FUELWOOD CONSUMPTION PATTERNS IN MBARALI DISTRICT, SOUTH-WESTERN TANZANIA

BY

KEGODE J.H. SAYO

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DECLARATIONS

Declaration by the Candidate

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Kegode H. J. Sayo

Signature ___________________________ Date ___________________________

(SES/PGE/10/10)

Declaration by Supervisors

This thesis has been submitted for examination with our approval as university supervisors:

Signature ___________________________ Date ___________________________

Dr. Adano Wario Roba

School of Environmental Studies, University of Eldoret

Signature ___________________________ Date ___________________________

Dr. Judith Beatrice Auma Oduol

World Agroforestry Centre (ICRAF), Nairobi

Signature ___________________________ Date ___________________________

Dr. Jonathan Muriuki

World Agroforestry Centre (ICRAF), Nairobi

ABSTRACT

Biomass fuels account for much of domestic energy consumption in many developing countries. Despite the significance of these fuels in domestic energy provision, their unsustainable consumption often occurs at the expense of environmental conservation. Agroforestry has often been cited as a possible intervention to reduce high dependence on natural resources, which is a characteristic of many developing countries. This study aimed to analyze the determinants of choice of sources of fuelwood and fuelwood consumption, with a view to contributing to policy discussions on reducing environmental degradation through agroforestry interventions. Cross-sectional data was obtained from two hundred and fifty four (254) randomly selected households from Mbarali district in south-western Tanzania. Household data was complemented with information from focus group discussions and key informant interviews. Multinomial logit regression model was used to identify the determinants of choice of fuelwood sources while the ordinary least squares regression model was used to identify determinants of household consumption of fuelwood. The results show that 88% of households consider fuelwood to be the most important fuel especially for cooking and that 74% of households that consume fuelwood depend on natural forests as the main source. The choice of fuelwood sources was influenced by species composition of the source and some household characteristics. Significant determinants of fuelwood consumption included age of the household head, income and price of kerosene. The results show that consumers, both households and other end users preferred *Faidherbia albida* for fuelwood which is the key agroforestry tree species in the area. Thus, fuelwood consumption maybe a threat to the success of agroforestry interventions that promote *Faidherbia albida* for soil fertility and environmental conservation. To exploit the potential of agroforestry, alternative sources of energy should be made available and affordable to the community; in addition to fostering strategies to promote adoption of efficient use of available energy. Cultivation of tree species with characteristics similar to the preferred fuelwood species, for instance, *Acacia tortilis* is also recommended to divert long term fuelwood demand away from natural forests and to reduce competition with *Faidherbia albida*. To the extent that consumer preferences are likely to change over time, further research using panel datasets is necessary to reveal inter temporal preferences for fuelwood sources.

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LIST OF ACRONYMS AND ABBREVIATIONS

CA:	Conservation Agriculture
CAWT:	Conservation Agriculture with Trees
EPT:	Energy Policy of Tanzania
FGDs:	Focus Group Discussions
FMNR:	Farmer Managed Natural Regeneration
ICRAF:	World Agroforestry Centre (International Centre for Research in Agroforestry)
IEA:	International Energy Agency
MDC:	Mbarali District Council
MNL:	Multinomial Logit
OLS:	Ordinary Least Squares
RUM:	Random Utility Model
TShs:	Tanzanian Shillings

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DEFINITION OF KEY TERMS

Fuelwood

Woody biomass used for fuel without processing (Johnsen, 1999). It is also defined as wood in the rough state to be used as fuel for purposes such as cooking, heating or power production (FAO, 2010a). It may also be termed as wood and wood pulp material obtained from trunks, branches and other parts of trees and shrubs used as fuel for cooking, heating or generating energy through direct combustion (FAO website).

Woodfuel

Woodfuel is a broad term covering the direct use of wood in cooking and heating; and consists of fuels such as fuelwood, charcoal, chips, sheets, pellets, and sawdust.

Biomass energy

Fuels that are obtained from living things like wood products, dried vegetation, crop residues and animal dung, and are either used in their primary form for example crop residues, fuelwood or are processed like charcoal.

CHAPTER 1

INTRODUCTION

1.1 Background to the study

Energy, in its various forms is a key driver for socio-economic growth and development. Biomass fuels have been and continue to be the most utilized form of energy across the world for a long time (IEA, 2006). These fuels comprise fuelwood and charcoal (which are collectively referred to as woodfuels), agricultural residues and animal dung. Woodfuels are important for two reasons: first, the livelihoods of a large segment of the population depend on them, and second, harvesting and using them unsustainably often occurs at the expense of environmental conservation; and this second reason is often the subject of discussion about deforestation and environmental degradation. This study focuses on fuelwood as an important household fuel in Mbarali.

The share of biomass in household energy demand varies widely across countries and regions and is reflective of the level of resource endowment, economic development and urbanization (IEA, 2006). Like in many developing Sub-Saharan African countries, biomass energy is a necessity for at least 90% of households in Tanzania (Kauzeni *et al.*, 1998). And as population grows, demand for energy is building up meaning that household consumption of woodfuels in Tanzania is unlikely to decrease in the near future (O’Keefe *et al.*, 1989; URT, 2003; Felix and Gheewala, 2011).

In the study area, households use woodfuels mostly for cooking and heating. It is also used in enterprises like brick making, brewing, baking and pottery, and in restaurants, schools and hospitals. Still, much of it is sold to consumers in urban and peri-urban areas as fuelwood and charcoal (Sheya and Mushi, 2000; Malimbwi and Zahabu, 2010; Felix and Gheewala, 2011). According to the IEA (2006), however, the use of fuelwood in itself is not a main cause for concern, but unsustainable exploitation and inefficient use of natural resources have adverse consequences on health, the environment and on economic development.

Natural forests contain significant biodiversity that supports the socio-economic well-being of people and the provisioning of ecosystem services (Adhikari, 2003), and make up the most common source of fuelwood for domestic energy in developing countries (Heltberg *et al.*, 2000; Pattanayak *et al.*, 2004; Damte *et al.*, 2012). Unsustainable harvesting of forest resources for provision of fuel could, however, result in deforestation and environmental degradation (URT, 2003; Malimbwi and Zahabu, 2010; Damte *et al.*, 2012), which raise great concern because of the negative externalities associated with these environmental problems (Baland *et al.*, 2009).

Forest degradation resulting from overexploitation would have an immediate impact on local populations in terms of decreased supply of fodder and leaf fall manure (Baland *et al.*, 2010), increased fuelwood scarcity, increase in prices of alternative fuels (Arnold and Perrson, 2003), as well as land degradation and micro-climatic changes. Studies within the region for example Brouwer *et al.* (1997), Kirubi *et al.* (2001) and Ndayambaje and Mohren (2011), point to an increased demand for fuelwood in the wake of dwindling natural resources which may lead to a persistent deficit between annual wood increment and fuelwood consumption.

Increased dependence on natural forests is likely to heighten pressure on wood resources thus, resulting in a cyclical pattern of forest destruction and subsequent disruption of the livelihoods of those who rely most on tree products. When this occurs, demand for vital tree products would consequently shift to trees on farm and to marginal lands. In light of this, communities are expected to develop strategies to cope with the possibility of an impending situation of fuelwood scarcity (Brouwer *et al.*, 1997; Cooke, 1998; Ndayambaje and Mohren, 2011). In order to minimize forest dependency, as well as resultant socio-environmental impacts and ensure continuous supply of forest products to communities, we must seek alternatives to cushion particularly poor people who have limited alternative household fuels from a potential energy-deficient situation.

A possible intervention is to expand sources of fuelwood to include plantation forests and trees on farm (Smiet, 1990; Jarju, 2008; Ndayambaje and Mohren, 2011; Iiyama *et al.*, 2013). Ndayambaje and Mohren (2011) reckon that intercropping trees with food crops on farms, managing naturally regenerated trees; planting trees on roads and other open spaces may be the fastest and most rational way of dealing with the fuelwood problem; and one which has environmental and socio-economic benefits. As a sustainable land use system, agroforestry involves planting trees alongside crops. It is a concept that has been promoted since the 1970s and 1980s (Kang and Akinnifesi, 2000) because of its potential to yield more benefits than either crops or trees grown on their own by optimizing tree-crop interactions (Kürsten, 2000; Ndayambaje and Mohren, 2011), to solve food and environmental problems (Kang and Akinnifesi, 2000) and to reduce pressure on forests through sustainably supplying trees on farm (Iiyama *et al.*, 2013).

In West Java, for example, Smiet (1990) reported that agroforestry based fuelwood production could sustainably meet annual demand of up to 90 million cubic metres in the country. In addition to providing fuelwood, agroforestry reduces the rate of environmental degradation while at the same time providing non-timber products and environmental services. If properly done, using the right species of trees, fuelwood can be produced on farm like any other crop (Ndayambaje and Mohren, 2011).

Because the use of fuelwood is consumptive, in most cases; it involves the removal of a whole tree or parts of it, and so there is likely to be a conflict between fuelwood use and the aforementioned non-consumptive benefits of agroforestry practices. For agroforestry to be useful, trees planted on farm should have multiple uses so that pressure on natural forests can be alleviated by providing alternative sources of timber, fuelwood and non-timber forest products.

The concept of Conservation Agriculture with Trees (CAWT) entails planting of tree species that provide multiple benefits, the most important being to enhance soil fertility. Evidence from Ethiopia (Poschen, 1986), Zambia (Garrity *et al.*, 2010), West Africa (Bayala *et al.*, 2011) and Malawi (Glenn *et al.*, 2012) shows that crop yields increased when crops were intercropped with *Faidherbia albida*. This intervention has multiple benefits such as improved yields and provision of timber and non-timber products. The increasing demand for energy, however, may mean that trees planted and/or managed on farm are felled to provide fuelwood. The threat facing agroforestry trees may be an indication that people either have no alternative sources of energy, they are unable to get the preferred fuelwood from forests or that they ignore the implications of their actions both in the short-term and long-term. This therefore requires that the dynamics of fuelwood consumption in the community are evaluated and points that require significant policy measures with positive impacts on environmental conservation identified in order to achieve long-term sustainability in energy supply and demand.

This study investigates two aspects of household fuelwood consumption: choice of fuelwood sources and quantities of fuelwood consumed by examining a cross section of households living in rural and peri-urban settings in Mbarali district, South-western Tanzania. The rest of this thesis is structured as follows: the remainder of Chapter 1 gives the problem statement, objectives, justification and the scope of the study. Chapter 2 is a review of the literature including the theoretical framework used in the study. Chapter 3 describes the study design and methodology. Descriptive and empirical results are presented and discussed in Chapter 4. The last chapter presents conclusions, recommendations and areas for further research.

1.2 Statement of the problem

Fuelwood is the most prominently used household energy in developing countries. As the population in these countries increases, there is heightened pressure on natural resources, especially forests, resulting in their destruction and in the deterioration of the livelihoods of people wholly reliant on them. Agroforestry is being promoted in the study area to boost farm productivity but forest destruction and fuelwood scarcity is likely to shift demand for fuelwood to trees on farms and in that way threaten the success of agroforestry.

Despite high household dependence on fuelwood and the rapidly diminishing forest resources in the study area, sufficient empirical evidence to support policies geared towards improving access to alternative household fuels or concerned with increasing the supply options of fuelwood is lacking. The effects of fuelwood scarcity and the response of communities towards it may vary from place to place, even within the same country; therefore evaluation of fuelwood consumption at localized levels is important.

Several studies on wood energy have previously been done in Tanzania. However, they considered fuelwood consumption at the national level or focused only on charcoal consumption, which tends to concentrate on urban areas or were linked to environmental compliance and conservation (Kaale *et al.*, 2000; Mwampamba, 2007; Malimbwi and Zahabu, 2010). These studies did not specifically take into account fuelwood consumption at localized settings. Even so, fewer studies in the Eastern Africa region have focused on the sources of fuelwood (Jumbe and Angelsen, 2006; Beyene, 2010) or paid attention to agroforestry in consumption patterns. Thus empirical evidence to support policy decisions in this regard is insufficient.

1.3 Objectives of the study

The overall objective of the study was to analyze the consumption patterns of fuelwood in Mbarali district.

The specific objectives were:

a) To analyze the determinants of household preference of fuelwood sources in the study area

b) To determine factors that influence the quantity of fuelwood consumed by households in the study area

1.4 Hypotheses of the study

The study tests the following hypotheses:

H_0: There is no significant relationship between tree species and choice of fuelwood source

H_1: There is a significant relationship between tree species and choice of fuelwood source

H_0: Factors other than income do not determine the quantity of fuelwood consumed by households in the study area

H_1: Factors other than income determine the quantity of fuelwood consumed by households in the study area

1.5 Justification of the study

Environmental degradation has been reported and documented in many developing countries. Clearance of natural forests has in some cases led to severe degradation and destroyed the local communities' resource base for timber, fuelwood and other non-timber forest products. About 38% of Tanzania's land area is covered by forests and woodlands (Sheya and Mushi, 2000), but forest cover is rapidly declining. The World Energy Council estimates forest loss in Tanzania to be 91276 hectares annually (WEC, 2010). The high rates of deforestation in the country are partly blamed on high dependence on fuelwood as a source of energy (Johnsen, 1999; Sheya and Mushi, 2000).

The energy policy of Tanzania (URT, 2003) recognizes the immense role played by fuelwood in energy provision and emphasizes the need to have affordable and reliable energy supplies in the country. It also highlights that conservation of biomass resources could be complemented by growing trees at the household level and beyond (Malimbwi and Zahabu, 2010). However, in the absence of affordable and available alternative sources of energy, households will continue to use fuelwood for the foreseeable future, thus, the importance of fuelwood to the country cannot be overstressed. It is therefore essential to understand how different factors affect choice of fuelwood sources and fuelwood consumption.

The high dependence on fuelwood and the degradation of woodlands may pose a threat to the success of agroforestry practices, as demand shifts to trees on farms. Thus, policies that aim to address the supply-side of fuelwood are necessary to ensure that households meet their daily energy needs while at the same time reducing the rate of environmental degradation brought about by wanton destruction of forests and unchecked fuelwood collection. Supplying more fuelwood may be one of the strategies towards meeting daily energy needs of those dependent on it.

By investigating patterns of energy use and their interaction with agroforestry across different locations, lessons can be drawn on the extent to which agroforestry lessens the burden on natural resources. Understanding how households choose where to get their fuelwood from, could give indications of which and how policy interventions should be implemented to influence consumption decisions and take into account future challenges related to fuelwood consumption. The scenario depicted in Mbarali where household fuelwood consumption is high may be representative of other countries in sub-Saharan Africa (Brouwer *et al*. 1997; Arnold *et al*., 2006; Ndayambaje and Mohren, 2011). Results will therefore be useful to policy makers and development practitioners keen on conserving the environment while meeting household energy needs in rural areas of Africa. This study will also add to the literature on household energy consumption and agroforestry; and also contribute to the empirical evidence that is wanting.

1.6 Scope of the study

This study was carried out in Mbarali district, Mbeya region in the south-western part of Tanzania and focuses on household fuelwood consumption. It seeks to determine how households meet their daily energy needs, what socio-economic and environmental factors influence their decisions on where to obtain fuelwood and how much of it to consume. Particular emphasis is placed on the agroforestry intervention in the study area and makes recommendations to promote sustainability in fuelwood consumption and environmental conservation. The main data for the study was obtained through household survey.

As much as large scale tree exploitation for tea and tobacco curing and charcoal production is of grave concern to Tanzania (Johnsen, 1999, Kaale, 2005; Malimbwi and Zahabu, 2010), this study focuses only on household fuelwood consumption, because it is the overall dominating use of fuelwood in the country (Johnsen, 1999). Moreover, the agroforestry project targets small-holder farmer households who are both producers and consumers of fuelwood and who are likely to influence the success or otherwise of the project. Charcoal and large scale fuelwood production for trade in urban centers in Tanzania is often from forest trees (Mwampamba, 2007) while industries are likely to use fuelwood from forests or their own plantations (Malimbwi and Zahabu, 2010). They may therefore not have direct impact on cultivated or managed fertilizer trees which were of interest in this study. Even if domestic fuelwood consumption were less than that of industries and commercial production of charcoal, the consequences of such consumption would be far reaching especially when the number of end users is taken into account.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter synthesizes literature on previous studies on household energy consumption, particularly in developing countries. Emphasis is placed on fuelwood consumption and its determinants. The chapter also highlights agroforestry in the study area and the fuelwood situation in Tanzania.

2.2 Trends in household fuelwood consumption

The use of biomass fuels in many parts of developing countries remains relatively high. In Africa, nearly 76% of the population (about 575 million people) primarily depend on biomass energy. Even though the consumption of other forms of energy may substantially reduce the share of biomass fuels by the year 2030, these fuels will still account for about 75% of household energy in Africa, and by then, the percentage of people using them will have risen by about 40% (IEA (2006).

Fuelwood is the most common type of biomass energy and continues to be the main form of energy consumed in households in developing countries in general. There exist differences in fuelwood consumption across regions and settlement locations. Asia accounts for nearly half of the world's fuelwood consumption, while in Africa, per capita use is estimated to be higher than that of Asian countries, and with growth in population, fuelwood consumption is still rising (Arnold *et al.*, 2006). While rural areas are largely characterized by extensive biomass use, especially fuelwood, urban dwellers are more likely to consume modern fuels due to availability and affordability. The prevalence of fuelwood use is mainly attributed to its widespread availability, traditional practices and its low cost to the consumer, which does not accurately reflect the opportunity costs of labour and time (Schlag and Zuzarte, 2008). High demand, low opportunity cost of fuelwood and relative availability may explain the current patterns of fuelwood use, which may be considered unsustainable.

Natural resources and especially forests are vital in the lives of rural populations. Besides fuelwood they provide timber and other important non-timber forest products including fodder, fiber, fruits and nuts, gums and resins. Primary products like fuelwood are normally collected without financial costs to the household but have large opportunity costs of labour and time (Heltberg *et al.*, 2000) and their collection is determined by socio-economic, demographic variables and labour opportunity costs of time (Adhikari, 2003). Apart from forests, fuelwood can be obtained from plantations, farms and other open places. In Vietnam, Linde-Rahr (2003) found strong substitution to exist between open access resources and user-right plantations as sources of fuelwood. Hence policies that increase fuelwood production in plantation areas may help reduce the rate of deforestation.

The consumption of fuelwood is of critical concern for two reasons. One is the health implication of inefficient use and the other is the environmental impact that often results from unsustainable harvesting of resources. Fuelwood is often used in stoves that burn inefficiently and produce emissions which are detrimental to people's health consequently imposing enormous costs to the community (IEA, 2006). Again, unsustainable exploitation of resources may result in depletion of the resources leading to a scenario of scarcity which disrupts availability and could render households vulnerable to livelihood insecurity (Dovie *et al.*, 2004, Arnold *et al.*, 2006).

In Africa, fuelwood and charcoal consumption are important drivers of dryland forest degradation (Kang and Akinnifesi, 2000). This is because household fuelwood collection often results from self-interested household behavior which is not hindered by any social norms or penalties imposed on them (Baland *et al.*, 2009). And since natural forests are common resources, households would seek to maximize their utility and get the most out of them, making them prone to overuse and eventual scarcity.

Continued reduction in fuelwood supply could subsequently encourage the use of more inferior and smokier alternatives like animal dung and crop residues (Abebaw, 2007; Suliman, 2010) which could aggravate the health implications and also reduce availability of these for other purposes like soil fertility improvement. Increasing shortage of fuelwood supply adds to the burden of fuel collection especially for women and children who are mainly involved in household energy provision.

Consumption patterns of fuelwood have been studied in different contexts, for example, by investigating choice of household energy (Israel, 2002; Gupta and Kohlin, 2006; Pundo and Fraser, 2006; Mekonnen and Kohlin, 2008; Mekonnen *et al.*, 2009; Suliman, 2010; Osiolo, 2012; Tchereni, 2013); by analyzing household consumption (Davis, 1998; Kituyi *et al.*, 2001; Chambwera, 2004; Abebaw, 2007; Shackelton *et al.*, 2007; Johnson *et al.*, 2012; Onoja and Idoko, 2012); examining cook stoves used (Adkins *et al.*, 2010; Nepal *et al.*, 2010; Johnson *et al.*, 2012); studying fuelwood collection (Heltberg *et al.*, 2000; Adhikari, 2003; Linde-Rahr, 2003; Pattanayak, 2004; Jumbe and Angelsen, 2006; Beyene, 2010) and investigating fuelwood scarcity (Brouwer *et al.*, 1997; Cooke, 1998; Johnsen, 1999; Mahiri, 2003; Dovie *et al.*, 2004; Damte *et al.*,2012). From these studies, it is notable that households determine their consumption of fuelwood by maximizing their utility and that consumption patterns vary from place to place. It is also noted that most communities in developing countries, particularly in Sub-Saharan Africa rely on primary products like fuelwood from natural resources.

Many of the studies on general fuelwood consumption have been carried out in Asian countries. Majority have investigated energy choice for domestic purposes, and not much has been done, especially in African countries, to understand particular aspects of fuelwood consumption in terms of collection patterns which is critical in environmental conservation and sustainability; and determinants of consumption which would make it possible to formulate relevant policies. Even fewer studies in the Eastern Africa region have focused on the sources of fuelwood. Some studies in Asia for example, Linde-Rahr (2003), explored the potential substitution between collection sites and the market alternative in Vietnam. Heltberg (2000), on the other hand assumed that in India, fuelwood only came from collection from common resources and private sources and was not bought, and did not include market as a source in the analysis. Empirical data from African countries nevertheless is insufficient.

Beyene (2010), for instance, specifically considered the impact of local level institutions and land tenure on choice of fuelwood source in Ethiopia and suggested that since land certification may take too long to have an effect on household fuelwood use decisions, planting more trees could be encouraged to increase supply of fuelwood. Jumbe and Angelsen (2006) focused on choice between forest reserves, customary forests and plantation forests as sources of fuelwood in Malawi and investigated environmental consequences only on forest reserves.

Both Linde-Rahr (2003) and Jumbe and Angelsen (2006) incorporated specific attributes of the different fuelwood sources including distance to the source and size of the source in the analysis. Although Jumbe and Angelsen (2006) rightly noted that tree species is quite critical in choice, like Linde-Rahr (2003) and Beyene (2010), they did not specifically include tree species in their analysis. The role, especially, of indigenous tree species to livelihoods in developing countries cannot be overstated and their destruction has immediate livelihood and long term environmental effects. It is therefore important to examine household energy consumption patterns in order to positively contribute to sustainable energy use.

2.3 Fuelwood situation in Tanzania

Like many developing countries, woodfuels account for the bulk of energy requirements in Tanzania. Different authors give varying figures: Johnsen (1999) and Sheya and Mushi (2000) found biomass consumption to be 92% whereas Malimbwi and Zahabu (2010) estimated consumption of fuelwood at 88% and charcoal at 4%. The Tanzania Demographic and Health Survey estimated the combined consumption of charcoal and fuelwood in the country at 94.6% (TDHS, 2010).

Energy supply and demand in Tanzania reflects the low level of industrialization and development in the country (IEA, 2006), with the rural population especially dependent on woodfuels and being almost exclusively alienated from modern sources of energy. Woodfuels are therefore likely to remain the major source of domestic energy and a key issue in economic and environmental discourses in developing countries for some time. The domination of fuelwood in the energy balance may not change in the near future (O’Keefe *et al.*, 1989; URT, 2003) because as population grows, the demand for household energy increases meaning that biomass fuels will continue to be the primary energy source for many households (Felix and Gheewala, 2011).

Although dryland forests and woodlands are the main sources of woodfuels consumed both in rural and urban areas, one of the objectives of the Energy Policy of Tanzania (URT, 2003) is to increase productivity of existing resources and to create new resources for energy production. Numerous renewable energy projects have in the past been implemented across the country. National tree planting initiatives, for example, were launched enthusiastically in the 1980s by establishing village woodlots and agroforestry practices on farms. Some of these initiatives, however, were not successful, with failure attributed to poor understanding of the socio-economic conditions affecting energy use (Johnsen, 1999) and the tree species provided were exotic like Eucalyptus, which did not provide other benefits to communities (O'Keefe *et al.*, 1989).

In addition to this, the failure to recognize indigenous systems of forest management and indigenous rights to resource use at policy level discouraged local communities from engaging in tree planting and reforestation projects (Malimbwi and Zahabu, 2010). Even though the impact of some of these initiatives on fuelwood availability was insignificant, there could have been benefits in some villages (Johnsen, 1999).

The HASHI[1] Project in Shinyanga, for instance, was one such successful initiative which involved regeneration and conservation of indigenous tree species on cropping and grazing lands by applying indigenous knowledge (Mlenge, 2004; Duguma *et al.*, 2013). Within this project,

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[1] A donor funded land rehabilitation project that promoted forest restoration in the Shinyanga region of Tanzania through use of traditional pastoralist practices.

local communities in the area were eventually able to restore degraded lands and obtain benefits from trees including fuelwood. Johnsen (1999), however, asserts that people will only be motivated to plant trees when the level of fuelwood scarcity reaches a certain critical point. When people can no longer find fuelwood within a reasonable distance, then there would be some motivation for planting trees. There have also been attempts to introduce and promote alternative wood saving technologies for among other reasons, their low cost and the availability of resources (Sheya and Mushi, 2000) to replace inefficient traditional cook stoves. Unfortunately they also have not been adopted widely enough as to have a significant impact on fuelwood consumption (Johnsen, 1999).

About 20% of the total land area in Mbeya region, is covered by forests most of which are found in Mbarali district (MDC, 2009). Farmers in the region also have private woodlots on their farms but they account for a very small percentage of the forests. Natural forests in this region are therefore the largest source of timber and non-timber forest products. With the high rates of deforestation shown above and future trends unlikely to decrease, solutions to avert a future fuelwood crisis have to be sought. The need to plant more trees on farm to provide fuelwood and other products therefore becomes imminent.

Kaale (2005) notes that Mbeya region is an area with moderate biomass fuel supply: fuelwood resources are relatively available and is one of the supply areas for urban Tanzania. However, it is important to note that continued population growth in the study area and elsewhere may in the long run constrain the available natural resources; which is why policies to improve fuelwood availability while at the same time conserving the environment need to be prioritized.

Effective policies must be based on empirical evidence and even though some empirical studies have been done in Tanzania, more studies addressing fuelwood consumption at local level need to be done. Mwampamba (2007), for instance, considered the implications of fuelwood consumption for forest availability while Kaale (2005) undertook a baseline survey of energy consumption at national level, Kaale *et al.* (2000) investigated fuelwood and charcoal uses in a wetland ecosystem and Malimbwi and Zahabu (2010) looked at the status of fuelwood consumption and potential for sustainable production through certification. Even with such studies, there is need for more evidence to facilitate formulation of relevant policies to protect the environment and ensure sustainability in fuelwood consumption.

2.4 Conservation Agriculture with Trees in the study area

The Conservation Agriculture with Trees (CAWT) project in Tanzania was initiated in 2010 to improve the livelihoods of smallholder farmers and at the same time conserve the environment. CAWT combines tree planting and conservation agriculture (CA) practices like minimum tillage, covering soil with organic matter like crop residues, trees and other crops and crop diversity and crop rotation. It is potentially a practicable and gainful option for creating sustainable agriculture, and adapting to climate change as it is expected to increase crop yields due to improved soil fertility and productivity. Through it, food security, environmental conservation and improvement in the livelihoods and welfare of smallholder farmers can be achieved (Garrity *et al.*, 2010). The concept of CAWT is broad, but this study focuses only on the tree planting aspect of CAWT, defined as agroforestry. Although CAWT is being promoted in African countries, the high demand for biomass fuels is increasingly posing a threat to trees on farms.

Fuelwood is a renewable source of energy and planting multipurpose trees of different species may help to increase its sources of supply. CAWT may therefore be complementary to fuelwood production and a solution to the increasing demand for fuelwood for domestic and small-scale industry use. The main agroforestry tree species in CAWT is *Faidherbia albida*, one of the fastest growing and largest acacias whose association with increased crop yields has been well documented (Poschen, 1986; Garrity *et al.*, 2010; Bayala *et al.*, 2011; Glenn, 2012). It is a nitrogen-fixing tree which sheds its leaves during the cropping season and grows them during the dry season when crops are harvested (Figure 2.1). It is therefore highly compatible with crops and does not compete for light, water or nutrients with crops. Besides soil fertility improvement, its leaves are used as livestock fodder (Orwa *et al.*, 2009). Fuelwood consumption, however, may be a major threat to this tree as members of the community in the region may increasingly cut or prune them to provide fuelwood for domestic uses in future.

Figure 2a: showing *Faidherbia albida* growing in a maize plantation
Source: World Agroforestry Centre©

Figure 2b:*Faidherbia albida* after crops have been harvested
Source: Author, 2013

Figure 2.1: Faidherbia albida on farm in different seasons

To ensure that the welfare of the community is maintained or enhanced and to curb further environmental degradation, the increasing deficit of fuelwood must be checked. One way to do this is through an on-farm energy production system that diversifies sources of the resource while at the same time conferring other benefits, in this case, gains associated with CAWT to small scale farmers. In this process, the dynamics of fuelwood consumption in the community should be evaluated and points of intervention which will have significant policy implications identified in order to achieve long term sustainability in energy supply and demand.

2.5 Theoretical Framework

The theoretical framework applied in this study is the basic microeconomic theory of the consumer which relates preference for goods and services to actual consumption and analyzes consumer behavior based on choices made in various situations. It is assumed that a consumer behaves rationally, and that he aims to attain the highest satisfaction and utility from consuming different goods or services (Beardshaw, 1992).

The theory stipulates that a consumer is able to compare between alternatives and that when given a set of alternative goods or services, he will choose a good or service based on the utility derived from consuming that good or service (Koutsoyiannis, 1991; Beardshaw, 1992). Individual preference for particular goods or services is revealed through the choices made and implies the maximization of the utility of the consumer. Revealed preference does not require the consumer to rank his preferences or give information about his tastes, but allows the understanding of consumer behavior by observing the choices made as long as the assumptions that he is consistent, his tastes are independent of choices made over time and do not change and that he is rational hold (Koutsoyiannis, 1991).

In the market place, a consumer is constrained by income and the prices of the alternatives he has to choose from (Beardshaw, 1992), and can therefore only make choices within this budget constraint. Thus, income sets a limit to the maximizing behavior of a consumer (Koutsoyiannis, 1991; Beardshaw, 1992). Based on the consumer theory, two models are used to address the objectives of the study. The Random Utility Model which is consistent with utility maximization (Train, 2002; Walker and Ben-Akiva, 2002) is applied in examining household choice of fuelwood sources in the study area while the energy ladder model is used to explain household consumption of fuelwood.

2.5.1 Random Utility Model

In the context of this study, a discrete choice model, the Random Utility Model (RUM), is used to investigate choice of fuelwood sources. The basic utility function, U_{hf}, for a household choosing a source of fuelwood is expressed thus:

$$U_{hf} = V_{hf} + \varepsilon_{hf} \quad (2.1)$$

Where V_{hf} is the observable component composed of variables that relate to the alternatives (sources of fuelwood) and variables relating the household (socio-economic characteristics) whose effects on the dependent variable are estimated statistically. ε_{hf} is the stochastic random component composed of unobserved factors that influence the choice of an alternative (Walker and Ben-Akiva, 2002). The observable component of the equation, $V_{hf,}$ is further expressed as follows:

$$V_{hf} = \beta_{1h}\beta_{2f} \; for \; \forall_f = 1,2,3 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \; (2.2)$$

Where f is a vector of fuelwood source attributes which associates households' utility for a particular fuelwood source based on the attributes identified; and h is a vector of household characteristics which are specific to each observation and do not relate in any way to the fuelwood source. 1, 2, 3 are the sources of fuelwood. Household characteristics do not change across the different sources of fuelwood, but they can only enter the model in ways that create differences in utilities over the alternatives. β_1 and β_2 are the unknown parameters that should be estimated. The decision on whether to collect fuelwood from a particular source is a function of factors pertaining to that source and to the household.

The utility function then becomes:

$$U_{hf} = \beta_{1h}\beta_{2f} + \varepsilon_{hf} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots ...(2.3)$$

Assuming that an individual, i, is rational, and will choose the alternative that gives him the highest utility, thus:

$$U_{i1} > U_{i2} > U_{i3} \ldots\ldots\ldots\ldots..U_{in} \; \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \; (2.4)$$

Where U_{i2}, U_{i3},……..U_{in} represents individual utilities derived from each of the other available options.

In this study, the probability that a household will choose one source of fuelwood, *f1*, from a complete set of alternative sources of fuelwood, C is given by:

$$p\left(\frac{f_1}{C}\right) = \{(V_{f_1} + \varepsilon_{f_1}) > (V_{f_n} + \varepsilon_{f_n})\}$$
……………………………………….(2.5)

n in Equation 2.5 represents all the other sources of fuelwood available for the household to choose from. This assumes that the utility derived from choosing source *f1* is greater than utility derived from using any of the other sources of fuelwood as shown in Equation 4.

Natural forests where people have traditionally obtained most of their fuelwood are rapidly diminishing. This means that consumers of products such as fuelwood, timber and other non-timber forest products that were previously obtained mainly from forests, must choose between forests and other available alternatives, and may therefore shift undue pressure to the available alternatives. In choosing where to obtain fuelwood in the study area, households may select from (i) natural forests, which fall under the jurisdiction of the state or the local authority (ii) their farms or (iii) the market. The selection of one source therefore implies that the utility derived by the household from that source is greater than that derived from the other two sources. In this study, the random utility method seeks to answer two critical questions; first, what factors determine where households get their fuelwood from and second what does this portend for agroforestry interventions such as CAWT?

2.5.2 Energy ladder and energy stacking models

The dynamics of domestic energy consumption have often been explained by the energy ladder model (Figure 2.2a) which attempts to demonstrate how households use different fuels and how they transition from traditional to modern fuels (Arnold *et al.*, 2003). The shift is considered to be progressive from traditional fuels (typically biomass fuels) to transitional fuels (kerosene, coal and charcoal) and finally to modern fuels (electricity and gas).

The energy ladder model considers energy switching as a central concept and implies that as household income increases, households tend to move up the ladder substituting one fuel with another at a higher level. This is attributed to the “income effect” where, as the wealth of an individual rises, demand increases; shifting the demand curve higher at all rates of consumption. Consumers then tend to substitute away from goods that they consider less costly and inferior, and instead prefer higher priced alternatives. Being at the lowest rung on the energy ladder, fuelwood, cow dung and agricultural residues are considered inferior goods which are likely to be abandoned with increase in income or accumulated wealth. Fuels found at the top of the ladder are considered most efficient and cleanest but come at a higher price. According to the fundamental theory of demand, the demand for these fuels would be low because of the associated high prices. So, as prices of fuels rise, consumers may be forced to substitute away from these fuels and adopt less costly alternatives.

While several studies attest to there being a relationship between choice of fuel and income (Hosier and Dowd, 1987; Farsi *et al.*, 2007; Mekonnen and Kohlin, 2008 and Van der Horst and Hovorka, 2008); some have also studied and identified factors other than income that affect demand for different fuels used by the household (Masera *et al.*, 2000; Heltberg, 2003; Gupta and Kohlin, 2006; Pundo and Fraser, 2006; Mekonnen *et al.*, 2009; Suliman, 2010; Osiolo, 2012). These latter studies have often critiqued the energy ladder model because of its tendency to mainly focus on income as the sole determinant of household fuel choice and subsequently consumption while ignoring other economic and non-economic factors that could influence consumption of a particular fuel.

Indeed studies such as Masera *et al.* (2000), Heltberg (2003), Mekonnen and Kohlin (2008) and Tchereni (2013) have shown that factors other than income do influence household choice. Heltberg (2003) asserts that although the energy ladder model has succeeded in capturing the strong income dependence of fuel choices and also found strong normality of modern fuel consumption, the fact that households consume a portfolio of energy sources at different levels of the energy ladder does not fit well with the model. In light of this, the energy stacking model (Figure 2.2b) which considers multiple energy use in the household was proposed (Masera *et al.*, 2000).

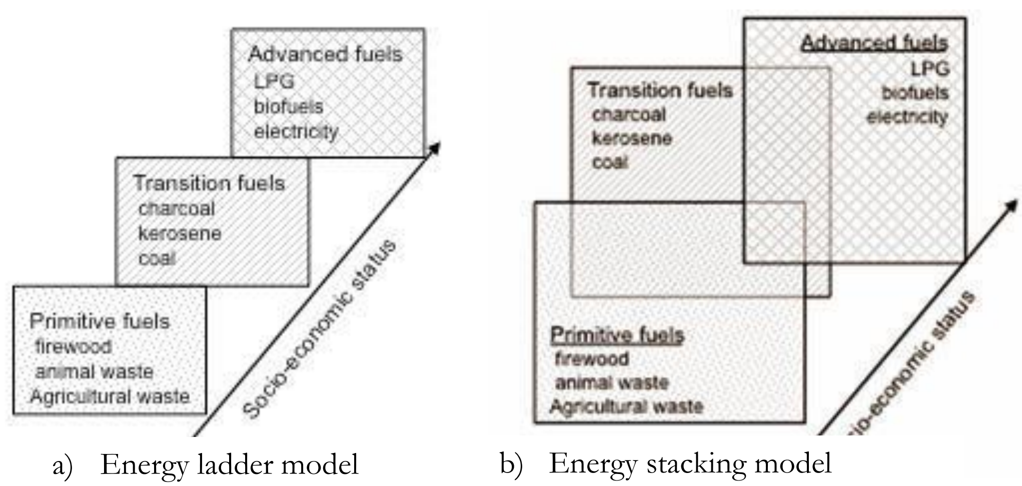

Figure 2.2: Energy ladder and stacking models

Source: Schlag and Zuzarte (2008)

The literature confirms that energy transition does not occur discretely; people prefer to use a combination of fuels at a point in time rather than one fuel at a time (IEA, 2006). If one uses electricity, he may still use fuelwood or charcoal for cooking. The most energy consuming activities of the household, such as cooking and heating, are usually the last to change. Reluctance to stop using fuelwood could also be attributed to familiarity with traditional cooking technologies and the taste and texture of food cooked using fuelwood. It is also possible that people may switch back to a lower ranking fuel even after adopting fuels that are higher on the ladder. Masera *et al.* (2000) observed that for a particular purpose such as cooking, different fuels could be used by the household, and that the household does not completely abandon one source of energy in favour of another one on the ladder, but starts to use one source while still using the lower rank one.

Fuel stacking happens for several reasons; in South Africa, Davis (1998) considers stacking to be a strategy employed by poor rural households because of the irregularity and variability of their income flows which may prevent them from consuming modern fuels. It could also be as a result of instability in supply as explained by Van der Kroon (2013). He reckons that erratic and non-reliable supply of modern fuels may cause households to keep other fuels as “back-up” to be used in the event that the preferred one is not available. He also notes that price fluctuations may make other sources of energy temporarily unaffordable. In Kenya, for example, the price of cooking gas and electricity tariffs fluctuate in response to international crude oil prices. When prices rise households may temporarily not afford to use gas or electricity for cooking. In such a case, the household may still use electricity but only for lighting and powering electronic appliances and opt for cheaper alternatives like charcoal or fuelwood for cooking. Since some households use multiple fuels at any one time, then, the estimation of consumption of one fuel should be carried out in the context of the other fuels used (Chambwera, 2004).

CHAPTER 3

STUDY DESIGN AND METHODOLOGY

3.1 Introduction

This chapter describes the study area and data used in the study. It discusses the study design, sampling and how data was collected, processed and analyzed. Empirical models used are also explained and the variables used in the econometric models and how they are expected to influence choice of fuelwood sources and consumption discussed. Lastly, ethical considerations and the limitations of the study are explained.

3.2 Empirical models used in the study

In order to address the objectives of the study two empirical models were used to analyze the data. The first is a multinomial logit (MNL) regression model which was used to analyze the determinants of choice of sources of fuelwood and the second is an ordinary least squares (OLS) regression model used to examine the determinants of fuelwood consumption.

3.2.1 Multinomial Logit Regression

Insert two sentences explaining why MNL not Tobit and linear regression here. Multinomial logit models have commonly been applied to empirical marketing research studies (Franses and Paap, 2010) where discrete choice data is being analyzed. It has also been widely applied in studying the determinants of selection of various fuels for domestic use in the Eastern African region, for example, by Pundo and Fraser (2006) in Kenya, Mekonnen and Kohlin (2008) in Ethiopia, Suliman (2010) in Sudan, Osiolo (2012) in Kenya and even Tchereni (2013) in Malawi, Southern Africa.

The MNL has a strong assumption of independence of irrelevant alternatives (IIA) which presumes that an individual's choice of an alternative relative to another would not change even if a viable alternative were added to or dropped from the choice set. In practice, an individual can switch between or among alternatives based on how he assesses the utilities derived from each alternative. As such, when IIA is violated, the MNL would be incorrectly specified, and the estimated coefficients would be biased and inconsistent. The general form of the MNL model is expressed as follows:

$$P(y = j/x) = \frac{exp(x\beta_j)}{\left[1+\sum_{h=1}^{J} exp(x\beta_h)\right]}, j = 1,2,3 \dots \dots . . J \dots\dots\dots\dots\dots\dots \quad (3.2)$$

Where, *y* denotes a random variable that takes on values (1, 2, 3…..J) for a positive integer J and *x* denotes a set of independent variables. *x* is a 1xK vector with first element unity and β_j is a $K\times 1$ vector with j = 2… J.

In this study, *y* is the dependent variable denoting the alternative sources of fuelwood available to the community (natural forests, own farms and markets), which are the decision categories while *x* are socio-economic characteristics of the household and specific attributes of the sources of fuelwood. What we are looking to estimate is how changes in household and source specific characteristics affect the response probabilities P(y = j/x), j = 1, 2, 3….. J. Since total probabilities must equal to 1, P(y = j/x) is determined once the probabilities for j = 1, 2… J are known.

The basis of the IIA assumption is the independent and homoscedastic disturbance terms of the basic model in Equation 3.1. The parameter estimates of the MNL model only provide the direction of the effect of the independent variables on the dependent (choice) variable;

thus the estimates do not represent the probabilities of choosing any of the available options. For this reason, the marginal effects are estimated; and then the expected changes in probabilities of a particular source of fuelwood being chosen with respect to a unit change in an independent variable from the mean are calculated. To obtain the marginal effects for the model, Equation 3.1 is differentiated with respect to the explanatory variables as shown in Equation 3.2:

$$\delta_{jk} = \frac{\partial_{Pj}}{\partial_{xk}} = P_j \left[\beta_{jk} - \sum_{h \neq j \in J} P_j \beta_{jk}\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.3)$$

In this study, an unordered limited dependent variable, source of fuelwood (*fwdsource)*, is empirically estimated by regressing it against a set of covariates using MNL. This enables one to understand the effects of variables in the model on household choice patterns and provides insightful supply side and demand side strategies to address energy issues, reduce unsustainable use of natural resources and reduce overexploitation of trees that are critical for agroforestry and soil fertility improvement on farm. The MNL is advantageous in that the probability expression is easy to compute. It allows analysis decisions across more than two categories in the dependent variable and therefore makes it possible to obtain choice probabilities of fuelwood sources. It is a robust model which yields good results and is applicable in practical situations where the basic IIA/IID assumption maybe violated. Models derived from utility maximization can also be used to represent decision-making that does not entail utility maximization (Tchereni, 2013).

3.2.2 Ordinary Least Squares

Previous studies have employed different empirical methods to analyze fuelwood consumption. Abebaw (2007) applied the Tobit model, while Onoja and Idoko (2012) used the two-stage least squares method. The Tobit model was inapplicable in this study because the actual estimated values of fuelwood consumed by each household were used in the analysis, and so the dependent variable was not censored, making it impractical to use the model. Preliminary examination of the dataset obtained could also not reveal any two stage effect in the consumption of fuelwood (see Hosier, 1985) rendering the Double Hurdle and the Heckman models inappropriate for this study. The reason is that nearly all respondents use fuelwood albeit to varying degrees, and therefore sample selection bias does not arise to justify a two-step regression. An OLS regression is therefore used to analyze the determinants of fuelwood consumption based on the data set in this study.

OLS is a generalized linear modeling technique which at the basic level represents the relationship between a continuous dependent variable and a set of explanatory variables, using a line of best fit.

The general equation of the model is written thus:

$$Y = \propto + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \cdots \beta_k X_k + e \text{... (3.4)}$$

Where $Y, X_1, X_2, X_3 . . . . X_k$ are observable random scalars (in this case, Y is the quantity of fuelwood consumed per year and the Xs are the independent variables used in the model) which have been obtained from the sample, $\propto$ is the constant term, $\beta_1; \beta_2; \beta_3 \; . . . . \beta_k$ are the parameters that are being estimated and e is the unobservable random disturbance or error term. The error term in the model is useful for presenting a unified treatment of the statistical properties of various econometric procedures (Wooldridge, 2002).

The regression parameters describe the change in the dependent variable Y that is attributed to a one unit change in any of the explanatory variables. Four functional forms can be used in this type of regression (linear, exponential, semi-log and double log). In this study, the double log or log-linear functional form is used, and was selected after an initial examination of the data suggested that both the dependent and some independent variables fitted a logarithmic form and that the relationship between consumption and its determinants was not necessarily linear. Logarithmic transformation does not normally reverse the direction of the relationship meaning that the ordering between x and $f(x)$ is preserved (Benoit, 2011). The equation therefore becomes:

$$lnY = \propto + \beta_1 lnX_1 + \beta_2 lnX_2 + \beta_3 lnX_3 \ldots\ldots\ldots \beta_k lnX_k + e \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.5)$$

In this study, the log of estimated total household fuelwood consumption per annum is modeled as a function of a set of covariates including age and level of education of the head of household, size and location of the household, the household's most preferred source of fuelwood, awareness of laws regulating natural resource use and environment conservation organizations in the area, and prices of fuelwood, charcoal and kerosene. In the log-linear functional form, the elasticities implied are constant. The coefficient on the natural log of the estimated price of fuelwood per kilogram is the short-run own price elasticity of demand. The coefficient on the natural logs of price of kerosene and charcoal are cross price elasticities of demand while the coefficient on the natural log of total income is the income elasticity of demand. Economic theory predicts that demand and price are inversely related and so if fuelwood is a normal good, its price elasticity of demand is expected to be negative.

3.3 Conceptual framework of the study

In energy consumption, a household makes a two stage decision: first, which fuel to consume and second, how much of it (Hosier, 1985). The choice of the fuel consumed reveals household's preferences and the quantity consumed indicates the demand for that fuel. In the context of this study, though, consumers may not have a wide variety of domestic fuels to choose from. After the choice decision is done, then a 'decision' on how much fuelwood to consume is made, albeit unconsciously, but can be estimated by observing various factors to establish what influences consumption levels of households. Another choice that households make is where to obtain the preferred fuel to be used. In this study, choice reveals the household's preferences among alternative sources of fuelwood. The two decisions are affected by household characteristics and/or external determinants which may be economic or non-economic.

Figure 3.1 shows the inter-relationship between the determinants of the choice decision and consumption. The choice of source is critical here because the aim of CAWT is to encourage on-farm cultivation or management of *Faidherbia albida* and in that way conserve soil and water but, high household reliance on farms for fuelwood may compromise the success of CAWT. Uncontrolled dependence on natural forests, again, would lead to deforestation and a vicious cycle of fuelwood scarcity that would lead to land fragmentation.

Unsustainable and inefficient consumption of fuelwood has serious socio-economic, health and environmental impacts (Dovie *et al.,* 2004; Arnold *et al.,* 2006; IEA, 2006). The application of this framework in the study demonstrates the interaction between various factors and household fuelwood consumption patterns and therefore indicates possible points of policy intervention that may be useful to promote sustainability and environmental conservation in consumption.

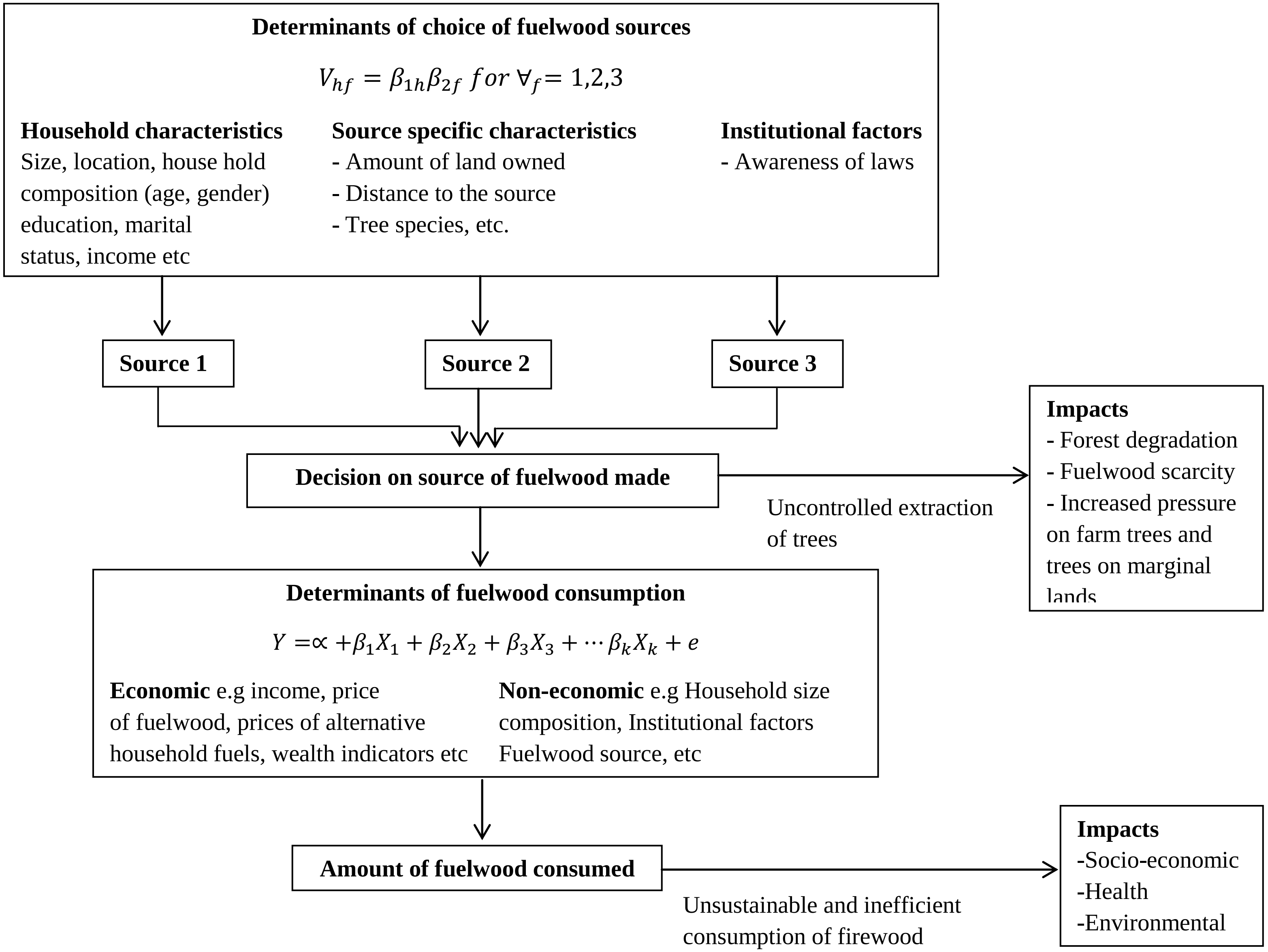

Figure 3.1: Conceptual framework of the study

3.4 Data

This study used both qualitative and quantitative primary and secondary data. The key type of data is cross-sectional. It is complemented with data from key informant interviews of other actors in the fuelwood value chain such as traders, and consumers like brick makers and institutional consumers including restaurants, secondary schools and hospitals. Focus group discussions (FGDs) were also carried out and data obtained from these used to triangulate the information obtained from the survey and interviews.

3.5 Study Area

The study was done in Mbarali district, south-western Tanzania. It is one of the areas in the East African region in which the CAWT project is being implemented as a key agroforestry intervention to enhance soil fertility and conserve water on farms.

3.5.1 Rationale for choice of the study area

One of the reasons that informed the choice of study site is that Tanzania is one of the most biomass-reliant countries. Biomass energy consumption at the household level was estimated at 90% (Kauzeni *et al.*, 1998) and 92% (Johnsen, 1999; Sheya and Mushi, 2000; Malimbwi and Zahabu, 2010). As population increases, demand for biomass fuels, especially fuelwood, for domestic use continues to rise (Felix and Gheewala, 2011). It is unlikely that household demand for fuelwood in Tanzania will decline meaning that this high fuelwood dependency situation will not change in the near future (URT, 2003). Mbarali district has several natural forests which was also an important criterion for selecting the site as this provides an insight into the influence of natural forests on the uptake of agroforestry practices.

3.5.2 Location of the study area

Mbarali district is one of the eight districts forming Mbeya Region in South-western Tanzania (Figure 3.1). Lying between 7ºS and 9 ºS and 35ºE and 38ºE, it is about 800km from Dar es Salaam. It is bordered to the north and east by the Iringa Region, to the south by Mbeya Rural District and to the west by Chunya District (URT, 1997). It is administratively divided into eleven units called wards or "*Shehia*" out of which four were considered for the survey. The administrative headquarters of the District is Rujewa, a small township with a population of about 30,000 persons.

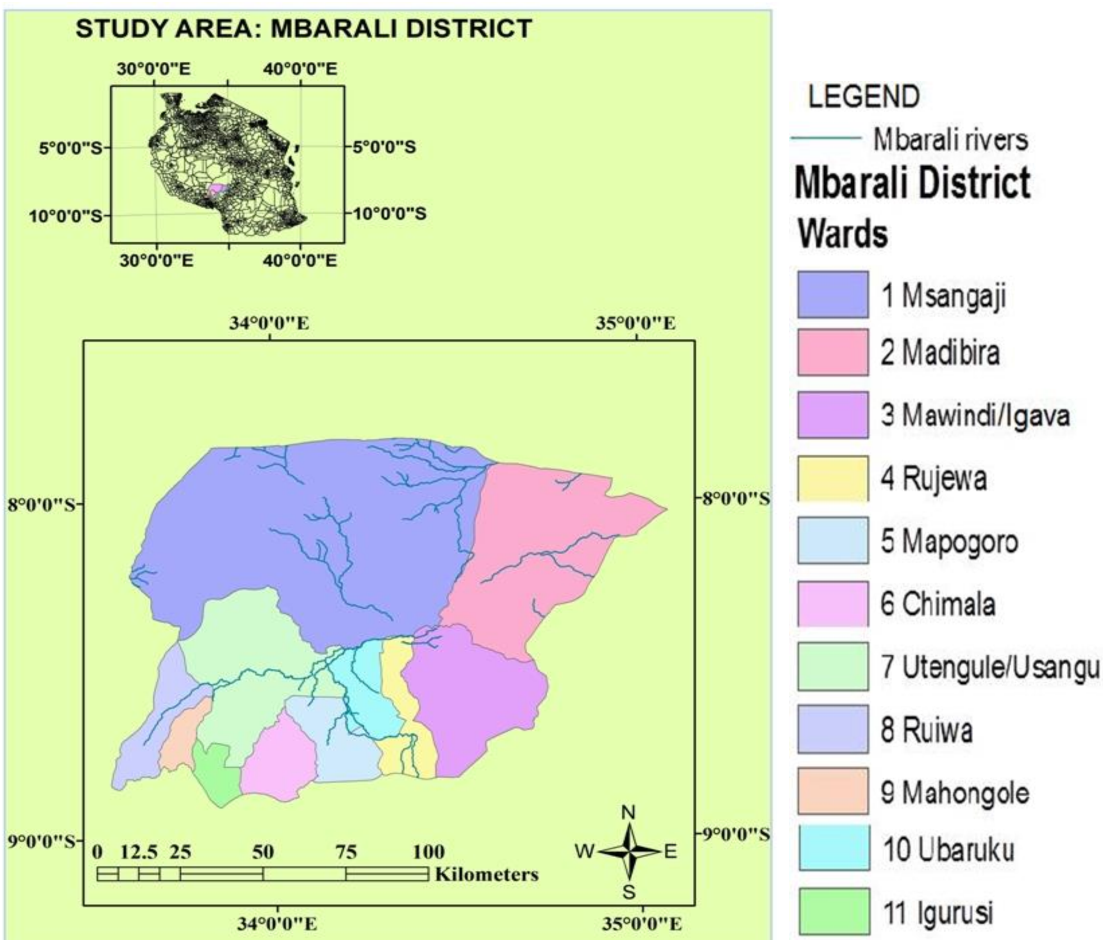

Figure 3.2: Map showing the study area

Source: Mbarali District Council, 2009

3.5.3 Topography, climate and other geographical features of the study area

Mbarali district has altitudes ranging between 1000 and 1400 metres above sea level. Daytime temperatures range between 25 º and 30 ºC, and the rainy season is between December and March. Mean annual rainfall is between 450-650m (FAO, 2010b) and the district covers an area of 15520 square kilometres. Of this land, 12.2% is arable and 40% of it is a protected area. Community-based natural forest reserves account for about 20000 ha of land in the district, while forests under the jurisdiction of the central government include Chimala Scarp (17,000 ha), Ikoga - Mapogoro (15,000 ha), Mwambalizi and North Usafwa forest reserves (MDC, 2009). Natural forests in the area are important resources providing timber and non-timber forest products as well as a range of environmental services, thus contributing to different extents to the livelihoods of communities. In the study area, fuelwood and charcoal are important household fuels.

3.5.4 Socio-economic profile of the study area

Mbarali is considered one of the most densely populated districts in Tanzania. The 2012 census estimated the total population of the district to be 300,517 persons, with an average household size of 4 persons. Population density is between 50 and 100 people per square kilometre. The annual inter-censal growth rate in Mbeya region is 2.7% which is also the average national growth rate (URT, 2013).

As an agricultural district, the main production system in this area is crop production and some livestock keeping. In the district, 83% of the population directly engages in agriculture. Most of the people practice small holder subsistence farming. Agriculture in the district is both rain-fed and irrigated, with the district having large tracts of land under irrigation schemes for rice production owned by the government, cooperative societies and individuals. According to MDC (2009), there were a total of 87 irrigation schemes in the district. The crop growing season ranges between 150 to 200 days per year normally from December to June (URT, 1997; FAO, 2010b).

3.6 Sampling

The sampling frame consisted of 3964 households from four wards. It was constructed with guidance from the local administrative officers. Out of 5 rural wards in which the CAWT project was initiated by ICRAF, 3 were randomly selected: Madibira (part of which was peri-urban), Igava and Mapogoro. A fourth ward, Rujewa which comprises a peri-urban population was also selected to enable comparison across settlement location and to analyze the impact of urbanization on fuelwood consumption decisions. Appendix 1 gives a summary of the sampling frame and the samples drawn according to wards and villages. The sample was stratified by location: whether rural or peri-urban and selection was done at the lowest administrative level (hamlet) proportional to the total number of households in each hamlet. The formula below was used to calculate a representative number of sample households:

$$n = \frac{z^2(p)(q)}{d^2} \quad \text{(3.1)}$$

Where n is the desired sample size, z is the statistical certainty related to the error risk. For an error risk of 5%, z is 1.96. p is the estimated prevalence of an indicator in the population, expressed as a fraction of 1 (where prevalence is unknown 50% is used to give the largest sample size). According to the literature, it was assumed that at least 88% of the population uses fuelwood, so p = 0.88. q = (1- p) and in this case, $q = 0.12$. d is the margin of error. In this study, a 5% margin of error was used. When actual figures were input into Equation 3.1, the result was 168.96. In order to obtain a more representative sample from the population, the resultant figure was rounded off to the nearest tenth (170) then a multiplication factor of 2 applied. Out of this number, 80% was the main sample, while 20% was the replacement sample. Thus, a stratified random sample of 270 households representing 7% of the population was drawn consisting of 200 rural and 70 peri-urban households. A replacement sample of 70 households (20 peri-urban and 50 rural) was also randomly selected. Replacement households were used in cases where members of the sampled households had moved out of the village, were unknown, had travelled or were unavailable during the tim of the survey. In some villages, however, even after using the replacement sample, the total number of interviewed households still fell short of the anticipated numbers. Consequently, the sample size reduced to 254 households (190 rural and 64 peri-urban). In addition to the household survey, 8 brick makers, 4 institutions, 7 traders were interviewed and 3 FGDs carried out.

3.7 Data collection, processing and analysis

The household survey was administered using a team of 10 enumerators and three supervisors. Enumerators were trained prior to the data collection exercise to make them understand the questionnaire and the objectives of the study. Pretesting of the survey tool was carried out before data collection in a village which was not part of the sample, after which some modifications were made to include relevant aspects that arose during FGDs and pretesting. The survey tool was written in English but translated into Kiswahili during data collection.

Actual household data collection was done during the dry season when the rate of fuelwood harvesting is highest. The enumerators under the supervision of the investigator and two other supervisors moved randomly from one household to the other among the selected households. Respondents were expected to be the heads of households, their spouses or in their absence, any member of the household above the age of 18 years and well-conversant with activities undertaken within the household.

In order to understand how to interpret findings and contextualize some responses, data collected was reviewed daily to ensure questions were well understood and responded to and to assess how to deal with unexpected situations. The questionnaire was semi-structured and focused on but was not limited to: general household socio-economic and demographic data, agroforestry practices, fuels used for different purposes, sources of fuelwood, challenges involved in obtaining fuelwood and amount of fuelwood consumed by households. The format included yes/no questions, open ended questions, actual weight measurements and pre-coded questions. The main questionnaire used in the study is given in Appendix 2.

Data collected during the survey was coded and entered into MS-Excel to edit, detect errors and omissions, and cleaned to ensure it was accurate, uniformly entered and well arranged to facilitate analysis. Data processing and analysis was done in Stata 13. Descriptive statistics such as graphs, percentages, averages, ranking and ratios were used to analyze household socio-economic characteristics, household fuel and source preferences, institutional factors and comparative analyses between rural and peri-urban households and households obtaining fuelwood from the identified sources. Inferential statistics and regression models were used to determine fuelwood consumption patterns and the factors affecting choice of source of fuelwood and the estimated amount of fuelwood consumed annually by a household.

3.8 Description of variables used in the models

Households vary in different aspects like size, location, composition and income; factors which could influence the choice and consumption patterns of energy, besides other goods and services. The selection of variables used in this study was based on similar empirical studies carried out in Sub-Saharan African and other developing countries, which reveal that different economic or non-economic factors influence consumption patterns of fuelwood. The variables used in this study are summarized in Table 3.1 and explained further below:

Table 3.1: Variables used in the analysis

Variable	Description	Where used
PERYRKG	Amount of fuelwood consumed annually	OLS
FWDSOURCE	Main source of household fuelwood	OLS and MNL
AGEHHEAD	Age of the head of household	OLS and MNL
GENDER1	Gender of the head of household	OLS and MNL
MSTATUS_HHD	Marital status of the head of household	OLS and MNL
FEMMEM	Presence of female members in household	OLS and MNL
HHEDUC_N	Level of education of head of household	OLS
HHSIZE	Household size	OLS and MNL
HHLOC	Household location	OLS and MNL
TOTHHINC	Total household income	OLS and MNL
OWNLAND	Whether the household owns land	OLS
LANDOWN	Size of land owned by household	MNL
TRANSEQP_N	Whether the household owns transportation equipment	MNL
DISTSOC	Distance to the source of fuelwood	MNL

ENERGDEV	If the household owns energy saving devices	OLS
LNPRICEKER	Natural log of price of kerosene	OLS
LNPRICECHAR	Natural log of price of charcoal	OLS
LNPRICEFWDKG	Natural log of price of fuelwood	OLS
ORGTRPL_N	If household knows any environmental institutions	OLS
AWAREBYL	If household is aware of environmental laws	OLS and MNL
NOFWTRSPP	Number of fuelwood trees preferred by household	MNL
FAIDHERBIA	If household prefers *Faidherbia albida*	MNL
BRACHYSTEGIA	If household prefers *Brachystegia spp*	MNL
ACACIA	If household prefers *Acacia tortilis*	MNL

PERYRKG: This is the continuous dependent variable in the analysis of household fuelwood consumption. It is the estimated quantity of fuelwood consumed by the household in a year in kilograms.

FWDSOURCE: This is the unordered limited dependent variable in the MNL regression. This variable is also used as an independent indicator variable in the OLS regression in determining quantity of fuelwood consumed. It is expected that households buying fuelwood from the market may consume less than those obtaining it for "free".

AGEHHEAD: The age of the head of household has been used in empirical studies on energy consumption to investigate whether the life cycle affects consumption of particular forms of energy and resource utilization. It is expected that quantity of fuelwood consumed would have a positive correlation with age, because of loyalty to use of fuelwood in households (Pundo and Fraser 2006). In relation to the source of fuelwood, age may increase the probability of collecting from the forest, as older people may consider going to the forest to collect other traditional products. On the other hand, as one becomes older, there is reduced physical ability to search for fuelwood in the forest; hence older people may consider it convenient to obtain fuelwood from the market.

GENDER1 and MSTATUS_HHD: The gender and marital status of the head of household are incorporated into both analyses to estimate any differences occurring between male-headed and female-headed households, married and non-married heads of households. Additionally, a dummy variable **FEMMEM**, is used to test whether having female members of economically productive age in the household would affect the choice of source of fuelwood and amount of fuelwood consumed. Households with female members are expected to have sufficient labour and are therefore able to collect fuelwood from natural forests and may also consume more fuelwood than those without.

HHEDUC_N: The level of education of the household head plays a role in energy use. Pundo and Fraser (2006) and Abebaw (2007) found that education improved the decision makers' knowledge of fuel attributes and their ability to understand costs and benefits involved in consumption of various forms of energy. Pundo and Fraser (2006) found that for both the household head and the spouse, the level of education improved knowledge of fuel attributes, tastes and preferences for better fuels. More educated people could consume less fuelwood because they better understand effects of forest destruction and therefore rely less on forests as sources of fuelwood and more educated women, they found, lacked time to collect fuelwood. In this study, only the level of education of the head of household, and not necessarily that of women, is considered, except where such a woman is the head of the household.

HHSIZE: Household size is deemed to correlate positively with fuelwood consumption perhaps because there are more people to cook for, increasing the demand for fuelwood in larger households. It is also expected that larger households have the capacity to collect fuelwood rather than purchasing because of the availability of labour (Jumbe and Angelsen, 2006). Therefore, it is expected that the probability to purchase fuelwood from the market will decrease with an increase in household size.

HHLOC: Household location is used in these analyses as a proxy for urbanization. Households living in peri-urban areas are likely to have better access to alternative fuels and may therefore consume less fuelwood than those living in rural areas. They may also be located further from forests and farms and nearer to markets therefore have lower propensities to collect fuelwood from forests and farms and conversely have higher probability to purchase from the market.

TOTHHINC: This is the total household income from farm and off farm sources. Income is the key factor in the energy ladder theory. Its impact on fuelwood consumption is such that as incomes increase, consumption of lower rung fuels such as fuelwood decreases. A household with higher income is therefore expected to consume less fuelwood than one with less income, because they can afford to use other fuels that are higher on the ladder. On the other hand, some authors for example Abebaw (2007) found consumption to increase with income and attributed it to higher rates of extraction of natural resources in which case, such households use more fuelwood, because they have comparatively more food to cook. Households with higher incomes are also able to purchase fuelwood from the market, therefore the probability to choose market is expected to increase with income.

OWNLAND AND LANDOWN: The variable 'OWNLAND' is a dummy variable (whether the household owns land or not) is a covariate in the OLS regression. Households that own land are more likely to have trees on farm and therefore an unlimited access to fuelwood. This may consequently trigger higher consumption of fuelwood. 'LANDOWN' is a continuous variable of the size of land owned by the household. Households having larger pieces of land are expected to have an increased probability of collecting fuelwood from own farms because they are more likely to practice agroforestry and have more trees on farm than those with smaller plots of land.

TRANSEQP_N: This dummy variable (whether a household owns any transportation asset such as bicycle, oxcart, power tiller or motorcycle) is used as a possible determinant of choice of fuelwood source in the MNL regression. It is included to estimate the significance of such assets on any of the sources of fuelwood identified.

DISTSOC: It is assumed that the average distance to the most common source of fuelwood has an inverse relationship with the probability of choosing that source of fuelwood as the preferred one. Proximity to the forest allows the household to extract more resources by reducing labour time and transportation costs (Mamo *et al.*, 2007). Abebaw (2007) used distance as a factor determining household demand for fuelwood and found a negative relationship in which consumption was determined to decrease with further distances to collection sites. In this study, the variable is only used in the MNL regression.

ENERGDEV: Energy saving stoves and devices have been promoted because they use less fuelwood. It is therefore expected that households that own such devices will consume less fuelwood than those that do not.

LNPRICECHAR, LNPRICEKER and LNPRICEFWDKG: These variables are prices of charcoal, kerosene and fuelwood, respectively, which are log-transformed in the OLS regression in order to directly give cross-price elasticies of demand of alternative fuels (charcoal and kerosene) on fuelwood consumed; and the own-price elasticity of fuelwood.

In the basic theory of demand, the quantity of a normal good demanded falls when its price rises, *ceteris paribus*. High prices of household fuels like gas and electricity leads to low demand (Mekonnen and Kohlin, 2008). If fuelwood is a normal good, then this law should hold true, meaning that consumption will rise when estimated price of fuelwood falls.

Access to alternative fuels is also an important factor in demand. It could be measured in terms of relative accessibility to or price of the alternative. In this study, the latter measurement is used. In the case of substitute goods, when the price of one commodity goes up, *ceteris paribus*, the demand for substitute commodities increases. In this study, comparison is made with more readily available alternatives like kerosene and charcoal. An increase in the relative prices of kerosene and charcoal will hypothetically raise the demand for fuelwood. However, Pundo and Fraser (2006) acknowledge that market price is an insufficient indicator of household choice since some types of fuel are obtained "free" or at very low price.

ORGTRPL_N and AWAREBYL: these dummy variables gauge household awareness of organizations involved in environmental work like tree planting and of laws governing protected areas like forests and natural resource use. They are meant to test institutional strength in controlling household fuelwood consumption and access to natural resources. Knowledge of such organizations and laws is expected to discourage, control or limit entry into areas such as forests mainly for purposes of conservation and also reduce amount of fuelwood consumed by the household.

The tree species preferred by the household for fuelwood **(ACACIA, BRACHYSTEGIA, FAIDHERBIA)** are expected to increase the likelihood of selecting the source where such trees are more readily found than the other sources. Likewise, households that prefer more tree species for fuelwood **(NOFWTRSPP)** are expected to obtain from natural forests where trees are abundant. These variables are only used in the MNL regression.

3.9 Ethical considerations

Approval to carry out the study was obtained from the Mbarali District Council and the District Forestry office. Through the district forester, the heads of the sampled wards were informed of the study prior to the household survey. Verbal consent was also obtained from the chairmen at both village and hamlet levels. Each household was informed that their participation in the exercise was voluntary and that the purpose of collecting data was academic. No payment or coercion was made to solicit participation by respondents. Respondents were expected to be household members above 18 years old.

3.10 Limitations of the study

The key objective of this study is to evaluate the use and consumption patterns of fuelwood in Mbarali district; it is therefore important to note that the study is limited to household consumption and does not consider commercial fuelwood use in the study area. There are also some other limitations to the data obtained and used in the analysis. Firstly, the data was collected in October 2013, during the dry season, when the rate of fuelwood collection is highest. The data may therefore not adequately take into account variations in consumption during the wet season.

Secondly, some of the variables used in the study were based on the respondents own estimation and may therefore not have been accurate, for example, distances to the sources of fuelwood and to the nearest office issuing permits. Other data collected also required the respondent to recall, which in some cases is misleading. The use of these variables has been minimized by not using them in the analysis. Thirdly, the survey tool was written in English but translated into Swahili during the data collection exercise. In cases where a questionnaire is translated from one language to another, some information may be lost. To rectify this, training of enumerators was carried out, and pretesting of the survey tool done in a village that was not part of the sample. The researcher and supervisors also conducted key informant interviews in order to validate and triangulate the data collected.

Lastly, some respondents may not have properly understood the objective of the research, which could have affected their responses. In order to ensure that responses were true and not biased, the supervisors and enumerators explained the purpose of the survey to the respondents and sought their consent before starting the exercise.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents both descriptive and empirical results and a discussion of the main study findings from the empirical models used.

4.2 Descriptive statistics

4.2.1 General characteristics of sample households

The mean age of the heads of households in the study area is 46.2 years, with the minimum and maximum ages being 17 years old and 86 years old respectively. About 56% of the heads of household are between the ages of 31 and 50 years old, while 31% are above the age of 50 years (Figure 4.1). The average household size is 5 with the largest household having 23 members. At least 79% of the households are male-headed.

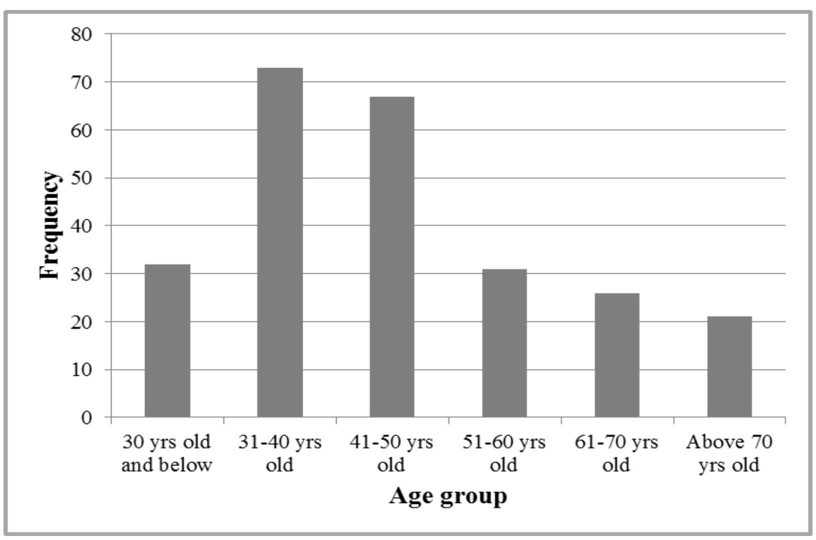

Figure 4.1: Age distribution of heads of households

Source: Household survey data, 2013

Table 4.1 gives summary statistics of the sample households. The level of education in Mbarali district is generally low as only 7% of heads of households have attained some post-primary education. This could explain why only a small segment of the population (2% of rural and 13% of peri-urban households) is regularly employed or considers skilled employment as very important.

At least 75% of the households live in rural areas and derive their livelihoods from agricultural activities. The average landholding is about 5 acres. Of the entire sample, 92% engage in crop production and some livestock rearing; and either owns the land on which they cultivate or lease it for these purposes. Nevertheless, some have diversified their sources of income into various activities like brewing, small-scale business and casual employment. As expected, rural and peri-urban households have higher proportions of farm income and off-farm income, respectively.

Interestingly, unlike other rural areas in Africa where fuelwood trading is an important economic activity that supplements household income, this is not the case for most rural households in South-western Tanzania. Results indicate that only 6% of valid responses consider fuelwood trading important. The low percentage may be attributed to abundance of woodland resources to which local communities have relatively easy access and/or an inadequately developed market for fuelwood.

Table 4.1: Summary statistics of sample households

Variable	Description	Mean/proportion	Std. dev.	Min.	Max.
AGEHHEAD	Age of the head of household	46.2	14.97	17	86
GENDER1	Gender of the head of household	0.79			
MSTATUS_HHD	Marital status of the head of household (1=Married, 0= Otherwise)	0.76			
HHSIZE	Household size	5.05	2.6	1	23
HHLOC	Location of the household (1=Urban, 0=Rural)	0.25			
PRODMEM	Total number of economically productive members in the household	2.56	1.51	0	9
PRODMEMF	Number of economically productive female members in the household	1.35	0.91	0	5
DEPENDANTS	Total number of dependants in the household	2.45	1.8	0	14
TOTHHINC	Total household income in TShs	2300232	2842224	8000	17388000
FARMINC	Farm income	1654996	2331057	0	17388000
OFFINCOME	Off-farm income	645236	1459729	0	9600000
LANDOWN	Size of land owned in acres	4.99	8.74	0	80
DISTSOC	Distance to the source of fuelwood in kilometres	2.83	2.41	0.05	17.5
TIME	Time taken to obtain fuelwood in hours	2.45	1.37	0.33	8
PERYRKG	Estimated amount of fuelwood consumed by the household in kilograms	3413	2172	0	15120
NOFWTRSPP	Number of fuelwood tree species used by the household	2.96	1.58	1	9
AWAREBYL	If the household is aware of laws governing resource use (1=Yes, 0=No)	0.43			
ACACIA	Preferred species is Acacia tortilis (1=Yes, 0=No)	0.11			
BRACHYSTEGIA	Preferred species is Brachystegia spp. (1=Yes, 0=No)	0.35			
FAIDHERBIA	Preferred species is Faidherbia albida (1=Yes, 0=No)	0.13			

Source: Household survey data, 2013

A common off-farm activity in the study area is brickmaking, shown in Figure 4.2; and stock piles of baked bricks or bricks ready for curing are a common sight in Mbarali. Brick making is a concern for environmental conservation because of the amount of fuelwood involved in curing.

Figure 4.2: Stock piles of bricks ready for curing using fuelwood

4.2.2 Forms of energy used in the households

At least 88% of the households surveyed use fuelwood and regard it as the most important fuel. When asked to rank other fuels used in the household, the rank for various fuels as very important is as follows: charcoal (11%), kerosene (0.4%) electricity (0.4%), and crop residues (0.4%). Results from FGDs and the household survey reveal that as a domestic fuel, fuelwood is mostly used for cooking, which is unsustainably done. In some households it was observed that cooking was being done in open areas often using inefficient traditional three stone or charcoal stoves. Besides cooking, other uses include:

heating space during the cold season, heating water, and lighting and for other less common activities including brewing, ironing and drying meat and fish.

For 74% of the sample households, fuelwood is ranked most important because it is easily available and for 32% of them because it is free or cheap if sold. About 3% of households rank it as not important because it causes pollution or because they do not have space for a fuelwood kitchen. In rental houses, particularly in peri-urban areas, use of fuelwood is in some cases prohibited.

Gas and electricity are not considered important by the majority even in peri-urban areas due to their high cost and non-availability. However, for those households who have access to these forms of energy, electricity is mainly used for lighting, charging phones and running household appliances while gas is used for cooking. In both settlement locations, 56% of households largely use kerosene for lighting, but some households (36% of rural and 19% peri-urban) prefer flashlights and special kinds of lamps known as Chinese lamps, which use batteries and are preferred because they produce better light, are cheaper and last longer than kerosene.

At least 36% and 40% of the households have ever used charcoal and crop residues respectively for cooking. Cow dung is not used as fuel by 98% of the households who rank it as least important, giving reasons such as not being aware that it could be used as fuel or not knowing how to use it (48%) and unavailability (34%); because they do not keep livestock or it is used mainly as manure.

4.2.3 Sources of fuelwood and agroforestry

In the study area, fuelwood is either obtained "free of charge" from woodland resources or purchased. The three common sources of fuelwood are: natural forests, own farms and market. Out of 235 households that consume fuelwood, 74% prefer collecting it from forests, 12% choose to fetch it from their farms where agroforestry is practiced, while 14% buy from the market.

Although 96% of rural households practice agroforestry, only 35% have deliberately planted the trees found on their farms. Most of the households practice farmer managed natural regeneration (FMNR), where the majority manages trees such as *Faidherbia albida* for soil fertility improvement and *Acacia tortilis* for fuelwood. The management of *Faidherbia albida* on farms as a soil fertility tree is supported by local indigenous knowledge which promotes it due to its association with high crop yields especially maize. Other trees found on farm like *Senna siamea* are not used for fuelwood because they are considered to provide shade in the homestead, while others like *Mangifera indica* and *Carica papaya* are important for their fruits. *Azaridachta indica* is commonly managed for medicinal purposes. (See Appendix 3 for a list of agroforestry and fuelwood tree species identified in the study area).

4.2.4 Ranking of fuelwood sources

The most common reasons cited by households for ranking natural forests as the most important source of fuelwood are that fuelwood is available in plenty, and forests are easily accessible with some households stating that they are nearer the homesteads than their farms are, besides having a wide variety of suitable fuelwood trees. In as much as the majority from the community depends on fuelwood from the forest, its production is not without challenges. For 58% of the households, this source is too far away, while 31% are worried by the threat posed by wild animals. On the other hand, 19% of households think that restrictions imposed by the law are a hindrance while 18% fear being arrested. For households that rank their farms as not important, it is for reasons such as having fewer trees (33%) or trees being unsuitable for fuelwood (24%) and fuelwood being only available seasonally (11%), usually after pruning trees occasionally in a year.

The market is preferred by some households because of its convenience as one does not have to gather fuelwood and for some, they are located near their homes. However, some of the challenges cited by households are that it is expensive (67%) or fuelwood is not sufficient or not always available (20%). Still in some places, fuelwood is not sold because there is no demand for it as a commercial product; hence traders in the commodity are few and far between.

4.2.5 Institutional awareness

In the study area there are laws and regulations established under the Ministry of Natural Resources and Tourism of Tanzania which govern use of natural resources. The laws include restrictions on harvesting specific tree species and on amount of fuelwood collected, on cutting green trees and transporting fuelwood by car or trucks and the need for an access permit amongst other regulations. More than half of the households (57%) are not aware of the laws. Out of the 43% that are aware of the laws, only about 49% fully comply with them, 45% partially comply while 6% do not comply at all. This finding points to low level of sensitization of the local communities and weak enforcement by the authorities concerned.

4.2.6 Preferred fuelwood tree species

Various end users and traders of fuelwood were asked to rank their most preferred fuelwood tree species. Table 4.2 shows preferred fuelwood tree species by end user. The most preferred species for households, institutions and traders is *Brachystegia spiciformis*, while *Faidherbia albida* is ranked second by all groups of end users surveyed and traders.

Table 4.2: Most preferred fuelwood tree species by end user

Rank	Households (n=254)	Brick makers (n=8)	Institutions (n=4)	Traders (n=7)
1	*Brachystegia spiciformis (25%)*	*Acacia tortilis*	*Brachystegia spiciformis*	*Brachystegia spiciformis*
2	*Faidherbia albida (14%)*	*Faidherbia albida*	*Faidherbia albida*	*Faidherbia albida*
3	*Brachystegia bussei (14%)*	*Grewia similis*	*Acacia tortilis*	*Combretum molle*
4	*Acacia tortilis (12%)*	*Brachystegia spiciformis*	*Senna siamea*	*Senna siamea*
5	*Grewia bicolor (8%)*	*Senna siamea*	*Dichrostachys cinerea*	*Acacia tortilis*

Source: Household survey data, 2013

Other commonly used tree species include *Acacia tortilis* which ranks 4th for households but is considered best by brick makers, *Grewia spp* and *Senna siamea* which are all easily available and are indigenous tree species. It emerges that *Brachystegia spp* are only found naturally growing in forests, and continuous dependence on this tree for fuelwood and charcoal has far reaching implications for environmental conservation because of the length of time they take to regenerate.

The results also suggest that fuelwood use may be in competition with agroforestry. *Faidherbia albida* is ranked second by all end users mainly because of the ease with which it can be obtained, especially from farms. It is the most common agroforestry tree managed by at least 55% of the rural households. Households may prune *Faidherbia albida* to obtain fuelwood, but other end users require fuelwood in bulk, and may therefore fell the tree. Traders like *Faidherbia albida* because it dries quickly and there is market demand for it, while institutions require a lot of fuelwood and pruned branches may be insufficient. Brick makers pose the biggest challenge to agroforestry since in most cases they use a whole tree to produce a stockpile bricks. Besides, they prefer to use green trees because they would burn slowly and for long thus producing bricks of good quality.

4.3 Testing of mean differences by most preferred source of fuelwood

Table 4.3 is a comparison of means of explanatory variables used in the MNL model, with sample households categorized by the most preferred source of fuelwood. One way ANOVA and χ^2 test were used to test for statistical differences between categorical and binary explanatory variables respectively. Bonferroni, Scheffe and Sidak statistical methods for correction were jointly applied to make pairwise comparisons amongst the three groups in Stata 13.

Results show that apart from household location and the three tree species analyzed, the results showed no significant differences between any pairs of categories in the other explanatory variables. According to Table 4.3, significant differences exist between households that get fuelwood from the market and those that obtain it either from the farm or from the forest in terms of household location. Households located in peri-urban areas were normally likely to obtain fuelwood from the market than those living in rural areas which tend to prefer the natural forests and their own farms.

Households buying fuelwood from the market do not seem to be keen on the tree species, while those fetching from farms and forests are inclined towards specific indigenous species. Households collecting fuelwood from their farms tend to prefer *Acacia tortilis* and *Faidherbia albida* which were identified as the most common agroforestry trees. Those that obtain from the forest mostly prefer *Brachystegia spp*, which is dominant in dry land areas and Miombo woodlands. Households collecting fuelwood from forests and farms tend to have a choice on the species to carry home while those buying from the market may have less control over the species to use as they have to purchase what is available in the market.

There are significant differences in households obtaining fuelwood from the three sources when preference for *Faidherbia albida* was considered. Pairwise differences were observed between households that obtain fuelwood from own farms and forests and households getting fuelwood from own farms and market. In this case, there was no statistical difference between households collecting fuelwood from the forest and those buying from the market.

Table 4.3: Comparison of means of variables used by source of fuelwood

Variable name	Description	ALL	Sources Forests	Farms	Market
		N=235	**n=173**	**n=28**	**n=34**
AGEHHEAD	Age of the head of household	46.20 (0.94)	44.99	49.63	48.17
GENDER1	Gender of the head of household	0.79 (0.03)	0.81	0.68	0.82
HHEDUC_N	Highest level of education attained by head of household				
	None	0.17	0.17	0.30	0.15
	Primary	0.76	0.78	0.67	0.7
	Post-primary	0.07	0.05	0.03	0.15
MSTATUS_HHD	Marital status of head of household (1=Married, 0=Otherwise)	0.76 (0.03)	0.78	0.63	0.77
HHSIZE	Household size	4.97(0.17)	5.02	4.79	5.00
HHLOC	Location of household (1= Peri-urban, 0=Rural)	0.20(0.03)***	0.14	0.18	0.48
FEMMEM	Household has productive female members (1=Yes, 0=No)	0.89(0.02)	0.9	0.78	0.94
TOTHHINC	Total household income in TShs	2144050 (178967)	2080995	1523704	2906691
	FARMINC: Proportion of income from farm sources	0.76	0.90	0.72	0.72
	OFFINCOME: Proportion of income from off farm sources	0.24	0.21	0.28	0.28
LANDOWN	Amount of land owned by the household in acres	5.26(0.60)	5.31	4.89	5.37
TRANSEQP_N	Whether the household owns transportation equipment (bicycle, power-tiller, oxcart or motorcycle) (1=Yes, 0=Otherwise)	0.83 (0.04)	0.80	0.70	0.91
DISTSOC	Distance to the source of fuelwood in kilometres	2.88 (0.15)	2.89	2.49	2.96
AWAREBYL	Awareness of laws regulating use of natural resources (1=Yes, 0=No)	0.43 (0.03)	0.43	0.50	0.52
NOFWTRSPP	Absolute number of tree species preferred for fuelwood	3.22 (0.10)	3.32	3.11	2.70
ACACIA	Species preferred is *Acacia tortilis* (1=Yes, 0=No)	0.11(0.02)***	0.07	0.30	0.20
BRACHYSTEGIA	Species preferred is *Brachystegia spp.* (1=Yes, 0=No)	0.37(0.03)***	0.47	0.04	0.17
FAIDHERBIA	Species preferred is *Faidherbia albida* (1=Yes, 0=No)	0.14(0.02)***	0.11	0.36	0.09

Standard errors are given in parentheses
*p<0.1,**p<0.05,***p<0.01 indicates that the mean difference between household sources of fuelwood (forest, own farm and market) is significant at 10%, 5% and 1 respectively

Source: Household survey data, 2013

4.4 Testing of mean differences by household location

Table 4.4 is a comparison of the means of explanatory variables of the sample households classified by household location with the aim of highlighting locational differences in understanding fuelwood consumption patterns between households. The Proportion Test and the Student's T-test are used to test the null hypothesis that there is no difference in the variables shown in the table when a comparison is made between the two groups. The T-test result of 3.98 indicates that the difference in fuelwood consumption between rural and peri-urban households is significant at 1%, thus rural households consume considerably higher amounts of fuelwood compared to peri-urban households.

Disparities exist in factors that may affect fuelwood consumption across the settlement locations. From the results, peri-urban households are generally larger in size, have older heads of households, earn more income and have more members in the productive age group. Rural areas tend to have more female-headed households, own larger pieces of land, have higher rates of fuelwood consumption and are nearer the sources of fuelwood.

But, the variables that are statistically significantly different between the two groups are age of head of household, number of economically productive members, whether the household has female members of productive age, annual consumption of fuelwood, total household income, and distances to sources of fuelwood and office issuing permits.

The mean annual consumption of fuelwood in kilograms is approximately 3472 kg per household, with the highest amount consumed estimated at 15120 kg (Table 4.1), which is by a rural household. The maximum amount of fuelwood consumed in the peri-urban areas is 5880 kg per year.

Table 4.4: Summary statistics of mean differences of variables used based on household location

Variable name	Description	Entire sample N=254	Rural n=190	Urban n=64	Proportion & T-test results[a]
PERYRKG	Estimated quantity of fuelwood consumed per year (kg)	3472 (141)	3742	2368	t = 3.98***
AGEHHEAD	Age of the head of household	46.20(14.98)	44.68	50.69	t = -2.81***
GENDER1	Gender of the head of household (1= male, 0=female)	0.79	0.8	0.75	z = 0.94
PRODMEM	Number of productive members in the household	2.56(0.22)	2.43	2.969	t = -2.51**
FEMMEM	Household has female productive members (1=Yes,0= No)	0.89	0.905	0.844	z = 1.36*
HHSIZE	Household size	5.047(0.16)	4.89	5.52	t = -1.67
None	Head of household has no formal education (HHEDUC_N)	0.17	0.19	0.09	
Primary	Head of household has primary level education (HHEDUC_N)	0.76	0.75	0.80	
Post-primary	Head of household has secondary level education (HHEDUC_N)	0.07	0.06	0.11	
TOTHHINC	Total annual household income (in thousands of TShs)	2300 (178)	2072	2977	t = -2.22**
OFFINCOME	Proportion of off farm income	0.76	0.8	0.63	
FARMINC	Proportion farm income	0.24	0.2	0.37	
Forest	Most important source of fuelwood is forest (FWDSOURCE)	0.74	0.78	0.54	
Farm	Most important source of fuelwood is farm (FWDSOURCE)	0.12	0.13	0.11	
Market	Most important source of fuelwood is market (FWDSOURCE)	0.14	0.09	0.35	
DISTSOC	Distance to the source of fuelwood	2.832(0.164)	2.637	3.721	t = -2.58***
DISTPERM	Distance to the office issuing permits	1.473(0.124)	1.637	0.985	T = 2.30**
OWNLAND	If household owns land (1=Yes, 0=No)	0.77(0.026)	0.78	0.73	z = 0.82
ENERGDEV	Ownership of energy saving cooking device in the household (1=Yes,0= No)	0.044(0.013)	0.016	0.125	z = -3.65
ORGTRPL_N	Knowledge of organizations that promote agroforestry (1=Yes,0=No)	0.177(0.024)	0.179	0.172	z = 0.13
AWAREBYL	Awareness of bylaws (1=Yes, 0=No)	0.433(0.031)	0.437	0.422	z = 0.21

Standard errors are given in parentheses

*p<0.1,**p<0.05,***p<0.01 indicates mean difference between rural and peri-urban households significant at 10%, 5%, 1% respectively.

[a]The Students t-test and Proportion test were used to test for statistical differences between rural and peri-urban households for continuous and binary variables respectively.

Source: Household survey data, 2013

4.5 Empirical results

4.5.1 Determinants of choice of fuelwood sources

In the Multinomial logit regression, ‘forest’, is used as the reference category and two non-redundant sets of parameter estimates which contrast (i) choice of farms against forests and (ii) choice of market against forests as sources of fuelwood obtained. The choice of the reference category has no effect on the results (Beyene, 2010), an outcome which is also true for this study. The resultant likelihood ratio chi-square value of -128.77 is highly significant indicating that the model has a strong explanatory power, and that a model with the independent variables included fits significantly better than a model without any predictors.

The results reveal limited differences between households that obtain fuelwood from forests and those that collect from farms, meaning that these households have similar characteristics. This may be because some farms were in fact carved out of forests, when the latter were cleared for agriculture, and therefore could be similar in certain respects for instance, distance. A number of covariates are however significant when the market is compared to the forest. Thus for any meaningful policy recommendations, the comparison between market and forest must be closely examined.

The ensuing coefficients of MNL are non-linear and unlike those of OLS cannot be directly interpreted. They only give the direction of change of the covariates on the dependent variable and not the actual magnitude of probabilities. Hence, after estimating the MNL regression, marginal effects showing probabilities of households choosing particular fuelwood sources are predicted (Table 4.5, Appendices 4, 5, 6).

4.5.2 Discussion of factors affecting choice of sources of fuelwood

The results reveal that apart from marital status of the household head, household demographic characteristics do not have significant effects on the decision to obtain fuelwood either from the forest or the farm. The findings of this study are similar to Beyene (2010) and are inconclusive as far as household size is concerned but contradict Jumbe and Angelsen (2010) and Heltberg (2000), who found household size to be a significant factor in the decision to collect fuelwood from forests. However, household composition has significant effect in the decision to purchase fuelwood from the market. A male-headed household is significantly more likely to obtain fuelwood from the market as compared to a female-headed household. This may be because; female-headed households are in most cases considered to be poorer than male-headed households and cannot afford to buy some commodities. Linde-Rahr (2003) found that poorer households are more likely to engage in forest activities rather than buy fuelwood from the market, whatever the measure of poverty used (Beyene, 2010).

A household with a married head is less likely to obtain fuelwood from the market, but has a higher chance of collecting it from the forest, while one with at least an economically productive female member has an increased likelihood of purchasing fuelwood rather than collecting from the forest or farm. This last result is not as expected because it is assumed that since fuelwood collection is mostly a women’s activity, their presence in a household would provide adequate labour needed to collect fuelwood from forests or farms rather than buying it. Contrarily, the results indicate higher likelihood of purchasing from the market. A possible argument could be that getting fuelwood from farms requires a lot of energy as it usually involves cutting or pruning trees which women may find physically daunting.

This reason could also apply to forests, because as fuelwood becomes scarce, dead wood may be difficult to find thus forcing people to cut the branches of trees.

Peri-urban households, as expected, rely less on the forest for fuelwood as the probability of choosing to collect from the forest decreases as one moves from rural to peri-urban areas. That peri-urban households have a higher likelihood of buying fuelwood from the market could be attributed to such households being closer to markets and further from or not having easy access to farms and forest resources. It could also be because of the tendency of people in peri-urban and urban areas to commoditize products which are not considered commercial products in rural areas. Rural households are less likely to prefer the market, because fuelwood is not a commodity that the average household would consider buying (Johnsen, 1999). The importance of location however has a higher significance for peri-urban households to choose the market (at 1%) than on the reduced likelihood of the same households not to choose the forest (at 10%). Household location has however, no conclusive effect on the decision to obtain fuelwood from the households' own farms.

Table 4.5: Determinants of the choice of fuelwood sources

Average marginal effects		**Sources of fuelwood**		
Variable	**Description**	**Forest dy/dx**	**Own farm dy/dx**	**Market dy/dx**
AGEHHEAD	Age of the head of household	-0.002(0.002)	-0.000(0.002)	0.002(0.002)
GENDER1	Gender of the head of household (1=Male, 0=Female)	-0.225(0.153)	-0.088(0.108)	0.313(0.112)***
MSTATUS_HHD	Marital status of head of household (1=Married, 0=Otherwise)	0.258(0.142)*	-0.001(0.107)	-0.257(0.096)***
HHEDUC_N	Highest level of education attained by head of household+			
	Primary	0.077(0.084)	-0.005(0.054)	-0.072(0.074)
	Post-primary	0.001(0.139)	-0.052(0.084)	0.051(0.120)
HHSIZE	Household size	0.001(0.014)	0.006(0.010)	-0.007(0.011)
LNTOTHHINC	Natural log of total household income	-0.014(0.026)	0.002(0.022)	0.012(0.019)
HHLOC	Location of household (1= Peri-urban, 0=Rural)	-0.119(0.069)*	-0.072(0.059)	0.191(0.044)***
FEMMEM	Household has economically productive females (1=Yes, 0=No)	-0.174(0.126)	-0.074(0.074)	0.248(0.115)**
TRANSEQP_N	Household owns transportation equipment (1=Yes, 0=No)	-0.028(0.048)	-0.011(0.037)	0.039(0.037)
LANDOWN	Size of land owned by household in acres	0.002(0.003)	-0.000(0.003)	-0.002(0.003)
DISTSOC	Distance to the most important source of fuelwood	0.015(0.013)	-0.005(0.010)	-0.010(0.010)
NOFWDTRSPP	Number of tree species used for fuelwood in the household	0.024(0.023)	0.017(0.015)	-0.040(0.020)**
ACACIA	Species preferred is *Acacia tortilis* (1=Yes, 0=No)	-0.139(0.074)*	0.154(0.051)***	-0.015(0.058)
BRACHYSTEGIA	Species preferred is *Brachystegia spp.* (1=Yes, 0=No)	0.258(0.091)***	-0.169(0.093)*	-0.089(0.053)*
FAIDHERBIA	Species preferred is *Faidherbia albida* (1=Yes, 0=No)	-0.017(0.081)	0.157(0.049)***	-0.140(0.073)*
AWAREBYL	Awareness of laws regulating use natural resource (1=Yes, 0=No)	-0.033(0.055)	0.044(0.040)	-0.011(0.043)

Figures in parentheses are standard errors

+No education is the omitted category under highest education of household head

*, **, ***: Explanatory variables are significant at 10%, 5% and 1% respectively

Model fit:

Log likelihood	-128.77
Number of observations	229
Prob>chi2	0.0000
Pseudo R^2	0.25

Source: Household survey data, 2013

The probability of choosing any of the three sources of fuelwood is significantly determined by the households' preferred fuelwood tree species; hence the null hypothesis that there is no significant relationship between choice of fuelwood sources and tree species is rejected. This finding is consistent with those of Jumbe and Angelsen (2006), even though in the latter study, the effects of particular species of trees were not specifically estimated in the analysis. The three tree species entered into the MNL model in this study all influence the choice of fuelwood source either positively or negatively.

Preference for *Acacia tortilis* significantly reduces chances of going to the forest by about 14% and increases the likelihood of choosing the farm by 15%. On the contrary, household preference for *Brachystegia spp.* significantly reduces the propensity to get fuelwood from own farm or market by about 17% and 9% respectively but raises the probability to collect from the forest by nearly 26%; while preference for *Faidherbia albida* increases chances of choosing own farms, it considerably reduces probability of going to the market by 14%.

As the descriptive statistics show, forests are preferred for among other reasons, the variety of tree species that are useful for fuelwood found in them. *Brachystegia spp.* is the most dominant species in the Miombo woodlands, and as such is found naturally growing in the forest. Apart from its relative abundance, households prefer this species because it produces embers which burn for long, easily kindles, does not emit much smoke and produces a lot of heat.

Conversely, *Faidherbia albida* and *Acacia tortillis* are the most common agroforestry species and there exists indigenous knowledge that supports their cultivation or on-farm management in the study area. They are therefore more likely to be found on farms rather than in the forest and this could explain the higher probabilities in the decision to fetch fuelwood from the farm rather than from the forest or market when these two tree species are considered. This finding concurs with information obtained from traders who, despite its relative availability sometimes do not stock *Faidherbia albida* because it is easily infested by insects when dry and this could explain why those who prefer it are less likely to go to the market.

Because of the importance of trees species, attempts to divert demand away from forest to farms should focus more on trees and their suitability for multiple purposes than on household socioeconomic factors, which like Jumbe and Angelsen (2006) found out, do not have a significant influence on the choice of source. FGDs revealed that households are concerned by the increased distances they have to walk and the increased time needed to find their preferred fuelwood. Although these variables yielded non-conclusive results in the model, they are nonetheless important in that they indicate an increasing scarcity of fuelwood, which may force households to turn to farms. In the absence of other tree species that can be used for fuel on farm, then *Faidherbia albida* is threatened.

As noted before, attempts to divert demand for tree products away from forests to farms in Tanzania through agroforestry programs have in some cases not been effective (Johnsen, 1999) partly because the interventions introduced exotic tree species which were not fully supported by local communities (O'Keefe *et al*., 1989). In fact, in some developing countries, such programs have been scaled back (Arnold and Persson, 2003). The HASHI Project in Shinyanga, Tanzania which was largely successful primarily relied on indigenous knowledge of the local people (Mlenge, 2004; Duguma *et al*., 2013). In Mbarali, farmers are aware of the benefits of having *Faidherbia albida* on farm. This knowledge could be extended further to encourage growing of tree species like *Acacia tortilis* for fuelwood in order to reduce dependency on *Faidherbia albida.* Unlike exotic species, *Acacia tortilis* is native to Tanzania, is drought resistant and can withstand extreme conditions like water logging and strong salinity. Additionally, it has a faster growth rate, easily coppices and can start providing fuelwood of high calorific value after 8 years. It is also nitrogen-fixing (Mbuya *et al.*., 1994; Orwa *et al.*., 2009). Thus seedlings can be made available to farmers and education on cultivation and/or management of the species done to promote it.

The actual number of tree species used by the household for fuelwood significantly and negatively correlates with obtaining fuelwood from the market. An increase in this number decreases the probability of choosing to obtain fuelwood from the market by 4%. This illustrates that households in the study area are well aware of different tree species and their uses and prefer to collect the species they consider best by themselves, instead of buying. Households that prefer more fuelwood trees are less likely to go to the market because traders, due to restrictions imposed on harvesting certain tree species, may be limited in the species of trees sold in the market as fuelwood. This observation agrees with the reasons cited for preference for forests due to availability of varied species of trees and with reasons given for not preferring the market.

Because they are basic to establishing sustainable land-use systems, markets are considered valuable in enhancing development of sustainable agroforestry systems (World Bank, 1992; Kürsten, 2000). Existence of a market stimulates production of a commodity and in the case of fuelwood; may be an incentive for on-farm fuelwood production and subsequent diversion of pressure from forests and from *Faidherbia albida*. Market factors can raise the opportunity cost of time (Pattanayak, 2004), and lower both the demand for fuelwood and fuelwood collection from forests. Forest access and resource extraction can also be better controlled with the presence of markets. By granting access to traders with permits, issuing rights to sell fuelwood from certain parts of the forest to specific traders and placing a ceiling on how much and when fuelwood can be obtained, law enforcement through issuance of permits to allow forest access would ultimately be more useful than is the case currently. Establishing markets would allow competition and motivate on-farm tree production as traders must meet public demand for fuelwood.

Other covariates including level of education of the head of household, distance to the source of fuelwood, size of land owned, total income and ownership of transportation equipment (bicycle, motorcycle, power tiller and ox-cart) are insignificant determinants in the choice model. And although they remain insignificant, some of them have important policy implications. Beyene (2010) found strong local level institutions to be significant in determining fuelwood sources and negatively correlated with collecting fuelwood from community forests, while Jumbe and Angelsen (2006) found that restrictions on fuelwood collection had no significant effect on diverting demand away from forests. In this study, households were asked if they were aware of bylaws regulating use of natural resources, with the expectation that awareness of such laws would stimulate demand away from natural forests. The results, however, are inconclusive and indicate low level of awareness and weak law enforcement in the study area, thus agreeing with the descriptive results and concurring with Jumbe and Angelsen (2006). Nevertheless, institutional factors have important policy implications for environmental conservation.

4.5.3 Determinants of fuelwood consumption

The results of the Ordinary Least Squares regression used to estimate the determinants of quantity of fuelwood consumed by households are given in Table 4.6.

Table 4.6: Ordinary least squares regression estimates of the determinants of fuelwood consumption

Variable	Description	Coefficient	S. Error
LNAGEHHEAD	Age of decision maker in years	0.456***	0.137
GENDER1	Sex of the decision maker (1=Male,0=Female)	-0.016	0.109
LNHHSIZE	Size of the household	-0.053	0.088
HHLOC	Location of the household (1=Urban, 0=Rural)	-0.532***	0.118
HHEDUC_N⁺	Highest level of education attained by the decision maker		
Primary	Highest level of education is primary	0.087	0.107
Secondary	Highest level of education is post primary	0.082	0.177
FEMMEM	Female adults present in the household	0.330**	0.161
LNTOTHHINC	Total household income	0.076**	0.033
ENERGDEV	Use of energy saving device (1=Yes, 0=No)	-0.270	0.186
OWNLAND	If household owns land (1=Yes, 0=No)	0.011	0.096
FWDSOURCE⁺	Main source of fuelwood		
Own farm	Own farm is the main source	0.053	0.117
Market	Market is the main source	-0.015	0.117
ORGTRPL_N	Knowledge of organizations that promote agroforestry	0.075	0.096
AWAREBYL	Awareness of natural resource management bylaws	-0.082	0.078
LNPRICEFWDKG	Natural log of price of fuelwood	1.0	0.650
LNPRICEKER	Natural log of price of kerosene	-0.816***	0.286
LNPRICECHAR	Natural log of price of charcoal	-0.117	0.214
_Cons	Constant (fuelwood consumed, when all other variables are zero)	7.439*	4.116
Number of observations		225	
F-Statistic		2.98	
Adjusted R^2		0.13	

*, **, ***: Variables are significant at 10%, 5% and 1% respectively

⁺No education and natural forest are omitted variables under education and fuelwood source respectively

Source: Household survey data, 2013

The OLS regression results give an adjusted R^2 value of 0.13, which, even though lower than what has been reported in other similar studies for example, Onoja and Idoko (2012) who had an adjusted R^2 value of 0.70; is still significant (Prob>F =0.0001). This indicates that the identified determinants significantly explain some variation in fuelwood consumption, thus supporting the rejection of the null hypothesis that factors other than income do not determine household consumption of fuelwood. Other studies such as Hosier (1985) have reported such low correlation on studies on domestic energy consumption in Kenya (R^2=0.21) and attributed the low values to failure to correctly predict human behavior using survey data.

4.5.4 Discussion of factors influencing consumption of fuelwood in households

The results shown in Table 4.6 suggest that households' socio-economic characteristics have a significant influence on the amount of fuelwood consumed. The age of the household head, locality of the household (urbanization), having female members of productive age in the household, income and price of alternative fuels like kerosene have significant influence on the quantity of fuelwood consumed.

Fuelwood has been the most utilized form of energy in developing countries for a long time. In many regions in Africa, it may be the only known, available and affordable fuel for domestic use. It is for this reason that perhaps households having older heads comparatively consume significantly higher quantities of fuelwood. A unit increase in the age of the head of household increases the amount of fuelwood consumed annually by 0.45%. This may be attributed to traditions, cultures and habits formed over time and which may be difficult to change. This result is consistent with findings by Osiolo (2012) who found households headed by older people spending more on fuelwood, assuming that the higher expenditure is due to higher consumption and Abebaw (2007), who reported similar results in Ethiopia. For agroforestry this result is undesirable, because it is the older population that most likely possesses the indigenous knowledge associated with on-farm management of *Faidherbia albida* and continued destruction of the tree for fuelwood will lead to erosion of such critical knowledge.

Although the gender of the head of household is not significant in determining quantity of fuelwood consumed, a household that has at least a female member of economically productive age consumes more fuelwood than those without. Irrespective of their number, a household having female members of productive age increases quantity of fuelwood consumed by 0.33%. In most African communities, collecting fuelwood is a women's activity. The presence of a productive female member in the household may suggest constant provision of labour towards this activity. This corresponds with Brouwer *et al.*'s (1997) findings that labour availability may determine the level of fuelwood use, although in the former study, labour provision was measured in terms of household size.

Female labour plays a critical role in household energy provision and has important policy implications. According to Israel (2002) and Pundo and Fraser (2006), women who were employed were more likely to use alternative fuels, and this could result in lower consumption of fuelwood. In Mbarali, most women are not employed, meaning that the opportunity cost of their time and labour is low and are therefore available to collect fuelwood for domestic use.

Households located in rural areas considerably consume more fuelwood than those in peri-urban areas. The results indicate that being located in a rural area increases the amount of fuelwood consumed by 0.53%, thus suggesting that urbanization is likely to reduce competition between fuelwood consumption and agroforestry. The higher level of consumption of fuelwood by rural households may be because the resource may be more abundant in rural areas or that rural households, unlike urban areas, may not have adequate access to other alternative sources of energy like gas and electricity due to poor infrastructure. In this study Madibira and Igava wards are not connected to the national grid making electricity inaccessible to households. In certain villages, households are located far from filling stations making kerosene intermittently unavailable to them. The high rate of fuelwood consumption is unfavorable because it may negate the gains associated with agroforestry.

In economic theory, the demand for a good is usually a decreasing function of its own price and also changes with respect to the prices of other goods depending on whether they are substitutes or complements. The relationship between price and demand is important in policy formulation especially when government, for example, contemplates offering subsidies to poor people to enable them access certain goods and services. In this study, the dependent variable (quantity of fuelwood consumed annually in kilograms), income, price of fuelwood, price of kerosene and price of charcoal are log-transformed so that the resultant parameter estimates are directly interpreted as elasticities.

The results show an insignificant coefficient of 1.0 on the log of price of fuelwood per kilogram. Thus the effect of the price of fuelwood on the quantity of fuelwood consumed is inconclusive. Although the signs are as expected and imply that both charcoal and kerosene are substitutes for fuelwood, only the cross-price of kerosene is significant. A 1% increase in the price of kerosene results in a 0.82% increase in the quantity of fuelwood consumed. Other studies like Onoja and Idoko (2012) in Nigeria concur with the findings in this study about the price of kerosene. The policy implication for this is that for there to be a decrease in the quantity of fuelwood consumed, the price of kerosene should be reduced, a proposition on which Gupta and Kohlin's (2006) cast doubt based on their findings from India where price of kerosene did not affect fuelwood demand. In considering kerosene use, however, health and environmental effects associated with petroleum products should be borne in mind.

When the elasticity of income is considered in light of the energy stacking model, then it is expected that as incomes increase, households would consume less of fuelwood as they embrace other fuels. The energy ladder model on the other hand expects a clear shift from consuming fuelwood with increased income. The income elasticity of demand for fuelwood is positive but inelastic. A 1% increase in income results in only a small increase (0.076%) in the quantity of fuelwood consumed. The marginal increase in fuelwood consumed as a result of increased income seen in this study resonates well with Arnold *et al.*'s (2006) observation that the effect of income on fuelwood consumption appears to be small regardless of how it is measured. The positive coefficient on the variable however, contradicts the energy ladder hypothesis which presumes a negative income elasticity of demand. This coefficient may suggest that higher incomes mean having more food to cook hence higher consumption of fuelwood. This result disagrees with findings by Onoja and Idoko (2012) and Osiolo (2012) who found income to be an important factor in fuel expenditures.

The constant term in the regression is also significant at 10% indicating that even when all other factors in the model are held constant, an average of 7.44kg of fuelwood would still be consumed by a household in a year. The results of other variables in the model such as household size, level of education, land ownership, possessing energy saving devices and awareness of bylaws regulating the use of natural resources remain insignificant. Nonetheless, variables such as use of energy saving devices in households may have important policy implications for fuelwood consumption as has been observed by Godfrey *et al.* (2010) and Osiolo (2012). They suggested that increased availability of energy saving devices may help address the issue of unsustainable fuelwood consumption in households.

The results of the OLS regression imply that fuelwood consumption in the study area is largely determined by factors that are not captured by the model. It is worth noting that relative availability of fuelwood in itself is an important factor in determining consumption (Hosier, 1985). People tend to use fuelwood sparingly where it is scarce because, its “price” in terms of opportunity costs involved in collection is high or may even turn to consuming other fuels. As mentioned earlier, the study area falls within Mbeya region which is classified as Category 2, having moderate biomass fuel supply (Kaale, 2005). This means that fuelwood resources are relatively available (although focus group discussion results indicate that availability is decreasing). For this reason, there may be differences in the determinants of consumption with resource constrained areas. In the Mbarali scenario fuelwood consumption may therefore be attributable to factors that have not been included in the model.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter gives the key conclusions and recommendations with respect to the two aspects of fuelwood consumption investigated (choice of fuelwood sources and amount of fuelwood consumed in households). To broaden the scope of application of the empirical results, areas of further research are proposed to corroborate the findings of this study.

5.2 Conclusion

The determinants of choice of fuelwood sources and the factors influencing quantity of fuelwood consumed by households were analyzed, with the aim of making recommendations that would be critical for agroforestry interventions. The analyses indicate that households in Mbarali district are highly dependent on fuelwood for domestic energy provision and on forests to provide it. Such high demand for forest fuelwood may eventually lead to fuelwood scarcity and/or imposition of restrictions on accessing natural forests subsequently shifting pressure to farms. In light of the discussions above, the quantity of fuelwood consumed is not only determined by income but also by other factors including prices of substitutes and presence of economically productive female members in the household which are critical for policy.

Results also show that there is low substitution between fuelwood and other fuels because households, even in peri-urban areas do not have access to alternative fuels particularly for cooking. Although, urbanization tends to reduce the consumption of fuelwood, contrariwise, it increases the consumption of charcoal. Therefore, policy actions focusing on charcoal must be cognizant of the fact that charcoal is mostly and largely produced from forest trees. In order for households to make any meaningful substitution, policies to ensure availability of alternative fuels and their prices must be considered. FGDs revealed that people are aware of solar as an alternative for lighting but are constrained by the high installation costs involved.

The results of the Ordinary Least Squares regression also imply that fuelwood consumption is influenced more by socio-cultural factors rather than economic factors, and that factors previously thought to influence consumption of fuelwood may only be applicable in specific scenarios, for instance in areas where supply is constrained. A cross-sectional survey may also not adequately capture variations in energy consumption over the year, making it necessary to consider seasonality.

As the population increases across sub-Saharan Africa, a key concern has been the conversion of forests into agricultural farms and continued extraction of fuelwood and cutting of trees for charcoal, and the impending threat of fuelwood scarcity. The decision to obtain fuelwood from various sources is determined more by tree species than by household socio-economic characteristics. Preference for *Brachystegia spp.* stimulates forest exploitation which has potentially dire environmental consequences. On the other hand, preference for *Faidherbia albida,* threatens the CAWT intervention, as demand shifts away from forests and markets towards farms. This notwithstanding, the apparent shift in demand to farms would not be entirely disadvantageous in that it would reduce destruction of natural forests and allow time and space for natural regeneration which is desirable for environmental conservation.

The importance of tree species in choice could however be exploited to encourage agroforestry. The local community in the study area possesses vital indigenous knowledge that can be harnessed to promote agroforestry. Since species like *Brachystegia spp.* take very long to grow, it might be necessary to promote other faster growing tree species with characteristics that households expect of fuelwood trees and that can provide timber and non-timber products within a shorter time period.

While natural forests in the study area are mainly under the jurisdiction of the state, law enforcement seems to be weak and households do not necessarily adhere to the regulations. Thus, they have become *de facto* open access resources. With open access, the rate of degradation is higher because there is little or no control over resource exploitation.

5.3 Recommendations

Based on the findings and conclusion of this study, various recommendations are made. First and foremost, it is important that the high consumption of fuelwood is checked. One way of doing this is by diverting demand away from fuelwood by enabling more people to affordably access alternative domestic fuels. For this to be done, the concerned authorities should consider cost-effective technologies, for example harnessing solar energy which is abundant in the country and which could provide the community with an affordable fuelwood substitute in addition to reducing the price of kerosene.

It may be useful to enhance agroforestry by promoting the cultivation and/or management of *Acacia tortilis* alongside *Faidherbia albida* for fuelwood to reduce dependency on the latter species. Because of its qualities, *Acacia tortilis* is likely to be a better alternative to fuelwood production than exotic tree species.

The results in this study show that availability of female labour in the household increases fuelwood consumption, and so, in line with market development, it may be beneficial to raise the opportunity cost of their labour time by creating income generating opportunities and consequently reduce time spent in collecting fuelwood.

It may also be necessary to strengthen local environmental institutions. Strong local level institutions may be needed to create more awareness on agroforestry and promote tree planting. To ensure environmental conservation, agroforestry could be encouraged as an environmental management intervention that is complementary to fuelwood production. Through such institutions, the accessibility by households to seedlings could be improved; and education and awareness about the need for sustainable resource use and conservation increased. Stronger institutions are capable of ensuring compliance with laws that govern local resource use. Increased sensitization of the community on the need to conserve, manage the environment and control the use of fuelwood is likely to reduce fuelwood consumed, and consequently reduce degradation of forests and haphazard felling of *Faidherbia albida*.

5.4 Further research

In analyzing fuelwood consumption, further studies that incorporate household cooking practices including whether the household engages in cooking for sale, whether the cooking area is protected, whether the household brews alcohol, how many times fire is lit in the household in a day or, whether the fire is extinguished after cooking should be considered to corroborate the findings of this study.

To draw lessons on appropriate interventions, studies may also be necessary to consider adoption of energy saving devices, seasonality in consumption as well as taking repeated measurements of fuelwood consumed in households within a given period of time.

Future research should make use of panel data to capture inter-temporal preferences for fuelwood sources and fuelwood consumption and may also be designed to have a wider geographical coverage with a larger data set. Further empirical evidence is necessary to corroborate the suggestion that stimulating the fuelwood value chain could encourage on-farm production of trees.

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APPENDICES

Appendix I: Sampling frame and sample for the study

Location	**Ward**	**Village**	**Number of hamlets**	**Total number of households**	**Sample**	**Number of Respondents**
RURAL	Madibira	Iheha	5	283	25	22
		Nyakadete	5	361	33	33
		Nyamakuyu	4	358	32	32
	Igava	Igava	5	310	28	23
		Igunda Muungano	5	377	33	33
	Mapogoro	Mtamba	5	355	25	23
		Mbuyuni	8	461	24	24
PERI-URBAN	Rujewa	Luwilindi Kanisani	1	114	15	15
		Luwilindi Barabarani	1	138	15	10
		Mkwajuni	1	114	15	15
	Madibira	Mkunywa	1	133	25	24
	TOTAL			3964	270	254

Appendix II: Household survey tool

World Agroforestry Centre

Household Survey of Rural Fuelwood Consumers in Mbarali District 2013

Researchers from the World Agroforestry Centre (ICRAF) and a student from the University of Eldoret are carrying out a study on **THE FUELWOOD VALUE CHAIN IN MBARALI DISTRICT, TANZANIA.** Your participation in the study is voluntary, and all the information will be treated as confidential and will be combined together with responses from other 200 households for analysis.

Household Number **(HHID)** ________________

Starting time **(START)** ________________ Finishing time **(END)** ________________

Survey Date: (dd /mm /yy) **(SURDATE)** ________________

Household head's name **(HHNAME)** ________________________________

Respondent's name **(RESPNAME)** ________________________________ **MEM** ________________

Respondent's contact **(CONTACTS)** ________________________________

(Instruction: Record the member number (MEM) of the Respondent from the Demography table on page 3 after the survey is completed)

SECTION A. IDENTIFYING VARIABLES:

Supervisor:	_____________	**SNUM**	___________
Enumerator:	_____________	**ENUM**	___________
District:	_____________	**DIST**	___________
Ward :	_____________	**WARD**	___________
Village:	_____________	**VIL**	___________

GPS Coordinates:

NORTHINGS __________________

EASTINGS __________________

Altitude MT. a.s.l

ALTITUDE __________________

Supervisors: 1= Martha Swamila, 2= Elijah Ngocho, 3= Hilda Sayo
Enumerators: 1=Sarah Raphael, 2=Amon Kimata, 3=Joseph Malambi, 4=Maximillian Joseph, 5=Boaz Mtokoma, 6=Grace Samwel, 7=John Bujimu, 8=Ephraim Angomwile, 9=Hope Muturu, 10=Albina Kaunda, 11= Elijah Ngocho, 12=Hilda Sayo, 13= Martha Swamila
District: 1=Mbarali
Ward: 11=Madibira, 12=Igava, 13=Mapogoro, 14=Rujewa
Village: 111=Mkunywa, 112=Iheha, 113=Nyakadete, 114=Nyamakuyu, 121=Igava, 122=Igunda-Muungano, 131=Mtamba, 132=Mbuyuni, 141=Rujewa

SECTION B: DEMOGRAPHIC AND SOCIO-ECONOMIC CHARACTERISTICS OF THE HOUSEHOLD

B1. Provide information on members living within the household and dependent on the household head in the table below

Member ID	Name of HH member	In which **year** was this person born?	What is the **sex** of member? ***1=male*** ***0=female***	Marital Status[1] ***See codes below***	What is the **highest** level of formal education completed[2]? ***See codes below***	Main occupation[3] ***See codes below***
MEM	**NAME**	**YBORN**	**GENDER**	**MSTATUS**	**HEDUC**	**OCCUPATION**
1 (head)						
2 (spouse)						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						

B2: Type of household **(TYPEHH) _______________**1= male headed (monogamous), 2= male headed (polygamous), 3= female headed (husband absent), 4= female headed (widowed), 5=female headed (divorced/separated), 6=female headed (single), 7= male headed (single), 8= male headed (divorced/separated), 9= male headed (widowed) 99= Other (Specify)…......

[1]**Marital Status (mstatus):** 1=Single, 2=Married, 3=Divorced, 4=Widowed, 5=Separated, 6=other (specify)
[2] **Education levels (heduc):** 0=None, 1=Std 1, 2=Std 2, 3=Std 3, 4=Std 4, 5=Std 5, 6=Std 6, 7=Std 7, 8=Std 8, 9= Form 1, 10=Form 2, 11=Form 3, 12=Form 4, 13= Form 5, 14= Form 6, 15= College 1, 16= College 2, 17= College 3, 18=College 4, 19=University 1, 20=University 2, 21= University 3, 22=University 4, 23= University 5 & above
[3]**Occupation**: 1=Farming, 2=Business, 3=Regular employment, 4=Casual off-farm employment, 5=Agricultural labourer, 6=other (specify)

SECTION C: FARM CHARACTERISTICS

C1. Rank the following economic activities on a scale of 1 to 3 in order of importance to the household. What is the main reason for the assigned ranks?

Economic activity	**Rank**[1] **RANKECON**	**Reason for rank** **RSNRNKEC**
Crop production		
Livestock production		
Regular off -farm employment		
Casual off -farm employment		
Casual agricultural jobs		
Business		
Brick making		
Charcoal burning		
Fuelwood trading		
Beekeeping		
Other(specify)		

[1]Rank:1= Most important, 2=Important, 3=Least important, 4=Not important

C2. Which are the **FIVE** main agricultural enterprises (crop and livestock) that you had on your farm in the previous season (**December 2012/June 2013**)? List the enterprises in a ranked order and give reasons for the ranks assigned to the first three most important activities.

Livestock enterprises **LIVEENT**	Rank **RANKLIV**	Reason **RSNLIV**	Crop enterprises **CROPENT**	Rank **RANCRP**	Reason **RSNCROP**

[1]**Codes for crops and livestock enterprises**: 1=maize, 2=sorghum, 3=sunflower, 4=rice, 5=beans, 6=groundnuts, 7=tomatoes, 8=vegetables, 9=onions, 10=mango, 11=Dual purpose cattle, 13=Dairy cattle, 14=Dairy goat, 15=Oxen, 16=, Meat goat, 17=Indigenous chicken, 18=Improved chicken, 19=pigs, 20=sheep, 21=other (specify)

Land Ownership

C3. Do you own land? 1=YES [……..] 0=NO […….] **OWNLAND**______________

C4. If yes, what is the type of land ownership? (1=communal, 2= Individual/Private, 3=state-owned, 4= sharecropping, 5=other (specify)

TENURE_______________

C5. How many acres of land does the household own? **LANDOWN** _______________

C6. How many acres of land has the household rented in? **LANDREN**________________

C7. How many acres of land has the household leased out? **LANDLSE**______________

C8. How many acres of land were under crop cultivation in the previous season (December 2012-June 2013)**? LANDCUL**_____________

C9. How many acres of land are under agroforestry? **LANDAF**____________

SECTION D: AGROFORESTRY

D1. Which tree species do you have on your farm? Please list in order of importance, the number of trees, where they are planted and three main uses of the tree products

Rank	Tree Species **TREESP**	Number of trees on farm **NOTREES**	Number planted	Number naturally regenerated	Where planted[1] **HABITAT**	MAIN USES OF AGROFORESTRY TREES (CODES)[2]		
			NOPLANT	**NOREG**		**USE1**	**USE2**	**USE3**
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								

[1]**where planted**: 1=along hedges, 2=intercropped, 3=homestead, 4=woodlot, 5=other (specify)

[2]**Uses**: 1=building materials, 2=timber, 3=poles, 4=essential oils, 5=medicine, 6=soil fertility, 7=fodder, 8=fuelwood, 9=fruits, 10=ornamental, 11=shade, 12=other (specify)

D2. Which agroforestry tree management activities do you undertake on your farm?

	Tree Species **TREESP**	Management activity[1] **MACTIVITY**	No. of times in a month **MMONTH**	How much it costs in TShs **MCOST**	Reason for undertaking activity **MREASON**
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

[1]1=Weeding, 2= Pruning, 3= Watering, 4=Manuring, 5=Spraying, 6= other (specify)

SECTION E: ENERGY USE IN THE HOUSEHOLD

E1. Please complete the following table with respect to different types of energy used in the household, with 1, 2 and 3 as most important, important and least important respectively

Type of energy	Rank[1] **ETYPERANK**	Reason for ranking **RANKRSN**	Have you ever used it? 1=Yes, 0=No **EVERUSE**	Main use **MENGUSE (codes)**[2]
Fuelwood				
Charcoal				
Kerosene				
Gas				
Electricity				
Crop residues				
Cow dung				
Solar				

[1]1=Most important, 2=Important, 3=Least important, 4=Not important

[2]**Energy uses**: 1=Cooking, 2=Drying, 3=Ironing, 4=Lighting, 5=Heating during cold season, 6=Other (specify)

E2. Indicate what quantity and how much money you spend on the different types of energy in the time periods specified in the table?

Type of energy	Quantity per week **QTYWEEK**	Unit[1] **UNITWK**	Quantity per month **QTYMNTH**	Unit **UNITMTH**	Amount spent per month (TShs) **EXPMNTH**	Number of months used per year **NOUSEYR**
Fuelwood						
Charcoal						
Kerosene						
Gas						
Electricity						
Crop residues						
Solar						
Other (specify)						

[1]**Unit**: 1=head load, 2=bicycle load, 3=bundle, 4=power tiller, 5=ox-cart, 6=tractor, 7=bag, 6=debe, 7=softi, 8=litre, 9=other (specify)

E3. Estimated average amount of fuelwood used in the household per day/week/month? (to be measured using tape/spring balance)

Quantity Per day **PERDAYFW** _______________ Unit **UNITFWD** _______________

Quantity per week **PERWKFW** _______________ Unit **UNITFWW** _______________

Quantity per month **PERMNTFW** ________________ Unit **UNITFWM** _______________

E4. Estimated average amount of charcoal used in the household per day/week/month? Please indicate unit of measurement

Quantity Per day **PERDAYCH** _______________ Unit **UNITCHD**_______________

Quantity per week **PERWKCH** ________________ Unit **UNITCHW**________________

Quantity per month **PERMNTCH** ________________ Unit **UNITCHM** ________________

E5: Rank the sources of fuelwood listed in the table below in order of importance. What is the main reason for the assigned rank? Which of the sources do you use? How much fuelwood do you obtain from these sources in a month? What is the mode of acquisition?

Source	Rank[1] **RANKSORC**	Reason for ranking **RSNSORC**	Do you use? 1=Yes, 0=No **USESORC**	Quantity per month **QTYSORC**	Unit **UNITSORC**	Mode of acquisition[2] **ACQSORC**
Natural forest						
Own farm						
Market						
Other (specify)						

[1] 1=Most important, 2=Important, 3=Least Important;
[2] Mode of acquisition: 1=Owned, 2=Purchased, 3=Free, 4=other (specify)

E6. Please complete the following table regarding the frequency of collection, distance and time taken to obtain fuelwood from each of the given sources.

Source	Frequency of collection/ week **FREQWK**	Frequency of collection/ month **FREQMNT**	Average distance in kilometers to source **DISTSOC**	Time taken including time for harvesting (hrs) **TIME**	Mode of Transport[1] **MODETRAN**	Approximate cost of transport per unit **TRANCOS T**
Natural forest						
Own farms						
Market						
Other (specify)						

[1]Mode: 1=foot, 2=bicycle, 3=motorcycle, 4=car, 5=ox- cart,6=power tiller, 7=tractor,8=pick up, 9=canter

E7. Please indicate the challenges faced in obtaining fuelwood from each of the following sources

Source	Challenges **CHALLENGE**
Natural forest	
Own farms	
Market	
Other (specify)	

E8. What type of cooking device is used in the household? (1= Three Stone, 2= Metallic charcoal stove, 3= Clay charcoal stove, 4= Kerosene stove, 4=other (specify)

COOKSTV_________

E9. Are there any energy saving devices used in the household? 1=YES [___] 0=NO [___] **ENERGDEV____________**

E10. What activities is fuelwood used for within the household? (List from the most common to the least common use)

ACTIVITY1____

ACTIVITY2____

ACTIVITY3____

E11. Please list some tree species that the household uses for fuelwood and rank them in order of preference. What are the reasons for the assigned ranks?

Tree Species **TREESPFW**	Rank[1] **RANKPREF**	Reasons for preference **RSNPREF**

[1]1Most preferred, 2=preferred, 3=least preferred

E12. How many trees has the household cut in the past one year? _____________**NOTRCUT**

E13. What were the reasons for cutting the trees? (1=fuelwood for use, 2=fuelwood for sale, 3=timber for home use, 4=timber for sale, 5=other (specify) ________**RSNTRCUT**

E14. Does the household plant any trees to replace the ones that are cut from the farm? 1=YES [___] 0=NO [___] **PLANTTR**_________

E15. Does any member of the household engage in sale of fuelwood and/or charcoal?
1=YES [___] 0=NO [___] **SALEFWD**_________ **SALECHAR**________

E16. If yes, where does s/he obtain the fuelwood and/or charcoal for sale from? (1=Natural forest, 2=own farm, 3=market, 4=other (specify) **SALFWDSRC**________

SALCHARSRC__________

E17. To whom does s/he sell MOSTLY? (1=other households, 2=restaurants, 3=brick makers, 4=charcoal burner, 5=traders, 6=institutions, 7=other (specify)

WHOMSELLF_______ **WHOMSELLC**___________

E18. What is the price per unit at which fuelwood and/or charcoal was sold?
PRICESELLF_______UNITSELLF________ PRICESELLC________UNITSELLC_______

SECTION F: WELFARE INDICATORS

F1. Please provide information on ownership of the following household assets

Row	**Asset**	**Does your household own: Yes=1, No=0 (If no go to next asset)**	**If yes….** Total Number
1	Vehicle (Car/truck)		
2	Bicycle		
3	Motorcycle		
4	Tractor		
5	Water pump		
6	Wheelbarrow		
7	Spray pump		
8	Mobile phone		
9	Electric/Gas Cooker		
10	Paraffin Stove		
10	Charcoal Stove		
11	Television set		
12	Refrigerator		
13	Power tiller		
14	Ox-cart		
15	Ox-plough		
16	Other (specify)		

Type of Housing

F2. Please provide information on the status of the house that your household lives

Roofing material of the household's most important residence		1=straw/thatch, 2=mud, 3=wood/planks, 4=iron sheets, 5=asbestos, 6=bricks/tiles, 7=tin, 8=cement, 9=other
Wall material of the household's most important residence		
Floor material of the household's most important residence		
Number of rooms (minus kitchen and bathrooms)		

Household income

Crop income

F3. How much income did the household receive from **crop** enterprises in the December 2012/June 2013 cropping year? (**Enumerator: Fill in either quantity & prices or approximate value of production**)

Enterprise		**Quantity produced and unit**		**Prevailing price**		**Approximate value of production**
		PRODQTY	**QUNIT**	**CPRICE**	**PUNIT**	**PRODVAL**
Cereals						
Maize	**1**					
Rice	**2**					
Sorghum	**3**					
Millet	**4**					
Other cereals	**5**					
Pulses& oil crops						
Beans	**6**					
Ground nuts	**7**					
Sunflower	**8**					
Cowpeas	**9**					
Green grams	**10**					
Pigeon peas	**11**					
Other pulses & oil crops	**12**					
Roots & tubers						
Irish potatoes	**13**					
Sweet potatoes	**14**					
Cassava	**15**					
Other roots & tubers	**16**					
Vegetables						
Onions	**17**					
Tomatoes	**18**					
Cabbages	**19**					
Other vegetables	**20**					
Fruits						
Bananas	**21**					

Avocado	**22**					
Mango	**23**					
Passion fruit	**24**					
Other fruits	**25**					
Cash crops						
Tea	**26**					
Coffee	**27**					
Sugarcane	**28**					
Other cash crops	**29**					
Agroforestry products						
Seedlings	**30**					
Timber	**31**					
poles	**32**					
Fuelwood	**33**					
Charcoal	**34**					

Unit codes: 1=100 kg bag 2=kgs 3=50 kg bag 4=crates 5=pieces/number 6=25kg bag 7=10kg bag 8=tonnes 9=debe 10=box/carton 11=wheelbarrow 12=cart 13=canter 14=pickup, 15=bunches, 16=bundles, 17=other (specify)

Livestock income

F4. Please provide information in the table below on livestock ownership and sales between **September 2012 and September 2013.**

Row	Type of livestock	Do you own 1=Yes 0=No **OWNLIVE**	Number owned between Sept 2012-Sept 2013 **NOWNED**	Number sold between Sept 2012 and Sept 2013 **NSOLD**	Price per animal **LIVEPRICE**	Total value **LIVEVAL**
1	Cross breed cattle					
2	Local cattle					
3	Improved goats					
4	Local goats					
5	Local sheep					
6	Improved pigs					
7	Local pigs					
8	Improved chicken					
9	Local chicken					
10	Donkey					

Sale of livestock products

F5. How much income did the household receive from **livestock products** between September 2012 and September 2013? (**Enumerator: Fill in either quantity & prices or approximate value of production**)

Enterprise		Quantity produced and unit		Price for largest sale/Prevailing price	Approximate value of production
		LPRODQTY	**LUNIT**[1]	**LPRICE**	**LPRODVAL**
Cow milk	**1**				
Goat milk	**2**				
Eggs	**3**				
Honey	**4**				
Fish	**5**				
Other products	**6**				

[1]**Unit codes:** 1=litre, 2=number, 3=crates, 4=other (specify)

Off-farm income

F6. List all off-farm income (including remittances, dividends and pension) earned by all household members between **September 2012 and September 2013.**

Person name (*As in demography table)*	Person ID (*As in demography table)*	Which **Income earning activity (ies)?** *(See activity codes below)*	Months involved in the activity in the last 12 months	What was the monthly estimate of income (TShs) from this activity
NAME	**MEM**	**ACTIVITY**	**ACTMONTH**	**INCMONTH**

Activity codes: 1=remittance, 2=Regular employment, 3=Dividends, 4=Pension, 5=Business, 6=Non-agricultural casual employment, 7=Brick making, 8=other (specify)

Household expenditure

F7. Please provide information on expenses incurred on food items indicated in the table below (**enumerators indicate approximate value of home produced foods**)

Expenditure item	Number of times consumed in a month **TIMESCON**	Amount spent per month in TShs **FDEXPMTH**
Maize		
Rice		
Other cereals (e.g. sorghum, wheat, millet)		
Vegetables		
Roots and tubers (cassava, Irish/sweet potato, yams)		
Pulses (e.g. beans, ground nuts, green grams, peas)		
Meat and meat products (beef, chicken, fish)		
Milk and milk products		
Sugar and beverages		

Expenditure on other items

F8. Please provide information on expenses incurred on the items indicated in the table below

Expenditure item	Amount spent per month in TShs **EXPMTHOTH**	**Amount spent per year in TShs EXPYROTH**
Education		
Clothing and footwear		
Health		
Shelter/rent		
Transportation		
Entertainment		
Other (specify)		

SECTION G: INSTITUTIONAL VARIABLES

G1. Are you or any member of your household aware of bylaws or regulations that govern harvesting and sale of fuelwood? 1=YES [___] 0=NO [___] **AWAREBYL___________**

G2. If yes, how have the bylaws or regulations affected the way you harvest and use fuelwood?

BYLAWEFF1____

BYLAWEFF2____

BYLAWEFF3____

G3. To what extent do you comply with the bylaws or regulations?
(1=Do not comply, 2=partially comply, 3=fully comply)

COMPLY___________________

G4. What is the reason for your answer in G3 above?

RSNCOMPLY____

G5. Are there organizations that promote tree planting or conservation of natural forests in this region? (1=YES [___], 0=NO [___], 99 =I don't know [___])

ORGTRPL_______________

G6. If yes, which ones are they?
ORGTRPL1_______________ORGTRPL2_______________ORGTRPL3__________

G7. In what ways have these organizations influenced the way you plant or manage trees on your farm? **ORGINFL**

____

____

G8. What is the distance in km from the homestead to each of the following?

a) Nearest source of electricity **DISTELEC** __________
b) Nearest filling station **DISTFST** __________
c) Nearest market **DISTMKT** __________
d) Nearest office issuing permit **DISTPERM** __________

Appendix III: Agroforestry and fuelwood tree species identified in the study area

Local name	Scientific name	Common English name	Common uses
Msukanzi	Acacia polycantha	Falcon's claw acacia,	Fuelwood, timber, posts, farm tools, medicine (leaves, roots), fodder (pods, leaves, seeds), ornamental, nitrogen fixation, soil improvement, gum, live fence.
Mhango, Mkungugu	Acacia tortilis/ Acacia spirocarpa	Umbrella thorn	Fuelwood, charcoal, timber, poles, posts, fodder (shoots, leaves, pods), bee forage, soil conservation, nitrogen fixation, shade (livestock), fences (cut branches), fiber (bark).
Mbuyu	Adansonia digitata	Baobab	Utensils, fodder (leaves, fruit), food (shoots, fruit), drink (seed pulp), medicine (roots, bark), bee forage, string, rope (bark fibers), gum, resin, dye (roots).
Mkola, Mbamba kofi	Afzelia quanzensis	Lucky-bean tree, pod mahogany, mahogany bean	Timber (construction, furniture), carving (doors, dhows, canoes), medicine (roots), shade, ornamental.
Mtangala, mfuho, mfugho	Albizia amara	Bitter albiza	Fuelwood, charcoal, timber, poles, tools, medicine (bark, leaves, roots), fodder (leaves), ornamental, mulch, nitrogen fixation, soil conservation, resin.
Msisina, mtonga	Albizia harveyi	Sickle-leaved ablbizia	Building materials, charcoal, domestic uses (tool handles),fencing (live, posts), fuelwood, gum, nitrogen fixing, medicine, resin, shade, timber (termite resistant)
Mchala, mkenge	Albizia petersiana	Many-stemmed albizia	Timber, fuelwood, building poles, tool handles, spoons, bows and carriage beams (wood). Medicine leaves, roots and bark).
Mringa, mlinga, muganga	Albizia versicolor	Poison-pod albizia	Fuelwood, charcoal, timber (small boats), tool handles, utensils (mortars), medicine (roots, bark), beehives, nitrogen fixation.
Mstafeli	Annona muricata	Soursop	Food (fruit), drink, medicine, ornamental, insecticide, fish poison.
Mwarubaini	Azadirachta indica	Neem tree	Fodder (leaves, oil-seed cake), bee forage, soil conservation, ornamental, shade, medicine, windbreak, insecticide (azadirachtin in leaves, etc.), oil (seeds), soap (seed oil).

Mtowo, mtobo, mtoho	Azanza garckeana	Snot apple	Fuelwood, charcoal, timber, tool handles, utensils, yokes, food (fruit), fodder (leaves), bee forage, fiber (bark), shade.
Mkonga	Balanites aegyptiaca	Desert date	Fuelwood, charcoal, poles, timber (furniture), utensils, tool handles, food (fruit), medicine (roots, bark, fruit), mulch. Shade, windbreak, gum, fencing (branches), oil (fruit.
Mkomba, mfumbi, mgombwali	Bauhinia petersiana	White bauhinia	Food (seeds), medicine (roots, leaves), fodder (leaves, pods), shade, ornamental, tannin (roots).
Mhama	Borassus aethiopium	Borassus palm/ African fan palm	Poles, timber (roofing, door frames), tool handles, carving (drums), food (fruit, seeds, young seedlings), (sap of flower shoots), medicine (roots, flowers, oil), fodder (fruit, young leaves), thatch, fiber (leaves), baskets, mats (leaf stalks, leaves), oil (fruit), brooms.
Msingisa	Boscia mossambicensis	Broad-leaved boscia	Building materials, fuelwood, fruit, medicine
Mtelela, mgegele, mhangali/a	Brachstegia bussei	Large leaved brachystegia	Fuelwood, charcoal, timber (joinery, roofing beams), handles (hoes), medicine (roots, bark), fodder (seeds), bee forage, fiber (bark), gum (resin).
Myombo, mkwee, mkuti, mnguti	Brachystegia spiciformis	Bean-pod tree	Fuelwood, charcoal, timber, beehives, utensils (storage pots), medicine (bark, roots), fodder (seeds), bee forage, shade, fiber rope (bark), dye (bark).
Mlangali	Bridelia micrantha	Bridelia	Fuelwood, charcoal, timber, poles (granaries), tool handled food (fruit), medicine (bark and roots), fodder (leaves), mulch, shade.
Msangala, mgando	Burkea africana	Burkea/ Wild syringa	Fuelwood, charcoal, timber (furniture), poles, utensils (pestles), fodder (leaves, fruit), bee forage, medicine (bark roots), tannin (bark).
Mlungu	Calodendrum eickii		Timber, fuelwood, tool handles, building poles and grain mortars, amenity and shade (tree), medicine (roots).
Mpapai	Carica papaya	Pawpaw/ papaya	Food (fruit), drink (fruit), medicine (roots), pickles, jam (fruit), meat tenderizing (leaves, fruit).
Mmulimuli, mlunda	Cassia abbreviata	Long-pod cassia	Fuelwood, timber (furniture, joinery), medicine (bark, roots), ornamental.

Mlimao	Citrus limon	Lemon	Fuelwood (twigs, dead branches), food (fruit, jam, pickle, chutney, candied peel), drink, flavouring (peel), oil (peel), medicine (juice, roots, leaves), ornamental, perfume (oil).
Mchungwa	Citrus sinensis	Sweet orange	Food (fruit)
Mning'ina, mkunguni, mnujaminzi	Combretum fragrans	Four-leaved combretum	Fuelwood, charcoal, medicine (leaves), bee forage.
Mlama	Combretum molle	Velvet-leaved combretum	Fuelwood, charcoal, poles, posts, timber (construction), tool handles, medicine (roots, leaves and bark), bee forage, mulch.
Msana	Combretum zeyheri		Building materials, fiber (roots-baskets), fuelwood, medicine, timber (soft, borer, termite proof)
Mtono, mponda, mkongolo	Commiphora ugogoensis		Beehives, bee plant, building materials, domestic uses (tool handles, spoons), furniture (local chairs), gum, shade.
Mdawi, mdavi	Cordia monoica	Grey-leaved cordia/ grey leaved saucer berry	Fuelwood, timber (construction, furniture), utensils (bows, traditional stools, walking sticks), food (fruit), medicine (roots, bark), fodder (leaves), bee forage, gum, fibers, fire making, glue (fruit).
Mchekechi	Crotolaria grandibracteata	Crotalaria	Fodder (leaves, twigs), bee forage, ornamental, nitrogen fixation, soil improvement.
Tunda damu, mgogwe, mtunguja	Cyphomandra betacea	Tree tomato	Food (jam, fruit, vegetable).
Msina	Dalbergia nitidula	Glossy flatbean	Fuelwood, charcoal, poles, tools (digging), handles, carving utensils (pestles), fodder, dye (bark, roots).
Mkrismasi, mkakaya	Delonix regia (Poinciana regia)	Flamboyant	Fuelwood, medicine (bark), bee forage, shade, ornamental, beads (seed).
Mpangala	Dichrostachys cinerea		Fuelwood, charcoal, poles, posts, tool handles, medicine (leaves, roots), fodder (leaves, pods), bee forage, nitrogen fixation, soil conservation, fibre (bark), live fence, dry fence.
Mti Ulaya, mlingoti	Eucalyptus spp	Eucalyptus	Fuelwood, charcoal, timber, poles, posts, medicine (leaves), bee forage, ornamental, windbreak, essential oils

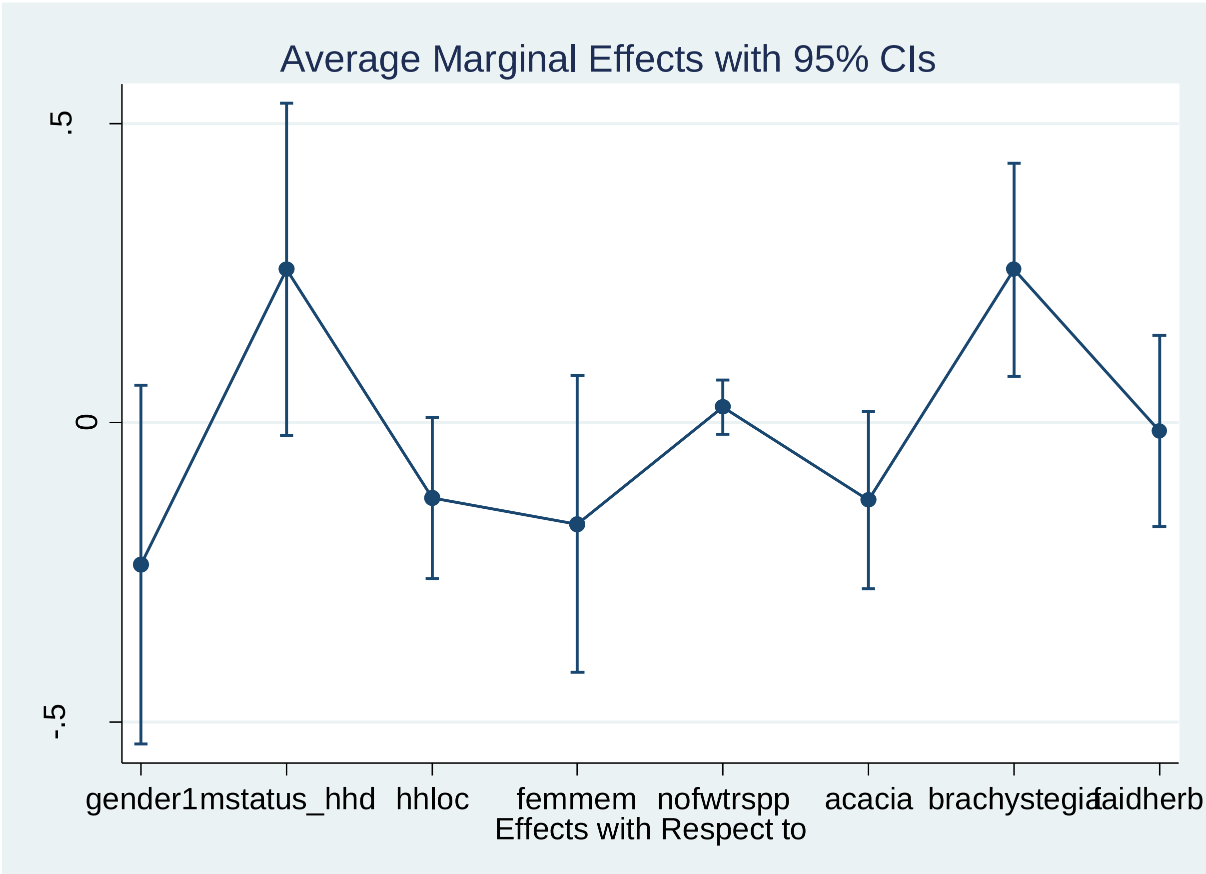
Mnyala	Euphorbia tirucalli	Finger euphorbia	Fuelwood, medicine (young branches), fish poison (latex), live fence, boundary marker.
Mpogoro, mgunga, mkababu	Faidherbia albida/ Acacia albida	Apple ring acacia/winter thorn	Fuelwood, charcoal, timber (construction), posts, utensils, flavouring (pod), medicine (bark), fodder (pods and leaves),shade, nitrogen fixation, soil conservation, soil improvement
Mtamba	Ficus natalensis		Planted as stakes for shade, windbreaks, avenues, and for boundary and grave marks. It is also used for pot plants. The latex is used for making birdlime. The bark is used as medicine for whooping cough by WaNyamwezi.
Mkuyu, mjombe	Ficus sycamorus	Sycamore fig	Fuelwood, carving, food (fruit), medicine (milky latex), shade, mulch, ornamental, soil conservation, soil improvement, bee hives, ceremonial.
Mperemehe, mkole, mkoma, mbaju	Grewia similis/ Grewia bicolor	False brandybush	Fuelwood, timber, tool handles, carving (clubs, javelins, walking sticks), medicine (roots, bark), fodder (leaves, fruit).
Mlangalanga, mlanga	Hagenia abyssinica	Hagenia	Fuelwood, timber (furniture, flooring, general purpose), carving, medicine (bark, roots, flowers), mulch, ornamental, soil conservation.
Mpimati, mtondo	Julbernardia globiflora	Julbernardia	Fuelwood, charcoal, tool handles, bee hives, medicine (bark), bee forage, storage pots (bark), ropes (bark), sacks (bark).
Msunguti	Kigelia africana	Sausage tree	The wood is used for bee hives, drums, water troughs, mortars, stools, milk pots and canoes. The fruits are used for fermenting local beer. The leaves and stem bark are used as medicine for venereal diseases, rheumatism, malaria, infertility, dysentery, epilepsy and headache. The tree is good for ornamental purposes because of its large red flowers and it's hanging sausage-like large fruits. It is also used as a bee forage.
Mvale, muvare	Lonchocarpus capassa	Lilac tree/rain tree	Fuelwood, timber, utensils (grain mortars), tool handles, food (seeds), medicine (roots), fodder (leaves), bee forage,

Mwembe	Mangifera indica	Mango	Fuelwood, food (fruit, juice), fodder (leaves), bee forage, shade, mulch, ornamental, soil conservation, windbreak, gum, dug-out canoes
Mwale, mvule	Milicia excelsa	Iroko	Fuelwood, charcoal, timber (furniture, boats), shade, ornamental, mulch.
Mfurusaje	Morus alba	White mulberry	Fuelwood, timber, tools, food (fruit, leaves), fodder (leaves, shoots), bee forage, soil conservation, ornamental, shade, windbreak, live fence, silkworms (leaves).
Mkami	Newtonia hildebrandtii		Timber (construction), utensils, carvings, fencing poles, pegs, combs and clubs, medicine (roots).
Mwanzi	Oxytenanthera abyssinica	Lowland/Wine/Wild bamboo	Poles (building), drink (young shoots tapped), fodder (leaves), soil conservation, basketry (trays, etc.), dry fencing, boundary marker.
Mparachichi	Persea americana	Avocado	Food (fruit), oil (cosmetics), shade.
Mmemena	Pseudolachnostylis maprouneifolia	Duiker berry	Fuelwood, charcoal, timber (joinery, local carpentry), fodder (leaves, fruit), medicine (roots, bark, leaves), shade, dye (fruit).
Mpera	Psidium guajava	Guava	Fuelwood, tool handles, posts, food (fruit, jam, jelly, juice), medicine (bark, leaves, roots), shade, soil conservation, live fence.
Msungura	Rhus natalensis	Red currant	Fuelwood, charcoal, timber, farm tools, food (fruit), medicine (bark, leaves), toothbrushes (stems).
Mbono	Ricinus communis	Castor-oil plant	Medicine (oil), oil (seeds), live fence, windbreak.
Mbwegele	Sclerocarya birrea	Jelly plum	Fuelwood, timber (general purpose), utensils (stools, grain mortars, beehives), carving, food (fruit), drink (fruit), bee forage, fodder (leaves, fruit), medicine (bark, roots, leaves), oil (seeds).
Mjohoro, mchongoma	Senna siamea	Iron wood/ yellow cassia	Fuelwood, charcoal, poles, timber (furniture), medicine, fodder (leaves), bee forage, ornamental, mulch, soil conservation, windbreak.

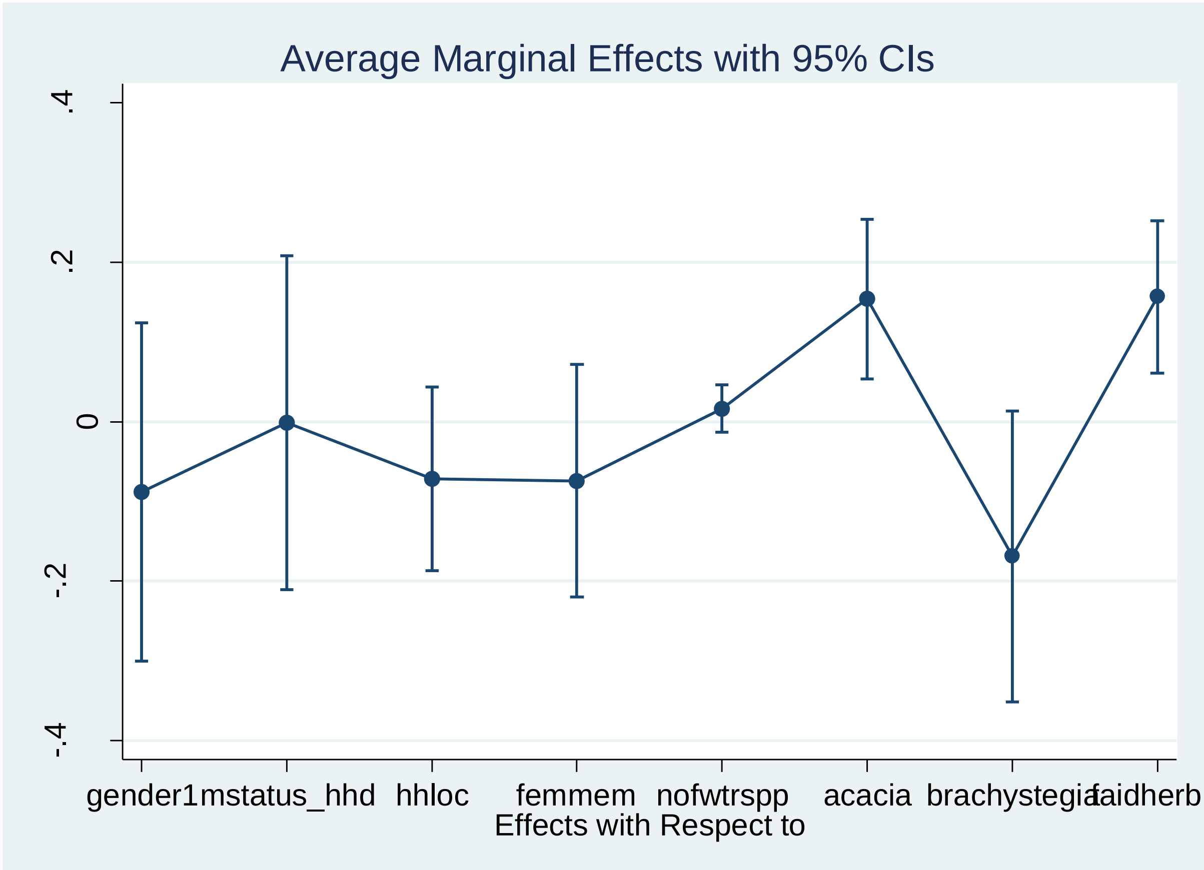
Mpande	Strychnos cocculoides	Corky-bark monkey orange	Building materials, domestic uses (tool handles), dye, fodder, fruit, medicine, shade, soap.
Mtangadasi	Strychnos spinosa	Elephant orange, spiny monkey ball;	Fuelwood, charcoal, timber (furniture, boxes), food (fruit), fodder, medicine (fruit, leaves, bark, roots).
Mvengi, mzambarau	Syzygium cordatum	Water-berry tree	Timber (construction, furniture), food (fruit), drink (fermented fruit), bee forage, medicine (leaves, bark, roots), dye (bark).
Mkwaju	Tamarindus indica	Tamarind	Fuelwood, charcoal, timber (furniture, boat building), utensils (pestles, mortars), poles, posts, food (pulp, drink), flavouring (fruit), medicine (twigs, bark, roots), fodder (leaves, fruit), ornamental, mulch, shade.
Mpululu	Terminalia sericea	Silver terminalia	Fuelwood, charcoal, timber (general, bedsteads), poles (building), posts, tool handles, medicine (leaves, roots), bee forage, rope (bark), red dye (bark).
Msada	Vangueria infausta	Wild medlar	Fuelwood, poles (houses), tools (digging), handles, food (fruit, seed kernel), medicine (roots).
Mnyinga	Xeroderris stuhlmannii	Wing pod	Fuelwood, charcoal, utensils (mortars, stools, milk pots), carving, fodder (leaves, fruit), famine food (seeds), medicine (sap, roots), shade, red dye (sap).
Mpingi	Ximenia americana	Wild plum	Fuelwood, tool handles, food (fruit), medicine (leaves, roots, bark), fodder, oil (seed).
Mlungulungu	Zanthoxylum deremense	Kokwaro	Fuelwood, tool handles, spoons, bows and charcoal (wood), medicine (bark).
Mtanula	Ziziphus mucronata	Indian jujube	Fuelwood, charcoal, timber (beds, dhow ribs), poles, utensils (bows, arrows), carving, fodder (leaves, fruit), bee forage, shade, soil conservation, resin, gum, windbreak, live fence, tannin, dye.

Sources of information: Mbuya LP *et al.* (1994) and ICRAF tree database: http://www.worldagroforestry.org/treedb/AFTPDFS

Appendix IV: Probability of choosing forests as sources of fuelwood



Appendix V: Probability of choosing own farms as sources of fuelwood



Appendix VI: Probability of choosing market as source of fuelwood