1.18E+00 (-0.26)	-1.39E-02 (-0.858)	-1.34E+1 (-1.343)
Shadow Wage for Females	-3.29E-02 (-0.624)	-3.3E+00 (-0.173)	9.59E-03 (0.284)	5.9135 (0.597)
Lambda		-137.9244 (-1.16)		-2.30E+02 (-1.188)

Table 6. Tobit results for Eucalyptus and other tree species found on household land in Tigray, Ethiopia during the major crop season of 1996.

Variable	Eucalyptus Trees		Other Tree Species	
	Planting Decision	Planting Extent	Planting Decision	Planting Extent
NONCONTROL	-2.39E-01* (-1.926)	1.41E+01 (0.301)	-9.15E-02 (-0.676)	-13.3575 (-0.522)
Microdam Age	1.99E-04 (0.009)	-14.9086*** (-2.587)	1.75E-02 (0.732)	2.8721 (0.689)
Rented Land for Cereal	-1.68E-02 (-0.71)	0.2907 (0.034)	7.13E-03 (0.276)	-2.9686 (-0.732)
Rented Land for Vegetables	-6.08E-02 (-0.525)	245E+01 (0.755)	1.18E-02 (0.091)	-40.903 (-1.473)
Total No. of Animals	1.30E-02 (0.723)	-4.07E+00 (-0.835)	3.06E-02 (1.553)	4.7779 (1.27)
Total Land	-2.96E-02 (-1.292)	1.53E+00 (0.199)	3.12E-02 (1.242)	14.808*** (4.094)
Total Days Spent Sick	1.27E-03 (0.99)	-2.30E-01 (-0.658)	2.83E-03** (2.1)	0.208 (0.804)
Improved Stove Use	6.52E-02 (0.367)	-1.60E+1 (-0.333)	-0.2805 (-1.403)	-65.5373 (-1.544)
Distance to Market	-1.26E-1*** (-2.785)	1.5718 (0.074)	0.2831*** (4.957)	23.043** (2.161)
Distance to Health Center	1.03E-01** (2.464)	1.40E+00 (0.076)	-0.2498*** (-4.776)	-22.4602** (-2.266)
Distance to Microdam	8.44E-02** (-2.496)	3.68E+00 (0.293)	-0.1489*** (-3.877)	-16.2812 (-1.33)
Distance to Fuelwood Collection	9.23E-03** (2.507)	2.78E-03 (0.002)	-1.26E-2*** (-2.963)	-0.3474 (-0.247)
Price of Cereal	3.11E-01** (2.119)	8.04E+01* (1.86)	7.04E-02 (0.427)	77.6889*** (2.854)
Price of Vegetables	-1.47E-01 (-1.524)	22.7579 (0.508)	0.2022* (1.914)	-8.3396 (-0.489)
Price of Fuelwood	-2.96E-03 (-0.191)	1.96E+00 (0.476)	-4.88E-2*** (-2.954)	-13.0867*** (-3.136)
Price of Agricultural Residue	-1.19E-02 (-0.994)	-1.12E+00 (-0.329)	-4.01E-2*** (-3.177)	-4.33E-02 (-0.013)
Male Days Sick with Malaria	-0.2891* (-1.814)	1.41E+02** (2.481)	0.1444 (0.868)	29.4286 (1.031)
Female Hired Wage Labor Rate	6.54E-03 (0.245)	2.21E+01** (2.45)	1.35E-02 (0.473)	-1.3028 (-0.198)
Shadow Wage for Males	1.79E-02 (1.263)	-4.2742 (-1.007)	-5.02E-03 (-0.362)	-2.7799 (-1.062)
Shadow Wage for Females	-3.95E-02 (-0.772)	8.7892 (0.406)	5.61E-02 (0.931)	13.6155*** (2.851)
Lambda		-2.19E+02 (-1.204)		116.3278 (1.276)

Table 7. Tobit results for Eucalyptus and other tree species found on governmental land in Tigray, Ethiopia during the major crop season of 1996.

	Eucalyptus Trees		Other Tree Species	
Variable	Planting Decision	Planting Extent	Planting Decision	Planting Extent
NONCONTROL	-7.33E-03 (-0.049)	-2.2959 (-0.3)	-0.2635 (-1.594)	-48.1451* (-1.709)
Microdam Age	1.13E-01*** (4.469)	2.1132 (1.027)	2.32E-02 (0.775)	-2.5741 (-0.518)
Rented Land for Cereal	-2.11E-02 (-0.751)	0.2585 (0.15)	-2.63E-02 (-0.633)	19.2377*** (3.241)
Rented Land for Vegetables	5.14E-02 (0.392)	2.4790 (0.455)	-4.09E-02 (-0.209)	-20.6551 (-0.792)
Total No. of Animals	1.09E-02 (0.487)	0.7975 (0.8)	4.18E-02 (1.547)	-4.8991 (-1.149)
Total Land	-2.39E-03 (-0.089)	1.723 (1.395)	-1.71E-02 (-0.548)	17.5156*** (5.185)
Total Days Spent Sick	3.36E-04 (0.24)	-7.05E-02 (-1.105)	-1.08E-03 (-0.539)	0.2582 (0.715)
Improved Stove Use	-1.15E-01 (-0.56)	0.7824 (0.082)	-0.4906* (-1.724)	-53.8302 (-0.969)
Distance to Market	-2.46E-1*** (-3.905)	-9.2554 (-1.588)	0.3422*** (5.41)	63.3736*** (4.702)
Distance to Health Center	2.60E-01*** (4.218)	12.2675** (2.052)	-0.1799*** (-3.288)	-59.1716*** (-8.496)
Distance to Microdam	-1.37E-1*** (-3.588)	-3.0502 (-1.028)	-0.3671*** (-6.206)	-9.2237 (-0.332)
Distance to Fuelwood Collection	7.65E-03* (1.71)	8.76E-02 (0.3)	8.79E-03 (1.34)	-1.4968 (-0.97)
Price of Cereal	-9.9E-01*** (-5.205)	-31.1683 (-1.48)	-0.6298*** (-3.193)	-19.3637 (-0.505)
Price of Vegetables	-6.90E-02 (-0.601)	-11.4912* (-1.754)	-0.1734 (-1.391)	-2.6973 (-0.096)
Price of Fuelwood	6.91E-02*** (-3.993)	-1.1520 (-0.766)	-8.29E-02*** (-3.989)	-9.6794 (-1.56)
Price of Agricultural Residue	1.02E-01*** (6.497)	2.0998 (1.219)	4.94E-02*** (3.22)	3.1919 (0.878)
Male Days Sick with Malaria	-3.21E-01* (-1.694)	-1.6996 (-0.153)	-0.1114 (-0.519)	101.8581*** (2.83)
Female Hired Wage Labor Rate	2.95E-02 (0.932)	0.2658 (0.16)	-9.80E-03 (-0.253)	24.2415** (2.395)
Shadow Wage for Males	5.95E-02 (1.597)	0.8645 (1.376)	-1.44E-02 (-0.378)	11.2432 (1.595)
Shadow Wage for Females	1.13E-02 (0.299)	-0.1668 (-0.136)	-6.68E-03 (-0.097)	17.4187 (3.637)
Lambda		44.1319 (1.867)		-38.6836 (-0.458)

Table 8. Hypothesis testing results for sickness and microdam variables, reporting the values of likelihood ratio test statistics.

Location of Planting	Tree Species	Sickness Variables (d.f. = 2)	Microdam Variables (d.f. = 2)
Agricultural Land	Eucalyptus Trees	10.14*** (0.01)	0.260 (0.88)
	Other Tree Species	8.034 (0.02)	13.195** (0.001)
Household Land	Eucalyptus Trees	3.95* (0.139)	6.53** (0.038)
	Other Tree Species	5.58** (0.06)	16.17*** (0.0003)
Government Land	Eucalyptus Trees	2.92	28.28*** (7.22E-7)
	Other Tree Species	0.68	56.28*** (6.1E-13)

APPENDIX A: INDIRECT UTILITY FUNCTION EXPANDED

Impact of Health and Microdams

More precisely, consider the impact of health and microdams to the indirect utility function $\hat{V}$,

$$\frac{\partial \hat{V}}{\partial H} = l_F p_F \frac{\partial F(.)}{\partial H} + l_A p_A \frac{\partial Q(.)}{\partial H} + \frac{\partial \hat{V}}{\partial \hat{w}} \frac{\partial \hat{w}}{\partial H}$$

$$\frac{\partial \hat{V}}{\partial D} = l_F p_F \frac{\partial F\mathbf{(.)}}{\partial D} + l_A p_A \frac{\partial Q\mathbf{(.)}}{\partial D} + \frac{\partial \hat{V}}{\partial \hat{w}} \frac{\partial \hat{w}}{\partial D} + \frac{\partial \hat{V}}{\partial H} \frac{\partial H}{\partial D}$$

The first two terms in represent the effects of health and microdams on production. The third term in represents changes in the opportunity costs of forgoing work and caring for the sick, from either direct health changes or effects of microdams, that cause changes in the implicit wage. Finally, the later term in the second condition measures the impact of dam-induced health changes on utility.

APPENDIX B: PLANTING DECISION LIMDEP OUTPUT FILES

The Decision to Plant Eucalyptus on Agricultural Land

```
--> select; lhs=aleucalp;rhs=noncntrl,hhage,hhsex,hheduc,mcrdmage,hhsize,rlan...
    ,rlandveg,animalno,landtot,rentfee,totsck
    ,impstove,dmarket,dhealthc,dmcrodam,dfwcarea,cerprice,vegprice,fwprice,ar...
    ,mhhalskm,fhrdlwgt,shadowm, shadowf$
```

```
Normal exit from iterations. Exit status=0.

              +---------------------------------------------+
              | Binomial Probit Model                        |
              | Maximum Likelihood Estimates                 |
              | Dependent variable             DHSEUCAL      |
              | Weighting variable                  ONE      |
              | Number of observations              559      |
              | Iterations completed                  7      |
              | Log likelihood function       -345.7362      |
              | Restricted log likelihood     -379.6970      |
              | Chi-squared                    67.92176      |
              | Degrees of freedom                   24      |
              | Significance level            .4492525E-05   |
              | Results retained for SELECTION model.        |
              +---------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
Index function for probability					
NONCNTRL	-.2386877682	.12395640	-1.926	.0542	.64221825
HHAGE	.1093636118E-02	.66102866E-03	1.654	.0980	160.77102
HHSEX	-.8000491835E-02	.53955716E-02	-1.483	.1381	16.898032
HHEDUC	.1685553854E-01	.30694448E-01	.549	.5829	.90339893
MCRDMAGE	.1986628786E-03	.22525140E-01	.009	.9930	4.9803220
HHSIZE	.3567067035E-01	.27137795E-01	1.314	.1887	4.9589982
RLANDCER	-.1677607612E-01	.23618185E-01	-.710	.4775	1.3937030
RLANDVEG	-.6083040236E-01	.11586098	-.525	.5996	.13273703
ANIMALNO	.1301857946E-01	.17996783E-01	.723	.4694	3.6046512
LANDTOT	-.2958816831E-01	.22897436E-01	-1.292	.1963	4.7792719
RENTFEE	.1863354846E-02	.12374402E-02	1.506	.1321	25.576512
TOTSCK	.1268083124E-02	.12806554E-02	.990	.3221	28.638640

IMPSTOVE	.6518179277E-01	.17775023	.367	.7138	.13416816
DMARKET	-.1258271001	.45180604E-01	-2.785	.0054	8.1398927
DHEALTHC	.1034661580	.41986276E-01	2.464	.0137	7.6280859
DMCRODAM	-.8436819194E-01	.33807234E-01	-2.496	.0126	1.5527191
DFWCAREA	.9230955721E-02	.36818629E-02	2.507	.0122	11.581208
CERPRICE	.3114639416	.14696789	2.119	.0341	1.7200670
VEGPRICE	-.1466085071	.96188717E-01	-1.524	.1275	2.2394454
FWPRICE	-.2957645064E-02	.15459386E-01	-.191	.8483	14.303435
ARPRICE	-.1194467153E-01	.12017698E-01	-.994	.3203	14.962809
MHHALSKM	-.2890561911	.15937335	-1.814	.0697	.21824687
FHRDLWGT	.6541635234E-02	.26752418E-01	.245	.8068	6.1826297
SHADOWM	.1790293771E-01	.14179744E-01	1.263	.2067	.53972987
SHADOWF	-.3950447424E-01	.51162859E-01	-.772	.4400	.16477246

Frequencies of actual & predicted outcomes
Predicted outcome has maximum probability.

Actual	Predicted 0	Predicted 1	Total
0	258	68	326
1	125	108	233
Total	383	176	559

The Decision to Plant Other Trees on Agricultural Land

--> select; lhs=alothtre;rhs=noncntrl,hhage,hhsex,hheduc,mcrdmage,hhsize,rlancer ,rlandveg,animalno,landtot,rentfee,totsck,impstove,dmarket,dhealthc ,dmcrodam,dfwcarea,cerprice,vegprice,fwprice,ar...,mhhalskm,fhrdlwgt, shadowm, shadowf$

Normal exit from iterations. Exit status=0.

```
+--------------------------------------------+
| Binomial Probit Model                      |
| Maximum Likelihood Estimates               |
| Dependent variable            DALEUCAL     |
| Weighting variable                 ONE     |
| Number of observations             559     |
| Iterations completed                 6     |
| Log likelihood function       -215.1556
| Restricted log likelihood     -264.0843    |
| Chi-squared                    97.85749    |
| Degrees of freedom                  24     |
| Significance level            .0000000     |
| Results retained for SELECTION model.      |
+--------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
NONCNTRL	.2341876711E-03	.15910141	.001	.9988	.64221825
HHAGE	-.1842921165E-03	.22898566E-03	-.805	.4209	160.77102
HHSEX	.3289124524E-03	.11318272E-02	.291	.7714	16.898032
HHEDUC	-.3884641708E-01	.42227619E-01	-.920	.3576	.90339893
MCRDMAGE	-.8625122927E-02	.27390555E-01	-.315	.7528	4.9803220
HHSIZE	.2922779330E-02	.33794238E-01	.086	.9311	4.9589982
RLANDCER	.2459603865E-01	.23862035E-01	1.031	.3027	1.3937030
RLANDVEG	.5033180149E-01	.13292000	.379	.7049	.13273703

ANIMALNO	-.1488444469E-01	.22317513E-01	-.667	.5048	3.6046512
LANDTOT	-.1375843210E-01	.27841055E-01	-.494	.6212	4.7792719
RENTFEE	.1333726538E-02	.12982232E-02	1.027	.3043	25.576512
TOTSCK	.3926481050E-02	.14990318E-02	2.619	.0088	28.638640
IMPSTOVE	.1034390550	.21793337	.475	.6350	.13416816
DMARKET	-.4046013135E-01	.48893855E-01	-.828	.4079	8.1398927
DHEALTHC	-.8677355298E-01	.44978830E-01	-1.929	.0537	7.6280859
DMCRODAM	.1832601015E-01	.41867113E-01	.438	.6616	1.5527191
DFWCAREA	.7909560094E-02	.40511192E-02	1.952	.0509	11.581208
CERPRICE	.2456727340	.17575178	1.398	.1622	1.7200670
VEGPRICE	-.9262296792E-01	.12577661	-.736	.4615	2.2394454
FWPRICE	.2875757699E-02	.19778095E-01	.145	.8844	14.303435
ARPRICE	.3733308507E-01	.15836547E-01	2.357	.0184	14.962809
MHHALSKM	-.4269599315	.21076638	-2.026	.0428	.21824687
FHRDLWGT	-.1534436767	.37751608E-01	-4.065	.0000	6.1826297
SHADOWM	.3006566253E-01	.14529331E-01	2.069	.0385	.53972987
SHADOWF	-.3287447076E-01	.52719322E-01	-.624	.5329	.16477246

Frequencies of actual & predicted outcomes
Predicted outcome has maximum probability.

	Predicted		
Actual	0	1	Total
0	445	13	458
1	80	21	101
Total	525	34	559

The Decision to Plant Eucalyptus on Household Land

```
--> select; lhs=hseucalp;rhs=noncntrl,hhage,hhsex,hheduc,mcrdmage,hhsize,rlan...
    ,rlandveg,animalno,landtot,rentfee,totsck
    ,impstove,dmarket,dhealthc,dmcrodam,dfwcarea,cerprice,vegprice,fwprice,ar...
    ,mhhalskm,fhrdlwgt,shadowm, shadowf$
```

```
Normal exit from iterations. Exit status=0.

              +---------------------------------------------+
              | Binomial Probit Model                       |
              | Maximum Likelihood Estimates                |
              | Dependent variable              DGVEUCA     |
              | Weighting variable                  ONE     |
              | Number of observations              559     |
              | Iterations completed                  6     |
              | Log likelihood function       -249.2375     |
              | Restricted log likelihood     -322.0623     |
              | Chi-squared                    145.6497     |
              | Degrees of freedom                   24     |
              | Significance level             .0000000     |
              | Results retained for SELECTION model.       |
              +---------------------------------------------+

+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+

          Index function for probability

 NONCNTRL -.7325876104E-02  .14884736        -.049   .9607  .64221825
 HHAGE    -.1629812821E-03  .26372664E-03    -.618   .5366  160.77102
 HHSEX     .7975355790E-03  .15871633E-02     .502   .6153  16.898032
 HHEDUC   -.6374138395E-01  .35947177E-01   -1.773   .0762  .90339893
 MCRDMAGE  .1129469999      .25272323E-01    4.469   .0000  4.9803220
 HHSIZE    .1151588643E-02  .32119623E-01     .036   .9714  4.9589982
 RLANDCER -.2106536207E-01  .28037897E-01    -.751   .4525  1.3937030
 RLANDVEG  .5139554270E-01  .13114109         .392   .6951  .13273703
 ANIMALNO  .1090171365E-01  .22397582E-01     .487   .6264  3.6046512
```

LANDTOT	-.2392841623E-02	.26895151E-01	-.089	.9291	4.7792719
RENTFEE	.9581340861E-04	.16315891E-02	.059	.9532	25.576512
TOTSCK	.3361258675E-03	.14033942E-02	.240	.8107	28.638640
IMPSTOVE	-.1149547777	.20521945	-.560	.5754	.13416816
DMARKET	-.2464007802	.63093280E-01	-3.905	.0001	8.1398927
DHEALTHC	.2597143521	.61573264E-01	4.218	.0000	7.6280859
DMCRODAM	-.1365996161	.38070526E-01	-3.588	.0003	1.5527191
DFWCAREA	.7650395778E-02	.44727320E-02	1.710	.0872	11.581208
CERPRICE	-.9900565563	.19020811	-5.205	.0000	1.7200670
VEGPRICE	-.6902104869E-01	.11485004	-.601	.5479	2.2394454
FWPRICE	-.6912419032E-01	.17309290E-01	-3.993	.0001	14.303435
ARPRICE	.1021437070	.15721826E-01	6.497	.0000	14.962809
MHHALSKM	-.3210911770	.18950603	-1.694	.0902	.21824687
FHRDLWGT	.2953561529E-01	.31679460E-01	.932	.3512	6.1826297
SHADOWM	.5945583388E-01	.37227697E-01	1.597	.1102	.53972987
SHADOWF	.1126861463E-01	.37625052E-01	.299	.7646	.16477246

Frequencies of actual & predicted outcomes
Predicted outcome has maximum probability.

	Predicted		
Actual	0	1	Total
0	384	28	412
1	85	62	147
Total	469	90	559

The Decision to Plant Other Trees on Household Land

```
--> select; lhs=hsothtre;rhs=noncntrl,hhage,hhsex,hheduc,mcrdmage,hhsize,rlan...
    ,rlandveg,animalno,landtot,rentfee,totsck
    ,impstove,dmarket,dhealthc,dmcrodam,dfwcarea,cerprice,vegprice,fwprice,ar...
    ,mhhalskm,fhrdlwgt,shadowm, shadowf$
```

```
          +------------------------------------------------------------+
          | Sample Selection Model                                     |
          | Probit selection equation based on DHSOTHRE                |
          | Selection rule is: Observations with DHSOTHRE =  1         |
          | Results of selection:                                      |
          |                   Data points     Sum of weights           |
          | Data set               557              557.0              |
          | Selected sample        224              224.0              |
          +------------------------------------------------------------+
```

```
+-----------------------------------------------------------------------+
| Sample Selection Model                                                |
| Two stage   least squares regression    Weighting variable = none     |
| Dep. var. = HSOTHTRE Mean=   60.24032738    , S.D.=   180.8889991     |
| Model size: Observations =     224, Parameters =  26, Deg.Fr.=    198 |
| Residuals:  Sum of squares= 4561153.404    , Std.Dev.=      151.77657 |
| Fit:        R-squared=  .292823, Adjusted R-squared =          .20353 |
|             (Note:  Not using OLS.  R-squared is not bounded in [0,1] |
| Model test: F[ 25,    198] =    3.28,    Prob value =          .00000 |
| Diagnostic: Log-L =  -1429.0435, Restricted(b=0) Log-L =   -1481.6670 |
|             LogAmemiyaPrCrt.=   10.155, Akaike Info. Crt.=     12.991 |
| Standard error corrected for selection.....    175.34                 |
| Correlation of disturbance in regression                              |
| and Selection Criterion (Rho).............    .66343                  |
+-----------------------------------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
NONCNTRL	-13.35748981	25.590632	-.522	.6017	.58482143
HHAGE	-.4210245928E-01	.37529494E-01	-1.122	.2619	153.30357
HHSEX	.1633484575	.16323026	1.001	.3170	18.674107

HHEDUC	-8.069129882	5.8686763	-1.375	.1691	1.1294643
MCRDMAGE	2.872142087	4.1709080	.689	.4911	4.9151786
HHSIZE	-14.49727740	5.2759796	-2.748	.0060	4.9903125
RLANDCER	-2.968623232	4.0570937	-.732	.4643	1.2656250
RLANDVEG	-40.90304557	27.769354	-1.473	.1408	.10491071
ANIMALNO	4.777910617	3.7627679	1.270	.2042	3.8794643
LANDTOT	14.80795285	3.6166708	4.094	.0000	5.0652085
RENTFEE	.1968578403	.34097638	.577	.5637	19.651071
TOTSCK	.2080444902	.25872590	.804	.4213	39.772321
IMPSTOVE	-65.53733498	42.445490	-1.544	.1226	.98214286E-01
DMARKET	23.04302759	10.662143	2.161	.0307	7.3625000
DHEALTHC	-22.46020749	9.9120596	-2.266	.0235	6.2535714
DMCRODAM	-16.28119344	12.238534	-1.330	.1834	.94196429
DFWCAREA	-.3474476670	1.4050286	-.247	.8047	7.1515402
CERPRICE	77.68892374	27.221071	2.854	.0043	1.6353393
VEGPRICE	-8.339603008	17.066290	-.489	.6251	2.1745536
FWPRICE	-13.08669002	4.1731650	-3.136	.0017	12.413348
ARPRICE	-.4333193408E-01	3.3807039	-.013	.9898	13.299464
MHHALSKM	29.42856752	28.544795	1.031	.3026	.31250000
FHRDLWGT	-1.302833458	6.5774380	-.198	.8430	6.3683482
SHADOWM	-2.779950220	2.6168976	-1.062	.2881	.61499597
SHADOWF	13.61554743	4.7761091	2.851	.0044	.32726285
LAMBDA	116.3278253	91.161607	1.276	.2019	.76204897

The Decision to Plant Eucalyptus on Government Land

```
--> select; lhs=goveuca;rhs=noncntrl,hhage,hhsex,hheduc,mcrdmage,hhsize,rlandcer
    ,rlandveg,animalno,landtot,rentfee,totsck
    ,impstove,dmarket,dhealthc,dmcrodam,dfwcarea,cerprice,vegprice,fwprice,ar...
    ,mhhalskm,fhrdlwgt,shadowm, shadowf$

Normal exit from iterations. Exit status=0.

              +---------------------------------------------+
              | Binomial Probit Model                       |
              | Maximum Likelihood Estimates                |
              | Dependent variable             DGVOTHRE     |
              | Weighting variable                  ONE     |
              | Number of observations              559     |
              | Iterations completed                  9     |
              | Log likelihood function       -175.0492     |
              | Restricted log likelihood     -284.1043     |
              | Chi-squared                    218.1102     |
              | Degrees of freedom                   24     |
              | Significance level             .0000000     |
              | Results retained for SELECTION model.       |
              +---------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
Index function for probability					
NONCNTRL	-.2635060471	.16535265	-1.594	.1110	.64221825
HHAGE	.1924703865E-02	.11920968E-02	1.615	.1064	160.77102
HHSEX	-.2108162951E-01	.12301461E-01	-1.714	.0866	16.898032
HHEDUC	-.6738331665E-01	.43556282E-01	-1.547	.1219	.90339893
MCRDMAGE	.2323465757E-01	.29972032E-01	.775	.4382	4.9803220
HHSIZE	.6905293875E-02	.34985621E-01	.197	.8435	4.9589982
RLANDCER	-.2632323243E-01	.41559209E-01	-.633	.5265	1.3937030
RLANDVEG	-.4094859075E-01	.19607793	-.209	.8346	.13273703
ANIMALNO	.4181991843E-01	.27034254E-01	1.547	.1219	3.6046512
LANDTOT	-.1710059618E-01	.31186109E-01	-.548	.5835	4.7792719

RENTFEE	-.3459992645E-03	.20688095E-02	-.167	.8672	25.576512
TOTSCK	-.1076111133E-02	.19951564E-02	-.539	.5896	28.638640
IMPSTOVE	-.4905764860	.28460022	-1.724	.0848	.13416816
DMARKET	.3421595277	.63245282E-01	5.410	.0000	8.1398927
DHEALTHC	-.1798668369	.54704290E-01	-3.288	.0010	7.6280859
DMCRODAM	-.3670515531	.59147610E-01	-6.206	.0000	1.5527191
DFWCAREA	.8794411056E-02	.65614959E-02	1.340	.1801	11.581208
CERPRICE	-.6297706702	.19725043	-3.193	.0014	1.7200670
VEGPRICE	-.1733656722	.12465520	-1.391	.1643	2.2394454
FWPRICE	-.8289582543E-01	.20783512E-01	-3.989	.0001	14.303435
ARPRICE	.4943140801E-01	.15351544E-01	3.220	.0013	14.962809
MHHALSKM	-.1114047260	.21462680	-.519	.6037	.21824687
FHRDLWGT	-.9803927368E-02	.38810431E-01	-.253	.8006	6.1826297
SHADOWM	-.1442160897E-01	.38106938E-01	-.378	.7051	.53972987
SHADOWF	-.6679232660E-02	.69038388E-01	-.097	.9229	.16477246

Frequencies of actual & predicted outcomes
Predicted outcome has maximum probability.

	Predicted			
Actual	0	1	|	Total
0	430	14	|	444
1	43	72	|	115
Total	473	86	|	559

The Decision to Plant Other Trees on Government Land

```
--> select; lhs=govothtr;rhs=noncntrl,hhage,hhsex,hheduc,mcrdmage,hhsize,rlan...
    ,rlandveg,animalno,landtot,rentfee,totsck
    ,impstove,dmarket,dhealthc,dmcrodam,dfwcarea,cerprice,vegprice,fwprice,ar...
    ,mhhalskm,fhrdlwgt,shadowm, shadowf$
```

```
Normal exit from iterations. Exit status=0.

              +---------------------------------------------+
              | Binomial Probit Model                       |
              | Maximum Likelihood Estimates                |
              | Dependent variable             DHSOTHRE     |
              | Weighting variable                  ONE     |
              | Number of observations              557     |
              | Iterations completed                  6     |
              | Log likelihood function       -295.5048     |
              | Restricted log likelihood     -375.3487     |
              | Chi-squared                    159.6877     |
              | Degrees of freedom                   24     |
              | Significance level             .0000000     |
              | Results retained for SELECTION model.       |
              +---------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
Index function for probability					
NONCNTRL	-.9147929680E-01	.13528422	-.676	.4989	.64093357
HHAGE	-.9354037814E-04	.24820803E-03	-.377	.7063	161.21364
HHSEX	.1978448444E-02	.15111932E-02	1.309	.1905	16.956912
HHEDUC	.3957069553E-01	.31481293E-01	1.257	.2088	.90664273
MCRDMAGE	.1752543331E-01	.23937198E-01	.732	.4641	4.9910233
HHSIZE	-.1558667158E-01	.29834630E-01	-.522	.6014	4.9624417
RLANDCER	.7126472241E-02	.25814012E-01	.276	.7825	1.3987074
RLANDVEG	.1179700267E-01	.12962804	.091	.9275	.13321364
ANIMALNO	.3059978079E-01	.19701995E-01	1.553	.1204	3.6122083

LANDTOT	.3115458145E-01	.25076193E-01	1.242	.2141	4.7811724
RENTFEE	-.1585780087E-02	.15631834E-02	-1.014	.3104	25.668348
TOTSCK	.2825392338E-02	.13451926E-02	2.100	.0357	28.734291
IMPSTOVE	-.2804586584	.19990188	-1.403	.1606	.13464991
DMARKET	.2830644674	.57108496E-01	4.957	.0000	8.1152603
DHEALTHC	-.2497494195	.52292010E-01	-4.776	.0000	7.6016158
DMCRODAM	-.1489328419	.38411203E-01	-3.877	.0001	1.5582944
DFWCAREA	-.1257401595E-01	.42432543E-02	-2.963	.0030	11.506095
CERPRICE	.7038547112E-01	.16477800	.427	.6693	1.7210367
VEGPRICE	.2022302798	.10565612	1.914	.0556	2.2388689
FWPRICE	-.4876885933E-01	.16509381E-01	-2.954	.0031	14.283160
ARPRICE	-.4007841036E-01	.12614452E-01	-3.177	.0015	14.944722
MHHALSKM	.1444012698	.16641602	.868	.3856	.21903052
FHRDLWGT	.1354832350E-01	.28618472E-01	.473	.6359	6.1868761
SHADOWM	-.5017331777E-02	.13853685E-01	-.362	.7172	.54296226
SHADOWF	.5605678034E-01	.60223685E-01	.931	.3520	.16265885

Frequencies of actual & predicted outcomes
Predicted outcome has maximum probability.

Actual	Predicted 0	Predicted 1	Total
0	288	45	333
1	94	130	224
Total	382	175	557

APPENDIX C: HYPOTHESIS TESTING LIMDEP OUTPUT

The Decision to Plant Eucalyptus on Agricultural Land

Eucalyptus Planted on Agricultural Land Original Model

Binomial Probit Model	
Maximum Likelihood Estimates	
Dependent variable	DALEUCAL
Weighting variable	ONE
Number of observations	559
Iterations completed	6
Log likelihood function	-215.1556
Restricted log likelihood	-264.0843
Chi-squared	97.85749
Degrees of freedom	24
Significance level	.0000000

Eucalyptus Planted on Agricultural Land With Sickness Variables Dropped

Binomial Probit Model	
Maximum Likelihood Estimates	
Dependent variable	DALEUCAL
Weighting variable	ONE
Number of observations	559
Iterations completed	6
Log likelihood function	-220.2255
Restricted log likelihood	-264.0843
Chi-squared	87.71751
Degrees of freedom	22
Significance level	.0000000

Eucalyptus Planted on Agricultural Land With Microdam Variables Dropped

Binomial Probit Model	
Maximum Likelihood Estimates	
Dependent variable	DALEUCAL
Weighting variable	ONE
Number of observations	559
Iterations completed	6
Log likelihood function	-215.2857
Restricted log likelihood	-264.0843
Chi-squared	97.59722
Degrees of freedom	22

| Significance level .0000000 |

The Decision to Plant Other Trees on Agricultural Land

Other Trees Planted on Agricultural Land Original Model

```
+---------------------------------------------+
| Binomial Probit Model                       |
| Maximum Likelihood Estimates                |
| Dependent variable              DALOTHTR    |
| Weighting variable                   ONE    |
| Number of observations               559    |
| Iterations completed                   7    |
| Log likelihood function        -166.8201    |
| Restricted log likelihood      -256.3725    |
| Chi-squared                     179.1048    |
| Degrees of freedom                    24    |
| Significance level              .0000000    |
+---------------------------------------------+
```

Other Trees Planted on Agricultural Land With Sickness Variables Dropped

```
+---------------------------------------------+
| Binomial Probit Model                       |
| Maximum Likelihood Estimates                |
| Dependent variable              DALOTHTR    |
| Weighting variable                   ONE    |
| Number of observations               559    |
| Iterations completed                   7    |
| Log likelihood function        -170.8372    |
| Restricted log likelihood      -256.3725    |
| Chi-squared                     171.0706    |
| Degrees of freedom                    22    |
| Significance level              .0000000    |
+---------------------------------------------+
```

Other Trees Planted on Agricultural Land With Microdam Variables Dropped

```
+---------------------------------------------+
| Binomial Probit Model                       |
| Maximum Likelihood Estimates                |
| Dependent variable              DALOTHTR    |
| Weighting variable                   ONE    |
| Number of observations               559    |
| Iterations completed                   7    |
| Log likelihood function        -173.4176    |
| Restricted log likelihood      -256.3725    |
| Chi-squared                     165.9099    |
```

```
| Degrees of freedom                     22      |
| Results retained for SELECTION model.          |
+-----------------------------------------------+
```

The Decision to Plant Eucalyptus on Household Land

Eucalyptus Planted on Household Land Original Model

```
+-----------------------------------------------+
| Binomial Probit Model                          |
| Maximum Likelihood Estimates                   |
| Dependent variable              DHSEUCAL       |
| Weighting variable                   ONE       |
| Number of observations               559       |
| Iterations completed                   7       |
| Log likelihood function        -345.7362       |
| Restricted log likelihood      -379.6970       |
| Chi-squared                     67.92176       |
| Degrees of freedom                    24       |
| Significance level          .4492525E-05       |
+-----------------------------------------------+
```

Eucalyptus Planted on Household Land With Sickness Variables Dropped

```
+-----------------------------------------------+
| Binomial Probit Model                          |
| Maximum Likelihood Estimates                   |
| Dependent variable              DHSEUCAL       |
| Weighting variable                   ONE       |
| Number of observations               559       |
| Iterations completed                   7       |
| Log likelihood function        -347.7127       |
| Restricted log likelihood      -379.6970       |
| Chi-squared                     63.96864       |
| Degrees of freedom                    22       |
| Significance level          .5673237E-05       |
+-----------------------------------------------+
```

Eucalyptus Planted on Household Land With Microdam Variables Dropped

```
+-----------------------------------------------+
| Binomial Probit Model                          |
| Maximum Likelihood Estimates                   |
| Dependent variable              DHSEUCAL       |
| Weighting variable                   ONE       |
| Number of observations               559       |
| Iterations completed                   7       |
```

```
| Log likelihood function       -348.9991     |
| Restricted log likelihood     -379.6970     |
| Chi-squared                    61.39595     |
| Degrees of freedom                   22     |
| Significance level             .1385670E-04 |
+---------------------------------------------+
```

The Decision to Plant Other Trees on Household Land

Other Trees Planted on Household Land Original Model

```
+---------------------------------------------+
| Binomial Probit Model                       |
| Maximum Likelihood Estimates                |
| Dependent variable             DHSOTHRE     |
| Weighting variable                  ONE     |
| Number of observations              557     |
| Iterations completed                  6     |
| Log likelihood function       -295.5048     |
| Restricted log likelihood     -375.3487     |
| Chi-squared                    159.6877     |
| Degrees of freedom                   24     |
| Significance level             .0000000     |
+---------------------------------------------+
```

Other Trees Planted on Household Land With Sickness Variables Dropped

```
+---------------------------------------------+
| Binomial Probit Model                       |
| Maximum Likelihood Estimates                |
| Dependent variable             DHSOTHRE     |
| Weighting variable                  ONE     |
| Number of observations              557     |
| Iterations completed                  6     |
| Log likelihood function       -298.2946     |
| Restricted log likelihood     -375.3487     |
| Chi-squared                    154.1082     |
| Degrees of freedom                   22     |
| Significance level             .0000000     |
+---------------------------------------------+
```

Other Trees Planted on Household Land With Microdam Variables Dropped

Binomial Probit Model	
Maximum Likelihood Estimates	
Dependent variable	DHSOTHRE
Weighting variable	ONE
Number of observations	557
Iterations completed	6
Log likelihood function	-303.5906
Restricted log likelihood	-375.3487
Chi-squared	143.5162
Degrees of freedom	22
Significance level	.0000000

The Decision to Plant Eucalyptus on Government Land

Eucalyptus Planted on Government Land Original Model

Binomial Probit Model	
Maximum Likelihood Estimates	
Dependent variable	DGVEUCA
Weighting variable	ONE
Number of observations	559
Iterations completed	6
Log likelihood function	-249.2375
Restricted log likelihood	-322.0623
Chi-squared	145.6497
Degrees of freedom	24
Significance level	.0000000

Eucalyptus Planted on Government Land With Sickness Variables Dropped

Binomial Probit Model	
Maximum Likelihood Estimates	
Dependent variable	DGVEUCA
Weighting variable	ONE
Number of observations	559
Iterations completed	6
Log likelihood function	-250.6985
Restricted log likelihood	-322.0623
Chi-squared	142.7276
Degrees of freedom	22
Significance level	.0000000

Eucalyptus Planted on Government Land With Microdam Variables Dropped

Binomial Probit Model	
Maximum Likelihood Estimates	
Dependent variable	DGVEUCA
Weighting variable	ONE
Number of observations	559
Iterations completed	6
Log likelihood function	-263.3781
Restricted log likelihood	-322.0623
Chi-squared	117.3686
Degrees of freedom	22
Significance level	.0000000

The Decision to Plant Other Trees on Government Land

Other Trees Planted on Government Land Original Model

Binomial Probit Model	
Maximum Likelihood Estimates	
Dependent variable	DGVOTHRE
Weighting variable	ONE
Number of observations	559
Iterations completed	9
Log likelihood function	-175.0492
Restricted log likelihood	-284.1043
Chi-squared	218.1102
Degrees of freedom	24
Significance level	.0000000

Other Trees Planted on Government Land Original Model

Binomial Probit Model	
Maximum Likelihood Estimates	
Dependent variable	DGVOTHRE
Weighting variable	ONE
Number of observations	559

Iterations completed	9
Log likelihood function	-175.3870
Restricted log likelihood	-284.1043
Chi-squared	217.4345
Degrees of freedom	22
Significance level	.0000000

Other Trees Planted on Government Land Original Model

Binomial Probit Model	
Maximum Likelihood Estimates	
Dependent variable	DGVOTHRE
Weighting variable	ONE
Number of observations	559
Iterations completed	9
Log likelihood function	-203.1780
Restricted log likelihood	-284.1043
Chi-squared	161.8526
Degrees of freedom	22
Significance level	.0000000

CURRICULUM VITAE

Amy C. Osorio

304 Cheatham Hall
Virginia Tech
Blacksburg, VA 24061

Phone: (540) 231-3695
Email: aosorio@vt.edu

EDUCATION

Masters of Science, Forestry, Forest Management and Economics, Expected June 2002
Virginia Polytechnic Institute and State University (Virginia Tech), Blacksburg, VA
Thesis: Incentives to Plant Trees in Tigray, Ethiopia: Interactions of Public Microdams and Health.
Advisor: Gregory S. Amacher

Bachelor of Science, Forestry, Environmental Resource Management, May 2000
Virginia Tech, Blacksburg, VA

WORK EXPERIENCE

Research Assistant, Virginia Tech, College of Natural Resources, 2002-
Project: Value of information in fire control policies
Duties: literature reviews and data collection

Teaching Assistant, Virginia Tech, College of Natural Resources, 2002
Course: Forestry Field Camp (junior level required field camp)
Professors: Gregory S. Amacher and B. Jay Sullivan
Duties: helped grade Forest Management and Economics student field reports.

Research Assistant, Virginia Tech, College of Natural Resources, 2000-2002

Project: Impacts of Microdams on rural households in Tigray, Ethiopia

Duties: Analyzed fuelwood and tree planting data to assess benefits and costs of public microdam projects on rural households, when these projects affect productivity and health.

Teaching Assistant, Virginia Tech, College of Natural Resources, 2001

Course: Natural Resource and Environmental Economics (undergraduate)

Professor: Gregory S. Amacher.

Duties: led exam and quiz review sessions; graded quizzes and exams.

Research Assistant, Virginia Tech, College of Natural Resources, 2000-2002

Project: Estimation of reservation prices for forest landowners

Duties: Provided assistance with the Virginia and Mississippi Landowner Surveys. Compiled mailing lists, assembled surveys, entered data.

Research Assistant, Virginia Tech, College of Natural Resources, 2000

Project: Deforestation, rents, and enforcement in Indonesia

Duties: data collection and entry

Work Study, Forest Ecology, Virginia Tech, Department of Forestry, 7/99-8/2000.

Duties: Responsible for daily maintenance of greenhouse experiment: Sample collection and processing for USDA funded research at the Savannah Research Site; Performed geo-statistical research on results.

Work Study, Forestry Extension, Department of Forestry, 1996-1998

Duties: Assembled Virginia Forest Landowner Short Course Notebooks; Updated and maintained a listing of Virginia, and other, forest landowners; Organized slides for Short Course presentations

Summer Intern, USDA Forest Service, 1998

Location: Clinch Valley Ranger District, Wise, Virginia.

Duties: Collected inventory data for an old-growth stand; Used GPS and GIS to record location of ponds, roads, power lines and other features; Assisted in amphibian, turtle and bird research; Performed other duties as needed

PRESENTATIONS AND PUBLICATIONS

Osorio, Amy C., Amacher, G.S and Ersado, L. 2002 "Incentives to Plant Trees in Tigray Ethiopia: Interactions of Public Microdams and Health," 2002 Southern Forest Economics Workshop, March 19, 2002

Osorio, Amy C., Amacher, G.S and Ersado, L. 2002 "Incentives to Plant Trees in Tigray Ethiopia: Interactions of Public Microdams and Health" Forthcoming in Proceedings of 2002 Southern Forest Economics Workshop, VA.

SPECIAL SKILLS

Computer Skills: Limdep, Lindo, Gams, ArcView, GS+, Surfer

Communication Skills: presented at a professional symposium, currently writing two papers for publication.

PROFESSIONAL ASSOCIATIONS AND ACHIEVEMENTS

Xi Sigma Pi

- Member since 1998
- Outstanding Member of the Year 2002
- Secretary 2002

Phi Sigma Alpha Psi

- Member since 1998