# Effects of Deforestation on Household Time Allocation among Rural Agricultural Activities: Evidence from Western Uganda

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# 1. Introduction

In recent years, there has been an increasing concern about the declining quality of forests and the negative consequences of this on climate change, soil degradation and flooding particularly in Uganda and the developing world generally, as well as on the availability of forest products such as fuel-wood. Household survey data (UBOS, 2007) show that the biomass supplies at household level has become more difficult. The National Forest Authority reveals that ground measurements of biomass stocks in all land cover classes (including farmland) show declining stocks of above-ground woody biomass and that Uganda moved into a national fuel-wood deficit as over 30% of the tropical high forest is now degraded and private forests are shrinking more rapidly than forests managed by the government.

A number of factors are believed to be the cause of forest degradation in Uganda. Among them are the conversion of forest into agricultural and grazing land and over-harvesting for fuel-wood, charcoal, timber and non-wood forest products. Given that many rural households in Uganda typically rely on self-collected fuel-wood as a source of energy for cooking, increased scarcity of these products, due to deforestation, is likely to increase time spent in collecting fuel-wood leaving less time for household members to spend on their farms and other activities. This is likely to affect household agricultural activities and probably output. As a result, households which are primarily fuel-wood collecting may have to re-allocate some of their time from other activities to collecting fuel-wood. This kind of switch in time allocation will affect agricultural time, water collection time, leisure-time and time spent on household core activities like cooking and child-care.

The main objective of this study is to examine the effects of changes in biomass availability on household time allocation and agricultural activities among rural households in Uganda. The specific objectives include analysing the consumption of fuel-wood by a sample of households in the rural areas of Uganda and how individuals in these households re-allocate to the collection of environmental products when the products become scarce. The study also analyses whether kerosene and other fuels are economically viable substitutes for fuel-wood and whether this substitution would help reduce wood fuel consumption and reduce deforestation. More specifically, it determines whether there are seasonal and gender differences with regard to time allocation household members as is frequently thought. In analysing the situations that may be caused by deforestation, we asses a major hypothesis that progressive deforestation is considerably changing the production functions of rural households. Therefore, the above situation makes Uganda to be a perfect case study for natural resource scarcity issues.

This study is structured as follows: Section 2 links the topic to the broader literature and Section 3 discusses the conceptual framework Section 4 presents the strategy to implement econometric tests on this topic with the data at hand. Section 5 describes the data and uses them to provide descriptive evidence on the links between deforestation, time allocation and farming activities. Section 6 discusses the econometric evidence and Section 7 concludes by summarizing the evidence and translating them into a number of recommendations for policy.

## 2. Relation to the literature and model

To account for member's roles in the agricultural household, economic research has been greatly affected by three steps in the general analysis of the family in the last thirty years (Schultz, 1999). First is the conceptualization of the unified family as a coordinator of the production and consumption of a group of persons over an extended period of the lifecycle, with the household production of consumption commodities for family use constrained by the pool of household endowments including time, market prices, and knowledge of home production possibilities (Becker, 1965; 1981). Second is the role of separability of production and consumption decisions in the agricultural household, which depends on the perfect substitutability of hired and family labour and the adequacy of factor markets (Barnham and Squire, 1979; Singh et al*.,* 1986). Third is the introduction of individualistic bargaining or collective coordination of the family that preserves the distinct endowments of the individual and the expression of possible differences in personal preferences (McElroy and Horney, 1998; Chiappori, 1988; Lundberg and Pollak, 1993; Duflo and Udry, 2004). This third innovation has relaxed the unified family model in different ways, and is still being extended and adapted to new problems or forms of game theory and econometrics.

A distinguishing feature of rural economies, in developing countries, is the prevalence of production at home, with the use of family members for labour or sources of capital. Agricultural production in Uganda comes primarily from family member's farms, with the different member's (children included) providing most of the labour. In general, each hour devoted to a home production activity by each family member competes with alternative activities such as work in the labour market, leisure or schooling. Furthermore, production at home is characterized by a division of labour based on gender and age (Buvinic et al., 1983; Jacoby, 1992). Many members of rural households provide labour on their farms and in the labour markets as well, and these choices depend on the valuation of the opportunity cost of their own labour.

The economic theory of the family (Ashenfelter and Heckman, 1974) and household time allocation (Becker, 1965; 1981; Gronau, 1973; 1977), proposes that family members specialize in activities in which they have a comparative advantage so as to maximize family welfare. Changes in the value of time of a family member, relative to that of other family members will induce an allocation of time of that family member toward the activity with the highest reward. Kimhi and Rapaport (2004) used a household model of time allocation in farm households and reveal that, the demographic composition of the household affects labour supply, namely, the existence of adult children and siblings of the farm couple tends to decrease farm laboor supply and increase non-farm labour supply.

Becker (1965) and Gronau (1977) extended the conventional labour supply model of consumption and leisure by incorporating home production as yet another activity that requires human labour. They argue that women's work at home can be valued in a way similar to market work, and that this work will respond to economic incentives such as changes in market wages, unearned income and productivity of work at home. While this extension was quite insightful, it had a few short-comings such as the fact that it paid little attention to male behaviour both inside and outside the household. It was also a model with an empirical focus on developed countries, where women's production is, perhaps, less interesting in a policy sense as there are few market failures (Ilahi, 2000). There was little application to developing countries where women's time in home production can be constrained by failure or absence of markets for basic services such as water and fuel-wood.

Links between using fuel-wood and deforestation are usually discussed from two perspectives: First, fuel-wood consumption is often identified as an immediate cause of deforestation to the extent that collection exceeds sustainable yield. Secondly, in areas which have been deforested, fuel-wood is thought to have become increasingly scarce (Dewees, 1989). Neither of these observations clearly describes the norm, although they have been widely accepted and form the rationale for many tree-planting interventions. The debate here may be due to the fact that, whereas timber harvesting is based on primary growth, fuel-wood harvesting may be based on secondary growth. Nankhuni and Findeis (2003) show that children are significantly involved in resource collection work and their probability of attending school decreases with increases in hours spent on this work.

This study is innovative in several ways: First, we include analysis of the consumption of an important environmental product, fuel-wood. So far, there are very few studies in Uganda which have done an economic analysis of the effects of deforestation on household fuel-wood use, collection and farm-time allocation. Secondly, we analyse the effect of seasonality on the consumption of environmental products and on labour allocation to agriculture. Seasonality is becoming widely recognized as an important factor in labour decisions, yet it has not been analysed in this context. Thirdly, we conduct a gender-disaggregated analysis of the effects of deforestation on rural farming activities. Last, but not least, development policy interventions, be they poverty alleviation, safety nets, basic services, projects or agricultural extension, have a lot to learn from information that comes from time allocation.

# 3. Conceptual framework

The analysis is based on the household production/utility model of Becker (1965). Households produce commodities by combining inputs of goods and time according to cost minimization rules of the traditional theory of the firm. The household maximizes utility subject to a set of constraints. This framework was modified by Gronau (1973; 1977) and used in several studies including Ilahi and Jaffarey (1999), Cooke (1996), Mekonnen (1998) and Heltberg et al. (2000), among others, as the basis of a model of home production and firewood collection. This study adopts the conventional approach with the household as the unit of analysis (see also Adhikari et al., 2004; Kimhi and Rapaport, 2004; Nankhuni and Findeis, 2003; Huffman, 1991; 2001; Khumar, 2002; Low, 1986). This is mainly because, in the rural areas of Western Uganda, farming systems tend to be household-based though a few individually managed farms exist.

Since fuel-wood collection is subject to the same labour, land and natural resource constraints as other household activities, including agricultural production, we cannot analyse it in isolation. The production functions assumed are based on the neoclassical model of household production described by Singh et al. (1986) and are a version of agricultural household models with a focus on fuel-wood collection as an activity distinct from market-work and housework. In this study, fuel-wood enters as an input into the home production function and its collection is associated with a potentially large opportunity cost in terms of collection time, which varies according to the density, distance and accessibility of local forest resources Heltberg et al. (2000).

The non-separable model is adopted because it is known that most rural households both collect and consume their fuel-wood, even if some of them (about 6%) participate in the local (informal and underdeveloped) fuel-wood markets. Although all households are faced with the choice of either collecting or purchasing their fuel-wood, they determine this based on their valuations of their own labour opportunities. All households in the sample consume fuel-wood. Those households that do not collect fuel-wood purchase it from informal markets (6%). In the presence of imperfect markets for fuel-wood and labour for their collection, it is relevant to compute price elasticities using some measure of virtual[1] (shadow) prices and wages instead of market prices.

Labour market opportunities, at existing wages in Uganda, are assumed to exist for both men and women. However, the local labour market adds complexity to the labour problem because imperfections in the rural labour markets – both gender and seasonal – make household labour supply and demand non-separable. Households can hire labour to work on the farms but do not hire labour for fuel-wood collection. The willingness to collect fuel-wood depends on each household's valuations of time and its preferences regarding the leisure-labour trade-off. Further, it is assumed that hired and family labour on the farm are not perfect substitutes because hired labour incurs an extra supervisory cost and is paid according to hours worked or area worked, which does not apply to family labour. Also, family labour includes children and aged people whose input is expected to be less than that of adults hired in as units of labour; they cannot therefore be perfect substitutes. They may be active as volunteers, or in home production, but not usually in the labour market.

The assumption of non-separability means that a utility maximizing household would determine energy production and consumption subject to a "virtual" or "shadow" price of energy which is unobserved and unknown, except to the household itself, and which varies between households depending on household and village characteristics (Sadoulet et al., 1998). We assume a representative household that maximizes its utility function subject to a set of production, budget and time constraints. The utility function is:

$$U = U(X, E^C, T\text{-}L_s; A, Z) \tag{1}$$

Where $X$ represents the consumption of non-fuel-wood products by the household, $E^C$ is the quantity of fuel-wood consumed by the household, $T\text{-}L_s$ is leisure by household members where $T$ is total household time available and $L_s$ is total household labour supply (this is the sum of household labour to different activities including collection of fuel-wood). $A$ refers to the state of the environment or resource endowment and $Z$ is a vector of household characteristics, including size, age and educational level of household members which may affect preferences[2]. The household faces the following constraints to their utility maximization:

$$E^C - E^G \geq 0 \tag{2}$$

The energy (fuel-wood) consumption $E^C$ may be purchased on the market or gathered from the forest or woodland, $E^G$. Collected and purchased fuel-wood are perfect substitutes in consumption. Equation 2 refers to households that are either buyers of fuel-wood (when the strict inequality holds) or those whose collections are sufficient to meet their needs (when the equality holds). Households are assumed to produce and consume their own products but can also purchase from the market. The labour supply for fuel-wood collection constraint is:

$$L_{de} - L_{se} \geq 0 \tag{3}$$

Where $L_{de}$ is the labour demand for fuel-wood collection and $L_{se}$ is the labour supply for fuel-wood collection. This equation refers to household's self-sufficient in labour for fuel-wood collection when equality holds, and those that hire labour when it does not hold. However, this is a simplifying assumption given that it is already known that households do not hire labour for fuel-wood collection; in principle, sellers of fuel-wood or labour for fuel-wood collection could also be accommodated in the model without changing basic results. The production function for fuel-wood gathering ($E^G$) is given by the function;

$$E^G = E^G (L_{de}, A, Z^v) \tag{4}$$

Production of fuel-wood depends on $L_{de,}$ $A$ and $Z^v$ a vector of characteristics describing the state of the environment and access conditions such as topography and agro-climatic factors. $L_{de}$ is labour demand and includes boys, girls and adult males and females. The more degraded the environment, the longer it will take to gather a unit of fuel-wood. Households in rural Uganda face different states of the environment and have differing household characteristics, and this may contribute to the variation of marginal products across households.

The household is involved in agricultural production, using hired or own labour. The household produces agricultural goods, $Q_a$, that it can also opt to purchase at price, $P_a$. If the household consumes less of its output than it produces, it may sell some of its surplus output at the same price, $P_a$. The household's agricultural production function is given by:

[illegible] (5)

This production function depends on adult male farm labour, $L_a^m$, adult female labour, $L_a^f$, boys, $L_a^b$ and girls, $L_a^g$. In this formulation, hired labour inputs and own household labour inputs are assumed to be imperfectly substitutable, although household male, female, boys and girls labour in agriculture may be substitutable. Production also depends on inputs in production, *inp,* such as livestock feed and manure. The stock of livestock owned by the household is taken as exogenous in this model. Finally, $Z^h$ is a vector of household endowments pertaining to farming (land, trees and family workforce).

We assume non-negativity assumptions for non-fuel-wood consumption, leisure and labour demand and supply, and fuel-wood consumption. Thus,

$$X \geq 0;\ T\text{-}L_s \geq 0;\ L_a^{m,f,b,g} \geq 0;\ L_s \geq 0;\ L_{de} \geq 0;\ L_{se} \geq 0;\ E^C \geq 0; \tag{6}$$

The amount of agricultural, environmental and other market goods that a household buys is constrained by the sum of income earned from the sale of agricultural goods, environmental goods, exogenous income plus wage income and non-wage income. The budget constraint is given by:

$$P_x X + P_e E^C = W_e L_{se} + (P_e E^G - W_e L_{de}) + P_a (Q_a - Q_h) + W_L + V \quad (7)$$

The variables $P_a$, $P_e$ and $P_x$ refer to prices of agricultural products, fuel-wood and other goods, respectively. $W_e$ is the wage rate (opportunity cost) for labour collecting fuel-wood; the term $(Q_a - Q_h)$ denotes a household's marketable surplus of agricultural goods, which may be negative indicating that a household is a net buyer of agricultural products; $W_L$ accumulates all wage income from labour they provide to both farm and non-farm activities outside the household and $V$ is the amount of non-wage income (measured by remittances) to the household. The expression $(P_e E^G - W_e L_{de})$ represents non-labour income from fuel-wood collection. In this expression, the value of leisure from both sides of Equation 7 and variables for men, women, boys and girls are left out for clarity of exposition.

Substituting the production functions for environmental and agricultural goods into the budget constraint (7), the household's Lagrange function for the problem may be written as:

$$\begin{aligned} Max\ \pounds &= U(X, E^C, T - L_s; A, Z) + \lambda\{W_e L_{se} + (P_e E^G (L_{de}, A, Z^v) - W_e L_{de}) + \\ &\quad P_a (Q_a - Q_h) + W_L + V - P_x X - P_e E^C\} + \phi(E^C - E^G) + \eta(L_{de} - L_{se}) \end{aligned} \quad (8)$$

where $\phi$, $\eta$ and $\lambda$, are Langragian multipliers attached to the constraints (2), (3) and (7), respectively.

Assuming interior solutions, the first order conditions for the household choice can be derived subject to the revised budget constraint and non-negativity conditions. These conditions are:

$$\frac{\partial}{\partial X} = \frac{\partial U}{\partial X} - \lambda P_x = 0 \quad (9a)$$

$$\frac{\partial}{\partial E^c} = \lambda(P_e - \frac{\phi}{\lambda} = 0 \quad (9b)$$

$$\frac{\partial}{\partial L_e} = \lambda(W_e - \frac{\eta}{\lambda} = 0 \quad (9c)$$

$$\frac{\partial}{\partial L_d} = \lambda(P_e \frac{\partial E^G}{\partial L_d} - W_e) + \eta = 0 \tag{9d}$$

or

$$P_e \frac{\partial E^G}{\partial L_d} = W_e - \frac{\eta}{\lambda} = 0 \tag{9e}$$

along with the non-negativity equations and constraints (2), (3) and (7)[3]. The results from these first order conditions are standard for household labour allocation models of this type. The general rule is that in equilibrium, the ratios of the marginal products of various activities are equalized with the relevant price ratios. Because so many activities are devoted to home production, in many cases the price of on-farm activities is the opportunity cost wage that could have been earned off-farm.

If $P_e$ and $P_x$ are interpreted as market prices, from the first order conditions, and if the market environment constraints (2) and (3) are binding, the relevant prices for decision making by the household concerning fuel-wood are (9b) and (9c)[4] and not simply the market prices. From Equation 9e, the value of marginal product of labour (left hand side of Equation 9e) is not the same as the market wage rate, $W_e$, for collecting environmental goods. This implies that the value of the marginal product of labour can be used as a shadow wage.

The prices in parenthesis in (9b) and (9c) are referred to in the international literature as shadow or virtual prices. These prices are important in that they reflect the relevant opportunity costs and benefits a household faces in making utility maximizing choices. Households would, therefore, respond directly to shadow prices rather than market prices (Thornton and Eakin, 1992; de Janvry et al., 1991). The relevant shadow wages would be larger or smaller than the market prices of fuel-wood or wages for fuel-wood collection, depending on the signs of $\frac{\phi}{\lambda}$ and $\frac{\eta}{\lambda}$. In their study Sadoulet et al. (1998) show that there would be different shadow prices and wages depending on the level of household sufficiency in fuel-wood or labour supply. It would also depend on whether the household is a net seller or buyer of labour or a fuel type. The reasons for the differences in prices and wages would arise due to transaction costs in buying or selling fuel-wood or labour, and cultural values. Also, household preferences for family labour for efficiency reasons or due to limited employment opportunities could be the other reasons for the existence of different wage rates for a particular activity. Going by these assumptions, in this study, the market constraints in (2) and (3), would provide the shadow wages (prices), when equality holds. These shadow wages (prices) would be those that equate household demand to household supply. In this formulation, the multipliers $\lambda$, $\phi$ and $\eta$, which are directly determined by the solution to the constrained maximization problem, determine shadow prices and thus the shadow prices (wages) are considered endogenous variables. In addition, if a commodity, in this case fuel-wood, is both produced and consumed by the household, shadow prices will be a function of both preferences and technology (Sadoulet et al., 1998).

Due to the absence of relevant market prices for hired labour for fuel-wood, this budget constraint will include shadow prices instead of market prices. If this is done, then the constraint to the maximization problem would be:

$$P_x X + P_e{}^* E^C = W_e{}^* L_{se} + (P_e{}^* E^G - W_e{}^* L_{de}) + P_a(Q_a - Q_h) + W_L + V \qquad (10)$$

Where $P_e{}^*$ and $W_e{}^*$ are the shadow price and wage for fuel-wood and fuel-wood collection, respectively.

If the above conditions are assumed to hold, the functions for fuel-wood collection would, therefore, take the form:

$$E^C = E^C(P_e{}^*, W_e{}^*, V, A, Z) \qquad (11)$$

Generally, the model shows that fuel-wood collection and participation in household agricultural tasks is determined by the opportunity cost of time. This is the kind of situation that usually prevails in rural areas of Uganda given the nature of the family system. These equations form the basis of the empirical models presented in the next sections.

# 4. Empirical strategy

The discussion in the foregoing section highlighted three objectives which form the basis of the empirical analysis. First, fuel-wood demand and supply is estimated. Secondly, the effect of household and community level characteristics on decisions to collect fuel-wood or work on the farm is estimated. Thirdly, a shadow value for household labour and fuel-wood prices is estimated. Several studies (de Janvry et al., 1991; Sadoulet et al., 1998; Singh et al., 1986; Thornton, 1994; Jacoby, 1993) estimate the shadow wage from a production function. We adopt this approach (Skoufias, 1994) in order to estimate the shadow wage using a production function approach. In the case of labour allocation to the farm, actual market wages rather than shadow wages are used.

## Estimation of fuel-wood production (collection) functions and shadow wages (prices)

In the estimation of the total production/collection functions, the factors influencing the amount of fuel-wood collected by the household are determined. We specify the Cobb-Douglas production function as:

$$\ln Y_h = \ln P_h \beta_h + H\,\alpha_h + D_h\,\delta_h + \varepsilon_f \tag{12}$$

where *ln* denotes the total output of fuel-wood produced (consumed) by household *h*, the vector $P_h$ denotes the quantities of inputs used by household *h* suggested by the theoretical model, $D_h$ represents household demographics, that is, household composition effects on fuel-wood collection such as the number of adults and youth separated into males, females, girls, children and boys; *H* is a dummy variable used to explain differences that may arise from factors other than the availability of fuel-wood such as agro-ecological factors or geographical location; that is, the quality of the environment; $\beta_h$, $\delta_h$ and $\alpha_h$ are parameter vectors and $\varepsilon_f$ is the error term summarizing the influence of all other variables not specified here.

We then use the function in (12) to determine the marginal products of labour, which are treated as shadow wages. In practice, an estimate of the shadow wage rate can be obtained from the marginal productivity of family labour in the production of a commodity. Following the approach used by Jacoby (1993), Skoufias (1994) and Mekonnen (1998), the marginal product of labour is computed as the product of labour input elasticities and the ratio of predicted quantity produced to time spent. This is specified as follows:

$$MP_h = \beta_h * \left(\hat{F}_h / L_h\right) \tag{13}$$

where $MP_h$ is the marginal product of fuel-wood collected by household *h*, $L_h$ is the labour time household *h* spends to collect fuel-wood, $\beta_h$ is the parameter estimate for the variable $L_h$, and $\hat{F}_h$ is the predicted quantity of fuel-wood collected by household *h*. The estimated shadow wages are household specific, because it is expected that in the absence of hired labour, the shadow wage rate would be a result of the household's attempt to equate supply and demand for its own labour, and this depends on household characteristics and resource endowments.

Before estimating the demand function for fuel-wood, further explanation is needed on two issues that may arise. First, since fuel-wood markets in the study area are "*thin*" and highly localized, this implies that market prices for fuel-wood may not accurately reflect the extent of fuel-wood scarcity faced by the household, especially for those not involved in the fuel-wood market. Moreover, even though there is some trading of fuel-wood at the closest trading centres, a majority of households in the sample are not involved in the market. However, saying that market prices may not reflect scarcity of fuel-wood for households should not mean that fuel-wood is not economically scarce. It simply means that alternative measures (shadow price) which are more specific to the household, should be used. Theoretically, this means that, for a majority of households, the shadow price will not equal the actual market price. Therefore, an alternative measure of this price that is specific to each household, that is, a shadow price[5] must be found. Therefore, the time they spend per trip should be a good indicator of how difficult it is for the household to get fuel-wood and hence it is an essential component in the computation of the shadow price for fuel-wood (Dasgupta and Maler, 1995).

Secondly, some households reported non-collection of fuel-wood and, therefore, do not have measures of shadow prices that are comparable to the ones used for the collectors. For missing shadow prices for non-collectors, average shadow prices of fuel-wood are used on the basis that if those prices are missing, it is much safer to take on average values in their absence. With respect to missing values for the shadow wages of households that do not collect fuel-wood, it is expected that the non-collecting households have an opportunity cost of labour higher than that of collectors. For this reason, the maximum shadow wages for the collectors is used as a measure of shadow wages for the non-collectors (see also Mekonnen, 1998). This expectation is based on the argument that they would have collected it if it had not been so, and that these households have almost similar characteristics.

After determination of shadow wages and prices, we estimated structural forms using a Two Stage Least Squares (2SLS) approach with all the labour categories being included as independent variables in the regressions of the other labour supply variables. With the help of this approach, the endogeneity of the shadow wages (prices) and fuel-wood demands for the wet and dry season were estimated.

## Estimation of labour allocation to fuel-wood collection and farming activities

To explain the determinants of household labour allocation to fuel-wood collection, the production (collection) function for fuel-wood should include both collectors and non-collectors. Since men, women, boys and girls are involved in collection activities, time spent by each of them is recorded separately. Due to the limited number of observations, time spent by boys and girls was aggregated for the regression analysis (see also Adhikari et al., 2004.

The econometric model to be estimated for fuel-wood collection activities, therefore, takes the following form:

$$E_{fi}^{t,w,m,y} = a_1 W_e^* + a_2 D_i + a_3 V_i + a_4 L_i + a_5 F_i + {}_5W_i + a_6 H_i + a_7 S_i + u_i \quad (14)$$

$E_f$ is the total time per week in fuel-wood collection for household *i=i(1,2,3…n),* while *t, w, m,* and *y* represent total, women, men and youth[6] (boys and girls) categories, respectively. $W_e$* is the shadow wage, $D_i$ stands for the household demographics and composition, $F_i$ is the ownership of land by the household, $V_i$ is total household off-farm income, $L_i$ and $W_i$ are household farm time and water collection (time per trip in hours) variables, respectively. $S_i$ price of substitutes and $H_i$ is a dummy variable used to explain differences that may arise from factors other than the availability of fuel-wood such as agroecological characteristics geographical location (Highlands or lowlands). The $a_i$*'s* are the unknown coefficients that measure the effects of the respective variables on $E_{fi,}$ and $u_i$ is the error term. Some variables, including shadow prices and wages, wage and agricultural income, household head's educational level, household size and remittances, were estimated in log form. The advantage of log transformation is that it helps reduce heteroscedasticity and also enables us to interpret the coefficients directly as elasticities.

Similarly, in order to explain the possible association between deforestation and household labour input in farming, the following farm labour input equations is estimated:

$$L_i^{t,w,m,y} = a_1 C_i + a_2 D_i + a_3 Y_i + a_4 V_i + a_5 T_i + a_6 W_i + a_7 H_i + u_i \quad (15)$$

In this formulation equation, $L_i$ is on-farm person time per day for household *i=i(1,2,3…n),* while *t, w, m* and *y* represent total, women, men and youth[7] (boys and girls) categories respectively. $C_i$ is the proportion of land area under crops, $D_i$ stands for the household demographics, $Y_i$ and $V_i$ are on-farm and off-farm income, respectively. $T_i$ and $W_i$ are the deforestation (time per trip) and water collection variables, respectively. $H_i$ is the dummy for agroecological characteristics. The $a_i$'s are the unknown coefficients that measure the effects of the respective variables on $L_{i,}$ and $u_i$ is the error term, presumed to have no correlation with the respective explanatory variables, and to have the usual properties for ordinary least squares (OLS) estimation. Finally, on estimation issues, since the dependent variable is continuous (labour input to farming in hours per day), the ordinary least squares (OLS) technique was used for the total equations because all households in the sample reported positive time on the farms.

Like any other econometric model, it is important to discuss some limitations of these models. First, all household farm-models discussed thus far assume preferences and incomes are shared by all household members. Although this assumption is convenient, it obviously represents a simplification of the real world, in which individual interests of household members may diverge and all incomes and activities may not enter into a "common pot". The critical issue here in terms of the choice of model is not whether the models discussed present simplifications of reality, but rather, what are their costs, in terms of explanatory power and potential prediction bias when compared to alternative behavioural equations for each household member and a more complex model of joint decision making. Modelling such situations requires detailed data (particularly related to individual specific transaction costs) as well as theoretical and econometric extensions of household farm models. Therefore, the modelling framework presented in this section could be extended to consider these issues, but data do not permit such extensions.

# 5. Data and descriptive evidence

## Data

The data for this study come from a household survey conducted in three rural districts (Masindi, Buliisa and Kyenjojo) of Western Uganda. Data was collected using questionnaires and focus group discussions. The questionnaires are pre-coded and interviewers were trained to use both the local language and English version of the questionnaires. The pre-test of the survey instrument was done to 20 households.

Households were selected from the sample frame, through a stratified random sampling procedure. The western region has 14 districts and these were split into two strata, high altitude and low altitude strata. From these strata, three districts were randomly selected. A multi-stage sampling procedure was adopted. From each of the selected districts, a random sample of two counties was selected. From each of the two selected counties, a random sample of two sub-counties was chosen and two villages were then randomly chosen from the sub-counties.[8] From each village, between six and 15 households were randomly interviewed. This was considered to be fairly representative of the village (the national household surveys use about ten households per enumeration area - village). This kind of sampling is done to cover variations in altitude, access to roads and markets, tribal groupings and degree of deforestation. A total of 287 households were interviewed. In the subsequent empirical work, we account for this stratification, by considering low and high altitude areas in our estimation. Data was collected through two separate sets of interviews, one round during the wet season and the other during the dry season. This was designed in order to capture seasonality in household activities.

## Profile of study area

The survey was conducted in the rural areas of three districts in Western Uganda; namely, Masindi, Buliisa and Kyenjojo. The three districts differ geographically, climatically and in terms of resource stock, agricultural opportunity costs for labour and household fuel-wood consumption. The district of Kyenjojo is generally at a higher altitude and located near several mountain masses of about 2,500 metres in height above sea level. The other districts of Masindi and Buliisa lie on plains (lowlands) standing at about 1,500 metres above sea level. Agriculture is the main economic activity and source of income in Western Uganda and it is typically rain-fed agriculture. Households rely heavily on forest resources as 99% use firewood for cooking.

Table 1 shows the descriptive statistics for selected variables during the wet and dry season.

**Table 1: Descriptive results**

| Variable | Wet Season Mean | Wet Season Std. Dev. | Wet Season Min | Wet Season Max | Dry Season Mean | Dry Season Std. Dev. | Dry Season Min | Dry Season Max |
|---|---|---|---|---|---|---|---|---|
| Household size | 7.15 | 2.82 | 1.00 | 16.00 | 7.50 | 2.94 | 1.00 | 16.00 |
| Age of household head | 46.41 | 14.15 | 22.00 | 81.00 | 43.29 | 13.12 | 20.00 | 86.00 |
| Years of educ of household head | 7.47 | 4.68 | 0.00 | 20.00 | 6.78 | 3.92 | 0.00 | 17.00 |
| Female household head | 0.08 | 0.27 | 0.00 | 1.00 | 0.09 | 0.29 | 0.00 | 1.00 |
| Prop. of children (0-6) in hh | 0.18 | 0.16 | 0.00 | 0.50 | 0.18 | 0.16 | 0.00 | 0.60 |
| Prop of female youth (6 to 14) | 0.16 | 0.15 | 0.00 | 0.67 | 0.16 | 0.14 | 0.00 | 0.56 |
| Prop of male youth (6 to 14) | 0.16 | 0.14 | 0.00 | 0.50 | 0.15 | 0.14 | 0.00 | 0.60 |
| Prop of male adults | 0.24 | 0.12 | 0.00 | 0.64 | 0.24 | 0.13 | 0.00 | 0.63 |
| Prop of female adults | 0.26 | 0.13 | 0.00 | 1.00 | 0.27 | 0.14 | 0.08 | 1.00 |
| Size of agric land | 6.12 | 5.00 | 0.40 | 30.00 | 5.10 | 3.75 | 0.38 | 21.00 |
| Collect time for water in hrs | 0.66 | 0.52 | 0.02 | 3.00 | 1.08 | 1.22 | 0.02 | 8.00 |
| Time per trip of fuel wood | 2.67 | 1.31 | 0.00 | 5.00 | 2.69 | 1.49 | 0.00 | 5.00 |
| Average no. of trips per week | 5.53 | 3.74 | 0.00 | 14.00 | 4.30 | 3.78 | 0.00 | 15.00 |
| Quantity of fuelwood per trip | 35.36 | 19.25 | 0.00 | 80.00 | 30.04 | 22.16 | 0.00 | 80.00 |
| Distance to fuelwood source | 2.96 | 1.04 | 1.00 | 4.00 | 2.87 | 1.06 | 1.00 | 5.00 |
| Mean farm hours for boys | 1.16 | 2.22 | 0.00 | 12.00 | 1.18 | 2.25 | 0.00 | 12.00 |
| Mean farm hours for girls | 1.36 | 2.13 | 0.00 | 9.00 | 1.35 | 2.41 | 0.00 | 12.00 |
| Mean farm hours male adults | 4.78 | 3.43 | 0.00 | 20.00 | 4.70 | 3.33 | 0.00 | 17.00 |
| Mean farm hours female adults | 5.27 | 3.33 | 0.00 | 20.00 | 5.28 | 3.33 | 0.00 | 17.50 |
| F/w collection time male youth | 0.25 | 0.55 | 0.00 | 3.00 | 0.05 | 0.25 | 0.00 | 2.00 |
| F/w collection time female youth | 0.49 | 0.74 | 0.00 | 3.00 | 0.19 | 0.54 | 0.00 | 3.00 |
| F/w collection time male adults | 0.32 | 0.58 | 0.00 | 3.00 | 0.29 | 0.62 | 0.00 | 3.00 |
| F/wood collection time female adults | 1.30 | 0.82 | 0.00 | 4.00 | 1.28 | 0.87 | 0.00 | 4.00 |
| F/wood collection time children | 0.03 | 0.17 | 0.00 | 1.00 | 0.01 | 0.12 | 0.00 | 1.00 |
| Mean monthly household expend | 48,788 | 73,790 | 0 | 600,000 | 60,822 | 117,216 | 500 | 1,000,000 |
| Mean monthly remittances | 23,804 | 66,755 | 0 | 470,000 | 14,436 | 39,036 | 0 | 240,000 |
| Monthly wage income | 162,534 | 133,570 | 1 | 1,068,000 | 151,792 | 117,588 | 1 | 660,000 |
| Mean monthly expend. firewood | 96 | 531 | 0 | 4,000 | 206 | 757 | 0 | 4,000 |
| Mean monthly expend kerosen | 1,056 | 1,164 | 0 | 7,000 | 817 | 806 | 0 | 7,000 |
| Mean monthly exp electric | 1 | 17 | 0 | 200 | 37 | 411 | 0 | 5,000 |
| Mean monthly exp charcoal | 280 | 961 | 0 | 5,000 | 704 | 1,812 | 0 | 9,500 |
| Mean monthly exp candles | 12 | 69 | 0 | 500 | 11 | 63 | 0 | 500 |
| Observations | 138 | | | | 149 | | | |

Source: Authors computation from survey data

Tests for difference of means shows most of the variables are not significantly different during the two seasons. On average, close to 50% of the population are below 14 years. The larger number of economically inactive members places a high dependence burden and stretches household resources, with the already meagre average monthly wage income of Ushs 156,957.[9]

One of the objectives of the study is to explore, in some detail, how households react to fuel-wood scarcity. The expectation is that, wood fuel scarcity would naturally lead to a rise in the price of charcoal and paraffin relative to other fuel types, and perhaps induce some kind of substitution to other energy forms. Table 2 shows household coping strategies grouped as leading to either substitution to other energy forms, technological substitution or some kind of income adjustment.

**Table 2: Coping with increasing scarcity of firewood**

| Coping strategies | No.hh | Percent | Effect |
|---|---|---|---|
| Shift to charcoal | 46 | 16.1% | Substitution effect |
| Shift to paraffin | 12 | 4.2% | |
| Shift to dung or grass | 105 | 36.7% | Substitution effect |
| Earn more money | 97 | 33.9% | Income effect |
| Use lid when cooking | 49 | 17.1% | Technological substitution |
| Extinguish firewood after cooking | 126 | 44.1% | energy conservation |
| Other reasons e.g., soaking food before cooking, Adding soda | 18 | 6.3% | |
| Not applicable | 23 | 7.7% | |
| Total sample | 287 | | |

Percentages do not add up to 100 because respondents cited more than one strategy.

Most respondents adopted conservation measures, and these included extinguishing firewood after cooking (44.1%) and soaking dry food and adding cooking soda before and during cooking (6.3%). Only about 17.1% of the respondents indicated that they often use a lid when cooking as a means of speeding up cooking and thereby reducing on the amount of firewood used. This implies that fuel-wood scarcity might lead households to become more technologically innovative. Interestingly, about 34% indicated that they would work to earn more money to buy fuel-wood as it gets scarce. Also, increased scarcity seems to push more households to use alternative energy. Approximately 37% of the respondents indicated that they would shift from firewood to cheaper forms of fuel like dung. Only 16% indicated they would shift to charcoal. This finding suggests that scarcity can induce households to engage in energy conservation, induce technological substitution and also shift to other forms of energy.

# 6. Econometric evidence

In presenting the empirical results, the production (collection) function for fuel-wood is first estimated. Secondly, we estimate shadow wages for Western Uganda (the study area). We then estimate a model for determinants of demand for fuel-wood, as well as labour-time allocation for fuel-wood collection. In doing so, we also examine the intra-household and gender breakdown of collection activities. The goal for this breakdown is to test the hypothesis that there exist gender and age differences to time allocation within the household.

## Deforestation and fuel-wood collection

In the estimation of fuel-wood collection functions for households, some potential sources of bias may arise. First, some individuals did not spend any time in collection activities. To solve this problem the censored version of the Tobit[10] (see Greene, 2000 model), which produces consistent and efficient estimates, was used. A second selection problem may arise due to an individual's choice of a collection site. Individuals collected fuel-wood from both own farms and communal forests. Fragmentation of land makes it difficult to assess the extent to which collection decisions (regarding where to collect) are influenced by availability of forest resources. Estimates for the production function for total collection of fuel-wood are presented in Table 3.

**Table 3. Estimates for fuel-wood collection function in kilograms per week (first stage regression results)**

| Dependent Variable: Amount of fuel-wood collected in Kgs/week | |
|---|---|
| **Variable** | **Coefficient** |
| Number of men in household | 0.114<br>[0.098] |
| Number of women in household | 0.159*<br>[0.207] |
| Time spent in collection | 0.574***<br>[0.032] |
| Number of children in household | 0.058<br>[0.045] |
| Highlands (1=Highlands; 0=Lowlands) | 0.215*<br>[0.056] |

*continued next page*

**Table 3 Continued**

| Dependent Variable: Amount of fuel-wood collected in Kgs/week | |
|---|---|
| **Variable** | **Coefficient** |
| Number of girls in household | 0.060<br>[0.059] |
| Number of years of schooling for household head | 0.005<br>[0.006] |
| Dummy for Season ( 1= Wet season; 0 = Dry season) | 0.198***<br>[0.064] |
| Constant | -0.815***<br>[0.167] |
| Number of observations | 287 |
| Log likelihood[11] | -256.21 |

Standard errors in brackets
* significant at 10%; ** significant at 5%; *** significant at 1%
The dependent variable, number of adult males and females, male and female youth, education years of household head and time spent are expressed in logarithms

The time variable is significant, has the expected positive sign and is consistent with the theoretical predictions. Among the household composition variables, the number of adult women was the only significant variable. The site dummy representing the agroecological zones (highlands versus lowlands) was positive and significant implying possible spatial effects of increased consumption of fuel-wood in the highlands due to the extra heating required given that this area is generally cold. The positive sign for the highlands could probably also indicate that more competition for fuel-wood resources means more consumption per household. The collection of fuel-wood products is highly seasonal. More fuel-wood was collected by households during the wet season. However, conclusions concerning the implications of these results cannot be made before undertaking further analysis - using time-related dependent variables. The fuel-wood collection functions, estimated here, are used to derive the shadow wages and prices, as illustrated in the next sub-section.

## Shadow wages/prices for fuel-wood

As explained in the theoretical section, the equation estimated in the previous regression, Table 3 (collection function), is meant to provide estimates of the marginal product of labour in fuel-wood collection. The process of computing the marginal revenue product of labour (shadow wage) is described in detail in the empirical model (Equation 13) and its estimation is based on Sadoulet et al. (1998), Skoufias (1994) and Jacoby (1993). Since in the estimation of the collection function, some dependent variables were expressed in logarithms and given the functional form used in this estimation, the marginal revenue product of labour is estimated by taking the product of the labour input elasticities (the parameter value for time input) and the ratio of predicted quantities collected to time spent.

Since fuel-wood markets are not perfect, shadow “prices” based on the time needed to collect a load of fuel-wood, and shadow wages, are used as indicators of scarcity.

These measures are household specific and to measure virtual or shadow prices of fuel-wood, the time spent to collect a unit of fuel-wood and the shadow wage is combined. In this study, the time spent by a household serves as a good indicator of the scarcity of fuel-wood. Shadow wages measure the opportunity cost of time, and therefore influence the shadow price of fuel-wood. The shadow wages are, therefore, assumed to reflect the relative fuel-wood scarcity each household faces. The greater the extent of forest degradation in a locality, the lower the marginal physical product of household labour in collection of fuel-wood and the higher its shadow price. In other words, the longer it takes to collect a unit of fuel-wood, the higher the opportunity cost of labour per unit of fuel-wood and thus the higher the shadow price of fuel-wood. The shadow prices, therefore, vary across households and seasons because they are based on household characteristics and endowments.

The estimated marginal physical product of household labour was 0.473kg per hour on average. If we compare by season, the marginal product of labour for collection in the wet season (0.479) was statistically different from that in the dry season (0.468). Given that these are household level marginal products (shadow wages), it is difficult to compare them with the average market wages. Multiplying the marginal products by the time per trip, gives the average household level shadow price of fuel-wood of about 97.07, while the shadow prices for the wet and dry season are 94.05 and 99.73, respectively. These shadow prices are not statistically different.

## Determinants of fuel-wood demand

In order to account for the potential presence of measurement error in the estimated household shadow wages and prices, and to correct for inconsistency that may be caused by endogeneity[12] of shadow wages and prices, which are included as explanatory variables in the demand equation, a Two-Stage Least Squares (2SLS) approach (see also Bluffstone, 2001) was applied. The instrumental variable approach (2SLS) was used since the marginal products used in the estimation of the shadow wages are derived from the first regression presented in Table 3. Shadow wages are included as endogenous variables in this regression. It can be argued that such an estimation strategy would lead to inefficient estimates and some circularity since the error terms may be correlated across the equations. However, this would not be a problem if the equations have identical explanatory variables (see Greene, 2000), which is the case with this study. Cross-sectional demand functions using 2SLS are estimated for the rainy and dry seasons separately. Because all households sampled indicated consumption/use of fuel-wood, there was no need to check for sample selection bias caused by exclusion of zero values.

The results for fuel-wood demand functions, with shadow wages and prices included, are presented in Table 4 under the columns "Wet" and "Dry" season. According to the estimated model, 38% and 32% of the variation in fuel-wood demand in the wet and dry season, respectively, was explained by the variables included in the model. Shadow wages have a significant and negative effect on amount of fuel-wood consumed by the household in the wet season, implying that, holding other factors constant, as shadow wages increase, households decrease their consumption of fuel-wood. The shadow price coefficient for fuel-wood demand is significant and positive in the dry season. Household size has positive and significant impacts on fuel-wood consumption. With one extra person in the household, the odds of a household increasing its fuel-wood collection are 38% and 58% higher in the wet and dry season respectively. On the supply side, larger household size also means more labour for fuel-wood collection. Marital status of the household head was negative and significant in the dry season.

**Table 4: Determinants of demand for fuel-wood (kg/week) - 2SLS**

| | Wet season | Dry season |
|---|---|---|
| Shadow wage for fuel-wood collection | -3.057*** | 1.634 |
| | [6.75] | [1.22] |
| Household size | 0.383** | 0.584*** |
| | [2.58] | [3.29] |
| Dummy: Female household head | -0.054 | -0.013 |
| | [0.16] | [0.04] |
| Dummy: Married household head | -0.001 | -0.657** |
| | [0.00] | [2.40] |
| High altitude | 0.728*** | -0.555** |
| | [4.65] | [2.09] |
| Ownership of agric land | 0.065 | -0.155 |
| | [0.65] | [0.97] |
| Education years of the household | 0.101 | 0.06 |
| | [1.42] | [0.65] |
| Log of wage income | 0.008 | 0.013 |
| | [0.16] | [0.33] |
| Log of household pct income | -0.001 | 0.099 |
| | [0.02] | [1.11] |
| Shadow price for fuel-wood | -0.176 | 0.252** |
| | [1.62] | [2.15] |
| Log of remittances | -0.008 | 0.022* |
| | [0.69] | [1.24] |
| Log of price of paraffin | 0.065** | -0.035 |
| | [2.38] | [0.49] |
| Log of price of charcoal | 0.060** | 0.070** |
| | [2.17] | [2.49] |
| Constant | 22.179*** | -8.632 |
| | [6.94] | [1.10] |
| Observations | 131 | 149 |
| Adjusted R-squared | 0.38 | 0.32 |

Absolute value of t statistics in brackets
* significant at 10%; ** significant at 5%; *** significant at 1%
Instrumental Variable Estimation (2SLS) [13]
The dependent variable is log of fuel-wood consumed (kg/week), number of household members size, education, Shadow Prices, wages, income, remittances in logarithms

Non-wage income, through remittances, increases demand for fuel-wood products in the dry season but not the wet season. Workers move back to the rural areas during the rainy season and therefore remittances decrease. On the other hand, in the dry season, there are more remittances as workers send more of their earnings back home, especially for the festive Christmas season. This result partly implies that in the dry season, households that earn remittances tend to increase their demand (consumption) either through purchases or gathering from the farm or forest. The dry season also coincides with the festive season of December and holiday time for school children hence demand for fuel-wood tends to increase. These estimated functional relationships imply that the amount of fuel-wood consumed does not entirely depend on household wealth variables. In sum, the results of the wealth variables show that there was limited wealth effect on fuel-wood demand.

The prices of charcoal and paraffin significantly affect fuel-wood demand. For charcoal, which is a close substitute for fuel-wood in rural areas, an increase in its price leads to an increased demand for fuel-wood. This is an expected result and happens in both seasons. An increase in the price of paraffin only affects demand for fuel-wood in the wet season and not the dry season. Finally, there was seasonal variation in consumption of fuel-wood across the districts. Fuel-wood demand was higher in the highlands, in the wet season, confirming our previous results and expectations. Possible reasons for higher fuel-wood demand in highlands (Kyenjojo) could be attributed to lower temperatures during the wet season. In the dry season, the highland areas consumed relatively less fuel-wood than the lowlands.

## Determinants of household labour allocated to fuel-wood collection

In this section, we focus on intra-household allocation of time for fuel-wood collection. Decision equations are estimated separately for men, women, and youth.[14] The key dependent variable was time allocated by different gender and age groups to fuel-wood collection. Total time spent by men, women, and youth constitute the dependent variables.

Tables 5 and 6 give the results of the cross-sectional demand for household labour input (time) for collection estimates for the wet and dry season, respectively. Shadow wages have significant and negative effects on total household and women's collection time, but increase men's collection time. Men increase their collection activities when fuel-wood becomes increasingly scarce in the wet season and decrease it with the presence of more women in the household. This result may be explained as an indication of men's relative valuation of the opportunity costs of their labour and by the fact that since the wet season is critical to household farming, when labour shortages occur in the household, men compliment women's activities in fuel-wood collection.

The results also show that the increase in total fuel-wood collection time in the wet season comes primarily from women's time. However, more women in the household lead to decreased collection times by youth. This result shows possible substitution between female labour on the one hand and boys and girls on the other, especially in the wet season when labour demands for farm and collection work are at a peak. With more women in the household, men, boys and girls tend to decrease their participation, probably diverting their time to other activities such as farming, leisure or grazing for men and possibly on-farm activities such as planting and weeding, and school time for the boys and girls. The result was replicated for the presence of more men in the household. However, the effect of more men in the household was of lower magnitude than that of women on men's collection time. With respect to the girls, their presence in the household significantly offsets (decreases) women's collection time, hence suggesting that girls substitute for adult female labour in fuel-wood collection. This is a clear case of intra-household substitution of labour.

**Table 5: Household labour allocation to fuel-wood collection (minutes/week): Wet season**

| Independent variables | Women | Men | Youth |
|---|---|---|---|
| Male youth | -0.082 | 1.992 | 1.531* |
| | [0.34] | [1.60] | [1.91] |
| Female youth | -0.528** | -2.352** | 3.281*** |
| | [2.29] | [1.98] | [4.10] |
| Male adults | -1.067*** | 4.587** | -1.846 |
| | [2.97] | [2.50] | [1.60] |
| Female adults | 1.791*** | -1.306 | -3.790*** |
| | [4.51] | [0.68] | [2.92] |
| High altitude | 0.227 | 4.766*** | 3.853*** |
| | [0.73] | [3.17] | [4.00] |
| Ownership of agric land | -0.251 | 0.522 | 1.637** |
| | [1.25] | [0.51] | [2.44] |
| Education years of household head | -0.123 | -0.328 | 0.612 |
| | [0.90] | [0.46] | [1.37] |
| Wage income | -0.003 | 0.418 | -0.386 |
| | [0.04] | [0.79] | [1.41] |
| Remittances | -0.071*** | -0.107 | 0.021 |
| | [2.88] | [0.87] | [0.26] |
| Price of paraffin | -0.043 | -0.16 | 0.627*** |
| | [0.79] | [0.55] | [3.06] |
| Price of charcoal | 0.048 | 0.626*** | -0.339* |
| | [0.86] | [2.64] | [1.96] |
| Shadow wage for fuel-wood collection | -2.664*** | 0.414 | -11.847*** |
| | [3.53] | [0.11] | [4.67] |
| Labour input to farm work in minutes | 0.799*** | -3.121*** | 1.249 |
| | [3.33] | [2.74] | [1.64] |
| Water collection time | 0.241* | -0.909 | -0.633 |
| | [1.76] | [1.50] | [1.45] |
| Constant | 16.393*** | 9.513 | 65.762*** |
| | [3.07] | [0.36] | [3.83] |
| Observations | 131 | 131 | 131 |
| Log likelihood | -211.54 | 135.61 | -193.76 |
| Chi-Squared | 74.33 | 56.65 | 100.61 |

Absolute value of t statistics in brackets
* significant at 10%; ** significant at 5%; *** significant at 1%

The price of charcoal was included in the model to gauge whether its price can be used as an important policy instrument. As expected, the coefficient on charcoal price is positive and significant for men. This implies that fuel-wood is a necessity to the majority of rural households in Uganda, especially in the context of limited access to electricity and other efficient forms of energy. The price of paraffin returned significant and positive results only for the youth. This result is difficult to explain. Fuel-wood collection is positively correlated with water collection and agricultural labour. An increase in time spent on the farm and collection water for women's had a significantly positive effect on their respective collection times. Another important variable is income received from work rendered outside the home. This result was negative for women implying that more remittances to the household would enable women to substitute purchased fuel-wood for collected fuel-wood thereby reducing their collection times. The ownership of land was positive and significant in the youth equations. Location remains important in men's and youth collection times.

Table 6 reports the results for the dry season estimates of time spent in collection of fuel-wood for the different categories. Shadow wages are significant and negative for men only. More girls significantly reduce men's collection time but increases youth collection times. This, like earlier results, implies some degree of substitution between the men and girls. Interestingly, women's collection time significantly increases with the number of education years of the household head and the number of women in the household. The land variable suggests that increased ownership of agricultural land significantly reduced collection time for women in particular. This could be because affluent households and women, who are the main collectors, have more opportunities to collect fuel-wood from their own farms. Location and number of men are important factors in men's labour allocation to farming in the dry season. Men's collection time significantly increases in the highlands compared with the lowlands. An increase in the price of paraffin increases the youth collection time in the dry season. Sometimes, households use fuel-wood for lighting during the dry season and this is an expected result, confirming possible substitution of fuel-wood for paraffin as a lighting source.

**Table 6: Labour allocation to fuel-wood collection (minutes/week): Tobit estimates - Dry season**

| Independent variables | Women | Men | Youth |
|---|---|---|---|
| Male youth | 0.252<br>[0.62] | 0.859<br>[0.57] | -0.697<br>[0.37] |
| Female youth | 0.408<br>[1.02] | -4.144**<br>[2.49] | 7.493***<br>[3.02] |
| Male adults | 0.669<br>[0.98] | 6.777**<br>[2.47] | 4.025<br>[1.17] |
| Female adults | 1.389*<br>[1.73] | 0.258<br>[0.09] | -4.197<br>[1.14] |
| High altitude | -1.306<br>[1.56] | 12.709***<br>[2.96] | 5.164<br>[1.23] |
| Ownership of agric land | -0.972**<br>[2.06] | -5.406<br>[1.66] | 0.723<br>[0.32] |

*continued next page*

**Table 6 Continued**

| Independent variables | Women | Men | Youth |
|---|---|---|---|
| Education years of household head | 0.588** | 0.043 | 2.22 |
| | [2.09] | [0.04] | [1.40] |
| Wage income | 0.031 | 0.815 | 0.303 |
| | [0.27] | [1.04] | [0.53] |
| Remittances | -0.013 | -0.291 | -0.084 |
| | [0.27] | [1.40] | [0.35] |
| Price of paraffin | -0.117 | -0.222 | 2.682* |
| | [0.55] | [0.31] | [1.76] |
| Price of charcoal | 0.092 | 0.304 | -0.404 |
| | [1.05] | [1.06] | [0.96] |
| Shadow wage for fuel-wood collection | -4.689 | -37.334* | -33.331 |
| | [1.27] | [1.94] | [1.65] |
| labour input to farm work in minutes | -0.59 | 2.545 | 2.301 |
| | [1.33] | [1.47] | [1.01] |
| water collection time | -0.043 | 1.366 | 0.514 |
| | [0.17] | [1.39] | [0.43] |
| Constant | 36.349 | 195.882* | 149.036 |
| | [1.65] | [1.70] | [1.25] |
| Observations | 149 | 149 | 149 |
| Log likelihood | -317.06 | -141.63 | -121.2 |
| Chi-Squared | 27.54 | 43.39 | 30.41 |

Absolute value of t statistics in brackets
* significant at 10%; ** significant at 5%; *** significant at 1%

## Determinants of household labour allocation to farming in Uganda

What are the consequences of increased deforestation for agricultural labour input, and what other factors influence household time inputs to agriculture? We answer these questions by examining the relationship between deforestation and participation in agricultural activities by household members in rural areas of Uganda. In the theoretical framework, we argued that the participation of households in agricultural activities depends on several factors including land-use, deforestation, on-farm and off-farm income, household consumption needs (household size and composition), availability of other labour and individual characteristics of household members such as education, gender and age. In this formulation, the variable of greatest interest is the degree of deforestation measured by the time taken to collect a unit of fuel-wood. *A priori,* up to some point deforestation should reduce labour time on the farm because it takes away time from farmers and their farms as they search for fuel-wood.

Table 7 presents the results of the estimation equations for household effort in agricultural production for the wet and dry season. The models were inspected and corrected for omitted variables and heteroscedasticity using the Ramsey reset test and Breusch-Pagan/Cook-Weisburg test[15], respectively.

With respect to the individual explanatory variables, area in crops has a significant positive effect on total household labour input to farming in the wet season only. This is an important result: the way in which the land is used combines with the total area cleared or deforested to determine household labour allocation to farming in Uganda. Off-farm income has a significant negative effect on household farm activities, as expected, apparently easing pressures on households to work on the farm in the wet season. Higher on-farm income (income from sale of agricultural products) tends to reduce household members' participation by facilitating their replacement by hired labour (see also Nieuwoudt and Vink, 1989). With increased incomes, as explained earlier, through the income effect, households would want to purchase more leisure if leisure is a normal good.

The effect of household size on household labour inputs to agriculture in both seasons is a positive and significant impact, as expected. The individual characteristics of the household head, education and age have the expected effects on household farm labour inputs. More educated household heads are less likely to work on farms, but only in the dry season. These results reveal a life cycle pattern of labour allocation (see also Low, 1986). The gender of the household head is positively associated with increased farm labour input in the dry season. Female headed households tend to be associated with increased labour input to farm work in the dry season.

Our results do not support the hypothesis of a negative relationship between total household labour allocation to farming and deforestation at the household level. However, the proportion of land area under crops, wage income and on-farm income, number of livestock owned, household size, age, gender and education of the household head are important determinants of total household farm labour allocation.

Livestock are used as a proxy for wealth and is found to be positively associated with increased labour input on farms in both seasons. Wealthier households have more land and livestock, and therefore, may spend more time farming. A test for the difference in the coefficients shows that the effects of livestock are not significantly different between the two seasons.

**Table 7: Household labour allocation to farming (hours/day)**

| Independent Variables | Total-Wet season | Total-Dry season |
|---|---|---|
| Time per trip of fuel–wood (in hours) | 0.288<br>[0.301] | 0.131<br>[0.309] |
| Household size | 1.123***<br>[0.158] | 1.274***<br>[0.148] |
| Age of the household head | 0.427**<br>[0.208] | 0.495***<br>[0.176] |
| Number of years of schooling for household head | -0.038<br>[0.100] | -0.193*<br>[0.098] |
| Household employed (hired) workers | 1.587<br>[0.988] | 0.32<br>[0.938] |
| Age of household head squared | -0.004*<br>[0.002] | -0.005**<br>[0.002] |

*continued next page*

**Table 7 Continued**

| Independent Variables | Total-Wet season | Total-Dry season |
|---|---|---|
| Livestock | 0.143** | 0.151** |
| | [0.066] | [0.071] |
| Dummy: Female headed household | -2.44 | 3.786** |
| | [1.655] | [1.581] |
| Proportion of area under crops, (proportion) | 1.337** | -0.378 |
| | [0.531] | [0.931] |
| Wage Income (off-farm income) | -3.183*** | -0.41 |
| | [0.967] | [1.401] |
| Agricultural income (on-farm income) | -1.133** | -0.708 |
| | [0.469] | [0.516] |
| Agroecological zone(1= Highlands; 0=Lowlands) | -0.992 | 0.433 |
| | [0.969] | [1.280] |
| Water collection time per trip (in hours) | 0.649 | -0.486 |
| | [0.840] | [0.388] |
| Constant | 23.662*** | 1.693 |
| | [8.745] | [11.279] |
| Observations | 171 | 188 |
| Adjusted R-squared | 0.46 | 0.49 |
| F-Value | 12.03** | 14.75** |

Standard errors in brackets
* significant at 10%; ** significant at 5%; *** significant at 1%

# 7. Conclusion and recommendations

Empirical evidence from the study reveals that decisions to collect and consume fuel-wood in rural areas of Uganda are determined by several social, economic and ecological factors. Women have been found to bear a larger burden of resource collection although men increase participation when these resources become increasingly scarce. Results also suggest that rural villages in Uganda are not homogenous entities (with regard to fuel-wood collection and consumption) that can be isolated and identified by a single objective. We also find some evidence of substitutability between male, female and girls' labour. Land holdings, household composition, individual characteristics and gender roles in the household exert more influence on fuel-wood collection than, for example, time spent on the farm or collecting water. Contrary to the belief that a high cost of environmental resources reduces time allocated to farming, we find that total agricultural time allocation responds to other factors such as the proportion of land area under crops, wage income and agricultural income.

Several policy insights can be obtained from this study. Low-cost strategies for reducing fuel consumption when fuel-wood is scarce should be developed. Fire management may be the most obvious low-cost means of reducing fuel-wood consumption. Emphasis on reduction of existing cultural rigidities can go a long way in reducing the burden women face in resource collection. Policies that reduce fuel-wood collection time and thereby increase the time available for other productive activities should be emphasized. There is need for concerted efforts to strengthen the forest department, and to encourage rural conservation units. Improving the performance of these institutions requires a stronger forest policy, enforcement of rights and less political interference. This also raises the need for increased community level management of forests.

# Notes

1. The concepts of virtual fuel-wood prices and wages are used to take account of non-market activities in fuel collection and consumption, which are common in rural Uganda.

2. At a later stage, we distinguish between male and female labour because of the gender segregation of labour in rural areas. For example, from the field observations, women face extra tasks in household activities such as cooking and caring for children, which men do not.

3. Lopez (1988) assumes X is the composite commodity (*Numeraire*) and its price, $P_x$, is set equal to 1.

4. Equation 9c also implies the transformation of leisure into labour supply for fuel-wood collection, and that is why $L_{se}$ (labour for fuel-wood collection) is used instead of leisure.

5. Note that the measure of shadow prices and wages is household-specific since differences are expected across households in terms of shadow wages and time per trip for various reasons, including household composition and resource endowment.

6. The analytical discussion suggests boys and girls are participants in fuel-wood collection and farm activities. Unfortunately, due to limited observations for each category as boys and girls, they were aggregated into a single 'youth' category for regression analysis but not for the descriptive analysis. Thus, it was not possible to include separate regressions for boys and girls but instead 'youth' was used in the estimation of collection equations.

7. Although the analytical model suggests boys and girls are major participants in on-farm activities, due to limited observations for boys and girls as separate categories, they were aggregated for regression analysis but not for the descriptive analysis.

8. The number of counties per district and sub-counties per county in Uganda vary from two to five while the number of villages per sub-county is more than five, in most cases.

9. This is slightly less that US 100 dollars (exchange rate is UShs 1600/US $).

10. In the context of time allocation, Skoufias (1994) warns that the Tobit estimator is restrictive, in that it presumes the determinants of participation in an activity are identical to the determinants of hours allocated to the activity. If the two were different, the estimated coefficients would be biased.

11. The model was subjected to the likelihood ratio test for mis-specification. The p-values returned indicated the model was not mis-specified.

12. The Durbin-Wu-Hausman test for endogeneity was conducted and the results indicated there was no endogeneity. The p-values (prob F= 0.0005) returned indicated OLS estimation was not consistent.

13. Instruments for shadow wage: household size, female head, marital status of head, Masindi, Buliisa, Kyenjojo, land owned, education years of household head, wage income, income from agricultural goods, remittances, shadow price, total collection time, boys and girls, male and female adults.

14. Girls and boys were combined into one group due to limited number of observations for participation for each category.

15. Ramsey rest test for omitted variables: Wet season - Prob>F =0.37 and Dry season - Prob>F=0.38. The estimates were corrected for heteroscedasticity using the method of White (1980).

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Abstract

Trees, in forested and agricultural landscapes, are particularly important because they disproportionately provide high values of environmental services and biodiversity. In this study, the link between deforestation, time allocation to fuel-wood collection and agriculture is analysed. A non-separable (non-recursive) model was developed to test the participation of households in fuel-wood collection and farming activities using data from rural areas of Western Uganda. Results of the quantitative analysis show that, the more traditional measures of economic conditions – shadow wages and prices, labour time, gender composition of the household, seasonality and agroecological differences – are important variables that affect household labour allocation decisions. The results provide no support to some of the previous studies which show that, as deforestation increases and fuel-wood gets scarce, household members will divert time away from farming. The fact that there is no evidence of labour relocation away from agriculture to fuel-wood collection implies that agriculture is such an extremely important activity and fuel-wood products have not become costly enough to significantly tighten household labour constraints. Efforts are needed to alleviate the labour bottlenecks of subsistence farmers through agroforestry programmes, efficient use of fuel-wood as well as the adoption of efficient cooking equipment, and fuel-wood substitutes which will relieve labour burdens in the collection of environmental goods or reduce collection time for fuel-wood.

**Key words:** *Forests, time allocation, agriculture, firewood households*