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COPING WITH FUEL WOOD SCARCITY: HOUSEHOLD RESPONSES IN RURAL ETHIOPIA

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Abstract

This study examines the coping mechanisms applied by rural households in the face of fuel wood scarcity by using survey data from randomly selected rural households in Ethiopia. The determinants of collection of other biomass energy sources were also examined. The results of the empirical analysis show that rural households residing in forest-degraded areas respond to fuel wood shortages by increasing their labour input to fuel wood collection. However, for households in high forest cover regions, forest stock and forest access may be more important factors than scarcity of fuel wood in determining household's labour input to fuel wood collection. The study also finds that there is limited evidence of substitution between fuel wood and dung or fuel wood and crop residues. Therefore, supply-side strategies alone may not be effective in addressing the problem of forest degradation and biodiversity loss. Any policy on natural resource management, especially related to rural energy, should make a distinction between regions with different levels of forest degradation.

Key words: Fuel wood, labor allocation, biomass, rural Ethiopia

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1. INTRODUCTION

Many people in developing countries rely on biomass energy sources, primarily fuel wood, dung and crop residues, for their energy needs.[1] Widespread poverty in many rural areas of developing countries, especially in sub-Saharan Africa, is considered to be the main factor for continued dependency on biomass energy sources, as is the continued use of biomass energy in traditional and inefficient ways. The continued dependence can be observed across developing countries in the form of forest degradation and deforestation. The continuing degradation and deforestation, particularly in Asia and sub-Saharan Africa, has, in turn, resulted in firewood scarcity.

Ethiopia is a typical example; nearly all of the rural population depends on biomass energy sources for cooking and other energy requirements. Of the different biomass energy sources, fuel wood accounts for around 78% of the total energy demand, while animal dung and crop residues account for 12% and 9%, respectively (Woody Biomass Inventory and Strategic Planning Project - WBISPP, 2004). As these resources must be collected from the available resource pool, such high dependence is likely to have a fundamentally negative impact on the availability of forest resources. A recent government forest policy document approved in 2007 also noted that fuel wood collection, together with land clearing for agriculture, illegal settlement within forests, logging and illegal trade have resulted in the deterioration of forests and forest resources. According to FAO (2009), the country loses about 141,000 hectares of forest each year. Cognizant of these problems, the Forest Development, Conservation and Utilization Policy and Strategy was approved by the Council of Ministers in April 2007, the first time that the Ethiopian government has developed a forestry policy. Though there is considerable policy interest within the government, the link between socioeconomic, environmental and institutional factors and biomass use is not well documented in Ethiopia. A better understanding of the interaction between rural people and biomass use, under different environmental conditions, may help policymakers design better strategies in order to conserve forests and forest resources more effectively in rural Ethiopia.

Fuel wood scarcity, especially in rural areas, has attracted the attention of many researchers and policymakers since the mid 1970's, because it is believed that the problem could have

[1] According to the International Energy Agency (IEA, 2002), 2.4 billion people in developing countries use biomass as a source of energy for cooking, heating and lighting needs.

serious, negative socio-economic consequences for rural livelihoods (Arnold et al., 2003; Mekonnen, 1999). For example, Dewees (1989) and Arnold et al. (2003) argue that scarcity increases the burden on women and children, on whom the task of biomass collection usually falls, influencing the amount of time women and children have for other tasks and activities. Furthermore, in the absence of sufficient fuel wood, increasing quantities of crop residues and animal dung get used for fuel, reducing the availability of livestock feed, soil conditioner and fertilizer. Dewees (1989) argues that fuel wood scarcity could result in increased deforestation, changes in cooking and eating habits, and the emergence of fuel wood markets.[2] However, each of the preceding changes can also occur for a variety of other reasons, not necessarily related to either the physical or the economic scarcity of fuel wood (Dewees, 1989).

Given the potential negative impacts of fuel wood scarcity, understanding the effects of and household level responses to (increasing) fuel wood scarcity represents an important research agenda, with the potential either to impact behaviour or to develop better forestry policy. Early studies examined these responses within the context of fuel wood production and consumption, and, although there are a number of studies of fuel wood production and consumption in Asian and African countries, the empirical evidence is still limited. Kumar and Hotchkiss (1988) find that households in Nepal cope with fuel wood scarcity by increasing time spent on collection. Similarly, Cooke (1998a, 1998b) concludes that when households in Nepal are faced with shortages of environmental goods, as measured by shadow prices, they spend increasing amounts of time collecting these environmental goods, without affecting agricultural productivity, such that the reallocated time must come from other activities, e.g., leisure. Brouwer et al. (1997) find that Malawian households switch to lower quality wood, economize on wood use and increase the number of collectors. Heltberg et al. (2000) find that households increase their collection time, in forest-degraded areas. Similarly, Palmer and Macgregor (2009) find that fuel wood scarcity has a positive effect on labour inputs to fuel wood collection. Both Heltberg et al. (2000) and Palmer and Macgregor (2009) examine the relationship between fuel wood scarcity and forest degradation using collection time per unit of fuel wood as an indicator for fuel wood scarcity. In contrast, van `t Veld et al.(2006) find that households in India do not spend more time searching for fuel wood, when biomass availability from common areas decreases. Instead, households are less

[2] See Cooke et al. (2008) for further implications of fuel wood scarcity on rural household welfare.

likely to collect from common areas at all, and are more likely to use privately produced fuel. Cooke et al. (2008), in their review, argue that there is a need for more evidence from African countries.

In addition to examining the direct household response to fuel wood scarcity, in terms of fuel wood collection efforts, the literature has also examined indirect responses, such as substitution towards other biomass energy sources. Both Heltberg et al.(2000) and Palmer and Macgregor (2009) find that there is limited evidence for substitution between fuel wood from commons and private fuels and fuel wood and dung in India and Namibia, respectively. Mekonnen (1999), using virtual prices, finds that dung and fuel wood are complements. Amacher et al.(1993) find that crop residues and fuel wood are complements in one region of Nepal, but are substitutes in another district of the study area. A review by Cooke et al. (2008) summarizes the cross-price evidence (substitution or complementation) between fuel wood and dung, and fuel wood and crop residues as mixed.

As the previous research suggests, fuel wood scarcity results in increased fuel wood collection efforts. However, it is also clear that the literature has not settled upon the appropriate indicator of fuel wood scarcity. In particular, Brouwer et al. (1997) argue that the distance to collection place and the collection time are not reliable indicators of firewood shortages, as so often postulated in the literature, because households from the same village often show considerable differences in collection strategies. In addition to not settling on a single indicator for scarcity, the literature does not generally relate household responses to forest status, a more appropriate indicator of scarcity, with the exception of Bandyopadhyay et al. (2006) and van `t Veld et al. (2006). As discussed by Dewees (1989) and Arnold et al. (2003) early analyses failed to distinguish between physical and economic measures of scarcity and abundance.

In this research, although we follow the literature in making use of collection time as an economic measure of scarcity, we are also able to control for physical measures of scarcity based on spatial data. As there are few studies combining spatial information with household level data (Dasgupta, 2005), one contribution of this research is to account for differences in household responses to fuel wood scarcity under different environmental conditions. Moreover, the spatial data enable us to separately analyse household’s fuel use behaviour by status of forest cover. Our study includes spatial data, incorporates biomass availability related to the level of forest degradation and includes household specific measures of fuel wood scarcity. Using mixed data, this study is able to consider: (i) whether or not households increase their fuel wood collection time, when faced with fuel wood scarcity; (ii) whether or not households respond differently to fuel wood scarcity in different forest conditions; and (iii) the relationship between fuel wood scarcity and the consumption of other traditional fuel sources, such as dung and crop residues. We consider these issues by empirically analysing the link between the socioeconomic, environmental and institutional factors that affect household coping mechanisms in the face of fuel wood scarcity, with special attention to the level of forest degradation.

The remainder of the paper is organised as follows. In the succeeding section, the theoretical and empirical framework is outlined. Given the nature of rural households in this study area, in particular, and other developing countries in general, the theoretical framework is based on the farm household model. Section 3 describes the study area, the nature and sources of the data, and provides summary statistics of that data. Section 4 presents empirical results and discusses those results within the context of the literature, while Section 5 concludes and discusses policy implications.

2. ANALYTICAL FRAMEWORK

2.1. The Farm Household Model

Rural households in Ethiopia are both producers and consumers of fuel wood and other biomass energy sources, suggesting that markets for biomass energy sources are missing or incomplete. Moreover, collection activities in rural Ethiopia do not involve hired labour, which is further evidence of missing markets. Given that many markets are missing, the appropriate analytical framework is a non-separable household model incorporating the consumption and production decisions of the farm household.[3] The main implication of the household model is the need for household specific shadow prices, in order to examine rural household behaviour towards consumption and production of, as well as labour allocation to, fuel wood and other biomass collection. Because the market price has a limited role for households that produce and consume all their fuel wood, Mekonnen (1999) and Cooke (1998a, 1998b) derive the household opportunity cost for collecting fuel wood and use it to

[3] For further details on agricultural household models, refer to Singh et al. (1986).

estimate the shadow price of fuel wood. The model developed for this study follows a similar strategy, although abstracts from a number of interesting details.

Consider a unitary peasant household with concave utility over net income, energy and leisure. In other words, $U = U(\pi, E, \ell;\ \Omega_U)$, where the first argument denotes net income, the second denotes energy and the third, leisure; these are conditioned on household preferences. Energy is assumed to be the sum of energy from all sources, firewood, dung and crop residues, respectively, such that $E = F_E + D_E + R_E$. Leisure is total time net of all labour supplied in all activities, such as labour supplied to the market and in the collection of fuel wood, dung and residues; therefore, $\ell = T - L - F_L - D_L - R_L$. Income arises from the sale of agricultural goods and fuel wood, although fuel wood could also be purchased, as well as wage earnings. Furthermore, agricultural production is assumed to depend on non-energy dung and crop residues, which are determined by their respective labour inputs, as well as technology, while fuel wood production is also determined by its labour input and the technology affecting production. Allowing a, f and w to represent the prices of agricultural goods, fuel wood and labour, net income is written as in (1), while the conditioning technology information, Ω_j, in each production function is product specific.

$$\pi = a[A(D(D_L; \Omega_D) - D_E, R(R_L; \Omega_R) - R_E; \Omega_A)] + wL + f(F(F_L; \Omega_F) - F_E) \qquad (1)$$

The preceding specification assumes: (i) all energy sources are perfectly substitutable, (ii) the trade-off for using dung or crop residues for energy is a reduction in agricultural output, (iii) the use of labour for any activity reduces leisure, and (iv) $A(0,0; \Omega_A) > 0$, i.e., if no fuel wood is available, households can still produce agricultural goods, while using all dung and crop residues for energy.

Maximizing household utility subject to the energy, leisure and profit constraints, as well as non-negativity constraints for each of the energy and labour choice variables yields a series of conditions specifying optimal household behaviour. The conditions yield a set of household level "market" equilibriums for each labour and energy type. Generally, households will equate the marginal utility of leisure with the marginal utility of profits times the value of the marginal product of labour in each of the three energy collection activities. Similarly, households will equate the marginal utility of energy with the marginal utility of profits times the marginal profit associated with that energy source. Importantly, the equilibriums are only a function of the exogenous information, Ω_j, and prices, a, f and w.[4] Once these equilibriums have been determined, it is possible to place the model within the context of this research. In terms of energy substitution, although it was subsumed in the model specification, energy substitution does not necessarily arise in the model, since substitution away from fuel wood toward either dung or crop residues reduces agricultural productivity. For example, if the value of agricultural goods is high enough, relative to fuel wood, households could prefer to focus on agricultural production, while purchasing their fuel wood from the market. Regarding household level responses to fuel wood scarcity, which would imply an increase in the market and shadow prices of fuel wood, households could choose to either work harder to reduce their expenditure on fuel wood (raise the market value of their sales) or cut their energy use to maintain their leisure and/or focus their efforts on agricultural production. Given the many possible household level responses, even within this simple theoretical construct, the impact of fuel wood scarcity on household behaviour is an empirical question, the methodology for which is considered, below.

2.2. Empirical Methodology

In the preceding subsection, we briefly described a simple model of household behaviour, in the face of fuel wood scarcity. That model yielded separate equations for each type of labour and energy included. However, the focus of the empirical research is only on a subset of these equations: labour devoted to fuel wood collection, participation in dung collected and participation in crop residue collection; the initial equations are intuitively subsumed in the three that are estimated.[5]

2.2.1 The Empirical Model

Guided by theory, but constrained by data limitations, the goal of the empirical analysis is to describe: the household level equilibrium allocation of labour to fuel wood collection activities, participation in and collection of dung and participation in collection of crop residue. In the sample, only 42.5% and 35% collect dung and crop residues, respectively.

[4] A more complex model would include a number of other factors and markets, such as home-produced goods and market-purchased goods, which would expand the set of exogenous information, but not change the general conclusions derived in the model.

[5] Unfortunately, the data do not allow us to separate dung used for agriculture (fertilizer) from dung used for energy or crop residues used for agriculture (livestock feed) from crop residues used for energy. Although the available data detracts from our ability to correctly quantify substitution across energy use, it is still possible to consider substitution across energy sources, although dung and crop residue collection in this data are not only collected for energy use.

Theory suggests that each of these equilibriums is determined by preferences, technology, prices, and other exogenous information, and that these equilibriums are interrelated. Therefore, the empirical strategy is based on the estimation of the following equations related to energy production and consumption by the household.

$$y = G_y(X_y, P) \tag{2}$$

In (2), $y = \{F_L, Q_D, Q_R\}$, where F_L, labour allocation to fuel wood collection, was described earlier, Q_D represents the quantity of dung collected, Q_R denotes the quantity of residues collected, X_y represents a vector of observable controls related to preferences and technology, for the outcome considered, while P represents prices, which might be shadow prices or market prices, depending upon the type of energy considered. In principle, equation (2) could be estimated as a system of equations; however, missing data problems, specifically data that is not missing at random, require a circuitous route.

In the sample used, described more fully below, price information is scant. For example, agricultural prices are not available and therefore those prices are ignored in the analysis. Similarly, labour is provided outside of the household for only a subset of households, and, therefore, wage data is missing for some households. Furthermore, a number of households do not collect fuel wood from the commons, such that fuel wood collection time, our measure of fuel wood scarcity, is not available for all households;[6] therefore we follow methodology similar to that proposed by Heckman (1979). Given that these prices are missing in the data, they are estimated and predicted via selection methods, based on (3) and (4).

$$\text{prob}(P > 0) = \Phi(X_P, Z_P) \tag{3}$$

$$P_{P>0} = P(X_P, \lambda_P) \tag{4}$$

In equation (3), Φ represents the cumulative normal distribution, and, thus, is estimated via a probit specification, X_P is a vector of control variables, while Z_P is a variable that affects participation, but is assumed to not affect the actual price, except through participation. From (3), it is possible to calculate the inverse Mills ratio, λ_P, which is included in (4) to correct for selection bias. Predicted values for the entire sample, based on (4), are incorporated into (2) for estimation using all of the available observations.

$$y = G_y(X_y, \hat{P}) \tag{5}$$

Equation (5) includes two generated regressors, and, therefore, the complete estimation process – the estimation of (3) and prediction of (4) for both wages and fuel wood collection

[6] By assumption, based on observation of the study areas, there are no markets for either dung or crop residues.

time, as well as the estimation of (5) – is bootstrapped to generate appropriate standard errors. The non-separability property of the household model implies that the functional form of the reduced form equations (5) cannot be derived analytically (Singh et al., 1986). Therefore all functions are assumed to be linear in their arguments.

2.2.2. Prices and Exclusion Restrictions

In empirical work on fuel wood scarcity, there are two types of scarcity measures: physical measures and economic measures. Physical measures, such as the distance from the forest or village level biomass availability, as applied by van `t Veld et al. (2006), control for the household's ability to directly access forests. Dewees (1989) and Cooke et al. (2008), however, argue that physical measures may not be a reliable indicator, since labour shortages are often more important for household fuel use decisions than physical scarcity of fuel wood. Therefore, the opportunity cost of the time spent collecting may be a better measure, although it is often unobservable. Two common proxies for the opportunity cost are exemplified by Cooke (1998a, 1998b), who uses the wage rate multiplied by the time spent per unit of environmental good collection, as her measure of scarcity, and Mekonnen (1999), who uses the marginal product of labour in energy collection multiplied by the shadow wage. In the absence of markets, household responses to fuel wood scarcity can be assessed through the impact of non-price variables on fuel consumption (Heltberg et al., 2000). Therefore, in line with Heltberg et al.'s argument, we use the time spent per unit of fuel wood collected (measured as hours/kg of fuel wood collected), as our measure of fuel wood scarcity. This better reflects the time cost of gathering fuel wood from the forest.

For households collecting from the commons, it is possible to observe our measure of the fuel wood shadow price. For those not collecting from the commons, on the other hand, it is necessary to predict those values, since they depend on either their own sources or market sources. However, it is not possible to calculate the shadow price of dung and residue collection, as most households in the sample collect these energy sources from their own fields; a market for these goods does not exist. Fuel substitution possibilities between fuel wood, dung and residues, are examined via the magnitude and sign of the shadow price of fuel wood (as measured by hours per kg of fuel wood collected from the commons) on the production and consumption of both dung and residues, as measured by participation in collection activities. However, estimation of the economic scarcity, due to missing data problems, requires an exclusion restriction. We use a physical indicator of scarcity, in the form of biomass availability from a GIS survey, as our exclusion restriction.[7]

Also, in the data, only a limited number of households earn income from off-farm activities, such that market wages are not observed for the entire sample. Therefore, we also estimate and predict the opportunity cost of labour, following selection methods (Heckman, 1979).[8] The primary exclusion restrictions for participation in off-farm labour activities include measures of farming activities, such as livestock and land holdings, as well as non-labour income, such as remittances. Larger farms are expected to require greater labour inputs, and, thus, reduce the likelihood that any member of the household works off the farm.[9] Furthermore, actual farm-size should not affect wages in the labour market. Finally, less than half of the sample collects either crop residues or dung; therefore, the quantities collected are also estimated via sample selection methods. The primary exclusion restriction for these quantities is household knowledge of the rules governing forest use.

2.2.3 Analysis Variables and Expected Effects

Although the main interest in the analysis is the effect of fuel wood scarcity on household behaviour, other household and community level variables are expected to affect behaviour, and are, therefore, included. As already discussed, the off-farm wage rate measures the opportunity cost of household time, although the marginal product of agricultural labour is also common in the literature (Skoufias, 1994; Jacoby, 1993). It is expected that higher opportunity costs reduce household fuel wood and other energy collection activities. The other price, collection time per unit of fuel wood, which is an additional measure of the opportunity cost of time (in fuel wood collection activities) is also expected to affect behaviour. Higher opportunity costs should reduce fuel wood collection efforts; however,

[7]Households located farther from town are more likely to collect fuel wood from communal forests, while households with more educated heads, greater forest access and are located farther from markets are less likely to collect from communal forests. Time spent collecting, on the other hand, is higher for households located farther from markets, but is lower for households with knowledge related to the rules governing forest use, and for households, whose head, has ever been a member of an organization. Although there is a negative selection effect, the effect is insignificant. The results are presented in Appendixes B and C.

[8] For more information on the estimation of Heckman's sample selection model and the marginal effects, see Greene (2003, pp 780-787).

[9]Off-farm labour participation is negatively associated with land size and livestock ownership. Participation is positively associated with the Amhara and Tigray regions. Education also increases the probability of participating in off-farm labour activities. The number of children below 5 reduces participation, although not significantly so. Furthermore, average schooling (positively), distance to town (negatively) and the number of male members of the family (negatively) are all significantly related to the off-farm wage rate. The participation and wage regression results are presented in Appendix A.

higher costs of fuel wood collection could either increase or decrease efforts related to collecting other energy sources, depending on the degree of substitutability. Van `t Veld et al. (2006) find that higher opportunity costs lead to substitution towards lower quality energy sources, while Mekonnen (1999) finds that fuel wood and dung are complements.

In an effort to control for preferences and technology, a number of household characteristics are also included, such as: the age, sex and education of the household head. Each is expected to reduce household collection activities. Households with younger heads are more inclined to participate in other activities and, hence, have less time available for fuel collection. Increased education is expected to increase the opportunity cost of time, thus reduce collection efforts. Educated households have greater access to private sources and are observed to purchase from the market. Similarly, educated households are more likely to understand the importance of dung and residues, as a fertilizer, in the production of agricultural activities. Children in the household, measured by the number of children below the age of five, are expected to reduce all labour inputs, since it is more difficult to leave young children unattended. However, a greater number of older household members increases labour supply, and, thus, is likely to increase all labour inputs. Similarly, older children would be able to attend to younger children, allowing other household members to work. However, it is also true that larger households are expected to require more energy for household activities, such as cooking and heating.

As an indicator for household wealth livestock ownership, land holdings and non-labour income are also included. Relatively wealthy households are expected to consume smaller quantities of traditional biomass fuels. According to the energy ladder hypothesis, as income increases households will shift to better energy sources, such as: kerosene, LPG and electricity. However, given the limited availability of these alternative sources, the energy ladder hypothesis does not hold much traction in the rural Ethiopian context; instead fuel-stacking behaviour could be more relevant.[10] However, it should also be noted that livestock holdings should increase the availability of dung. Similarly, land holdings are likely to increase the availability of crop residues, although households with large land holdings have more agricultural production and require more dung and residues for fertilizer.

[10] The discussion of the fuel-stacking behaviour of rural households is not the interest of this study. Masera et al. (2000) critiques and provides an alternative to the energy ladder hypothesis.

The impact of variables related to forest stock, level of biomass, forest access and local institutions are also assessed in the analysis. The forest stock measures the number of people per hectare of forest and is included to account for forest quality. Population density measures the number of people per hectare of the village to account for local area demand. Biomass availability is a more accurate combination of forest stock and population density. It is measured as the amount of biomass per hectare of forest per capita; it is more accurate because the numerator is taken from a GIS survey. Reduced forest stocks and increased densities are expected to decrease the marginal product of fuel wood collection labour inputs, which could increase or decrease collection efforts depending upon whether or not the household needs to satisfy a minimum energy requirement and the ability of households to substitute across energy sources. Finally, local level institutions are included to account for the level of protection accorded to the commons within the community. Although the data is not complete, we create a dummy variable indicating household awareness of government rules related to forest use. Greater awareness is expected to reduce fuel wood collection labour inputs, and, assuming substitutability across energy sources, increase the collection of dung and crop residues.

3. STUDY AREA AND DATA

The data arises from a survey conducted under the auspices of the "Household Forest Values under Varying Management Regimes in Rural Ethiopia" project.[11] Data was collected from four regions in the country, namely: Amhara, Oromiya, Tigray and Southern Nations, Nationalities and People's (SNNP) regions. Within those regions, a total of ten Woredas were chosen purposively: three from Amhara, three from Oromiya, three from SNNP, and one from Tigray.[12] The current sustainable land management program (SLM) in the country informed site selection.[13] One of the goals of site selection was variation in forest cover, agro-ecology, and local level institutions, and, therefore, four kebeles were selected from each Woreda, two from within and two from outside the SLM programme. Therefore, the total number of sample sites is 40. The households to be surveyed were obtained from

[11] Individuals with extensive fieldwork experience were chosen to supervise the data collection efforts, while the enumerators were selected, based on their experience in a similar survey; enumerators received three days of training before entering the field; the entire process was monitored.
[12] Woreda is an administrative division of Ethiopia managed by a local government, which is equivalent to a district. Kebele, or peasant association, is the lowest administrative unit. A woreda is composed of a number of kebeles.
[13] The Ministry of Agriculture and Rural Development of Ethiopia runs the program, which is funded by external donors such as the World Bank and the Global Environment Facility Trust Fund.

household lists available from the kebele administration offices; 15 households were selected from each kebele, yielding a total of 600 households to be interviewed.[14]

The survey data includes information on household characteristics, health and social capital, consumption and production of various agricultural products and market purchased goods, labour allocation towards various agricultural products and market purchased goods, labour allocation related to various agricultural and non-agricultural activities, information on credit markets, the household's perception of forest values, rules and regulations, forestry programs and questions related to valuations and household time preferences. In addition to the household level survey, focus group discussions were held at each sample site for purposes of gathering villagers' attitudes and perceptions regarding forest management rules and regulations, use of technology, and other relevant information. In addition to the primary (survey) sources, field visits were undertaken to gather information about the study sites at the grassroots level, including information on local forest types, watershed area, area of woredas and kebeles, the woreda and kebele populations, the location and type of farming system and related information.

3.1. GIS Data

One of the major advantages of this study is the availability of GIS information. Specialist foresters, GIS experts who can integrate aerial photographs with ground-level forest and vegetation information to create a measure of forest cover, collected the GIS data. Information from the GIS survey, such as forest cover, total area of each sample site, and total biomass availability in each site are incorporated in the analysis.[15] From the forest cover data, we were able to identify and classify study sites into two groups: relatively high forest cover (HFC) and relatively low forest cover (LFC), the latter of which is often referred to as a degraded area in what follows. Households living in areas where the forest cover is less than 30% of the total area are classified under LFC, while households living in areas where forest cover exceeds 30% are classified as HFC. Accordingly, 62.1% of the sample households

[14] The first household in the kebele was selected randomly from the list, while the remaining households were chosen systematically; For example, if there are 150 households in the kebele, then the first households is chosen randomly. In other words, if the 4th household on the list was randomly selected, the 14th, 24th, and so on, households were chosen until 15 households were included.

[15] One of the project team members undertook the Biomass estimation. The Biomass regression equations he used for estimating the biomass of tropical trees is based on Brown et al. (1989) and Brown and Iverson (1992)

belong to the LFC and 37.9% reside in HFC regions.[16] Unfortunately, forest cover data was not available in Mustembuay, Yelen, Gosh Beret and DebreTsehay, due to the lack of satellite imagery. However, that information gap was filled from community survey estimates.

3.2. Energy Use

Modern fuels including electricity are not common sources of household energy in these study regions. Instead, most energy sources (dung, crop residues and fuel wood) are obtained from own fields, natural forests and state or government forests. Very few households, only 4.5% in the sample, purchase fuel wood. However, nearly all households collect either dung or crop residues for own consumption, while all households collect and consume some fuel wood, as part of their energy requirement. Approximately 48% of the sample households collect their fuel wood from commons, while 42.6% and 35% of the sample households are collecting/using dung and crop residues for energy, respectively.

Energy in Ethiopia is primarily used for cooking, heating and lighting. *Injera*, traditional pancake-like bread, requires baking, which is the most energy consuming activity in Ethiopia in both urban and rural areas, and that baking is primarily undertaken through the burning of fuel; other biomass energy sources, such as dung and crop residues, are less preferred sources of energy for household cooking (Zenebe, 2007). However, the nature of the relationship between fuel wood and dung and crop residues is still an empirical issue. These biomass energy sources have other alternative uses. Households use biomass, primarily dung, as a fertilizer and, primarily crop residues, as livestock feed. Biomass is also used for construction purposes; crop residues are common roofing materials, while dung is commonly used for floors and walls.

We expect that increased availability of fuel wood would release dung and residues for these other non-energy purposes. However, about 48% of the sample households responded that they would not reduce their dung consumption, even if more fuel wood became available,

[16] Sample site forestry cover ranges from 65 to 4613.74 hectares, while the forest coverage proportion ranges from 3.9% to 77.4%. On average, sample sites are 26.9% forest. Though there are many ways of classifying forests (for example, low, medium and high forest cover), we prefer to divide the sample in to two. As the sample size decreases, it will reduce the statistical power of a test. As a result, we chose 30% arbitrarily since our objective is to see whether households behave differently in different forest conditions.

while others reported that they would increase their usage of dung, if more fuel wood became available. Survey responses of this nature provide some indication of the difficulty faced by policymakers, as the responses suggest that supply-side strategies, alone, are not likely to effectively address rural energy shortages or reverse the decline in agricultural productivity resulting from the diversion of dung and crop residues for energy needs (IFPRI, 2010). Until there is an increase in alternative energy sources or improvements in the efficiency of, especially, cooking technology, the dominance of biomass energy resources will continue into the foreseeable future in Ethiopia. Therefore, it is necessary to understand the manner in which households use the available energy sources, and design ways to sustainably manage the available resources.

3.3. Descriptive Statistics

Table 1 presents a summary of the descriptive statistics of the explanatory variables used in the empirical analysis. The summary is presented for two categories (based on forest cover status), separately. A simple comparison of these statistics suggests large differences between the two groups across a number of variables. For example, average land size and livestock holdings are higher in the relatively high forest cover (HFC) areas, while non-labour income in the form of gifts, remittances and aid is higher in the relatively low forest cover (LFC) areas of this sample. The forest stock, measured as the total number of people per hectare of forest, is 24.82 and 2.78 persons per hectare of forest for the LFC and HFC areas, respectively. By definition, our measure of forest access, the number of people in the community per hectare of the kebele area, is higher in the LFC. Similarly, there is a significant difference between LFC and HFC areas in terms of biomass availability. The mean values of forest stock, forest access, and the level of biomass for the LFC clearly indicates that it is highly degraded compared to HFC. Other individual and household characteristics such as age and gender of the household head, the education level of the household head, family size, the number of male and female members 10 years old or older are more or less the same in the two groups, suggesting that the sampling strategy was reasonable, and that the analysis should be able to detect differences in household behaviour that can be attributed to biomass availability.

Table 1. Summary of Descriptive Statistics by Forest Status

DESCRIPTION	LFC (N=368)		HFC (N=224)		TOTAL (N=592)		Difference in means
Variable	Mean(μ_0)	S.D.	Mean(μ_1)	S.D	Mean	S.D.	$(\mu_0 - \mu_1)$
HOUSEHOLD LEVEL VARIABLES							
Age(Age of the HH head)	45.43	11.98	46.08	13.87	45.68	12.72	-0.650
Sex(Sex of the HH head; 1 if male, 0 if female)	0.91	0.29	0.91	0.29	0.91	0.29	0.004
Educhead(Education of HH head; 1head can read and write, 0 otherwise)	0.48	0.50	0.53	0.50	0.50	0.50	-0.047
livestock (Livestock ownership in tropical livestock unit, TLU)	4.45	2.80	6.24	4.83	5.13	3.80	-1.786***
landha(land size in ha)	1.37	0.97	2.62	2.11	1.84	1.62	-1.249***
Family_adeq(Family size in adult equivalent)	5.70	1.97	5.80	2.29	5.74	2.10	-0.107
Male10(Number of male members age ≥ 10 years)	2.31	1.29	2.31	1.40	2.31	1.33	0.000
Female10(Number of Female members of HH age ≥ 10 years)	2.15	1.08	2.20	1.28	2.17	1.16	-0.050
Child5 (Number of children ≤ 5years)	1.08	0.93	1.24	1.12	1.14	1.01	-0.155**
Nonlabor(Amount of non labour income in Birr)	311.05	1044.8	168.85	726.9	257.2	939.2	142.20**
Avschooling(Av. schooling level of the family; years of schooling divided by No. of family members above 6 years old)	3.88	2.28	3.57	2.01	3.77	2.19	0.309**
VILLAGE LEVEL VARIABLES							
Forest_acess(Number of people/ HA in the kebele)*	2.81	2.79	1.35	1.16	2.26	2.42	1.46***
Forest_stock(Number of people/ HA of forest)	24.82	24.67	2.78	1.72	16.48	22.22	22.04***
Bio-hh (Biomass availability per household (Kg/ha/hh)	12.18	13.65	49.56	70.87	26.32	48.37	-37.37***
govt_rules(Dummy =1,if a HH is aware of government rules, 0 otheriwse)	0.48	0.50	0.53	0.50	0.50	0.50	-0.05

*Information for 4 sample sites (Mustembuay, Yelen, GoshBeret and Debretsehay) was obtained from villagers estimation (no information from spatial data).

The primary outcome variables of interest in this analysis – labour inputs and the total collection of three types of biomass energy – are summarized in Table 2. In order to calculate the values in the table, data on conversion factors were collected from each district for each type of fuel and for each type of forest product. The quantity of fuel wood, dung and residues were recorded using local units, and later converted into standard weight measures, kilograms. The data is based on annual figures, since all biomass energy sources are collected throughout the year. In particular, the data on number of trips per week (by each member of the family) to collect each type of biomass fuel were asked of the household. A follow-up question related to the amount of biomass fuel collected per trip was also asked. Since the amount of biomass collected may vary between seasons for some households, the same questions were asked for both the summer season and the winter season. The total quantity (per season) was calculated as the product of the number of trips per week and the amount of biomass collected per trip, while the sum across the seasons yields the total quantity. Given that no labour is hired for collection, such that family members collect all of the biomass, a household based summation is an appropriate measure of total collection.

Table 2: Descriptive statistics of labour supply and production of biomass energy sources

	N	Mean	S.D.	Min	Max
Annual time(hrs/year)					
Total time fuel wood	577	302.58	342.59	6.07	3796
Total time dung	252	107.31	170.47	2.60	1534
Total time residues	206	152.37	196.23	1.73	1560
Annual Quantity (kg/year)					
Quantity of fuel wood collected	577	2303.39	1542.01	273.00	10920
Quantity of dung collected	252	1919.61	1967.68	145.60	15600
Quantity of crop residues collected	206	1315.07	1320.08	22.75	10400

*The number of observations (N) refers to those households who participated in collection of the fuel.

4. REGRESSION RESULTS

The main objective of the study is to analyse rural household responses to fuel wood scarcity, as measured by collection time per unit of fuel wood collected (in hours/kg). The study emphasizes the time allocation decision of rural households, testing whether or not households shift towards other traditional biomass energy sources and/or increase their time allocation towards fuel wood collection, when faced with firewood shortages. The analysis is based on the estimation of labour allocated to fuel wood collection, the quantity of dung produced and the quantity of crop-based biomass residues produced. Each of these equations are estimated as functions of the quality of the local forest cover available to the households, as well as a number of household level controls, including the off-farm wage; however, since many households do not have members working outside the household, the wage must be estimated for these households. Furthermore, as many households also do not make use of the commons to collect firewood, the shadow cost of fuel wood collection was also estimated for these households.

4.1 Labour Allocated to Fuel Wood Collection

Unlike other studies related to rural energy, we were able to classify study areas based on forest cover using GIS information, allowing us to consider the possibility that forest cover affects the quantity of labour allocated to fuel wood collection. The household labour allocation towards fuel wood collection was estimated separately for degraded forest areas (LFC), and less degraded forest areas (HFC). A Chow test for pooling across this measure of forest cover was also applied, and the results rejected the hypothesis that the estimates could be pooled, at a one per cent confidence level ($F_{(16, 545)} = 2.04$, p-value = 0.0001).

Table 3 presents the regression results of fuel wood collection labour inputs for the LFC, HFC and pooled samples, where the labour input is measured as the natural log of total household time, in hours, allocated to fuel wood collection. In line with many similar studies, the shadow price (collection time per kg of fuel wood collected) in the pooled regression is positive and statistically significant at the 5% level.[17] For households in close proximity to degraded forests, the shadow price is positive and significant at the 10% level; however, for households living near higher quality forests, the shadow price is not a significant determinant of total collection time. Therefore, as forest resources become increasingly scarce in an already degraded area, rural households respond by increasing total fuel wood collection time. Any attempt to generalize the responsiveness of demand or production of fuel wood to increasing forest scarcity, without taking into account the forest status of the study area, therefore, would be misleading.

The impact of community level variables related to forest stock, forest access and local institutions are also included in order to examine their influence on fuel wood collection. In the analysis, forest access, as measured by population density, is positively and significantly correlated with fuel wood collection time in LFC areas, but the correlation is insignificant for

[17] The results for the participation regression equations for predicting the time spent collecting fuel wood are presented in Appendixes B and C, respectively.

HFC areas. This result is similar to Heltberg et al. (2000), in that households respond by increasing their collection time in areas where population density is relatively high. Similar to both Heltberg et al. (2000) and Palmer and MacGregor (2009), we find that forest stock, measured by the number of people per hectare of forest, is negatively correlated with the time spent collecting fuel wood in the pooled regression. We find a similar result in the HFC regression, but there is no significant influence on LFC households. In terms of the community level knowledge dummy variable, we find that households that are aware of forestry rules and regulations undertake significantly more hours to collect fuel wood in the pooled regression, although it is not significant in either the HFC or LFC regions.

Household characteristics, such as age, sex and the education level (except for the HFC) of the household head have no impact on fuel wood collection labour inputs, irrespective of the status of forest cover. In contrast to Heltberg et al. (2000), the number of female household members aged 10 years old and older was found to be an insignificant determinant of fuel wood collection time. The number of children is also insignificant in both the HFC and LFC regions, although it is positive and significant for the pooled regression. In contrast, the number of male household members negatively impacts collection time in LFC regions, although the relationship is insignificant within HFC regions and for the pooled sample.

Table L3: Regression – Labour Input to Fuel Wood Collection (from all sources)

	POOLED	HFC	LFC
Variable	Coef	Coef	Coef
Collection time	3.963**	3.817	5.704*
	(2.25)	(5.97)	(3.57)
Wage rate (predicted)	-0.652**	-0.005	-0.422
	(0.35)	(0.76)	(0.36)
Age of HH head	-0.152	-0.384	0.114
	(0.24)	(0.34)	(0.31)
Sex of HH head	-0.050	0.045	-0.093
	(0.17)	(0.26)	(0.21)
Education of head	-0.081	-0.272*	0.029
	(0.11)	(0.21)	(0.18)
Land size in hectare	0.429***	-0.107	0.702***
	(0.15)	(0.26)	(0.25)
Livestock ownership in TLU	-0.144	-0.104	-0.093
	(0.12)	(0.16)	(0.15)
Government rules	0.261***	-0.008	0.257
	(0.11)	(0.72)	(0.24)
Amount of Non-labor income	0.000**	0.000*	0.000
	(0.00)	(0.00)	(0.00)
Number of children under 5	0.104**	0.067	0.079
	(0.05)	(0.08)	(0.07)
Number of male members above 10 years	-0.056	0.034	-0.104*
	(0.06)	(0.07)	(0.07)
Number of female members above 10 years	0.013	0.029	-0.021
	(0.05)	(0.07)	(0.06)
Forest access	0.112***	0.056	0.103***
	(0.03)	(0.26)	(0.04)
Forest stock	-0.009***	-0.173*	-0.004
	(0.00)	(0.11)	(0.00)
Biomass availability	0.002**	0.003**	0.015**
	(0.00)	(0.00)	(0.01)
Constant	6.266***	6.516***	4.001***
	(1.18)	(2.64)	(1.54)

*The numbers in brackets are bootstrapped standard errors. *, **, and *** represents significance level at 10, 5 and 1%, respectively. The dependent variable is the log of the total household annual labour time (in Hours) allocated to fuel wood collection. Livestock (in TLU), land (in ha) and Age are in log form. Variance inflation factors were considered for multicollinearity; all were under 5, and deemed acceptable. HFC and LFC represent the relatively high forest cover and low forest cover regions, respectively.

The impact of wealth indicators, such as land and livestock on time use and the impact of non-labour income on time use, were also considered. Contrary to Heltberg et al. (2000), but similar to Chen et al. (2006), land holdings are positively related to labour inputs in both LFC and pooled regressions (but not in HFC regions). Since the dependent variable (total annual time spent for fuel wood collection) and land size are in log-log form, the estimated coefficient can be interpreted as an elasticity. As such, a 10% increase in land size is associated with a 7% increase in total collection time for LFC households. Similar to Heltberg et al. (2000), livestock ownership has no significant impact on fuel wood collection time. The effect of non-labour income is positive and significant for HFC households. The effect of the opportunity cost of time is also examined by considering the effect of the predicted wage rate on the fuel wood collection time. As expected, higher wages, or higher opportunity costs of time, result in reduced fuel wood collection time in the pooled regression. However, the results are statistically insignificant when we consider the level of forest degradation.

The elasticity estimates show that an hour increase in collection time per kg of fuel wood results in a 5.7% increase in total household fuel wood collection time in LFC areas, while the pooled result implies an increases of about 4%. Heltberg et al. (2000) find that a 10% increase in collection time per unit of fuel wood results in an 8.9% increase in labour time for fuel wood collection in rural India. The pooled results are also in line with those of Kumar and Hotchkiss (1988), Amacher et al. (1993), and Palmer and MacGregor (2009).[18] However, none of the previous studies are able to describe the difference between households living in close proximity to either highly degraded or less degraded forests. Intuitively, labour input is expected to be less elastic when considering the production of basic commodities; however, in the face of increased degradation, some substitutes become more plausible, raising the observed elasticity.[19]

This study is also different from other studies, with the exception of studies by van `t Veld et al. (2006) and Bandyopadhyay et al. (2006), in that it incorporates information on biomass availability obtained from GIS data. According to van `t Veld et al. (2006), per capita biomass availability is an exogenous physical measure of firewood availability. This, however, may not truly reflect the physical scarcity of firewood, as a few large trees may

[18] We cannot calculate elasticity directly. However, the value of the elasticity based on Heckman estimates without bootstrapping yields an elasticity estimate that is smaller than that of Heltberg et al. (2000).

[19] A simple descriptive analysis of the responses of surveyed households with regard to their coping mechanisms to fuel wood scarcity supports this finding. More than 44% of the sample households responded that they increase their collection time, when there is a shortage of fuel wood. Others (21%) reduce consumption. The literature also confirms the negative and small own-price elasticities, implying that households respond to increases in shadow prices by reducing their consumption (see for example, Cooke, 1998a and 1998b; Mekonnen, 1999; Helberg et al., 2000 and Palmer and MacGregor, 2009).

yield significant biomass. In contrast to van `t Veld et al. (2006), our estimation results show that biomass availability is positively correlated to total fuel wood collection time. Van `t Veld et al. (2006) find that higher biomass availability in a village increases the use of commons resources, but does not affect the time spent collecting.

4.2 Other Biomass Production and Consumption Activities

As previously uncovered, the fuel wood labour input elasticity is affected by the quality of the forest cover accessible by these households, and the results suggest that households in highly degraded forests must increase their labour input further, cut their fuel wood consumption or turn to other sources of energy. In Table 2.4, we report the total production function of dung and residues, because the Chow test fails to reject the null hypothesis that the coefficients are the same in both equations (LFC vs HFC areas) for dung, though it is different for crop residues. Note also that only 27 households participated in the fuel wood market. Of these, 12 households collect fuel wood from private or common sources, while the rest depend on purchased fuel wood only. Because of the small numbers of market participants, we do not distinguish between collecting and purchasing households, as was the case in Palmer and MacGregor's (2009) Namibian study.[20]

In order to examine the effect of fuel wood scarcity on the consumption of other biomass energy sources (dung and crop residues), selection regressions of dung collection and crop residue collection activities were also estimated.[21] The sign and significance of the fuel wood shadow price in the dung and residue functions suggest the nature of the relationship (substitutability or complementarity) between these two types of biomass energy sources and fuel wood. Here the results are not statistically significant.

[20] Substitution from private trees, dung and residue consumption, and market purchase account for only a small proportion of coping mechanisms for fuel wood shortages in our surveyed households, and, thus, these are ignored in the analysis.

[21] Results for the participation component of the selection regressions are presented in Appendixes D and E for dung and crop residues, respectively. Higher wages and larger family sizes increase the probability of dung collection, while greater land holdings, greater forest access, greater biomass availability and higher average schooling levels in the household reduce the dung collection participation probability. The crop residue participation probability is higher for male-headed households with greater land holdings and greater forest access, but it is lower for larger livestock holdings, greater forest stock, and better knowledge of the rules governing forest access.

Table 2.4: Heckman Estimates of Dung and Crop Residues Collection

	DUNG	RESIDUE
Variable	Coef	Coef
Collection Time	1.359	-2.808
	(3.37)	(4.43)
Wage rate(predicted)	0.236	0.126
	(0.43)	(0.41)
Education of head	0.253**	-0.029
	(0.13)	(0.20)
Sex of HH head	-0.333**	-0.173
	(0.20)	(0.33)
Amount of Nonlabor income	0.000**	0.000**
	(0.00)	(0.00)
Livestock ownership in TLU	0.081	0.137
	(0.13)	(0.17)
Land size in hectare	0.201	-0.007
	(0.19)	(0.24)
Family Size in Adult equivalent	0.069**	-0.006
	(0.04)	(0.05)
Forest Stock	-0.002	0.013*
	(0.00)	(0.01)
Forest Access	-0.009	-0.189***
	(0.04)	(0.07)
Average schooling level of the family	-0.066**	-0.051*
	(0.03)	(0.04)
Inverse mills ratio	0.023	-1.027***
	(0.19)	(0.37)
Constant	6.163***	8.426***
	(1.32)	(1.53)

The numbers in brackets are the bootstrapped standard errors. The dependent variables of the regression equation are collection of dung and crop residues in kg per annum (in log form), land size and livestock are also in log form. *, **, and *** represents significance level at 10, 5 and 1%, respectively.

Based on intuition, we expect that biomass availability affects participation, but has no independent effect on the total quantity. Furthermore, a variable indicating awareness of government rules related to forest use should determine participation, but not the total quantity of collected biomass, and, therefore, this variable represents another exclusion restriction. Based on simple Heckman estimates, the Wald test of independent equations rejects the null hypothesis of no correlation between the two disturbance terms (in the outcome equation and selection equation) at a 1% level of significance. Hence, the selection model is appropriate and should be used to avoid inconsistency in the parameter estimation.

As suggested earlier, degradation could affect substitutability, and, hence, influence either the participation elasticity or the production elasticity, given participation. We consider these possibilities by including various measures of forest accessibility in the regressions. Our results suggest that increased forest stocks (people per hectare of forest) are associated with reduced participation in residue collection activities, but positively and significantly affect the amount of residues collected, given participation; however, there is no influence on either dung collection participation or collection, given participation.[22] We further find that an increase in forest access (people per hectare of kebele area) increases the probability of participating in residue collection, but is negatively correlated with the amount of residue collected, given participation. Finally, participation in dung collection is reduced when forest access (people per kebele hectare) rises, while the total dung collection quantity, given participation, is not affected by population density in the area. Given that approximately 50% of households use dung and fuel wood at the same time, it is not all that surprising that forest degradation is not strongly correlated with dung participation or total collection. Furthermore, the small and highly fragmented nature of per capita land size in highly populated regions explains the relationship between forest access and residue collection activities. Intuitively, agricultural production, which provides residues as a by-product, in these areas is also small; thus, although more households participate, there is less opportunity to collect.

Since larger family size implies greater demand for energy sources, we find that it does increase the likelihood of participating in dung collection activities as well as the quantity of dung collected. However, it does not have a significant effect on either the participation decision or the quantity of crop residues collected. Unexpectedly, the education level of the household head is significantly and positively related the amount of dung collected for fuel. However, the average education level of the whole family is negatively related to the probability of collecting dung and the amount of dung collected. Land holdings are negatively related to the decision to collect dung, but positively related to the decision to collect crop residues. The quantities of dung and crop residues collected are not affected by the size of land holdings. Amacher et al (1999), using land holding as a proxy for income, finds that larger (and wealthier) households consume less residues, leading them to conclude that residues are inferior goods for the rich. On the contrary, we find an insignificant relationship between livestock ownership and the quantity of both dung and residues

[22] Heltberg et al. (2000) finds a negative relationship between forest stock and private fuel consumption, while Palmer and MacGreger (2009) find a negative relationship between forest stock and dung collection.

collected, given participation. In other words, as opposed to the energy ladder hypothesis, dung and residues are not perceived as inferior goods in this sample of Ethiopian households.[23] We also included the predicted wage rate in the dung and residue collection regression and found no significant influence on the amount of either dung or residues collected.

4.3 Discussion

The literature on the relationship between fuel wood use and dung use, as well as fuel wood use and crop residue use, is mixed. Cook et al. (2008) survey a number of papers in the literature finding evidence of substitution, as well as complementation. For example, Amacher et al. (1993) find evidence of substitution between fuel wood and agricultural residues in one of their survey districts in Nepal. On the other hand, Mekonnen (1999) finds that dung and fuel wood are complements in the northern highlands of Ethiopia. According to our results, the effect of collection time on the production and consumption of dung and crop residues is insignificant. In other words, when fuel wood is scarce, households in this area of rural Ethiopia do not readily switch to other biomass energy sources. Our results are consistent with analyses from Nepal (Kumar and Hotchkiss, 1988, and Amacher et al., 1993), India (Heltberg et al., 2000) and Namibia (Palmer and MacGregor, 2009).

In this analysis no direct substitution between fuel wood and other biomass energy sources was uncovered, although forest cover and forest access effects do suggest indirect substitution patterns. Furthermore, the availability of more fuel wood (in the form of increased biomass per household) does not necessarily reduce consumption of other biomass energy sources, though it decreases the likelihood of participating in dung, supplementing Mekonnen's (1999) findings that rural households in northern Ethiopia do not use less dung, when more forest biomass is available, due to the complementarity between dung and forest biomass, when it comes to cooking. For policymakers, the implication of this result is that the development of plantations and other measures to increase the supply of fuel wood may not have a significant impact on reducing the demand for alternative energy sources, which, at least from a policy perspective, have higher values in maintaining soil fertility. However, it should be noted that we are not able to separate dung and crop residue use for energy from dung and crop residue use for fertilizer.

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[23] The energy ladder hypothesis states that high-income households reduce consumption of lower quality energy sources (Leach, 1992).

5. CONCLUSION AND POLICY IMPLICATIONS

This paper reports results from an analysis of household survey data collected in rural Ethiopia. The survey was conducted in order to examine rural household coping mechanisms, when faced with fuel wood shortages. The study aimed to address whether households in rural Ethiopia respond to fuel wood shortages by increasing their labour input to fuel wood collection or switch to other biomass sources, which are considered as inferior goods by some scholars. By using information from a GIS survey we have classified our study area into two regions: low and high forest cover areas. Rural household behaviour towards fuel wood was examined separately for LFC and HFC areas, while pooled regressions were considered for the collection or production of other biomass sources, i.e., dung and crop residues.

The results of the analysis suggest that household responses to fuel wood scarcity depend on the status of forest degradation. Households living in a degraded environment respond to fuel wood scarcity, as measured by collection time per kg, by increasing their labour input to fuel wood collection. However, this is not the case for those living in high forest cover areas (HFC). Households in HFC areas respond neither to the physical measure nor economic measure of fuel wood scarcity. For households in HFC regions forest stock (negatively) and biomass availability (positively) may be more important factors than scarcity of fuel wood in determining household labour input allocation.

The analysis also uncovers no evidence of substitution between fuel wood and dung and crop residues. Households do not switch to dung and crop residues when faced with fuel wood shortages. Similar to what has been found in Nepal and Namibia, consumption of other biomass energy sources may not necessarily decrease, when more biomass is available. The implication of our finding is that supply-side strategies, alone, may not be effective, if the aim is to reduce forest degradation and biodiversity losses and simultaneously increase the supply of dung and residues for soil management.

Population pressure in all regions, in general, and in LFC regions, in particular, contribute to forest degradation and a loss of biodiversity, as is easily observed in rural Ethiopia, where encroachments for agriculture and grazing are common. As explained by Heltberg et al. (2000), the underlying factors responsible for forest degradation or deforestation in the area need to be addressed if specific forest policies, such as afforestation and area enclosure establishments, are to be effective at the local level.

Finally, there is a need to make a distinction between forest degraded regions and relatively good forest cover regions, when planning for natural resource management and use by the surrounding people. Further investigation could consider whether the increase in labour input to fuel wood collection, when fuel wood becomes more scarce, comes at the expense of other productive activities, such as agricultural production in forest-degraded regions (Cooke, 1998a and 1998b; Bandyopadhyay et al., 2006). Moreover, it is necessary to identify which members of the household are most affected by fuel wood scarcity in environmentally degraded regions.

REFERENCES

Amacher, G., W. Hyde, and B. Joshee. (1993), 'Joint production and consumption in traditional households: fuel wood and crop residues in two districts of Nepal', *Journal of Development Studies* 30, 206–225.

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.

Arnold, M., Kohlin, G., Persson, R., Shepherd, G. (2003),'Fuelwood revisited–what has changed in the last decade?', *Center for International Forestry Research (CIFOR), Occasional Paper No. 39.*

Bandyopadhyay, S., P. Shyamsundar., and A. Baccini. (2006), 'Forest, Biomass use and Poverty in Malawi', Background paper for the Malawi Poverty Assessment. *World Bank Policy Research Working Paper, 4068.*

Brouwer, I.D., J.C. Hoorweg-Marti, and J. van Liere. (1997), 'When Households Run out of Fuel: Responses of Rural Households to Decreasing Fuel wood Availability, Ntcheu District, Malawi', *World Development* 25, 255-266.

Brown, S, A.J.R. Gillespie, and A.E. Lugo. (1989), 'Biomass estimation for tropical forests', *Forest Science* 35, 881-902.

Brown, S., and L.R. Iverson. (1992), 'Biomass estimates for tropical forests', *World Resources Review* 4, 366-384.

Chen, L., Heerink, N.,and M. van den Berg. (2006), 'Energy consumption in rural China: a household model for three villages in Jiangxi Province', *Ecological Economics* 58, 407–420.

Cooke, P. (1998a), 'Intrahousehold labor allocation responses to environmental good scarcity: a case study from the hills of Nepal', *Economic Development and Cultural Change* 46(4), 807-830.

Cooke, P. (1998b), 'The effect of environmental good scarcity on own-farm labor allocation: the case of agricultural households in rural Nepal', *Environment and Development Economics* 3,443-469.

Cooke, P., W.F. Hyde, and G. Köhlin. (2008), 'Fuelwood, forests and community management–evidence from household studies', *Environment and Development Economics* 13, 103–135.

Dasgupta, S., U. Deichmann, C. Meisner, and D. Wheeler. (2005), 'Where is the poverty-environment nexus? Evidence from Cambodia, Lao PDR, and Vietnam', *World Development* 33(4), 617-638.

Dewees, P.A. (1989), 'The woodfuel crisis reconsidered: Observations on the dynamics of abundance and scarcity', *World Development* 17(8), 1159-l172.

FAO. (2009), *State of the world's forests*. Rome, Italy.

Greene, W. (2003), *Econometric Analysis*. New York: Macmillan, 5th edition.

Heckman, J.J. (1979), 'Sample Selection Bias as a Specification Error', *Econometrica* 47(1), 153-161.

Heltberg, R., T.C. Arndt, and N.U. Sekhar. (2000), 'Fuel wood consumption and forest degradation: A household model for domestic energy consumption in Rural India', *Land Economics* 76(2), 213-232.

IFPRI (International Food Policy research Institute). (2010). Fertilizer and Soil Fertility Potential in Ethiopia: constraints and opportunities for enhancing the system. Working paper,ifpri@cgiar.org.www.ifpri.org.

International Energy Agency (IEA). (2002), *World Energy Outlook*. Paris: OECD.

Jacoby, H. (1993), 'Shadow wages and peasant family labour supply: an econometric application to the Peruvian Sierra', *Review of Economic Studies* 60, 903–921.

Kumar, S.K., and D. Hotchkiss. (1988), 'Consequences of Deforestation for Women's Time Allocation, Agricultural Production and Nutrition in Hill Areas of Nepal', International Food Policy Research Institute (IFPRI), Research Report No. 69, Washington, D.C., USA.

Leach, Gerald. (1992), 'The Energy Transition', *Energy Policy,* 116-123.

Masera, O.R., B.D. Saatkamp, and D.M. Kammen. (2000), 'From linear Fuel switching to multiple cooking strategies: A critique and alternative to the energy ladder model', *Journal of World Development* 28(12), 2083-2103.

Mekonnen, A. (1999), 'Rural Household Biomass Fuel Production and Consumption in Ethiopia: A Case Study', *Journal of Forest Economics* 5(1), 69-97.

Palmer, C., and J. Macgregor. (2009), 'Fuelwood scarcity, energy substitution, and rural livelihoods in Namibia', *Environment and Development Economics* 14, 693–715.

Singh, I., L. Squire, and J. Strauss. (1986), *Agricultural Household Models.* Baltimore: John Hopkins University Press.

Skoufias, E. (1994), 'Using shadow wages to estimate labor supply of agricultural households', *American Journal of Agricultural Economics* 76, 215-227.

Van `t Veld, K., U. Narain, S. Gupta, N. Chopra, and S. Singh. (2006), 'India's firewood crises re-examined', *Discussion Paper*, Resources For the Future. Washington.

Woody Biomass Inventory and Strategic Planning Project (WBISPP). (2004), *Forest Resources of Ethiopia*, Addis Ababa, Ethiopia.

Zenebe G. (2007), *Household fuel consumption and resource use in rural-urban Ethiopia*, PhD Dissertation, Addis Ababa University.

APPENDIX A: Heckman wage regression estimates

Participation Equation

Variables	**Coef**
Age	-0.371
	(0.31)
Sex of the household head	-0.213
	(0.21)
Distance to town in km	0.097
	(0.11)
Livestock ownership in TLU	-0.322***
	(0.13)
Land size in hectare	-0.569***
	(0.18)
Location dummy 1 for Amhara &Tigray , 0 otherwise	0.368***
	(0.13)
Number of children under five	-0.108
	(0.07)
Average schooling level of the family	0.090***
	(0.03)
Amount of Nonlabor income	-0.005
	(0.02)
Number of male members of the family	0.016
	(0.04)
Constant	1.023
	(1.12)

The dependent variable(wage rate), age, land size, distance to town (in the participation equation) and non- labour income are in log form.

Wage Regression Equation

Variables	**Coef.**
Average schooling level of the family	0.062**
	(0.03)
Distance to town in km	-0.020**
	(0.01)
Location dummy 1 for Amhara &Tigray , 0 otherwise	0.232
	(0.15)
Whether any member of the family has attended any type of training or not	-0.112
	(0.13)
Number of male members of the family	-0.093**
	(0.04)
Inverse mills ratio	2.18**
	(0.99)
Constant	1.35*
	(0.70)

APPENDIX B. Participation in collection from communal forests

Variable	Coef
Predicted wage	-0.360
	(0.43)
Distance to town in km	0.103***
	(0.02)
Land size in hectare	-0.071
	(0.16)
Education of the HH head	-0.222**
	(0.12)
Government rules	0.114
	(0.11)
Family size in adult equivalent	-0.029
	(0.03)
Distance to market in km	-0.081***
	(0.02)
A dummy variable if the head is a member of any organization	0.137
	(0.12)
Forest Access	-0.053**
	(0.03)
Biomass availability	0.001
	(0.00)
Constant	0.820
	(1.18)

APPENDIX C. Selection regression of time spent per unit of fuel wood collected in communal forests

Variable	Coef
Predicted wage	0.014
	(0.06)
Land size in hectare	0.017
	(0.02)
Education of the HH head	0.026
	(0.03)
Distance to town in km	-0.008
	(0.01)
Government rules	-0.026*
	(0.02)
Family size in adult equivalent	0.002
	(0.01)
Distance to market in km	0.008*
	(0.00)
A dummy variable if the head is a member of any organization	-0.034*
	(0.02)
Forest Access	0.002
	(0.01)
Inverse mills ratio	-0.181
	(0.45)
Constant	0.253
	(0.22)

APPENDIX D. PARTICIPATION IN DUNG COLLECTION

Variable	Coef
Collection time	1.598
	(4.77)
Wage rate (predicted)	1.602**
	(0.76)
Education of the HH head	-0.095
	(0.17)
Sex of HH head	-0.275
	(0.26)
Amount of Nonlabor income	0.000
	(0.00)
Livestock ownership in TLU	-0.154
	(0.15)
Land size in hectare	-0.786***
	(0.30)
Family size in adult equivalent	0.123**
	(0.05)
Government rules	0.062
	(0.20)
Forest Stock	0.002
	(0.01)
Biomass availability	-0.023*
	(0.02)
Forest Access	-0.067*
	(0.05)
Average schooling level of the family	-0.082*
	(0.06)
Constant	-3.210*
	(2.12)

APPENDIX E. PARTICIPATION IN CROP RESIDUE COLLECTION

Variable	Coef
Collection time	-0.079
	(3.53)
Wage rate (predicted)	0.012
	(0.32)
Education of the HH head	-0.185*
	(0.14)
Sex of HH head	0.314*
	(0.23)
Amount of Nonlabor income	0.000
	(0.00)
Livestock ownership in TLU	-0.214**
	(0.12)
Land size in hectare	0.263*
	(0.17)
Family size in adult equivalent	0.040
	(0.04)
Government rules	-0.739***
	(0.14)
Forest Stock	-0.020***
	(0.01)
Biomass availability	0.001
	(0.00)
Forest Access	0.201***
	(0.05)
Average schooling level of the family	0.017
	(0.03)
Constant	-0.597
	(1.03)