CHAPTER I

INTRODUCTION

Forests are the main source of livelihood for many poor households in developing countries in general and Africa in particular (WRI, 2005; Narain et al., 2008a). The Ethiopian forests provide a wide variety of wood and non-wood products such as honey, incense, medicinal plants, bamboo, foodstuffs, etc. They are socially and commercially significant to the livelihoods of rural households. Some studies show that forests provide up to 40 percent of the total household income (Cavendish, 1999b; Mamo et al., 2006). Like other many developing countries, forests are also a very important source of energy for both rural and urban households in Ethiopia. In Ethiopia, households consume about 92% of all biomass energy, with the remaining being consumed by small-scale industry and food enterprises (Nune et al., 2010). The urban population is also highly dependent on fuel wood and other biomass energy sources such as charcoal, dung and residues for their cooking activities.[1] In the rural areas of the country, where more than 85 per cent of the total population lives, the traditional fuel sources contribute 99.9 per cent of the total energy consumption, which is constituted 81.9% fuel wood, 9.3% cattle dung, 8.3% crop residues and 0.4% charcoal (Bewket, 2003). Moreover, biomass energy use in both rural and urban Ethiopia is characterized by a very low efficiency of 5 to 10% (ADC, 2003), which can readily be improved with appropriate intervention measures such as introducing and disseminating improved biomass cook stoves.

Despite the contribution of the forestry sector to the livelihoods of the people and the country as a whole, the country loses about 141,000 hectares of forest each year (FAO, 2009)[2]. For a country with a total of 80 million people and around 70 million of livestock population, forest degradation, deforestation, overgrazing, and land degradation are serious environmental problems that negatively affect the welfare of the people and the overall economy of the country (MoFED, 2002)[3]. The literature also associates the use and extent of natural

[1] The proportion of urban households who are dependent on biomass energy sources ranges 89-95%. Recent estimates on this figure cannot be found.

[2] Different documents report different deforestation rate for Ethiopia. It ranges between 140,000-200,000 ha per year. For example, according to the world rain forest movement (2002) the deforestation rate for Ethiopia is around 200,000 hectares/year.

[3] The terms forest degradation and deforestation are sometimes used interchangeably in the literature. But in this case deforestation is the removal of a forest or stand of trees where the land is thereafter converted to a non forest use. But forest degradation is the deterioration of forest quality

resources degradation or forest product extractions in developing countries to rapid population growth, rural poverty and open access (Dayal, 2006; Bluffstone, 1998). In Ethiopia, many factors contribute to the forest degradation and deforestation problem. Harvesting fuel wood and logging, clearing for agricultural land and grazing, expansion of rural areas and villages into forest regions and lack of clear forest and land tenure policies are believed to be the major factors of forest degradation and deforestation in Ethiopia (Mulugeta and Melaku, 2008). High population growth which results in increase demand for agricultural land, fuel, and other forest products, and poverty also contribute to the current problem of the forestry sector in Ethiopia. In addition, policy failure due to implementation problem may lead to more deforestation and forest degradation problem as this may, among other things, create a property right regime closer to open access (Mekonnen and Bluffstone, 2008).

As described above, land clearing for agriculture is one of the main causes of forest degradation and deforestation in Ethiopia. Ethiopia is highly populated with the rank of second in Africa and around 85% of its population are living in rural areas. The majority of these households have an average land size of less than 1 hectare and characterized by low production and productivity (Birhanu, 2009). As a result of high population and fragmented land size, farmers in Ethiopia are clearing land for agriculture purpose. This is considered as one of the available options for smallholder farmers in Ethiopia who produce over 90% of agricultural products and manages 95% of the cultivated land (Birhanu, 2009). As a result of this practice, the country is experiencing severe land degradation due to loss of soil fertility status.

High and growing demand for fuel wood is one of the main causes of forest degradation and deforestation in Africa in general and Ethiopia in particular (World Growth, 2009). Some authors have questioned the link between fuel wood collection and deforestation. They argue that woodfuel supplies are often a by-product of forest clearance for agriculture and other purposes, but it cannot be considered as the primary cause of forest clearance (see a review by Arnold et al., 2003). These people further argued that the bulk of woodfuel consumption in developing regions comes from trees and shrubs growing outside of forest areas-in fallow lands, brushland, private woodlots, and scattered throughout the agricultural landscape. On the other hand, there are empirical evidences that show the link between fuel wood consumption and forest degradation/deforestation especially in Africa where people are highly dependent on traditional sources of energy for their cooking, heating and lighting activities.[4] It is also believed by the government of Ethiopia that this is one of the main causes of deforestation in the country. High dependence of urban households on woody materials such as charcoal and fuel wood also contributes to the current environmental problems of the country. Various factors such as poverty, unavailability of modern fuels, culture and norms have hindered the transition to modern fuels. As a result, fuel stacking is the main feature of the country (Mekonnen and Kohlin, 2008). Due to the above mentioned factors the current fuel wood demand in the country far exceeds the supply.

In most of the developing countries the critical forestry problems all boil down to lack of clear property rights (Mekonnen and Bluffstone, 2008). Mekonnen and Bluffstone (2008) also explained the main underlying causes of forest degradation and deforestation in Ethiopia. These are market failure, policies and institutions failure. Policy failure occurred due to problems related to design and implementation problems in the policies. Problems with policy and implementation may lead to further degradation and deforestation of forests as it creates a property right regime closer to open access.

As frequently mentioned in other studies poverty also contribute to the current problem of the forestry sector in the country. In Ethiopia, declining standard of livelihood of the farming communities and their close dependence on forests have led to clearing for subsistence farming, cutting of trees for fuel wood and charcoal production, construction material and over-grazing (Bekele, 2001). Alleviating rural poverty and conserving forest resources pose a major economic and moral challenge for governmental and nongovernmental organizations interested in forest conservation initiatives (Reddy and Chakravarty, 1999).

Other factors such as political instability and forest fires, though cited less frequently, are important contributors to the deforestation problem in Ethiopia. Ethiopian farmers have been using fire as a means of production or as a farming tool for a long time. It is believed that fires in different parts of Ethiopia damage every year large areas of forests.

[4] This means fuel wood is one of the main causes of deforestation in many sub-Saharan African. For example, a study by Bandyopadhyay et al. (2006) indicates that fuel wood collection is one of the main causes of deforestation in Malawi. In Vietnam fuel wood collection is the prime cause of deforestation, which accounts for more than 60% of the total Vietnamese deforestation (World Bank 1995, cited in Lind-har, 2003).

Lack or shortage of fuel for cooking and depletion of forest resources used for rural people as a source of food and cash, scarcity of feed for livestock, reduced capacity for carbon sequestration, and biodiversity loss are some of the consequences of forest degradation and deforestation. This will in turn lead to declining agricultural output and decreased household welfare. For example, as a result of deforestation, among other factors, over 1.5 billion tons of soil are washed away annually from the highlands of the country (Girma, 2001). According to Girma, the country also loses about 1-1.5 million tons of grain as a result of soil nutrient loss.

Although there is a growing literature on rural households and forest resource use (particularly on some Asian countries), the available evidences on developing countries in general and Africa in particular are still scanty. Data on environmental resources in general and forest resources in particular do not exist in many developing countries particularly in Africa (Cavendish, 2000). As a result, we have little understanding of the relationship between rural households and forest resource use in the region as a whole.

Understanding these gaps, this thesis tries to investigate the relationship between rural household energy use and forest degradation and empirically examine and understand the link between forest dependency and property rights regimes. Moreover, by recognizing the role of urban households in the current environmental problems of the country this thesis also tries to address one of the demand side strategies, adoption of biomass saving technologies, by using survey data collected from urban households in Ethiopia. Given the paucity of empirical works in this area, the thesis also adds to the limited empirical evidence on the various aspects of the forest people interactions. The implications of the findings of the study for conservation and sustainable use of forests are also highlighted in each chapter of the thesis. The thesis consists of four individual essays presented in chapter two to five.

The second chapter of this thesis deals with rural household's energy use and resource allocation. It is widely recognized that, in addition to other factors, the high dependence on biomass for energy leads to depletion of forests and forest resources in Ethiopia. Currently the country's forest stock is estimated to be between 4-5% of the total land area[5]. Empirical

[5]Various documents indicate different figures on the current forest coverage of the country.

evidences show that a decrease in environmental goods such as fuel wood availability negatively affects the welfare of rural households. This is mainly due to additional burden on women and children, decrease in agriculture productivity as a result of reallocating labour away from agriculture and use of dung and residues as fuel, and declines in nutrition and health (Kumar and Hotchkiss, 1988; Cooke et al., 2008; IEA, 2004). Moreover, increasing scarcity further increases forest degradation and deforestation as households are required to go further into open access forests. Therefore, this chapter tries to understand the coping mechanisms of rural households when forests are scarce. We use a farm household model as a conceptual framework since forest goods are produced and consumed by the household in the study areas.

The analysis was undertaken separately for different forest degradation level (classified based on forest cover) using GIS information to see whether there is any difference in the response of households to fuel wood scarcity. In addition to the standard socioeconomic variables, we have also included other variables obtained from the GIS information such as biomass availability and forest stock and community level variables such as population density. The chapter also examines the possible relationship that exists between fuel wood consumption and other biomass energy sources (dung and residues). The detail estimation for each type of biomass energy sources are presented in the chapter. Important variables that affect household labour allocation to biomass fuel collection are identified and policy implications are highlighted.

Among other factors, lack of clear property rights and tenure insecurity are considered as the main causes of forest degradation and deforestation in Ethiopia. Rural households collect fuel wood from different sources: private, community, and state or natural forests-which are considered as de facto open access forests. As part of the supply side strategies the Ethiopian government has distributed seedlings to farm households with the goal of reducing pressure on open access forests. However, we do not have evidence whether this policy has shifted households away from other open access sources. An example from Vietnam shows that households respond to changes in shadow prices and affect their fuel wood consumption choices among the various sources (Linde-Rhar, 2003). In general, there is a lack of empirical evidences on the choice of fuel wood sources by rural households in Ethiopia. The impacts of different households and community level variables on the determinants of fuel wood collection from each regime should be examined empirically. Specifically, we examine and highlight the implications of tenure insecurity and local level institutions on use of resources from open access forests. In chapter three of this thesis, we have attempted to address this issue by using a random utility framework. We use data collected from two regions and employ a discrete choice model for our empirical analysis. Based on the findings, the implications of tenure insecurity, local institutions and different forest property rights regime on the sustainable use of forests are discussed in the chapter. The findings will help policy makers identify area of intervention for forest conservation and management.

Chapter four deals with forest resource use, property rights and local institutions in Ethiopia. As discussed earlier, in addition to fuel wood, rural households in Ethiopia collect a variety of non-wood forest products from community, private, and other open access forests. In the analysis of forest poverty link, many people argued that poverty forces rural households to depend on the surrounding natural resources for survival. The implication of this is that increase in the income of households will reduce dependence on forest resources and hence decrease in forests degradation and deforestation. However, in addition to poverty, local level institutions and clear property right regimes may help limit the amount of forest resources extracted and the way the resources are utilized. The nature of the link between property right, local institutions and resource use may also depend on the type of natural resources in general and forest resource in particular. It is, therefore, necessary to identify the determinants of forest dependency under different property right regimes. There is no consistency in the literature regarding measure of forest dependency. As opposed to most other related studies, we consider different measures for forest dependency, which will enable us to check the robustness of our results. The determinants of forest resource use for each type of property right regimes are estimated using appropriate econometric strategies. We have also tried to assess the contribution and significance of forest products to the livelihood of the rural people in the study area.

We have also tried to understand the impact of local level institutions on forest dependency in community forests. It is widely argued that devolution of natural resource management is the most viable option for ecological and economic sustainability of the natural resources. It improves the forest cover and biophysical conditions thereby providing economic benefits to the local people. Ethiopia has practiced the transfer of the management of forest to the local community over a decade. The development of participatory forest management program (PFM) is considered as a viable option for forest conservation and is being practiced in different parts of the country. However, the evidence on the determinants of forest products collection in a community forest and equity implications of the transfer of ownership of forest management to the locals is not clear. Therefore, chapter four discusses the role of local level institutions in the use of forest products in a community forest and the implications of transfer of the rights to the local community on forest dependency.

The apparent link between woodfuel use and forest degradation and deforestation formed the basis for policy and programme interventions in many developing countries over the past 30 years (World Bank/ESMAP, 2001; cited by Bensel, 2008). Demand side and supply side interventions were designed in many developing countries. The supply side strategies focus on increasing the supply of fuel wood through more plantations, tree planting, supply restriction and enforcement of property rights. The demand side programmes focus on the promotion and dissemination of improved biomass stoves or on efforts to facilitate inter-fuel substitution away from wood fuels.

By recognizing the role of urban households in the current environmental problems of the country, chapter five focuses on analysing one of the demand side management adopted by the current government of Ethiopia, i.e. dissemination of energy efficient technologies which is considered as technological substitutes for fuel wood (Amacher et al. 1992). The role of urban households in forest degradation and deforestation in developing countries should not be overlooked. The urban demand for energy contributes to the problem of forest degradation and deforestation in some areas (Barnes et al., 2004). As in many sub-Saharan countries of Africa, urban households in Ethiopia are highly dependent on biomass energy sources such as fuel wood, charcoal, and dung for cooking. Adoption of improved biomass stoves reduces fuel wood consumption. According to EPA (2004), sufficient distribution of these improved biomass stoves will have significant contribution in reducing environmental degradation in general and forest resource degradation in particular. Moreover, stoves may provide other benefits such as reduced indoor smoke, reduces time for cooking, etc. Given all these benefits, not all households own and enjoy the benefits of these technologies. Many studies such as Barnes et al. (1994) mentioned that there are a variety of factors including fuel wood scarcity and stove characteristics that affect the adoption and use of improved stoves. However, most of these studies are qualitative in nature and there are still very few household studies that formally estimate the degree of influence of different factors on the adoption and efficient use of improved biomass stoves. The chapter tries to find some empirical evidences on why some households do not adopt the technology while others are benefiting from it using a dynamic framework. Because of data limitations, we concentrate on the socioeconomic characteristics that affect the speed of adoption of fuel saving technologies in urban Ethiopia. Some of the main determinants of adoption of the technology were identified and policy implications are indicated.

In conclusion, the study will add to the current state of knowledge on the link between people's livelihood and forests in Africa in general and Ethiopia in particular. The results will help the government or policy makers and other stakeholders understand the role of forests to improve rural livelihoods and the factors that contribute to the misuse of forests and forest resources. It will help policy-makers and development planners in the design of policies and programs aimed at poverty reduction and improving the degradation of forest resources in rural Ethiopia.

In order to achieve the above objectives the data collection method and the study area are briefly explained below. We used different data sets collected in different parts of the country. We used the survey data collected for the project 'Households forest values under varying management regimes in Ethiopia' to address the second and fourth chapters of the thesis. This project was designed by the Environmental Economics Policy Forum for Ethiopia (EEPFE) based on the outcome of a meeting on forestry research and policy which was held in March 2008. The discussions with government officials focused on new developments and issues for research in forestry. A key issue that came out from the workshop was the need to inform policy makers about the importance of forests/trees in general and their role in the lives of households in particular. In the meeting, the government officials strongly felt that the research on forestry would be very useful if it focuses on sites within watersheds that are identified by the government for an integrated program called Country Partnership Program for Sustainable Land Management (CPPSLM). This program is run by the Ministry of Agriculture and Rural Development and funded by the World Bank and Deutsche Gesellshaft für Technische Zusammenarbeit (GTZ).

Research sample sites were selected using purposive sampling based on certain criteria such as forest cover, institutional differences, agro-ecology, accessibility, etc. Sample sites were selected with in and outside the watershed. Households were selected based on a simple random sampling technique in order to make the sample representative. The total number of sample households was 600. Survey questionnaire includes questions on household characteristics, health and social capital, agricultural production, energy consumption and production, forestry programs, institutions and forest products, shocks and expenditure, off-farm income and remittances, credit, experimentally generated information on households risk preferences.

In addition to the household survey, focus group discussions were held in each Kebele (peasant associations). The purpose of the focus group discussions were to get villagers' attitude and perception regarding the natural resource/forest management, on the current problems related to forests, grazing land, shocks, use and availability of technology, etc. The contents of the survey are clearly explained in each chapter of the thesis. There are 40 communities in the survey. In each village or community, 8-10 individuals were chosen for the focus group discussions. Experienced field supervisors and enumerators were chosen for the survey and three days training were given before they went to the actual survey work in the field. This project is unique in that it has a spatial data obtained by hiring foresters. The spatial data has detail information on biomass availability for each Kebele (peasant associations) and for each type of forests, forest area, GPS points for each Kebele, and number of trees per ha per Kebele.

In addition to the above data, we used two additional surveys collected in the year 2009 and 2007. Data from the rural households' survey collected in the East Gojam and South Wollo zones of the Amhara regional state was used for addressing the issue of property rights and choice of fuel wood sources in rural Ethiopia. The total number of households interviewed was 1760. Community level surveys were also conducted in 14 sites. The second one is different_from the other surveys in that it was conducted in urban areas and focus on only improved biomass cook stoves. Hence, for the analysis of adoption of fuel saving technologies we used survey data collected by Megan Power limited company in different towns of the country in 2009.

In sum, the use of different data sets obtained from different parts of the country allows us to explore and understand different issues on the forest-people interaction from both rural and urban side. As environmental problems are geographic specific, policies designed to address issues related to forest depletion will be most successful if they take into account local, social, economic, and natural resource conditions of the area.

CHAPTER II

RURAL HOUSEHOLDS COPING MECHANISMS TO FUEL WOOD SCARCITY IN ETHIOPIA

Abstract

This study examines the coping mechanisms of rural households to 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 no evidence for substitution between fuel wood and dung or fuel wood and crop residues. Supply side strategies alone may not be effective in addressing the problem of forest degradation and biodiversity losses. Any policy on natural resource management in general and rural energy problems in particular should make a distinction between regions of different forest degradation level.

1. INTRODUCTION

Many people in developing countries rely on biomass energy sources, primarily fuel wood, dung and crop residues, for their energy needs.[6] 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 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 the 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 policy-makers 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

[6] 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.[7] 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

[7] See Cooke-St. Claire 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 the virtual price of fuel wood, 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 neo-classical household production 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.[8] 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

[8] 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.[9] 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.[10]

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.

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

[10] 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), $y = \{F_L, Q_D, Q_R\}$, whereF_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;[11] 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

[11] 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 response 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' argument, we use the time spent per unit of fuel wood collected (measure 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 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.[12]

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).[13]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.[14] 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,

[12]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.

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

[14]Off-farm labour participation is negatively associated with land size and livestock ownership. Participation is positively 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 B

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 either 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, is 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. Additional variables include a measure of forest access – greater access lowers the cost of collection activities – and forest management institutions – tighter control over forests is expected to increase the cost of collection activities.

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.[15]However, it should also be noted that livestock holdings should increase the availability of dung. Similarly, land holdings are likely to

[15] 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.

increase the availability of crop residues, although households with large land holdings have more agricultural production and require more dung and residues for fertilizer.

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.[16] 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.[17] The current sustainable land management program (SLM) in the country

[16] 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.
[17] 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.

informed site selection.[18] 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 household lists available from the Kebele administration offices; 15 households were selected from each kebele, yielding a total of 600 households to be interviewed.[19]

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.[20] From the forest cover data, we were able to identify and classify study sites into two groups: relatively high forest

[18] 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.
[19] 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.
[20] 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)

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 belong to the LFC and 37.9% reside in HFC regions.[21] Figure 1 outlines forest cover (in %, obtained by dividing total forest area by the total area of the kebele) and total biomass (in tons) for each of the kebeles. 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.

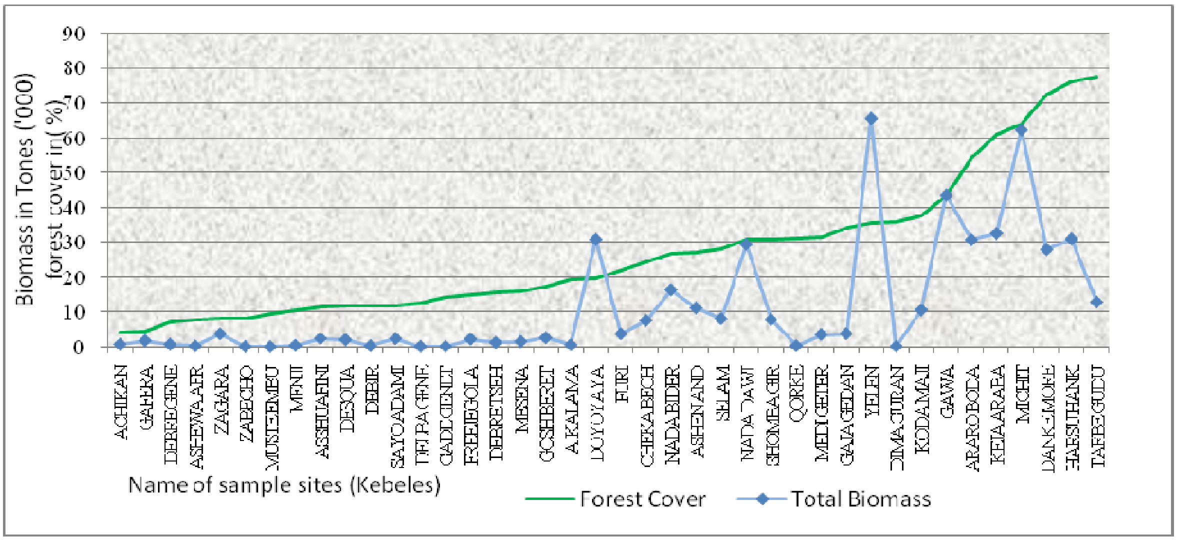

Figure 2.1. Forest Cover (%) and Total Biomass (in tons) for each Kebele

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

[21] 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.

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, 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 2.1 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 the 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, and the number of children whose age is below 5, 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 2.1. 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 ≤ 5 years)	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 2.2. In order to calculate the values in the table, data on conversion factors were collected from each district for each type of fuel, for each type of forest product and for each type of agricultural 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 2.2: 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 2.3 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.[22] 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 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

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

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 2.3: 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).[23] 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.[24]

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 yield significant biomass. In contrast to van `t Veld et al. (2006), our estimation results show

[23] 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).

[24] 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).

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 either increase their labour input further or 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.[25]

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 was also undertaken.[26] 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.

Table 2.4: Heckman Estimates of Dung and Crop Residues Collection

[25] 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.

[26] 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.

	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. The numbers in brackets are the bootstrap standard errors. *, **, 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.[27]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

[27] 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.[28] 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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[28] 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.