ENERGY CONSUMPTION AMONG RURAL HOUSEHOLDS IN MUKARO LOCATION OF NYERI COUNTY, KENYA

By

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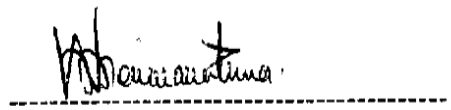
Reg. No.: C50/8600/2006

A Project Paper Presented in partial fulfillment for the requirements of the degree of Master of Arts in Environmental Planning and Management, University of Nairobi, Department of Geography and Environmental studies

August 2013

DECLARATION

This Project paper is my original work and has not been presented for a degree in any other University.



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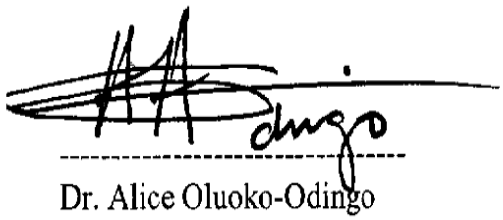

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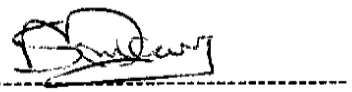

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Date:....19/8/13

DEDICATION

To the two gentlemen who have inspired, motivated and energized me to complete this work, My Dad, Chrisberg and Martin, my husband.

ACKNOWLEDGEMENT

For the gift of life and health, without which this work would not see the light of day, I thank God

I would like to thank my supervisors Dr. Alice Oluoko-Odingo and Dr. Mikahtsa S. Mukhovi who took time to read my work, guide me and hold my hand all through.

I would like to acknowledge the assistance of Catholic Academic Exchange Programme (KAAD) Germany, who sponsored my education at the Masters Degree level.

Special thanks to my Dad, Chris whom we spent with many hours in the field collecting data for this Project paper. Your assistance was invaluable. My gratitude to Joseph Kahoro, a student at Egerton University, who assisted in collecting the required data for this Project paper.

I am grateful to my sister Pascaline and Peter, my brother who assisted in typing my work at the early stages of this work.

Many thanks to Mr.Wambugu of the Ministry of Energy, Nyeri for providing me with valuable information on energy use in Nyeri County

I would like to acknowledge Mr. Fredrick Mwangi of the University of Nairobi for his assistance in data input, cleaning and analysis in SPSS.

LIST OF ABBREVIATIONS AND ACRONYMS

CBO	Community Based Organization
CBS	Central Bureau of Statistics
FAO	Food and Agriculture Organization
GNP	Gross National Product
Ha	Hectare
Kg	Kilogram
Km	Kilometer
KNBS	Kenya National Bureau of Statistics
KSh	Kenya Shilling
LPG	Liquefied Petroleum Gas
M	Meter
NCST	National Council for Science and Technology
NGO	Non-Governmental Organization
SPSS	Statistical Package for the Social Sciences

ABSTRACT

The purpose of this study was to investigate energy consumption by rural households in Mukaro location, Nyeri County. Specifically, the study looked at wood fuel consumption and factors affecting wood fuel consumption. The study went further to identify the strategies adopted by households in dealing with reduced wood fuel availability as well as investigating if the strategies adopted had any environmental or socio-economic effects on the households.

The research used the questionnaire as the main tool to collect data though other methods like interviews were applied. The study interviewed 138 households sampled using simple random sampling. The data collected was analyzed using inferential statistics. Hypothesis testing was done using chi-square, regression and qualitative analysis.

The results of study showed that wood fuel was the major source of energy for rural households in Mukaro location, Nyeri County. Further, household income, distance travelled to access wood fuel as well as the household size determined the amount of wood fuel consumed by a household. The study also discovered that fuel wood was slowly becoming unavailable and as such households had developed various strategies to cope with reduced wood fuel availability. Among the major coping strategies indentified were use of twigs, reduction in consumption and increase in distance travelled to access wood fuel. The study found out that these coping strategies had some environmental and socio-economic effects on the rural households. They included reduced tree cover, more time spent in collecting fuel wood and increase in distance travelled to collect firewood. Though continued use of wood fuel contributed to reduced vegetation in the area, the study discovered that it was not the sole contributor to reduced vegetation; there were other factors like demand for timber and clearing land for farming.

From the findings, the study recommends the following: increased recognition of wood fuel consumption as a source of energy by policy makers, expansion and diversification of household income streams to enable households transition to “green energy”, subsidies on energy saving jikos and fast growing tree seedlings in order to promote energy efficiency, conservation and agroforestry, concessions and credit availability of solar and biogas equipment to reduce on the high installation costs and encourage their use.

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CHAPTER ONE: INTRODUCTION

1.1 Introduction

This chapter gives the background to the study, states the problem being investigated and lays out the objectives of the study from which the hypotheses were drawn for statistical testing. Additionally this chapter justifies the need for the study, gives the limitations of the study as well as states how the researcher overcame the limitations. Finally the chapter gives the operational definitions of terms used in the study.

1.2 Background to the Study

Energy is an important aspect of every economy. It drives the economic growth and development of a country. At the household level energy satisfies basic human needs for food, lighting and heating, while at the national and local levels, it plays a decisive role in employment and income creation (GVEP 2006). Biomass fuels are the most important source of primary energy in Kenya with wood fuel consumption accounting for over 68 per cent of the total primary energy consumption (GVEP 2006). Biomass contribution to Kenya's final energy demand is 70 per cent and provides for more than 85 per cent of rural household energy needs (ROK 2011b). According to Mugo & Gathui (2010) biomass energy is expected to remain the main source of energy for the foreseeable future. In Kenya energy sources can be classified into two categories: a) traditional that includes wood, charcoal and other biomass, and b) conventional, such as petroleum products and electricity (Kamfor 2002). These categories are highlighted in the National Atlas of Kenya classifying Kenya as dependent on three major sources of energy: wood fuel, petroleum and hydro-electricity (ROK 2003). Modern fuels are popular because they burn cleanly but are expensive to obtain while traditional fuels tend to smoke and are cheaper to obtain. The transition from traditional fuels to modern fuels in developing countries has been slow partly due to the sluggish economic growth in these countries.

In 2000, the biomass demand in Kenya stood at 34.3 million tonnes compared to an estimated sustainable supply of 15 million, thereby indicating a deficit of over 56 per cent; the demand was estimated to be growing at 2.7 percent per year while the sustainable supply was growing at a slower rate of 0.6 percent per year (ROK 2008). Up to 43% of the national consumption was from sustainable supplies while 57% was from

unsustainable supplies (Mugo & Gathui 2010). The demand and supply imbalance is exerting significant pressure on the remaining supplies especially the forests accelerating land degradation. Kamfor (2002) estimates the biomass deficit in Nyeri County at 571,010 tonnes per year. This is despite the fact that Nyeri County is categorized as a high potential area. A 1988 study in Bungoma County of Kenya revealed that wood fuel was supplying only 54% of the energy required for cooking and heating annually while the rest, 46% was from crop residues implying an increasing trend in the use of such materials (Mugo & Gathui 2010). Increased use of crop residues for energy is an indication of increasing scarcity of fuelwood (Foley and Barnard 1984; Mugo & Gathui 2010). Population growth, lack of access to biomass substitutes and continued poverty have been the main factors behind wood fuel demand. These factors have accelerated the rate of wood fuel consumption and in turn depletion of existing stocks.

For a long time, lack of appropriate policy, legislation and political will has hindered development of the biomass energy subsector (Mugo & Gathui 2010). In comparison to the conventional energy sector, which has comprehensive 5-10 year plans, planning for household and biomass energy in most sub-Saharan African countries is often incoherent and sporadic and starved of the necessary budgetary allocation (ADB 2007). Wood fuel scarcity received genuine attention in Kenya during the 1980s. Triggered by a looming crisis, the Central Bureau of Statistics, the Ministry of Energy and the Beijer institute each carried out national surveys to determine wood fuel demand and supply in the 1980s. In 1995-6 National Land Degradation Assessment and Mapping (NLDAM) project carried out an assessment on wood fuel consumption in Kenya. This was followed by the Kamfor company study in the year 2000 on the major energy sources used by households and small scale industries and service establishments in the country. These studies have contributed to assessing the gap between wood fuel demand and supply. This study intends to contribute to existing information by providing empirical evidence on how households are responding to the increasing gap between wood fuel demand and supply.

Compared to industries and institutions domestic households are the major consumers of biomass energy in Kenya (GVEP 2006). Rural households consume wood fuel in the

form of firewood while the urban households consume it in the form of charcoal. In rural households, women are tasked with the duty of collecting firewood. Not only are they, the main users of the commodity, they are also the suppliers and they spend considerable time collecting it and where it is not readily available they have to purchase it or the charcoal substitute (Kgathi 1997). Due to ever-decreasing wood fuel supplies rural women are often also forced to walk longer distances to get the commodity, with one head-load taking between 3 to 5 hours collection time and many women walk 6 to 19 km with a head-load each weighing 21-38 kilograms (Kaumbutho & Simalenga 1999).

Rural households develop different strategies to cope with decreasing fuelwood availability (Brouwer 1997). Besides the negative ecological consequences of fuelwood scarcity, many of the common responses to fuelwood scarcity have negative social and economic consequences (Mugo & Gathui 2010). It is often assumed that these various responses in a population can be used as indicators of fuelwood scarcity and that these responses will occur more frequently in areas with less fuelwood availability (ETC 1987b; Brouwer 1997). As the immediate source of fuelwood becomes depleted, distances, and thus times, travelled for its collection increase (Mugo & Gathui 2010). People start with increasing collection efforts, together with economizing in fuelwood use and shift to lesser quality fuel (Brouwer 1997). The actual responses depend on individual decisions at household level and are dependent on the available labor, household entitlements, access to woodlands as well as cultural practices (Brouwer 1997).

According to Mugo & Gathui (2010) to address wood fuel scarcity problems in Kenya, it will be necessary to map out the biomass energy characteristics in each County, district, and location as the beginning of a process of identifying key problem areas and identifying specific intervention points. A better understanding of household responses to wood fuel scarcity may help policymakers design better, more effective strategies to addressing the wood fuel scarcity problem. The study has presented empirical evidence on the coping strategies that rural households have adopted in coping with decreasing wood fuel availability in Mukaro location, Nyeri County.

1.3 Statement of the Research Problem

Energy plays a very significant role in socio-economic development and environmental protection. Among other sources of energy, biomass plays the biggest role given that it "is a primary source of energy for close to 2.4 billion people in developing countries (*ADB 2007)"*. Biomass fuels are the most important source of primary energy in Kenya with woodfuel consumption accounting for over 68% of the total primary energy consumption (ROK 2004). According to the National Development Plan 2002-2008, over 93 percent of the rural population is dependent on wood fuel. Subject to its sustainable exploitation, biomass is not only a vital source of energy for many today but is likely to remain an important source of energy in the future (Karekezi et al. 2006; ADB 2007). This then, makes it a very important source of energy given that majority of the population rely and will continue to depend on wood fuel as the major source of energy.

Biomass energy will continue to be the primary source of energy for the rural population and urban poor for as long as it takes to transform the rural economy from subsistence to a highly productive monetised economy (ROK 2004). Various factors have contributed to continued reliance by rural households on wood fuel as the main source of energy. Among this factors include low household incomes, lack of affordable alternative sources of energy among others. Studies on wood fuel consumption in Kenya have consistently indicated diminishing supplies. This study looked at the various factors influencing wood fuel consumption in Mukaro location, Nyeri County. The study gives empirical evidence on the factors affecting wood fuel consumption with an aim of establishing challenges that can be addressed to reduce the heavy reliance on wood fuel as a source of energy by rural households.

The continued high dependence on wood fuel and other forms of biomass as a dominant primary source of energy has contributed to unsustainable harvesting of biomass with attendant negative impacts on the environment (ROK 2004). Traditional biomass energy use has direct negative impacts on women and children, who are the most vulnerable group in terms of biomass energy scarcity and adverse indoor air pollution impacts. Given the potential negative impacts of fuelwood scarcity, understanding its effects and households' responses to (increasing) fuelwood scarcity represents an important research

agenda, with the potential to impact behavior and develop better policies (Damte et al. 2012). This study has examined the effects of wood fuel use with an aim of making recommendations for future use.

As a result of the existing wood fuel scarcity households develop various strategies to deal with reduced wood fuel availability. Early studies examined responses to scarce fuel wood within the context of fuel wood production and consumption (Damte et al. 2012). This study examines the strategies that rural households in Mukaro Location have adopted to cope with wood fuel scarcity with the intention of establishing the environmental and socio-economic impact such strategies have on the rural households.

There have been two studies on biomass energy undertaken by the Ministry of Energy, one in 1980 and the other in 2000 respectively. These studies looked at the demand and supply factors of energy consumption without much emphasis on how households respond to the negative gap between demand and supply. This study went further to identify the environmental, social and economic effects of the coping strategies that households had adopted to decreasing wood fuel availability as a result of the sustained negative gap between fuel wood production and consumption. Nationwide studies have been conducted; however, studies at the village level have not been conducted exhaustively leaving room for more studies to be done at the local level. The study has identified possible areas of intervention by the government and non-governmental organizations in addressing the various energy challenges that rural households face.

1.4 Research Objectives

General Objective

The study examined energy consumption by rural households in Mukaro Location, Nyeri County.

Specific Objectives

1) To establish the sources of energy for rural households in Mukaro location, Nyeri County.
2) To find out the factors affecting energy consumption among rural households in Mukaro location, Nyeri County.
3) To identify the challenges that rural households in Mukaro location, Nyeri County face in sourcing for energy
4) To identify coping strategies that rural households in Mukaro location, Nyeri County have adopted in response to challenges faced.
5) To investigate the environmental and socio-economic effects associated with the strategies adopted to cope with the various challenges faced in sourcing for energy in Mukaro location, Nyeri County.

1.5 Research Hypothesis

The following four hypotheses were derived from the research objectives:

1) There is no difference in wood fuel consumption as compared to electricity, LPG, paraffin and solar energy consumption by households in Mukaro location, Nyeri County
2) There is no relationship between factors affecting wood fuel consumption and consumption in Mukaro location, Nyeri County
3) There is no difference in coping strategies adopted by households in the various sub-locations within Mukaro location, Nyeri County
4) Household responses to reduced wood fuel availability do not have any environmental or socio-economic effects in Mukaro location, Nyeri County.

1.6 Justification for the Study

Biomass is a primary source of energy for close to 2.4 billion people in developing countries (ADB 2007). Wood fuel continues to be the leading source of energy for the majority of population in Kenya: of the 20 million people depending on fuel-wood, 89 per cent are in rural areas and 9 per cent in urban settlements (GVEP 2006). The study therefore looked at a very important energy resource that is used by majority of Kenya's rural population and which will continue being an important source of energy.

Fuelwood scarcity, especially in rural areas, has attracted the attention of many researchers and policymakers since the mid-1970s because it has serious, negative socio-economic consequences for rural livelihoods (Arnold et al. 2003; Damte et.al, 2012). Despite this, enough attention has not been given to assessing the different aspects of fuel wood scarcity. This study identified the various factors that influence household energy consumption and their responses to wood fuel scarcity.

Data and information on household energy consumption and biomass energy use in most sub- Saharan countries is outdated and often unreliable (ADB 2007). To fill this gap, the study has presented information on household energy consumption in Mukaro location, Nyeri County. This information is relevant in guiding policy makers and creating awareness at the local level. In addition most of the studies concerning energy have been done at the national level with limited attention to the local areas. This study contributes to existing studies at the local level.

Most of the studies examine energy consumption within the context of supply and demand ignoring other factors that affect consumption. For example there is limited documented evidence on strategies that rural households have adopted in coping with reduced wood fuel in the various villages in Kenya since most studies are conducted at national level. This study presents empirical evidence on the strategies that rural households have adopted in coping with decreased wood fuel availability in Mukaro location, Nyeri County. The study went further to examine the environmental as well as socio-economic effects of the coping strategies adopted by households.

1.7 Scope and Limitations of the Study

1.7.1 Scope of the study

The study looked at the sources of energy for the rural households in Mukaro location, Nyeri County. Though there are many sources of energy, the study gave more attention to wood fuel since it is the major source of energy for rural households. Use of some sources of energy like biogas, sawdust and solar was negligible. Having focused more on wood fuel as the source of energy the study looked at the factors affecting wood fuel consumption in particular household income, distance to source and household size. Further the study brought out the coping strategies that rural households had adopted in dealing with reduced wood fuel supplies and how these coping strategies were affecting the environment as well as the socio-economic status of the households. These were the issues within the scope of the study and were investigated within Mukaro location, Nyeri County.

1.7.2 Limitations of the study

- Poor road network

The road network in rural Kenya has remained largely underdeveloped. The researcher had to walk long distances to access households thereby spending a lot of time trying to access households. This was made more difficult on rainy days when the roads were muddy. The area was also diverse and needed someone who was conversant with the area. The researcher engaged local residents who were conversant with the area and were able to access it without much difficulty.

- Estimation of daily consumption of fuel wood.

It was expected that quantities of wood fuel consumed by households are not measured on a daily basis. The researcher also expected that amounts estimated orally might not be accurate. To overcome this challenge the researcher requested the households to lay a bundle of firewood used in a day and weighed the same using a weighing scale. The researcher also weighed the amount of charcoal used per day as well as sawdust for the households that were using that particular source of energy.

1.8 Operational Definitions

Biomass: Organic matter which can be used as a renewable energy source.

Charcoal: Fuel that is produced after burning wood with a controlled supply of oxygen.

Coping Strategy: Is used to describe what households do when faced with a threat (wood fuel scarcity)

Deforestation: The negative reduction of forest cover from the original status.

Energy: A source of usable power, such as petroleum or wood fuel

Energy consumption: Refers to using up of a particular type of energy mainly for cooking and heating. In this study consumption is used to refer mainly to quantity used more than quality of the energy.

Forest: Any land containing vegetation association dominated by tress of any size, whether exploitable or not, capable of producing wood or other products, potentially capable of influencing climate, exercising an influence on the soil, water regime, and providing habitat for wildlife.

Fuel wood: Wood that is used directly in combustion as firewood. In this study the term fuel wood is used interchangeably with the word *fire wood*

Githeri: A mixture of cooked maize and beans

Green energy: Biogas and Solar

Households: A domestic unit consisting of the members of a family who live together along with non relatives such as servants.

Non forest area: Areas including turf and grass, other grass, agricultural field, non-forested wetlands, tidal wetlands and barren land.

Source: A thing/point from which something can be obtained. In this study the word source in the context of 'source' of wood fuel is used interchangeably with the word 'type' of wood fuel

Wood fuel: This refers to charcoal and fuel wood (firewood)

CHAPTER TWO: THE STUDY AREA

2.1 Introduction

This chapter describes the study area in terms of its position and size, physiographic and climatic conditions as well as administrative boundaries. The chapter also gives the population and density of the study area as well as states the economic activities the populace is engaged in. Moreover, the chapter gives an overview of the energy situation of the area, the vegetation, environmental conservation and management practices of the study area.

2.2 Human and Natural Environment

2.2.1 Position and Size

Nyeri County covers an area of 3,337 km^2 and lies between longitudes 36° and 38°east and between the equator and latitude 0° 38' south (ROK 2002b). It borders the following counties; Laikipia to the North, Meru to the North East, Kirinyaga to the East, Muranga to the South, and Nyandarua to the West. Nyeri North district covers an area of 2,287 km^2 while Nyeri South district covers 1,050 km^2. These two districts constitute Nyeri County.Nyeri County lies between 3,076 metres to 5,188 metres above sea level.

2.2.2 Physiography

The main physical features of the county are Mount Kenya (5199m) to the east and Aberdare Ranges (3999m) to the west (ROK, 2002b), while the western part of the county is flat, the topography of the southern part is characterized by steep ridges and valleys, with Karima, Nyeri and Tumutumu hills on this part. To some extent these hills and mountains affect the rainfall pattern, thus influencing the mode of agriculture production in the County. The major rivers in the County are Sagana and Chania. These two rivers together with other streams make the County self sufficient in surface and sub surface water resources. The two forest ecosystems, that is, Mt. Kenya and Aberdares forests, are under the jurisdiction of the Forest department while the forested hills, Karima, Tumutumu and Gatumbiro hills, are under the administration of local authorities. According to the District Fact Sheet, the gazetted forest area is 115,199.04 hectares (ha) while the size of non-gazetted forests is 4000 ha (ROK 2002b).

2.2.3 Climate

Due to the location of the County, being within the highland equatorial zone of Kenya, Nyeri County experiences equatorial rainfall. The long rains occur from March to May, while the short rain falls from October to December with occasional disruptions in this pattern due to changes in climatic conditions. Annual rainfall ranges from 500mm in the dry areas of Kieni to 1500mm in the Aberdare ranges and areas around Mt Kenya (ROK, 2002b). The monthly average rainfall is between 500mm and 2400mm per annum.

The temperature in the County is lower in the higher areas like the Aberdare ranges which experiences colds of up to 8°c in the cold seasons of June/July while in the low areas of Mathira, Tetu and Othaya, the temperature is 7°c. During the hot seasons of January to March, the average district temperature is about 28°c. The monthly mean temperature ranges from 12.8°c to 20.8°c.

2.3 Salient features of Municipality division

1. Before Tetu division was split into Tetu East and Tetu West, Municipality division was the smallest division in the County occupying 167km^2. It has the highest population density of 711 persons per square kilometer. The chosen area of study which is Mukaro location is the larger location of the two (Mukaro and Kiganjo) that comprise Municipality division. It has a higher population density than Kiganjo.

   With limited financial resources this characteristic enabled the researcher to study many households concentrated in a small area. Also, given that the division has the highest density, then its demand for energy would most likely be higher than other divisions making it a good case study on how the population has responded to reduced wood fuel availability.

2. Municipality division has a relatively moderate climate compared to other divisions which are on the extremes of the County. It receives average rainfall. The weather is neither too cold like the areas around the aberdares and Mt. Kenya nor too hot like the dry area of Kieni. This means that vegetation sprouts at a rate that is neither too fast nor too slow and that the vegetation is neither too dense nor too scattered.

3. Municipality division has a mixture of urban and rural population. The division hosts Nyeri town which is the central and largest town of the district. The population of Municipality division works in the formal and informal sectors as well as in small-scale urban agriculture and livestock production. The mixed population is a salient feature of Mukaro location. The study was therefore able to investigate a mixed population that is likely to be using both traditional as well as modern sources of energy.

2.4 Population Density and Settlement

According to the Kenya National Bureau of Statistics, as at the year 2009 the population of Nyeri County stood at 693,558 persons with 324,659 persons in Nyeri North district and 368,899 in Nyeri South district. Nyeri County has a total of 201,703 households with 95,608 households in Nyeri North district and 106,095 households in Nyeri South district. Of the 2 districts constituting Nyeri County, Nyeri South has a higher density of 351 persons per km^2 compared to Nyeri North with 142 persons per km^2, however, the population density of the County is 208 people per km^2.

According to the 2009 Population and Housing Census; Municipality Division had the highest population with 119,273 people in 36,412 households. The average household size of Municipality Division is 3.2 persons. Kieni East and Kieni West are the least populated divisions with a population density of 120 and 109 persons per square kilometer (ROK, 2002b) respectively though the divisions cover the largest area of Nyeri County. This is because they are lowland potential areas with less rainfall.

The settlement pattern of the County is influenced by rain and soil fertility with areas that receive less rainfall having a more scattered settlement pattern as compared to those with ample rainfall (ROK, 2002b). The majority of the population are found in the high potential areas of Othaya, Tetu, Mukurwe-ini and Mathira while low potential areas with less rainfall have less population densities.These are Kieni East and Kieni West Divisions.

There was a 17% increase in population from the year 1999 to 2009 from 101,238 persons to 119,273. The number of households increased from 28,712 to 36,412 an increase of 26% from year 1999 to 2009. The study shall use statistics for the year 2009 which are the most recent statistics.

2.5 Administrative Boundaries

Table 2.1 Administrative Boundaries

Districts	Divisions	Local Authorities	Towns
1. Nyeri North 2. Nyeri South	1. Othaya, 2. Tetu East 3. Tetu West 4. Mukurweini 5. Municipality 6. Kieni east 7. Kieni west 8. Mathira	1. County council of Nyeri 2. Nyeri municipal council 3. Othaya town council 4. Karatina Municipal council	Nyeri Karatina Kiganjo Mweiga Othaya

Nyeri County is one of the 47 Counties in Kenya. It is divided into 2 districts. The County has 8 divisions which apart from Tetu and Kieni double up as constituencies. Tetu constituency comprises of Tetu East and Tetu West divisions while Kieni constituency comprises of Kieni east and Kieni west division. Nyeri County is further sub-divided into 37 locations and 192 sub-locations. Kiganjo and Mukaro make the two locations of Municipality division with Mukaro having a higher population than Kiganjo. Mukaro consists of 18 sub-locations while Kiganjo consists of four sub-locations. Nyeri Municipality is a Parliamentary constituency known as Nyeri Town Constituency. It was established in 1988 covering an area of 169.56 km^2 with a population of 119,273 persons (2009 census). Nyeri Town which is the main town is located in this constituency, it has 11 administrative locations namely Mukaro, Kiganjo, Kirichu, Mathari, Nyaribu, Kamakwa, Karia, Muruguru,Chania, Nyeri central and Gatitu. These locations except Mukaro constitute wards for Nyeri Municipal council.

Table 2.2 Area of the County by Divisions (km^2)

Division	Area (km^2)	Locations	Sub-locations
Tetu East	75.1	3	17
Tetu West	142.5	3	19
Mukurweini	178.6	7	28
Mathira	296.6	7	39
Municipality	167.8	2	22
Othaya	174.5	6	28
Kieni West	623.3	5	20
Kieni East	817.1	5	20
Total	2,475.5	38	193

Source: KNBS, 2010

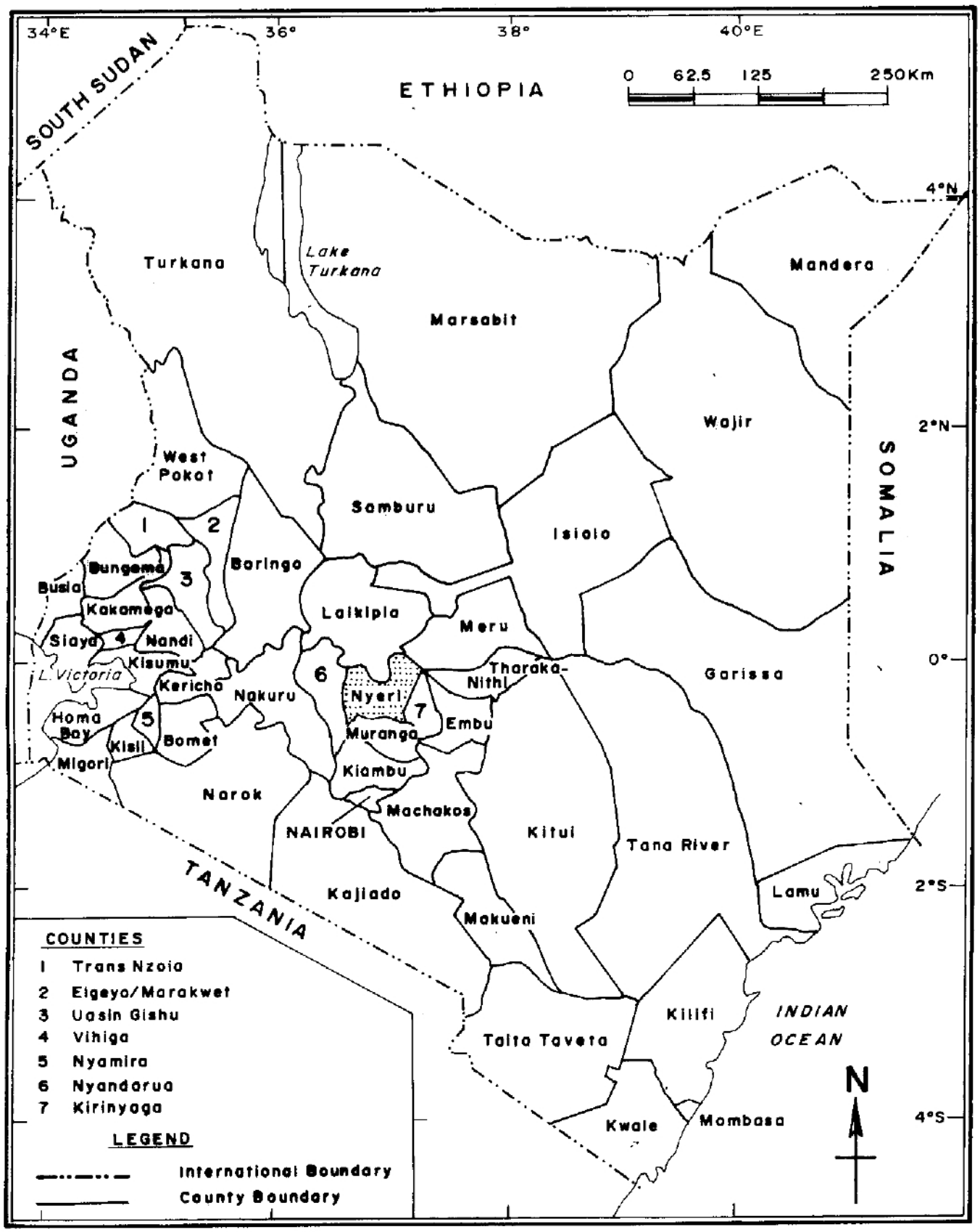


Figure 2.1 Location of Nyeri County in Kenya.
Source: District Development Plan, 2002-2008.

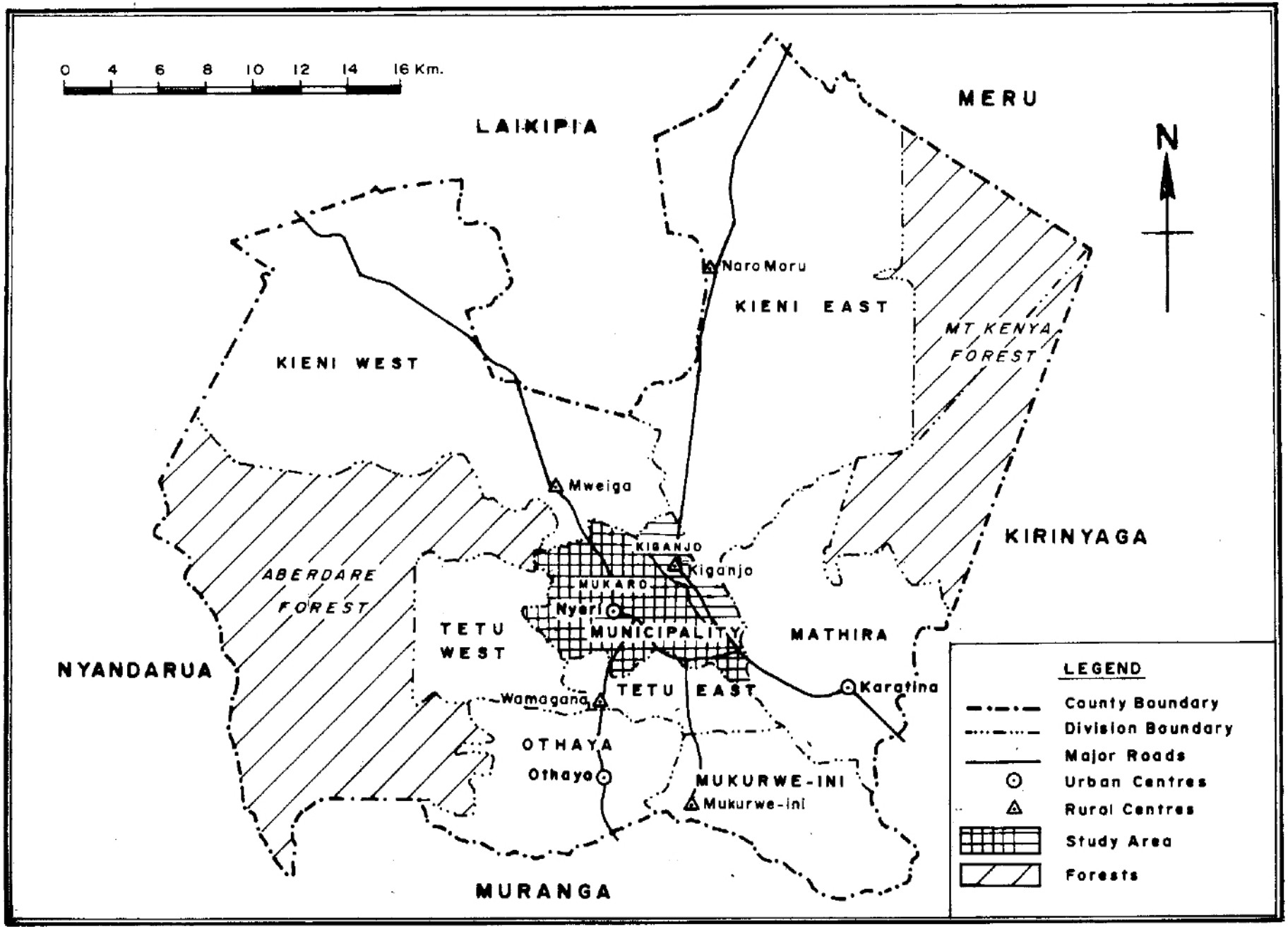


Figure 2.2 Nyeri County Administrative Boundaries

Source: District Development Plan, 2002-2008 and KNBS, 2010.

2.6 Economic Activities

2.6.1 Agriculture

Majority of the people in the County depend on the agricultural sector for their livelihood, with 90% directly or indirectly employed in the sector. Coffee, Tea, and dairy farming are the main agricultural activities in the County. The main food crops grown are maize, beans and Irish potatoes. 90% of the production is majorly through small scale farming. The temperature and rainfall patterns have a great influence on the County's economic activities and in particular agricultural activities.

The majority of the population in Mathira, Tetu, Mukurwe-ini, Othaya and Kieni divisions practice crop and livestock farming. Tetu, Othaya, Mathira and Mukurwe-ini grow both food and cash crops while in Kieni which is a relatively low potential land with low rainfall grows subsistence and drought resistant crops.

There has been a general increase in agro-forestry through the involvement of non-resident cultivators who tend to the trees as they carry out their normal farming activities. The co-operative sub-sector has been important in the marketing of agricultural produce and other products and services. It also assists in the provision of farm inputs, credit facilities and training.

2.6.2 Fish Farming

The County is well endowed with rivers, dams and a number of private ponds which provide a favorable environment for fish farming. Fish farming has been showing an upward trend in the recent past as more members of the population embrace the consumption of fish, especially tilapia as an alternate cheap source of protein.

2.6.3 Other Activities

There are several industries in Nyeri County; these include Mt. Kenya Bottlers, Highland Water, Central Kenya Coffee Mills, Kenya Cooperative creameries, Maisha Floor mills besides several tea factories.

Fifty percent of the County population is engaged in forest related activities like saw mills and furniture works. The main forest products are timber, fencing poles and firewood.

2.7 Energy

The County is under supplied with energy (ROK 2002a). Majority of the population in the County rely on wood fuel as their primary source of energy. Electricity accounts for about 10 percent of the energy consumed in the County. By the year 2009 only 26.3% of households in Nyeri County had electricity. 0.4 percent of households in the County use solar power while 80 percent use fuel wood and charcoal. 90 percent of the households in the County use Kerosene, gas or biogas. According to the Nyeri District Development Plan 2002-2008 the development priority in the energy sector is to shift from the traditional fuels to modern types of energy in order to protect the environment and ensure there is adequate energy to stimulate economic growth.

2.8 Vegetation, Environmental Conservation and Management

2.8.1 Vegetation

Generally, Nyeri County is well covered with vegetation. The western part of the County is flat whereas further southwards the topography is often characterized by steep ridges and valleys, occasionally interrupted by hills such as Karima, Nyeri and Tumutumu. Land ownership is largely smallholder (average small scale farm size is 0.6 hectares) and the drier part of it covered with ranches and large scale irrigations (average large scale farm size is 4 hectares).

The size of the gazetted forest is 115,119.04 hectares while the size of the non-gazetted forest is 4,000 hectares (ROK 2002b). The Aberdares area has unusual vegetation, rugged terrain, deep ravines cutting through its forested eastern and western slopes, clear water streams and waterfalls combine to create an area of great scenic beauty. Mt. Kenya slopes are cloaked in forest, bamboo, scrub and moorland giving way to high central peaks of rock, ice and snow.

Though the County is widely believed to be an agriculturally high potential district with plenty of rainfall, 51 percent of the district is semi-Arid. Kieni East and Kieni West Divisions form the largest part of the County and they are semi-arid. Kieni is characterized by low primary vegetation productivity and high geographical and seasonal variability in water availability (both surface and accessible ground water). This explains the scant vegetation in Kieni East and Kieni West Divisions.

2.8.2 Environmental Conservation and Management

The district development plan 2002-2008 identifies various factors that have contributed to environmental degradation in the County. Key among these factors are:

Population: The results of the 2009 census indicated that the population of Nyeri County grew from 677,216 to 693,558 persons that is by 2.4%. Population pressure and unsustainable natural resources utilization has accelerated degradation, this has been more so in the areas of Aberdares and Mt. Kenya forests which have been put under severe pressure through unsustainable exploitation (ROK 2002b). This has resulted to destruction of the County's important catchment areas affecting river flows.

Deforestation: it is closely linked to population. As the population depletes the resources around them they resort to the forested areas leading to deforestation. Deforestation affects the quality of the forest ecosystem reducing its ability to provide for mankind. Deforestation in the area has increased as people clear land for agriculture. However, with the ban on agricultural activities in the forest ecosystems the situation is expected to improve. To address the issue of forest destruction, the District development plan 2002-2008, proposed that committees be formed by the forest department together with communities living adjacent to the forests in order to involve the communities in forest management and find ways of sharing the benefits of the forests sustainably.

Environmental conservation efforts in the area have created a thriving business for tree seedling farmers who get their seeds and seedlings from the mountain as well as the Aberdares forest. More farmers are planting trees in an effort to increase tree cover in the area which has been depleted by farming and charcoal farming.

CHAPTER THREE: LITERATURE REVIEW

3.1 Introduction

This chapter reviews existing literature on various aspects of energy. This includes: importance of energy to the economy, statistics on wood fuel supply and demand in Kenya and specifically in Nyeri County, effects of wood fuel consumption to the economy as well as to rural households, rural household responses to the challenges facing them in sourcing for wood fuel, effects of these responses to the environment and socio-economic status of rural households. This chapter reviews and criticizes the various studies that have been done in the past in relation to wood fuel consumption and their importance while identify the gaps to be addressed. Finally, the chapter states and explains the study's conceptual framework.

3.2 Importance of Energy to the Economy

Economic development is a complex process involving capital accumulation, labour productivity increases, enhancement of human capital, societal transformation and increased economic output (Hosier 1985). Energy plays an important role in economic development and also protection of the environment. It is the most important single source of renewable energy providing over 9% of the global total primary energy supply with more than two billion people depending on wood energy for cooking and/or heating, particularly in households in developing countries (FAO 2011) At the individual level energy satisfies basic human needs for food, lighting and heating, while at the national and local levels, it plays a decisive role in employment and income creation (GVEP 2006). However for most economies especially developing economies only the conventional types of energy (petroleum, electricity) are considered while computing Gross National Product (GNP). Kamfor (2002), states that there is often a strong positive correlation between increased *per capita* consumption of conventional energy and a country's expanding GNP. Energy consumption is strongly related to levels of economic activity in a country, the more energy that is consumed by an economy the more vigorous that economy is assumed to be (Hosier 1985). In Kenya, the contribution of the energy sector to the overall tax revenue is about 20%, equivalent to 4% of GDP (ROK 2004).

There is now universal acceptance that energy is a necessary but insufficient requirement for economic growth (FEMA 2007). Two in five people worldwide rely on fuel-wood or charcoal

as their sole source of domestic energy for heating or cooking and of today's 2000 million users, some 1000 million face fuel shortages as supplies of wood fuels dwindle, among them 100 million already experience virtual 'fuel-wood famine' (FAO 1995). Most if not all the developing countries rely on biomass energy as opposed to other forms of energy like electricity and petroleum. Statistics by FAO (2005) state that wood fuel provides more than 70 percent of energy in 34 developing countries and more than 90 percent in 13 countries (including 11 in Africa). Over 85 % of the population in Kenya rely on traditional fuels such as wood, charcoal, dung, and agricultural residues for cooking and heating (ROK 2011b)

Energy is a crucial input to the respective sectors of the economy which include households; enterprise sectors (comprising industry, large, small and medium enterprises), building and commerce and j*ua kali:* transport; agriculture; service sector (ICT, financial and banking, tourism etc); basic services – health, education, water, etc; electricity generation; and Government – civil and military (GVEP 2006). The commercial energy sector in Kenya is dominated by petroleum and electricity as the prime movers of the modern sector of the economy, while wood fuel provides energy needs of the traditional sector including rural communities and the urban poor (ROK 2004). Nyoike (1993) classifies wood fuel consumers into rural households, urban households, industries and institutions. However studies generally divide consumers of energy in Kenya into five sectors: household sector, commercial sector, manufacturing sector, transport sector and agricultural sector (Nyoike 1993). The same broad categories are supported by Bhagavan (1996) who states that the Kenyan economy relies on six different types of energy: wood fuel, petroleum fuels, electricity, ethanol, wind and solar with the last two sources of energy being limited in use (Bhagavan 1996).

3.3 Wood Fuel Supply and Consumption

3.3.1 Wood Fuel Supply and Consumption in Kenya

At the national level, wood fuel and other biomass account for about 68% of the total primary energy consumption, followed by petroleum at 22%, electricity at 9% and others at about less than 1%. About 75 percent of the rural population in Kenya depends on fuel-wood as their primary source of energy while the urban population uses charcoal. There has been an increasing trend in the demand for this resource. The amount of energy consumption from this source has increased significantly, an average annual growth rate of about 6 percent between

1984 and 1989 (Nyoike 1993). According to Bhagavan (1996) in Kenya like other developing countries, the economy is divided into the modern and traditional sectors, the traditional sector is dependent on wood fuel (fuel-wood and charcoal) as a source of energy while the modern sector uses electricity and petroleum. The dualism is an important determinant of Kenya's energy supply matrix and wood fuel is the predominant energy source in the traditional sector (Bhagavan 1996).

Kamfor (2002) classifies Kenya's energy sources into two categories: a) traditional that includes wood, charcoal and other biomass, and b) conventional, such as petroleum products and electricity. During a workshop on poverty and linkages: energy access for the rural poor, Mbuthi (2005) noted that fuel-wood is the largest form of primary energy consumed in Kenya, accounting for about 68 percent followed by Petroleum and electricity at 22 percent and 9 percent respectively, while solar, wind, biogas, bagasse and micro-hydropower account for the remaining 1 percent (Mbuthi 2005). According to the National Development Plan 2002-2008, Kenya's wood fuel demand is increasing at an estimated rate of 5 percent per year (ROK 2002a). Over 93 percent of the rural population is dependent on wood fuel. Kenya's recorded sales of fuel-wood and charcoal products in 2007 was estimated at 88,200 stacked cubic metres, an increase from 44,000 stacked cubic metres in 2006 (CBS 2004). These were recorded sales by the Kenya Forest Service. Currently the demand for wood production in Kenya stands at 13.7 million cubic meters and is expected to outstrip the sustainable supply coming from the indigenous forests, plantations and the arid and semi-arid lands (ROK 2002a). On the current trends of wood and other forest products needs, the Kenya Forestry master plan states that the demand for charcoal can still be met although it is transported to the towns from as far as 200 Kilometres (KFD 1994). Further, fourteen districts are regularly experiencing fuel-wood deficits and it is expected that the fuel-wood deficits will extend to other districts, and that the feared fuel-wood crisis will actually occur (KFD 1994).

In Kenya, the wood stocks are being depleted to satisfy the demands of fuel-wood and charcoal. According to Ludeki (2006) some of the challenges that necessitated the formulation and adoption of Forestry Policy 2005 is increasing demand for wood fuel especially wood fuel, timber and unsustainable exploitation practices especially forest plantations. Due to lack of a serious campaign to replace the cleared stocks, the demand is slowly outstripping supply

(Ludeki 2006). In a vicious cycle, as standing stocks begin to be depleted, yields are further decreased and stock depletion is further accelerated (O'Keefe et al. 1984a). O'Keefe et al. (1984a) projected stock depletion at 21.62 million tonnes per year by 1995 having escalated rapidly from the 1980s with the trend holding on.

The sources of wood fuel can be both forested and non-forested areas. In the rural neighborhoods of developing countries, wood is sometimes traded informally or in the marketplace but the majority of users harvest it as a 'common property resource' from forests and from scattered pockets or belts of trees at field margins or roadsides and on waste or common ground (FAO 1995). Central Bureau of Statistics (2004) estimated the supply of wood fuel in 2007 by gazzetted forests at 8 percent with on-farm production supplies of wood fuel accounting for 84 percent. However, it is difficult to estimate the amount of wood fuel obtained from non-forested areas because most people in the rural areas do not keep such records. It is estimated that Kenya has a sustainable wood fuel supply of 15 million metric tonnes against a demand of 35 million metric tonnes, creating a deficit of 60 percent (Kamfor 2002). Kamfor (2002) foresees that this would therefore imply that the demand for wood fuel will outstrip supply of the same leading to increased pressure on the environment and particularly on the forest resource.

About 18 percent of the urban population use charcoal and improved cook stoves, and to make one metric tonne of charcoal 8.5 metric tonnes of fuel-wood is required at an efficiency of 10-14 percent (Kamfor 2002). The United Nations (1997) estimated the demand for wood energy would increase at an annual rate of 6.5 percent up to the year 2010, after which demand would grow at an average annual rate of 3.8 percent while the annual rate of increase in charcoal demand projected at 11.4 percent will result in a shortfall of about 23.3 million tonnes by the year 2010. It is thus important to increase the existing stocks to meet the rising demand. The Ministry of Energy in the 1988/89 household survey determined per-capita consumption using the 1989 census data at an average of 761 kg/year. The Kenya Forestry Master Plan (1994), projects fuel-wood demand to be 31,720,000 m^3 by the year 2010, 35,880,000 m^3 by 2015 up from 27,693,300 m^3 in the year 2005. This indicates rising demands which must be met by adequate and sustainable supplies if we are to avoid a continuous increase in the deficit. Further, this supports the fuel wood gap theory of a looming crisis unless significant measures are taken.

3.3.2 Wood Fuel Supply and Consumption in Nyeri County

The Kamfor Company study gave demand /consumption of biomass in central province to be 4,628,861 tonnes per year in 2000 while the supply was 1,328,707 tonnes per year this gives a biomass deficit of 3,300,154 tonnes, a 71.30 percent deficit. With a biomass deficit of 71 percent, the results placed central province as third highest in biomass deficit. In the analysis of biomass energy balances per district biomass demand of Nyeri County was 823,010 tonnes against a supply of 252,000 tonnes (208,508 tonnes of woody biomass, 42,392 tonnes of farm residue and 1,100 tonnes of wood wastes). The biomass deficit in the County is therefore 571,010 tonnes per year.

According to the Nyeri district development plan 2002-2008, Nyeri County has two forest ecosystems: Aberdares and Mount Kenya under the the Kenya Forest Service and three isolated forested hills, that is, Karima, Tumutumu and Gatumbiro hills which are under the local authority management. These are the sources of forested supplies for the County. Such supplies however are restricted and not readily available to the community. Households then have to continue relying on wood fuel supply from on farm production. With the County boasting of two major forests: the Aberdares and Mt.Kenya, the forest cover is generally higher than in other Counties. However with time, the forest cover is gradually reducing due to increased wood fuel demand (ROK 2002b). The Nyeri district development plan, 2002-2008 indicates that 88 percent of the population in Nyeri County is rural while the urban population which is approximately 82,000 persons forms about 12 percent of the County's population. Majority of the population in the County is dependent on wood fuel as the major source of energy: 80 percent of the County's population (ROK 2002b).

According to the Nyeri County fact sheet 2002, the area under study, Municipality division, has the highest population in Nyeri County (603 persons per km^2). The division is located at the centre of the County. Mt. Kenya and Aberdare forests are to the right and left sides of the County respectively. Only a small section of the division borders Aberdares, thus making the division reliant on on-farm wood supplies.

3.4 Effects of Wood Fuel Consumption

The major environmental problems facing the developing world are depletion and degradation of tropical forests, soil erosion, sedimentation and degradation of soil systems, fuel-wood shortage, air and water pollution, extinction of species and reduction in biological diversity or genetic erosion (Bowonder 1984). Bowonder (1984) further observes that except water pollution all the other problems are linked to energy use in rural areas. Problems of fuel-wood supply and demand are linked closely to other factors such as demographic trends, alternative fuel availability, social patterns, economic projections, biomass availability and government policies (O'Keefe et al. 1984b). United Nations identifies five key factors that influence fuel-wood consumption: household incomes, consumer preference and fuel availability, fuel substitutability, climate, household size and population increase with household size and population increase related to environmental degradation (FAO 1997). Large households consume more fuel than a small household (Omosa 1987) An increase in population results not only in an increased demand for wood and woody products but also in a growing demand for agricultural products (FAO 2011). This results in competition between wood energy demand and demand for agricultural products. Further, holding population density constant, rainfall determines biomass production rates and indirectly influences the consumption of traditional fuels. Areas with low rainfall will not support high levels of wood off-take thus high consumption of wood in such areas will result in land degradation. Such are the effects of unsustainable wood consumption.

While in 1980 more than half of the wood supply came from the net annual production of the growing stock, by the year 2000, it was predicted that more than 70 percent would have to be provided from the growing stock itself (Kamfor 2002). As a result Kamfor (2002) states that the increasing size of the wood demand being met by the gradual erosion of the growing stock capital was predicted to lead to widespread deforestation and general environmental degradation. The same observation was made by Food and Agriculture Organization noting that although most current wood fuel are derived from by products (residuals and wastes), in the future more will be derived directly from forests and tree plantations (FAO 2007). The positive and negative implication of increased use of wood as fuel will depend on the rationality of future energy, environmental, forestry and industrial policies, including the role of incentives and taxes for the promotion of wood as fuel.

The environmental impacts of charcoal making and fuel-wood cutting to meet rural and urban demands can be extremely severe especially in ecologically sensitive areas like the ASALs. In his study on the effects of use of biomass energy by rural households on the dryland environment of Mwingi district, Gikonyo (2004) observed that the key environmental impacts arising from unsustainable biomass use for energy from the study were: deforestation; destruction of water catchment and subsequent drying of rivers and water resources scarcity; soil erosion; loss of fertility and air pollution. Conversely, FAO (1997) observes that fuel-wood is not a common problem in the ASAL areas of Kenya since the population is low and sparsely distributed, and a wide variety of vegetation species is available for use as fuel-wood. United Nations further explains that most shortages experienced in the ASAL areas are due to the demand from the high-potential agricultural areas as well as the major urban centers, therefore imposing no danger of land degradation arising from unsustainable consumption of fuel-wood. However, in some of the arid and semi-arid areas despite the low levels of human settlement the rate of wood utilizations has exceeded the ability of these fragile ecosystems to regenerate setting the pace for land degradation. This crisis could spill over to other sectors of the economy leading to vicious circles of environmental degradation.

Increased demand of wood fuel in the urban areas has led to sourcing of the commodity in ecologically fragile environments impacting negatively on the water resources and soils (O'Keefe et al. 1984a). O'Keefe et al (1984a) further note that the impact on the soils is being felt by decreasing agricultural production while water scarcity has highlighted the destruction of fragile ecologies. Demand for these fuels in and around towns and cities can affect rural livelihoods and environmental stability in outlying areas, where the living resource is harvested (FAO 1995). When and where a ready market for charcoal exists this necessitates supply of the same. In Somalia, for example, the inhabitants of the capital city, Mogadishu, used around 42,000 tonnes (about half a tonne each) of wood fuel in 1983, mainly as charcoal, such concentrated urban purchasing power of large cities such as Mogadishu makes it worthwhile for traders to transport fuels there from rural areas; thus wood fuel resources are consequently depleted at ever increasing distances from the city (FAO 1995). This is usually a major cause of deforestation for rural areas. According to Food and Agriculture organization, as long as there is a demand for wood fuel in the urban and peri-urban areas the rural areas will continue supplying wood energy. However, fuel gathering and production in the rural setting is integrated with

other land use aspects, so it may be difficult to trace a direct link between wood fuel use and deforestation (Karekezi & Mackenzie 1993).

In Nyeri County the encroachment on forest resources has contributed to among other things scarcity of water. Water supply is inadequate in the County especially due to the semi-arid condition of 50 percent of the area of the County (ROK 2002b). Water shortage has also been compounded by the destruction of catchment areas and wanton destruction of forests in both the Aberdares and Mt. Kenya forests (ROK 2002b). The Nyeri district development plan 2002-2008 however notes that with the restrictions on forest resources tightening there is less extraction of wood from the forests with supplies increasingly being taken from farms.

Wood fuel does not only have negative impacts on the environment but also has social, economic and health effects associated with its consumption. According to Gikonyo (2004), increased distances to source biomass energy; increased durations spent in biomass energy collection; use of monetary resources in purchasing of previously free firewood and cheap charcoal; loss of cultural practices associated with use of biomass energy; food security; disease and gender inequality are some of the social and economic impacts of unsustainable wood fuel consumption. Some of these impacts were brought out by Omosa (1987) in her study on the causes and effects of fuel-wood scarcity in Bura irrigation settlement scheme where she concluded that tenants walked long distances to access fuel wood, spent many hours gathering fuel-wood and spent large sums of money purchasing the same.

The type of energy used in households greatly affects the health of livelihood of women and young children who spend a good amount of their day in activities related to energy collection and cooking (Nassuna 2007). Along with the collection of domestic water supplies, the collection of fuel wood is one of the most time-consuming tasks undertaken by rural women – with the amount of time increasing as supplies become scarcer as a result of deforestation (Carr & Hartl 2010). Carr & Hartl (2010) further note that the provision of fuel encompasses not only time spent in travelling, cutting and carrying, but also in preparation of fuel for burning and use, which can take more time than the actual collection itself.

3.5 Household Responses to Reduced Wood Fuel Availability

Rural households develop different strategies to cope with decreasing fuelwood availability (Brouwer et al. 1997). In principle, all consumer groups avail themselves a range of options to adapt their consumption pattern to changing conditions (FAO 1997). In a situation of decreasing fuel-wood availability, households will search for alternative sources by either ascending the hierarchy to charcoal, kerosene, gas or electricity or descend to agricultural residues and animal dung.

"For example, in response to reduced availability of fuelwood, a rural household could in principle: consume less by adopting fuelwood saving practices, substitute fuelwood partly with other biomass fuels or fossil fuels, pay more at local markets, spend more time in collecting fuelwood for free from distant locations, harvest fuelwood non-sustainably from trees nearby, grow additional fuelwood in the homestead, grow (additional) trees on agricultural land, change cooking practices (diets) so that less fuel is required and adopt a combination of options and/or other solutions (FAO 1997)." Adaptations also occur in type of fuel used, by a switch to fuel of an inferior quality or to wood from fruit trees (Brouwer et al. 1997). In contrast Damte et al. (2012) found out that 'households in rural Ethiopia do not readily switch to other biomass energy sources.' In Malawi, Brouwer et al, (1997) found out that the women in Malawi switched to twigs, greater amounts of which must be collected because of their poor burning qualities. In a study on Household Responses in Rural Ethiopia, Damte et al. (2012) concluded the following:

> "Households living in a degraded environment (low forest cover area) respond to fuelwood scarcity (measured by collection time per kilogram) by increasing their labor input to fuelwood collection. However, this is not the case for those living in high forest cover areas (HFC). Households in HFC areas respond neither to the physical measure nor economic measure of fuelwood scarcity.
>
> Brouwer et al. (1997, p. 30)"

Besides the negative ecological consequences of fuelwood scarcity, many of the common responses to fuelwood scarcity have negative social and economic consequences: as the immediate source of fuelwood becomes depleted, distances, and thus times, travelled for its collection increase (Mugo & Gathui 2010). Rural women and children in many African countries spend a significant portion of their time gathering and collecting woodfuel, crop

residues and animal dung for use in cooking and space heating *(ADB 2007)*. As fuel wood scarcity intensifies in many rural areas, the local women are finding their domestic chores increasingly difficult as they are compelled to walk longer distances (Muchiri 2008). This is further supported by (Dewees 1989; Damte et al. 2012) and (Arnold et al. 2003; Damte et al. 2012) who argued that scarcity increases the burden on women and children, who are the primarily collectors of biomass, significantly decreasing the amount of time they have for other tasks and activities. Brouwer et al, (1997) summarized responses of rural households to fuelwood scarcity as follows:

a. Fuel collection: under fuel collection the responses were increase in distance, increase in collection time, change in who collects (more children, older women, men), increase in frequency of collection and change in weight of bundle collected
b. Type of fuel used: use of less preferred types of fuel (twigs, crop residues), increase in purchase of fuelwood and increased use of fruit trees
c. Fuel use: reduction in energy end-uses, decrease in stock building and decrease in sales and exchange of fuelwood

These responses to wood fuel scarcity were similar to the findings of this study. Among the responses that the study established were; increase in distance, increase in frequency of collection, use of less preferred types of fuel and reduction in energy end-uses

3.6 Studies on Wood Fuel Demand and Supply and their Importance

The recognition of a wood fuel crisis in the late 1970's led to an awakening in developing countries. The prediction of a wood fuel crisis in developing countries in the 1980s was based largely on looking at supply and demand from forest plantations and natural forests. What followed was a series of surveys and studies conducted by various governments, non-governmental organizations and individuals or experts to establish the actual status. Of importance in Kenya were 3 studies conducted in the late 1970s and early 1980's:

In the year 1978 the Central Bureau of Statistics (CBS) in conjunction with the National Council for Science and Technology (NCST) conducted a nationwide survey on household energy consumption. This survey intended to obtain an accurate picture of domestic energy consumption at the national level (Hosier 1985). The survey measured the quantities of different

fuels used, namely: fuel-wood, charcoal, paraffin, Liquified Petroleum Gas, and electricity. The questionnaire used contained a one-page matrix listing fuel- types along the vertical axis and quantities consumed, distance travelled along the horizontal axis (Hosier 1985). The results of this survey were published in 1980. According to the results, the average Kenyan household uses nearly 4.6 tonnes of fuel-wood and 0.8 tonnes of charcoal annually, the total quantity of wood required to meet this demand is 25.1 million tonnes or 35.2 million m^3 (Hosier 1985). This first attempt at quantifying domestic energy consumption paved way for future studies.

In the year 1980, the Forestry Department conducted a survey on wood fuel use in Kenya. It was based on the assumption that an energy crisis was in existence and hence the need to review the national energy strategy. The survey interviewed domestic, institutional as well as industrial users. However, the original intent of the study was to survey only institutional and industrial users as supplements to the CBS study (Hosier 1985). But due to delays in the results of the CBS survey the Forestry department had to conduct their own survey on domestic consumption, the survey used simple stratified random sampling in its methodology (Hosier 2005). According to Hosier (2005) the national household demand for wood fuel was 25.4 million m^3. The study also revealed that about 80 percent of all the wood fuel consumed comes from private farms, woodlands or trust lands while only 13 percent come from government controlled forests.

The above two studies though criticized by different scholars gave direction and set a basis upon which subsequent studies were carried out. Hosier (2005) criticized the two studies especially on the methodology used in conducting the surveys and the units of measurements used. Both studies used different units of measurements with the CBS using tonnes and the Forestry department using cubic meters this in turn made it difficult for comparison and gave different results. However, it would be fit to say that they were pioneer studies on wood fuel consumption in Kenya.

In the early 1980s the Beijer institute under its Kenya Fuel-wood Cycle Project (KFC) conducted a study on household energy consumption in rural Kenya. The study had 3 set goals: to provide a reliable estimate of rural household energy consumption in Kenya, to provide useful explanatory insights into the process determining rural household energy consumption and finally to provide a foundation for future energy work at the local and national levels

(Hosier 1985). The methodology of the study in particular the design of the questionnaire and sampling frame were given special attention. This was to avoid the "*methodological pitfalls of its predessors"* (Hosier 1985). The results of the study were given in terms of consumption per household per year. Fuel-wood consumption was 4.75 tonnes per household per year while charcoal consumption stood at 0.66 tonnes per household per year (Hosier 1985). The Beijer Institute has since conducted surveys under the Kenya Wood fuel Development Project (KWDP) project funded by the Dutch government and implemented by Beijer Institute (1984-1988) as a follow up of Kenya Fuel-wood Project.

The above three are among the earliest studies conducted on wood fuel consumption in Kenya. Other studies have since been done both at institutional level and individual level. Among them, the Kenya charcoal survey: a study on charcoal production systems conducted by Bess as part of the Ministry of Planning and National Development's long range planning programme in 1989. The study examined the dynamics of charcoal production and its effects on rural land use and ecology.

After a long duration without a nationwide survey, the Ministry of Energy (MOE) commissioned the Kamfor Company Limited to examine the major energy sources used by households and small scale industries and service establishments in the country in the year 2000. The study was timely and necessary since there had not been an examination of the country's overall energy sector since the 1980 Beijer Institute's study (Kamfor 2002). The first objective of the study was to develop a policy strategy for providing Kenyan households and cottage industries with their respective energy needs in a cost effective manner and with minimum negative environmental effects. The second objective was to outline a cost-effective priority investment and technical assistance programme to address energy-related problems of medium and low income households and cottage industries. The study looked at all the 7 provinces in the country dividing the districts in the provinces into 3 Agro-ecological zones; high, medium and low. The household energy survey used a questionnaire administered to 2,300 households in 15 representative rural districts and five major urban centers. In all, a total of 230 clusters comprising of 1,790 rural and 510 urban households (Kamfor 2002). Biomass consumption as at the year 2010 was projected at 44,599,347 tonnes against a sustainable supply of 16,634,550 tonnes. The results of the study showed a continued deficit of biomass

upto the year 2020. Biomass deficit for the year 2015 was projected at 31,180,555 tonnes and 33,856,589 tonnes by the year 2020.

In the year 2009 Kenya Institute for Public Policy Research and Analysis (KIPPRA) was contracted by The Energy Regulatory Commission (ERC) to carry out a comprehensive study and analysis on energy consumption patterns in Kenya. The report of the study findings were released in July 2010. The study found out that the key drivers of energy choice for majority of the energy type include income of household head, employment level, price of energy, education level, total energy expenditure and location by region among other factors. Some of the drivers like household income and price came out strongly during this study being some of the factors that affected energy consumption in Mukaro location, Nyeri County.

The KIPPRA study established that an increase in income will lead to higher consumption of fuel wood, kerosene, charcoal and LPG suggesting that these fuels have price elasticities like normal goods. The highest elasticities (greater than one) are for fuel wood and kerosene implying that an increase in total energy expenditure will lead to more than proportionate increase in the expenditure shares (KIPPRA 2010). Further KIPPRA (2010) noted that, the lowest expenditure elasticities are for LPG and charcoal implying that an increase in total energy expenditure will lead to less than proportionate increase in the expenditure shares.

Other studies have been conducted at the local level by various researchers. Mary Omosa conducted a study in the year 1987 entitled The Fuel crisis in rural Kenya: a socioeconomic analysis of the causes and effects of the fuel-wood scarcity in Bura Irrigation settlement scheme, Tana River District. The main objective of the study was to explain factors that influence fuel wood consumption among the tenants in Bura Irrigation settlement scheme. The study found out that fuel wood consumption is influenced by household size, consumer's age composition, level of education, adaptation to the prevailing conditions and availability and accessibility of the resource area. Some of the factors like level of education were identified by KIPPRA (2010) as drivers of energy consumption. The study found out that one of the factors affecting energy consumption was household size and accessibility of the resource, thus agreeing with some of the results in Omosa's study.

Omosa (1987) found out that farmers (tenants) walked long distances and spent many hours gathering and/or large sums of money purchasing the same, cut down on the number of meals cooked per day, reduced time for other activities or leisure due to collecting Fuelwood from far distances. These effects were similar to the effects of wood fuel consumption established under this study in Mukaro location.

Mutua (2006) carried out a study in Kitui District on Biomass energy consumption. The study focused on biomass energy consumed, their sources, demand-supply (im)balance and the associated impacts to the environment. The study involved eleven urban settlements, picking a sample of 104 households and 48 institutions. According to Mutua (2006) charcoal and fuel wood form the bulk of biomass energy consumed in the urban settlements with charcoal forming 46 percent and Fuelwood 30 percent. About 95 percent of the households purchase charcoal and 37 percent of the households purchase fuel wood (Mutua 2006). Moreover, the study identified the following impacts of biomass energy consumption; unsustainable use of natural vegetation, drying of rivers and depletion of water source, increase in fire incidences, soil erosion, loss of soil fertility, air pollution and climate change. However, Mutua (2006) pointed out that when collected and used directly near its source, biomass has a moderate to high net useful energy yield.

Nzamba (2007) carried out a study on factors influencing the adoption of solar energy technology in Katulani sub-location, Kitui district. The study sought to establish the factors that limit widespread adoption of solar as the alternative source of energy in Katulani sub-location. The study sampled 100 respondents. According to Nzamba (2007) 75 percent of the households did not use solar mainly because of cost of installation yet the sub-location has sunshine throughout the year. This finding was similar to this study, which found out that the adoption of solar energy was negligible mainly due to cost of installation.

The energy studies at the local are individual based without much coordination hence it becomes difficult for researchers to access a common database on the various studies that have been conducted in the Country. The above mentioned studies have been significant in providing data and guidelines on national household energy consumption. However various gaps emerge from the studies:

a. Various studies have looked at energy consumption at a national level, with few and scattered studies at the local level. This leaves room for energy studies to be conducted at the local levels. This study fills in this gap by providing more information on energy consumption and in particular wood fuel consumption in Mukaro location, Nyeri County.

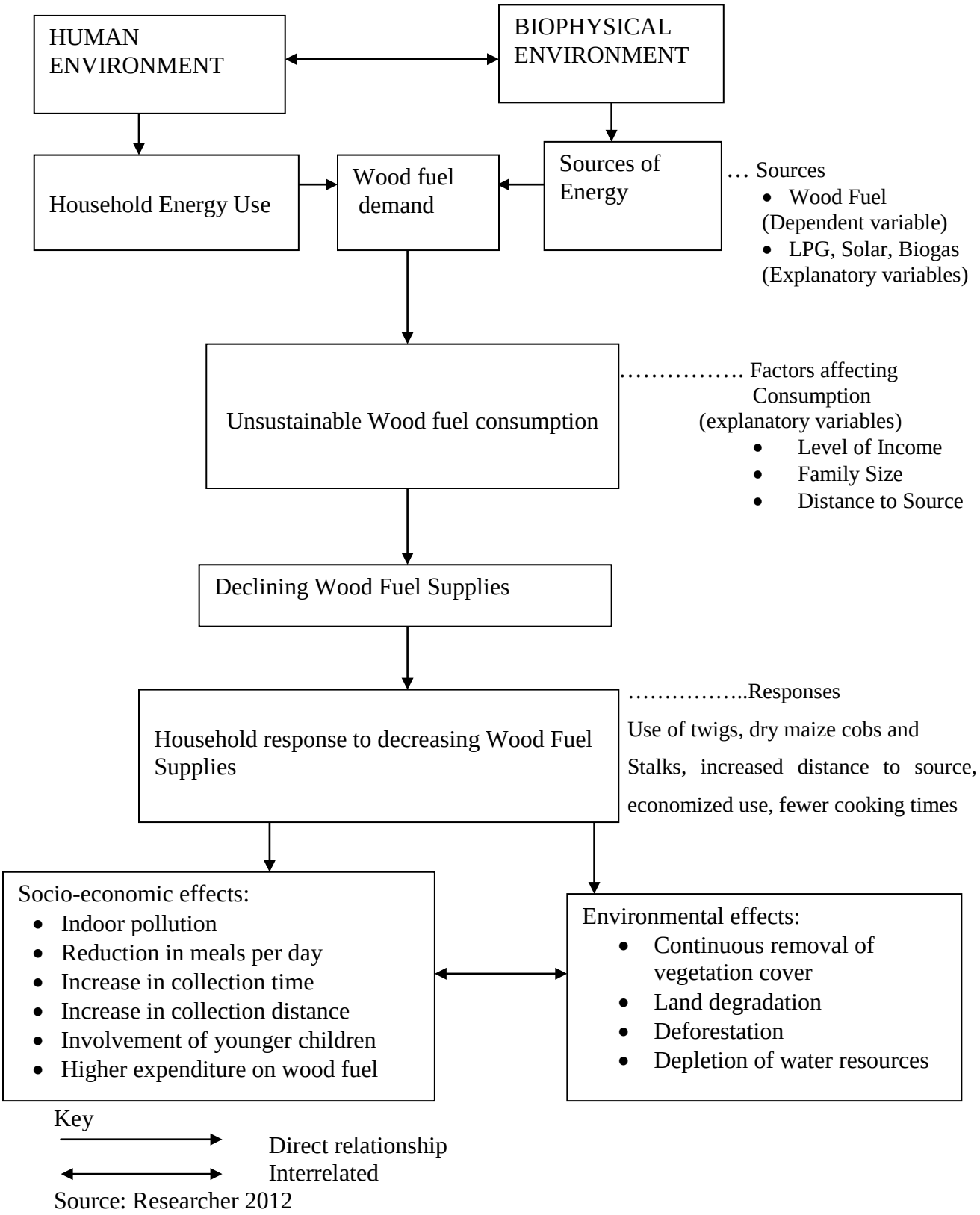
b. Studies have looked at energy consumption from a supply demand perspective. Though this provides a general picture on the energy situation whereby most studies have identified a deficit, there is need to identify the factors affecting energy consumption. Moreover there have been few localized studies that have brought out the responses of households to the energy deficit and specifically to wood fuel deficit. This study fills in the gap by providing empirical evidence on the various strategies that households have adopted in coping with wood fuel scarcity in Mukaro location, Nyeri County.

c. Data on consumption of wood fuel especially in the rural areas has not been well documented and where it has been is most likely outdated. This study has contributed to existing data by providing recent information on energy consumption in Nyeri County. The study has gone further to document household responses to wood fuel scarcity as well as the environmental and socio-economic effects of the responses. Information collected shall be useful to the Government and NGO's in drafting energy policies in the County.

3.7 Conceptual Framework

Conceptual framework shows the relationships involved in analyzing the research problem. The framework began with identifying the interaction between humans and the biophysical environment. The human environment generates demand for energy which is supplied by the biophysical environment. The demand for energy in particular wood fuel is primarily for domestic use, which includes, cooking and heating. Wood fuel is sourced from forest as well as non forest resources (physical environment) like plantations and farms. Various factors determine how much wood fuel a household consumes. Such factors include household size, income, availability of wood fuel and distance to source. Continued reliance on wood fuel and lack of replenishment of wood fuel resources has resulted to reduced wood fuel availability. This has presented a significant challenge to rural households as they struggle to meet their daily energy demands. With alternative energy options being expensive as compared to wood fuel, rural households have had to develop coping strategies to respond to this challenge. A household may choose to adopt one or a combination of various coping strategies. These strategies have diverse effects on the socio-economic status of households as well as on the physical environment.

Fig 3.1 Conceptual Framework



Source: Researcher 2012

CHAPTER FOUR: RESEARCH METHODOLOGY

4.1 Introduction

This chapter presents the sources of data, methods of data collection, instruments used to collect primary data and the sources of secondary data. The chapter explains the sampling procedure and gives details on data presentation techniques used in the study. Finally, the methods used to test the study's hypotheses are explained in this chapter.

4.2 Sources of Data

4.2.1 Primary Data

i. Questionnaire

The questionnaire was the main research instrument used to collect primary data. The questionnaire was chosen because of ease in administration to a large sample and is free of interviewer's biasness. It contained both structured, closed ended questions as well as open ended questions. It also contained a set of matrix questions. The likert scale was used with the matrix questions since this is the most commonly used rating scale.

The questionnaire was structured into 4 parts:

Part 1: this section collected background information on the respondents. This included information on family size and position of the respondent in the household.

Part 2: this section gathered information on various factors that affect energy consumption, that is, the type of energy that households were using, quantity of energy consumed, cost of energy, distance travelled to source for energy and the number of times the household sourced for a particular type of energy.

Part 3: this part sought information on the challenges that households were facing while sourcing for energy and the coping strategies that households had adopted to deal with the challenges.

Part 4: this was the final section of the questionnaire. It gathered data on the environmental and socio-economic effects associated with household responses to the challenges facing them while sourcing for energy.

While administering the questionnaire, answers were sought preferably from the women in the households, since they were assumed to be tasked with the responsibility of collecting firewood and looking for charcoal. Administration of questionnaires by interviewing the respondent was chosen so that the questions could be well read out and answers clearly written down. This also increased the chances of the number of questionnaires answered unlike the self administered questionnaires and saved on time that would have been used to collect the questionnaires. It also saved on time that would have been used on sending follow up letters and reduced on the expenses of sending the same.

ii. Observation

The study also used observation method to collect primary data. Households were requested to gather a bundle of firewood which they approximately used in a day. The researcher used observation method to verify some of the estimates the households gave. Observation method was also be used in addition to answering part four of the questionnaire. The Researcher made a general observation on the environment to assess the state of the environment. Through observation the researcher was able to identify some of the coping strategies that households were using to deal with the energy challenges.

iii. Measurements

The study made use of various measurements to collect primary data. To determine the weight of firewood used per day, women were asked to lay out a bundle of firewood equivalent to the amount used per day. This bundle was measured using a weighing scale by the research team. The study measured the amount of firewood and charcoal in kilograms. The study also took data on the amount of Kenya shilling used in purchasing both a bundle of firewood and a bag of charcoal. Electricity consumed was measured in kilowatts per month while LPG consumed was recorded using the number of kilograms used per month. To determine income levels, the households were requested to estimate how much they earn per month in Kenya shillings. Access to wood fuel was measured by the number of kilometers travelled.

iv. Interviews

The questionnaires were administered using interview method. Data from key informants was also collected using interview method. Key informants for this study included officials in the

energy department, forest department, environment department and Non-Governmental Organizations (NGO's) that were involved in the energy and environment sectors. They were important sources of information on interventions that have been put in place to address the various challenges that households were facing in energy consumption. Among this group of key informants were the energy suppliers who provided significant information on energy demand and consumption. Structured interview schedules for energy suppliers and other key informants were designed and used to collect the required information. However, additional information offered was captured in the form of notes.

4.2.2 Secondary Data

This formed the bulk of literature review chapter of the study. Secondary data formed the background information and brought out the need for the collection of the primary data.

The secondary data was sourced from published and unpublished books, relevant reports, magazines and journals, government publications, research projects and thesis and also from the internet.

4.3 Sample Size and Sampling Technique

4.3.1 Sample size

The following formula was used to determine the sample size as recommended by Mugenda & Mugenda (1999).

$$n=\frac{z^2\,pq}{d^2}$$

Where:

n= the desired sample size

z= the standard normal deviate at the required confidence level

p= the population in the target population estimated to have the characteristics being measured

q= I-p

d= the level of statistical significance set

In the year 2000, fuel wood supplied 89% of rural energy with a per capita annual consumption of 741 kg (Mugo & Gathui 2010). This is supported further by the National Development Plan 2002-2008, which states that over 93 percent of the rural population is dependent on wood fuel.

Given this previous data the study assumed that 90 per cent of the population had the desired characteristics the study was looking for.

With the desired level of accuracy at 0.05 and the z-statistic at 1.96 the sample size was calculated as follows:

$$n = \frac{(1.96)^2 (0.90)(0.10)}{(0.05)^2}$$

$$= 138$$

4.3.2 Sampling Technique

The study population consisted of 12,660 households in 9 sub-locations of Mukaro location, Nyeri County. Since it was impossible to study the whole population due to time and financial limitations the population was sampled. This reduced the number of households that the researcher needed to interview thus saving on time and financial costs.

The study used multi stage sampling technique. This technique was chosen since it was administratively convenient and financially economical. It also gave the flexibility of combining different sampling techniques. Picking of the study area was done via 6 stages:

Stage 1: choosing the County

Nyeri County was chosen purposely because of familiarity thus easing the process of data collection

Stage 2: choosing the District

Nyeri County has 2 districts Nyeri South and Nyeri North. For this study Nyeri South was purposely chosen at this stage because it had a higher population than Nyeri North.

Stage 3: choosing the Division

Nyeri South has 5 divisions: Municipality, Mukurweini, Othaya, Tetu East and Tetu West. Out of the 5 divisions, Municipality and Othaya have a good combination of rural and urban population. Municipality division was chosen through simple random sampling

Stage 4: choosing the Location

Municipality division has 2 locations, Mukaro and Kiganjo. Through simple random sampling Mukaro was chosen

Stage 5: choosing the sub-locations

Mukaro location consists of 18 sub-locations. The study picked half of the sub-locations using simple random sampling. This gave equal probability to all sub-locations. Fishbowl technique with replacement was used. All the 18 subjects were placed in a container and each picked randomly with replacement. Once a sub-location was picked then it was returned to the container. If a sub- location was picked twice then it was ignored. The following sub-locations were picked, Ruringu, Gitathini, Riamukurwe, Mathari, Gatitu, Muthua-ini, Mununga-ini, Kinunga and Chorongi. Muthuaini was picked twice but ignored the second time and another sub location picked.

Stage 6: Picking sample households from sub-locations

The study then picked 138 households from the 9 sub locations for the study. From each of the 9 sub locations the study selected households proportionately according to the population of the sub-location. That is, the total population of the sub-location divide by the total population of the 9 sub-locations multiplied by the required sample size which is 138. The sub-location with the highest population had the highest number of households to be sampled while the one with the least population had the least number of households to be sampled. For each sub-location the household to be interviewed was selected using systematic random sampling. The first household to be interviewed was picked randomly; thereafter the study took every K^{th} case. The sampling interval which is the distance between the households selected for the sample was calculated by dividing the total number of households by the sample size from each sub location.

Table 4.1: K^{th} case calculations and number of households to be picked in each sub-location

Sub location	Total no of households	No. of households to be studied	K^{th} case
Ruringu	4785	52	92
Gitathini	706	8	88
Riamukurwe	894	10	89
Mathari	2094	23	91
Gatitu	650	7	93
Muthua-ini	939	10	94
Mununga ini	776	8	97
Kinunga	370	4	93
Chorongi	1446	16	90
Total	12660	138	

4.4 Data Presentation and Analysis

4.4.1 Data presentation

The study has presented data mainly in two forms: tabulation and diagrammatic representation.

Tabulation

This entails presenting data in an array of rows and columns. Use of tables condenses large mass of data, enables comparison to be made easily among classes of data and also takes up less space than data presented in narrative form (Alabi 2007). The study has tabulated data obtained for some of the objectives of the study. Due to the simplicity that comes with use of tables, it can be difficult to see numerical relationships and patterns, a graph makes these clearer (Joyce et. al 2008). Beyond use of tables the study has also used diagrammatic representation.

Diagrammatic representation

Diagrammatic representation brings out the visual impact in a better way. The study has used Pie charts, bar graphs, histograms and photographs to present data. Pie charts have been used to present data on household income and show the changes in wood fuel consumption as a result of change in price. The study has used bar graphs to present data on sources of energy and to

show the various types of coping strategies that households have adopted in response to declining wood fuel supplies. Graphs make it easier to report patterns and relationships, shapes of distributions, and trends. In addition the study has used photographs to show information captured during data collection in the study area.

4.4.2 Data Analysis

The study used both quantitative and qualitative techniques of data analysis.

Percentage

This is a proportion of a particular value in relation to 100. The study used percentages to standardize values for comparison purposes. The study calculated the proportion of respondents using a particular source of energy, proportion of respondents purchasing energy, proportion of households in each income bracket among others.

The Mean

This is the arithmetic average of a set of data and is obtained by summing up all the scores and dividing by the total number of cases. It was the most frequent measure of central tendency used in the study as is with other studies conducted by various researchers. For example, in a study on responses of rural households to decreasing fuelwood availability in Ntcheu District, Malawi, Brouwer (1997) used averages and distributions in calculating type of fuel used, fuel supply (collection or purchase), exchange and presence of stock of fuel-wood.

The study calculated the average consumption of firewood and charcoal used by households per week, the average income of respondents, the average household size and the average distance travelled to access firewood.

The Mode

It is the most frequently occurring value in a set of observations. The mode was used to show the source of energy used frequently, the most frequent family size and the most frequent income bracket.

Standard deviation and the variance

Standard deviation indicates the extent to which scores in a distribution deviate from their mean or in other words how tightly the scores are clustered around the mean. It is obtained by

subtracting the mean from each score to obtain the deviation. If we square each deviation, sum the squared deviations and then divide by the total degrees of freedom, we obtain the variance. By taking the square root of the variance, we obtain the standard deviation. When the scores are close together and the bell-shaped curve is steep, the standard deviation is small but when the scores are spread apart and the bell curve is relatively flat, then the standard deviation is relatively large.

Chi-square test (X^2)

A Chi Square (X^2) statistic is used to investigate whether distributions of categorical variables differ from one another. The Chi Square statistic compares the tallies or counts of categorical responses between two (or more) independent groups. Under Chi square, the observed data is compared with data we would expect to obtain according to a specific hypothesis. The data is arranged in rows and columns. The cells contain the frequencies of each observation. The Chi Square test yields one value which should be equal or greater than zero. The calculated Chi Square statistic is compared to the Chi Square value from the tables. If the calculated Chi Square statistic is greater than the Chi Square table value then the null hypothesis is rejected and the alternative hypothesis accepted.

Though the Chi-square test is a non-parametric test and often regarded as a less powerful technique of establishing relationships compared to other correlational techniques, the study took a sample big enough to ensure the results were more reliable.

Chi Square test was used to test hypothesis one and three. It was best suited to test these hypotheses for the following reasons:

a. Simple random sampling was used
b. The population was more than 10 times larger than the sample
c. The variables under study were categorical

Regression analysis

Regression analysis is a statistical technique for studying linear relationships. It assumes a general form for the relationship, known as the *regression model*:

$$Y = \alpha + \beta_1 X_1 + ... + \beta_k X_k + \varepsilon \, .$$

Y is the dependent variable, while X_1,..., X_k are the *explanatory variables* or the independent variables. α, β_1,..., β_k are regression coefficients.

Regression analysis helps one understand how the typical value of the dependent variable changes when any one of the independent variables is varied, while the other independent variables are held fixed. There are some basic assumptions of multiple regression analysis which the data being analyzed was required to meet in order to give a valid result.

1. Variables are normally distributed
2. There needs to be a linear relationship between the independent and dependent variables
3. Variables are measured without error
4. Independence of observations
5. Data needs to show homoscedasticity, that is**,** the variances along the line of best fit remain similar as you move along the line.

The study used SPSS to run the regression model defining the direction of the relationship between the various explanatory variables with the dependent variable and gave a regression model. The ANOVA table generated indicated how the regression model predicted the outcome variable. It assisted in rejecting or accepting the null hypothesis.

The study used regression analysis to test hypothesis two: there is no relationship between the factors affecting wood fuel consumption and consumption in Mukaro location, Nyeri County.

Qualitative analysis

In qualitative analysis 'the researcher is interested in analyzing information in a systematic way in order to come to some useful conclusions and recommendations (Mugenda & Mugenda 1999).' Due to the nature of the study qualitative analysis was used to analyze data on the following objectives: Identifying the challenges that rural households faced in sourcing for energy, identifying the coping strategies that rural households had adopted in response to reduced wood fuel availability and investigating the environmental and socio-economic effects associated with the coping strategies adopted.

The study also used this statistical technique to test hypothesis four: household responses to reduced wood fuel availability do not have any environmental or socio-economic effects in Mukaro location, Nyeri County which was qualitative.

CHAPTER FIVE: FINDINGS AND DISCUSSION

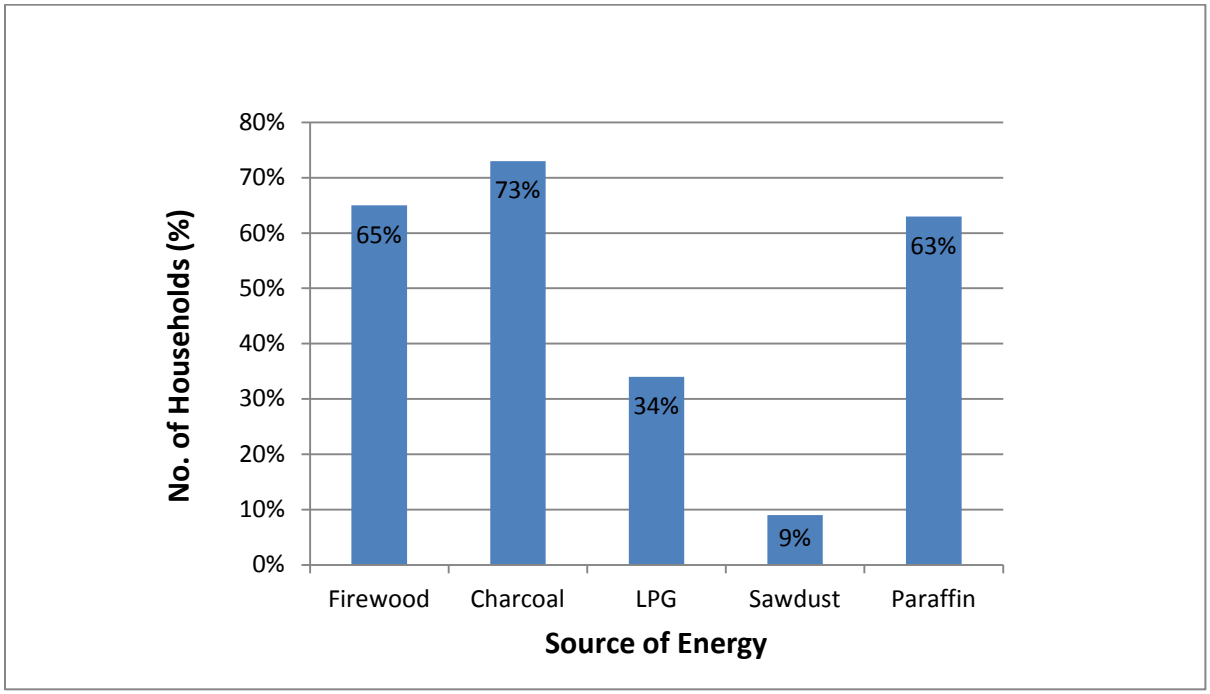
5.1 Introduction

This chapter presents and explains the empirical results of the study. It gives the results of data analysis according to the objectives of the study. The results are presented in tables, graphs and photographs (plates). Further the chapter explains and gives the results of hypothesis testing. Hypothesis testing is done using chi-square and regression analysis and the results presented mainly using tables.

5.2 Sources of Energy

One of the main objectives of the study was to identify the sources of energy used by households. Figure 5.1 shows the percentage number of households utilizing different types of energy. However, most households had more than one source of energy. For example, the source of lighting was in most cases different from the source of cooking.

Figure 5.1 Sources of Energy



Source: Researcher, 2012

Figure 5.1 shows that wood fuel which comprises firewood and charcoal was the most popular source of energy used by households mainly for cooking. This has been a traditional source of

energy and still remains popular despite the fact that supplies are dwindling. With reduced supplies households in the area had stopped lighting fires for the sole purpose of warming the house. On average a household in Mukaro location consumed 88 kilograms of firewood per week. Most of the firewood consumed was collected from non forest sources (only 36% of households purchased firewood) with households travelling an average distance of 984 meters to access firewood. Fuelwood was consumed in the form of split wood, branches and twigs. Split wood and branches were more popular since they burn longer than twigs. Most women preferred to use split wood from blue gum and wattle trees. Branches from the Grevilea tree were commonly used when harvested. The forest authority once in a while allowed the neighboring households to collect firewood from the forest especially when they pruned the trees. There are no localized forests in Municipality division forcing homesteads to purchase firewood. Households purchasing firewood spent an average of Ksh 280 per week.

Plate 5.1 A woman carrying a load of firewood

Plate 5.1 shows a woman carrying a load of firewood that would serve the family energy needs for about two days. She had sourced the firewood from within her homestead. During the field research it was common to meet with women carrying such loads of firewood.

Charcoal was also a popular source of energy in Mukaro location with a household consuming an average of 16 kilograms per week. Charcoal was more popular with households located at the shopping centres and in the urban area. Most of the charcoal consumed was sourced from Kieni which is about 50 kilometers away. 98% of the households using charcoal were purchasing it, spending an average of Ksh 240 per week.

Out of 138 households interviewed there was no single household using biogas. For the eight households using solar, it was used only for lighting purposes. In an interview with a government official, the reason behind very low use of biogas and solar is high installation costs. A domestic biogas or solar package would cost a household between Ksh 70,000 to Ksh 100,000 which is high, considering that the average household income in the study area fell between kes 5,000 and 10,000. It was no wonder that according to the records in the Ministry of Energy, Nyeri office only about 18 households had installed biogas.

LPG use was not widespread and was popular with households that were in the higher income group. For the 47 households consuming LPG, the level of consumption was low, it was used sparingly. Factors like price and access to LPG contributed significantly to low consumption of LPG. LPG was not readily available in the shopping centres and most households had to travel to town to access it. LPG was also considered an energy resource for the '*haves*' who could afford to purchase it.

63% of the households interviewed were using Paraffin. Paraffin was used by the rural households for lighting while some households located in the shopping centres and town used it for cooking. Paraffin use was slightly high due to the fact that most households had no connection to electricity thus used paraffin for lighting. Interestingly, households with electricity connections stocked low amounts of paraffin to cater for the days with power blackouts.

Of all sources of energy sawdust had the least number of users, its unpopularity being due to non availability and the tendency to smoke a lot compared to other sources of energy. Most

sawmills in the area were closed when access to forests in the area was restricted making sawdust unavailable. In most instances households were using sawdust to cook foods that took long before they were ready or to warm bathing water. In one of the households using sawdust, it had been acquired from a neighbor who had cut down a tree, instances which were not common in the area hence she indicated that she sometimes travelled far to access sawdust. Plate 5.2 shows sawdust that was piled in a corner of the respondent kitchen for household use.

Plate 5.2 Sawdust piled in a kitchen

Hypothesis 1

H0: There is no difference in fire wood consumption as compared to charcoal, electricity, and LPG consumption by households in Mukaro location, Nyeri County

H1: There is a difference in fire wood consumption as compared to charcoal, electricity and LPG consumption by households in Mukaro location, Nyeri County

To test this hypothesis, Chi Square (X^2) test was used. The observed contingency table generated was a 5 by 5 contingency table (omitting the 21-25 row). Table 5.1 shows the initial observed contingency table.

Table 5.1 Initial observed contingency table

Range	Qty of firewood in a month (Kgs/100)	Qty of charcoal in month(Kgs/10)	Qty of LPG in a month(Kgs)	Paraffin in a month (Litres)	Quantity of electricity (kilowats/10)	Totals
0-5	117	91	124	112	119	563
6-10	9	19	4	11	9	52
11-15	2	15	0	1	0	18
16-20	0	0	0	4	0	4
21-25	0	0	0	0	0	0
26-30	0	3	0	0	0	3
Totals	128	128	128	128	128	640

In table 5.1, the rows represented the amount consumed of each source of energy in a range while the columns represented the source of energy. While analyzing the data the range of 21-25 was eliminated since it had nil observations. When this data was subjected to Chi Square test the expected contingency table had some values that were less than one.

According to Preacher (2001) use of the Chi Square test is inappropriate if any expected frequency is below 1 or if the expected frequency is less than 5 in more than 20% of the cells. One of the solutions to this problem is to take a large sample. However, this would have been very costly and time consuming. Kirkman (1996) gives two solutions to deal with the problem of contingency tables with sparsely populated cells or small frequencies; he recommends either use of Fisher exact test or re-binning. He says “in many contingency tables the "outcomes" are related to each other and can be legitimately combined to fold rarely populated cases into similar but more commonly populated cases (Kirkman, 1996)”. This is the definition of re-binning. In Fisher exact test the observed outcomes are embedded in a universe of similar tables that have the same outcome probabilities. This produces very many tables making the test very tedious. Kirkman (1996) states that unless under special instances Chi square should be used as compared to Fisher exact test. Given this argument, the rows with few frequencies were eliminated to avoid having expected values of less than one. It was assumed that the frequencies were very small as such their elimination would not cause any significant difference in the results obtained. The observed contingency table now became a 2 by 5 contingency table. Table 5.2 shows the observed contingency table

Table 5.2 Observed contingency table with fewer rows

Range	Qty of firewood in a month (Kgs/100)	Qty of charcoal in month(Kgs/10)	Qty of LPG in a month(Kgs)	Paraffin in a month (Litres)	Quantity of electricity (kilowats/10)	Totals
0-5	117	91	124	112	119	563
6-10	9	19	4	11	9	52
Totals	126	110	128	123	128	615

Observed contingency table 5.2 gave an expected contingency table with expected values of more than 5. Table 5.3 shows the expected contingency table

Table 5.3 Expected contingency table

Range	Qty of firewood in a month (Kgs/100)	Qty of charcoal in month(Kgs/10)	Qty of LPG in a month(Kgs)	Paraffin in a month (Litres)	Quantity of electricity (kilowats/10)	Totals
0-5	115.0	101.0	117.0	113.0	117.0	563
6-10	10.7	9.30	10.8	10.4	10.8	52
Totals	126	110	128	123	128	615

RESULTS:

Chi Square statistic calculated was 16.4. The degrees of freedom (df) equals 4 (that is, *rows-1 x columns –1*) and the predetermined alpha level of significance 0.05. Reading from the Chi square distribution table with 4 degree of freedom, the value was *9.488*. This therefore meant that the Null hypothesis (H_0) was rejected and alternative hypothesis accepted. Thus, from the Chi square test the study concluded that there was a difference in firewood consumption as compared to charcoal, electricity and LPG consumption by households in Mukaro location, Nyeri County

These results confirmed what was expected from the study given the reliance on firewood as a source of energy by the rural population. About 65% of the households interviewed were using firewood. Majority of the households that were not using firewood were living in the urban area where the design of the houses did not give much room for firewood use. Despite the growing

unavailability of firewood, it still remained more available than other sources of energy. The study found out that firewood was no longer a freely available communal resource as sources were slowly becoming depleted, but households continued to rely on it because it was relatively cheaper compared to other sources of energy. Given this situation the results of the Chi square test confirmed what was expected.

5.3 Factors Affecting Energy Consumption

There were various factors affecting energy consumption by rural households in Mukaro location, Nyeri County. The same factors posed challenges to households in sourcing for energy.

5.3.1 Price

Just like other commodities one of the factors that influenced consumption of wood fuel was price. 35.5% of the household's interviewed were purchasing firewood while 71% of the households interviewed were purchasing charcoal. The price of firewood differed in various sub locations though to a small extent. From the interviews, the price of wood fuel was an indicator of reduced wood fuel availability, with 34% of the households using firewood and 35% of households using charcoal indicating that they had reduced the amount of wood fuel consumed as a result of increase in prices. The suppliers priced wood fuel depending on the distance travelled to acquire the wood fuel and price at which they bought the wood fuel. Wood fuel availability also determined the prices. Of the households purchasing firewood, 39% of the households indicated that the prices of firewood had increased in the past one year while 75% of the households consuming charcoal indicated that the price of charcoal had increased in the last one year. Households reacted to change in prices by either reducing consumption, increasing their consumption while for some change in price did not affect the amount of wood fuel they consumed. Figure 5.2 and 5.3 show the responses of households to change in wood fuel prices. From the Interviews households were asked if they had changed the amount of wood fuel consumed as a result of change in prices. Figure 5.2 shows that majority of the households did not change the amount of firewood consumed as a result of change in prices. Most households were still consuming the same amount of firewod despite increase in prices. The probale effect of this was that households were spending more to purchase firewood. This also showed the importance of firewood as a source of energy for the rural households.

Figure 5.2 Change in consumption as a result of increase in prices of firewood

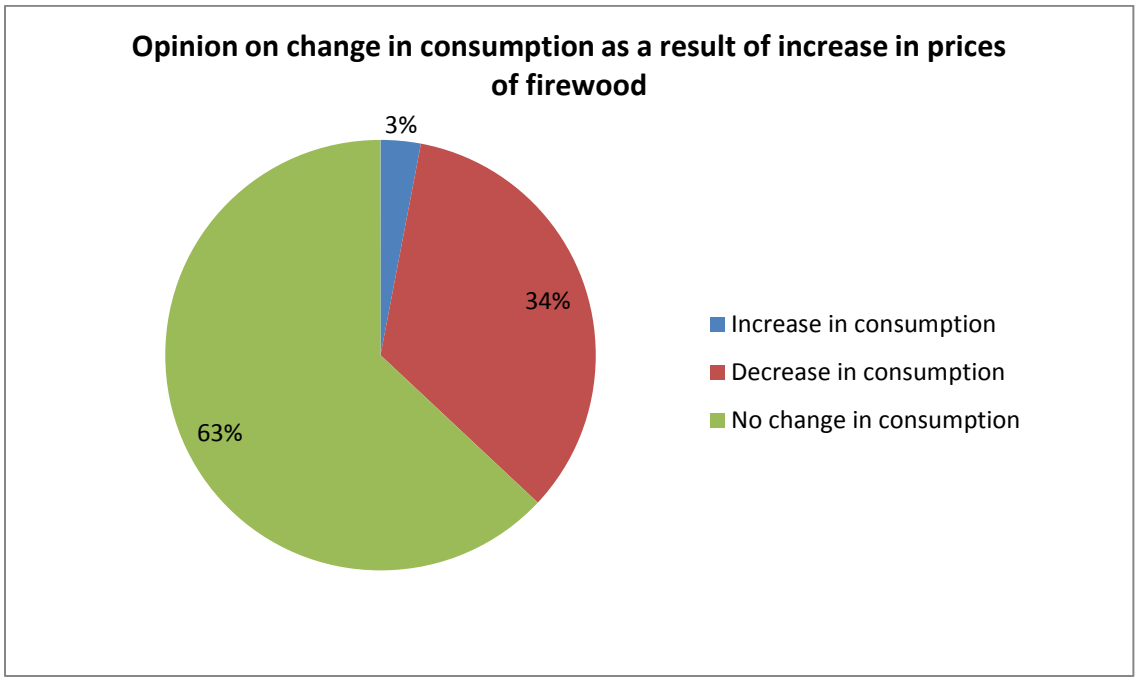
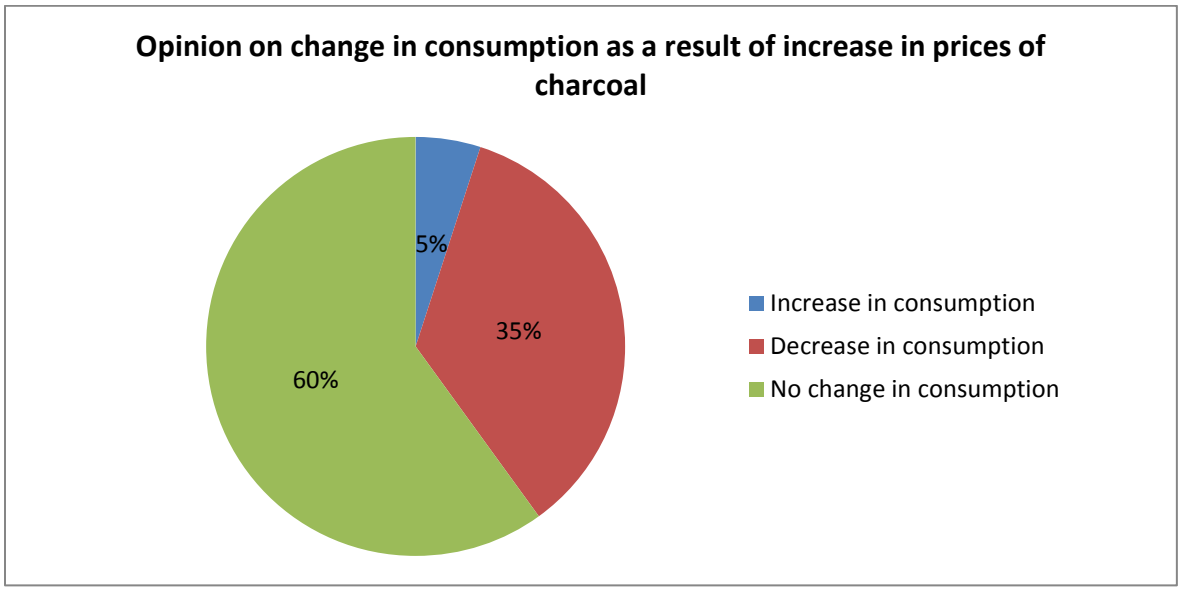


Figure 5.3 Change in consumption as a result of increase in prices of charcoal



Similarly figure 5.3 shows that majority of the households using charcoal did not change the amount they were consuming as a result of change in prices only 5 percent of households reduced their consumption as a result of change in price of charcoal.

Charcoal and firewood accounted for the largest source of energy for rural households in Mukaro location and was more affordable compared to other sources of energy like paraffin, electricity and LPG which were relatively more expensive than wood fuel. For this reason, households would not easily switch from fuel wood and charcoal to other sources of energy despite an increase in prices. Secondly, given the importance of wood fuel as a major source of energy especially for cooking, households could not fail to use the resource. From the interviews with firewood and charcoal suppliers, the demand for wood fuel exists; their major challenge was to meet the demand. Price remained a challenge to rural households due to constant increase while the purchasing power remained low.

5.3.2 Distance to source

Charcoal was accessible to households that could afford to buy. It was sold in the shopping centres and in some instances supplied to the homesteads. For the households using charcoal there was no change in distance travelled to obtain charcoal; they could access charcoal from the same points of access. As for firewood, 24% of the users indicated that the distance to access firewood had increased in the past one year. Distance travelled to obtain firewood had increased on average from 200 meters to 1.68 kilometers. However, despite the increase in distance majority of the households did not adjust the amount consumed downwards since they felt they needed to use the same amount of energy. With reducing fuel wood availability, increase in distance to source will remain a challenge as households continue to source firewood further from their homesteads.

Out of the 90 households collecting firewood 22% had increased the number of times they collected firewood in a week from an average of 2 times a week to 3 times a week. Since firewood was not readily available, households were collecting more times in order to get the required quantity. Each household was engaging at least one member to collect firewood. In 98% of the households it was the woman who was tasked with the responsibility of looking for firewood. She would then involve younger members of the family to assist her with the responsibility of collecting firewood; this was necessitated more by reduced firewood supplies. This task deprived the woman of time to be engaged in other economically productive activities like farming yet she was supposed to till the land to provide food for the family while the men engaged in formal and informal employment. The study found out that 13% of the households

collecting firewood had involved younger children to assist in collecting firewood. This could be an indicator of growing firewood scarcity. As long as wood fuel remains or continues to be scarce this will continue to rob the woman most of her time as she searches for a dwindling commodity.

5.3.3 Household size

The average household size in Mukaro location was 4 persons. The mode also was 4, meaning that most households had 4 persons. Table 5.4 shows the frequency of households under each family size.

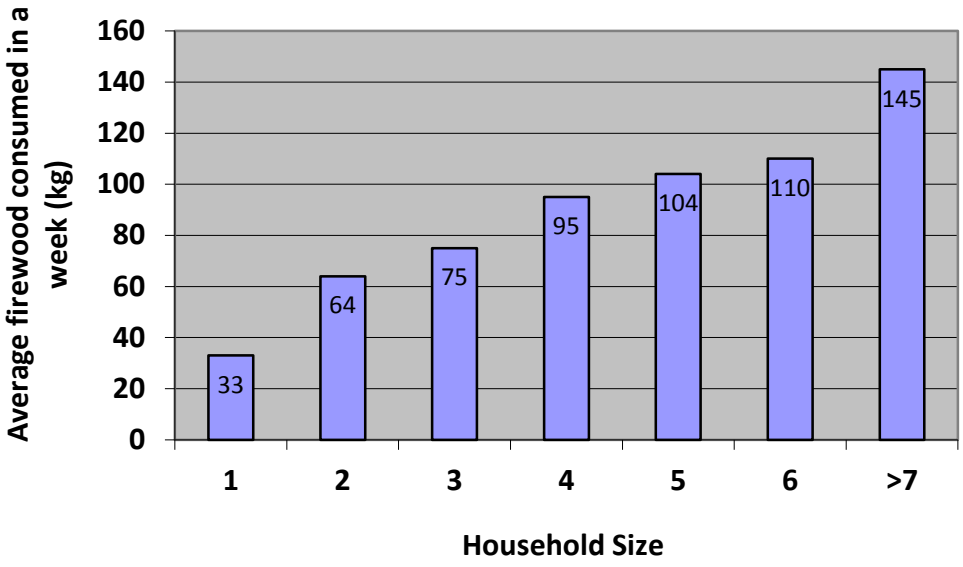
Table 5.4 Household Size frequency

Household size	1	2	3	4	5	6	7	>7
Frequency	12	23	33	34	17	11	3	5

The results of the study showed that the larger households (more than 5 persons) were consuming more than the smaller households (1-3 persons). The small households consisted of one to three persons, whereby it was either a widow, a couple whose children had grown up and left the household or a young couple yet to have children or with a single child. Such households consumed less as opposed to large households with more than five persons. Apart from the reason that such households would demand more fire wood for cooking and warming bath water, the high consumption can be explained by the fact that such households had more persons available to collect firewood.

Figure 5.4 shows the average fuel wood consumption according to the household size. It shows an increase in the average amount of firewood consumed per week as the household size increases.

Figure 5.4 Average Firewood Consumption vis-à-vis Household Size

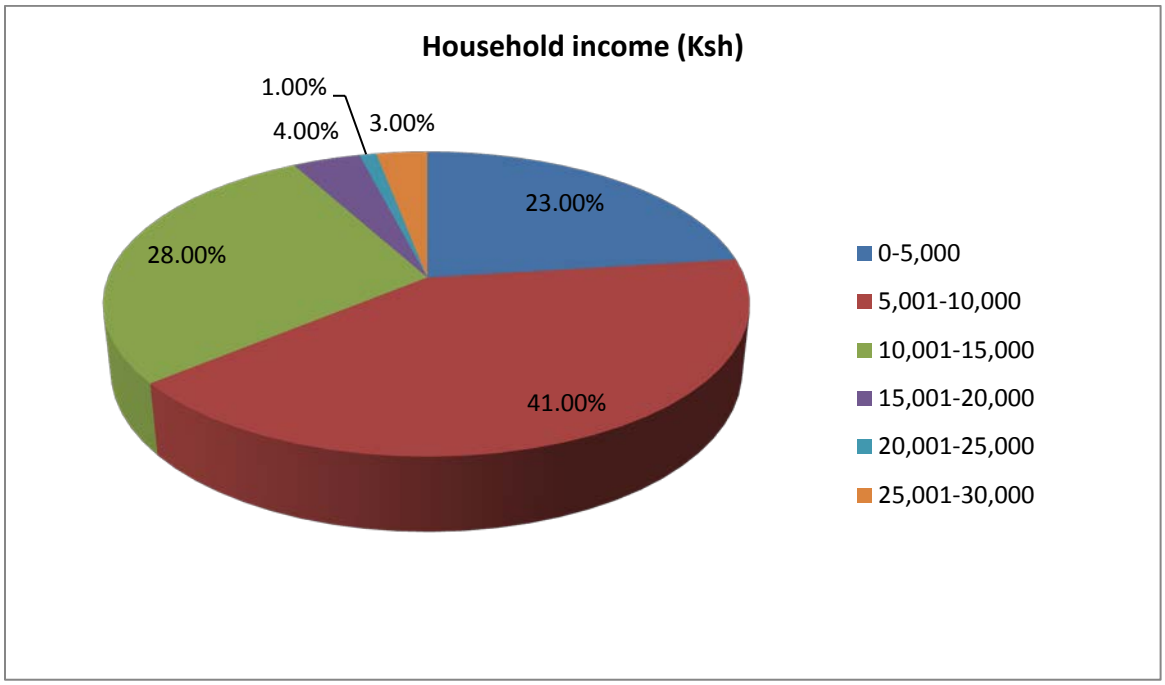


5.3.4 Household income

Figure 5.5 shows that the average income of the sampled households was in the bracket of Ksh 5,000 – 10,000. Figure 5.5 also indicates that only 8% of the households were earning a monthly income of more than Ksh 15,000.

This could explain why most households in the location were using wood fuel as their major source of energy due to low purchasing power. Majority of the households earned their income from farming and employment. The men were engaged in temporary (casual) as well as permanent employment while most of the women were engaged in farming activities.

Figure 5.5 Household income



The family income determined to some extent the type of fuel the household relied upon. Given the average income at between Ksh 5,000 and Ksh 10,000 most households opted to collect firewood as opposed to purchasing the same in order to reduce the costs. The effect of low incomes versus the need of energy came out in interviews, wood fuel suppliers pointed out that some households would buy wood fuel on credit, that is, pay at a later date. Some households would join efforts to buy a bundle of firewood and split amongst themselves. This was an indicator of low purchasing power of a commodity which the rural households cannot do without. Households with slightly higher incomes (Ksh 10,000-15,000) could afford to purchase charcoal and save on time used to collect firewood. Households with higher incomes (more than Ksh 15,000) were less than 10% of the sampled population. These households could afford to buy LPG. Table 5.5 shows the average energy consumption for households in various income brackets. Households in the lower income brackets (Ksh 0-10,000) were consuming more of wood fuel while those in the higher income brackets (more than Ksh 15,000) were using more of LPG, paraffin and electricity. Sawdust was also popular with households in the lower income brackets (Ksh 0-10,000). Most of the households with higher incomes were located in the urban area where they were using LPG and paraffin for cooking and electricity for lighting.

Table 5.5 Household Income and Energy Consumption

Income (Ksh)	Average consumption of firewood per week (kg)	Average consumption of charcoal per week (kg)	Average consumption of LPG per week (kg)	Average consumption of Sawdust per week (kg)	Average consumption of Paraffin per week (liters)	Average cost of electricity per month (Ksh)
0-5,000	85	16	1	5	713	125
5,001-10,000	64	11	3	2	644	260
10,001-15,000	32	10	5	1	545	345
15,001-20,000	42	8	8	0	667	675
Over 20,000	25	8	5	0	854	705

Hypothesis 2

H0: There is no relationship between factors affecting wood fuel consumption and consumption in Mukaro location, Nyeri County

H1: There is a relationship between factors affecting wood fuel consumption and consumption in Mukaro location, Nyeri County

This hypothesis was tested using regression analysis. **Regression analysis was chosen to test this hypothesis due to the following reasons:**

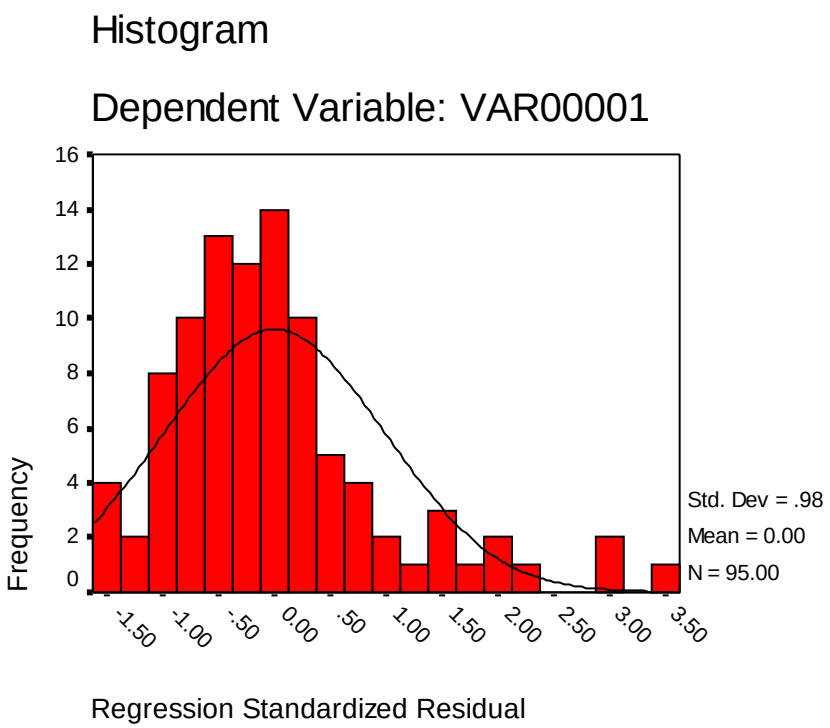
1. **The data met the regression assumptions (*see table 5.18* for data used to test the hypothesis)**
2. **It was the appropriate statistical tool to measure the changes in the dependent variable as a result of changes in the independent variables.**

Assumption tests

Assumption 1: variables are normally distributed.

Non-normally distributed variables or variables with substantial outliers can distort relationships and significance tests. Outliers can be identified through visual inspection of histograms. Using SPSS a histogram (figure 5.6) was generated from the data. Visual inspection of the histogram indicated the presence of a few outliers which despite elimination did not cause significant change in the results hence were not eliminated.

Fig 5.6 Histogram showing normality of regression variables



Assumption 2: Existence of a linear relationship.

The test of linearity was done using F test for lack of fit. This is a hypothesis test of whether the pattern between the variables is linear, or a higher order polynomial term (square or cube) is needed in the regression. The test was done using SPSS

A null hypothesis (Ho) for the test was set; a linear model is appropriate. The alternative hypothesis was a linear model is not appropriate. Failure to reject Ho satisfies the assumption. The study tested each independent variable against the dependent variable. The dependent variable was wood fuel consumption while the independent variables were distance travelled to collect firewood, household income and family size

a) Independent variable: distance travelled to collect firewood

Ho: a linear model is appropriate

H_1: a linear model is not appropriate

The results of the lack of fit test for independent variable distance travelled to collect firewood against dependent variable wood fuel consumption are summarized in table 5.6

Table 5.6 Lack of Fit Tests for the independent variable distance travelled to collect firewood

Source	Sum of Squares	df	Mean Square	F	Sig.
Lack of Fit	66545.512	12	5545.459	1.880	.049
Pure Error	238944.334	81	2949.930		

In the lack of fit test, the probability of the F test statistic (F=1.880) was p = .049, less than the alpha level of significance of 0.05. The null hypothesis that "a linear regression model is appropriate" was rejected. The alternative hypothesis that "a linear regression model is not appropriate" was supported by this test. However, p=0.049 is almost equal to the alpha level of significance of 0.05 thus this independent variable, under this study, shall be assumed to have a near linear relationship with the dependent variable and the assumption of linearity is satisfied.

b) Independent variable: household income

Table 5.7 Lack of Fit Tests for the independent variable household income

Source	Sum of Squares	df	Mean Square	F	Sig.
Lack of Fit	4948.892	4	1237.223	.394	.812
Pure Error	279154.674	89	3136.569		

Ho: a linear model is appropriate

H_1: a linear model is not appropriate

From the results in table 5.7, F test statistic (F=0.394) was p = .812, greater than the alpha level of significance of 0.05. The null hypothesis that "a linear regression model is appropriate" was not rejected. The alternative hypothesis that "a linear regression model is not appropriate" was not supported by this test. Thus, the assumption of linearity is satisfied

c) Independent variable: family size

Table 5.8 Lack of Fit Tests for the independent variable family size

Source	Sum of Squares	df	Mean Square	F	Sig.
Lack of Fit	13784.717	6	2297.453	.788	.582
Pure Error	253710.907	87	2916.217		

Ho: a linear model is appropriate

H_1: a linear model is not appropriate

From the results in table 5.8, F test statistic (F=0.788) was p = .582, greater than the alpha level of significance of 0.05. The null hypothesis that "a linear regression model is appropriate" was not rejected. The alternative hypothesis that "a linear regression model is not appropriate" was not supported by this test. Thus, the assumption of linearity is satisfied

Assumption 3: Variables are measured without error

This assumption was tested in SPSS using "casewise diagnostics" to help detect possible outliers. As per the results presented in table 5.9 three cases were picked out. However, after isolating the cases, it was observed that they did not cause any significant difference in the results hence they were not excluded from the data.

Table 5.9 Casewise Diagnostics

Case Number	Std. Residual	VAR00001	Predicted Value	Residual
26	3.027	280.00	123.6777	156.3223
29	3.549	294.00	110.7274	183.2726
82	3.011	252.00	96.5222	155.4778

Dependent Variable: Wood fuel consumption

Assumption 4: Independence of observations

This assumption assumes that the residuals are not correlated serially from one observation to the next, that is, the size of the residual for one case has no impact on the size of the residual for the next case. This was checked in SPSS using the Durbin-Watson statistic. Table 5.10 presents the results of the Durbin-Watson statistic test.

Table 5.10 Regression Model Summary for Durbin-Watson statistic

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.454(a)	.206	.180	51.64190	.206	7.863	3	91	.000	2.017

Explanatory variables: (Constant), Number of family members, Household Income, Distance
Dependent variable: Wood fuel consumption

The value of the Durbin-Watson statistic ranges from 0 to 4. As a general rule of thumb, the residuals are uncorrelated if the Durbin-Watson statistic is approximately 2. A value close to 0 indicates strong positive correlation, while a value of 4 indicates strong negative correlation. For this case the value of Durbin-Watson was 2.017 indicating no serial correlation.

Regression Analysis

This hypothesis had one dependent variable, wood fuel consumption, and three independent variables, that is, number of family members, distance travelled to collect firewood and household income. The data was regressed using SPSS and the following results were achieved.

Table 5.11 Regression Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.454(a)	.206	.180	51.64190

Explanatory variables: (Constant) Number of family members, Household Income, Distance

Table 5.11 shows R and R Square values. The R value indicates the degree of correlation. For this model the R value was 0.454 which indicated an average degree of correlation. The R square and adjusted R square values are statistics derived from the regression equation to quantify model performance. Their values range from 0 to 100 percent. The R Square value was 0.206 indicating that the weighted combination of the independent variables explained only 20% of the dependent variable. The adjusted R Square value estimates the expected shrinkage in R Square that would not generalize to the population because our solution is over-fitted to the data set by including too many independent variables. The adjusted R square value for this case was 0.180 which was close to R square 0.206 anticipating minimal shrinkage. The adjusted R is normally slightly lower than the R value.

Table 5.12 ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
	Regression	62905.712	3	20968.571	7.863	.000(a)
	Residual	242686.646	91	2666.886		
	Total	305592.358	94			

Explanatory variables: (Constant), Number of family members, Household Income, Distance
Dependent Variable: Wood fuel used per week in kg

Table 5.12, the **ANOVA** table, indicated that the regression model predicts the outcome variable significantly well. The **Sig.** column indicates the statistical significance of the regression model. In this case $p<0.05$, this indicated that, overall, the model applied can statistically significantly predict the outcome variable. *F value 7.863 was greater than F table value of 2.6802, thus the null hypothesis was rejected*

Table 5.13 Regression Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
(Constant)		76.765	16.501		4.652	.000
Current distance		.001	.004	.019	.204	.839
Household Income		-14.205	4.661	-.287	-3.048	.003
Number of family members		12.000	3.071	.367	3.908	.000

Dependent Variable: Quantity of firewood used per week in kg

Table 5.13 on coefficients indicates if they are statistically significant and if so, the direction of the relationship. α is the regression intercept. It represents the expected value for the dependent variable if all of the independent variables are zero. For this case the value was 76.76

For the explanatory variable current distance b=0.001 this indicated a positive relationship, the p value was 0.839 which indicated that the coefficient was not statistically significant given 95% confidence level. This was explained by the fact that most households were accessing wood fuel from a small radius within their homesteads. Thus, distance to source of wood fuel was not a major factor in determining how much wood fuel was consumed. The coefficient of the variable was very small and did not predict the dependent variable. Having no strong theoretical reason to keep it, it was removed from the regression equation.

The coefficient of the second explanatory variable household income was -14.205. The p value showed that the coefficient was statistically significant. The coefficient was negative indicating a negative relationship between household income and wood fuel consumed. The effect of household size (b=12.00) was significant and its coefficient was positive indicating that the larger the family the more wood fuel was consumed. This coefficient was also statistically important.

RESULTS:

The regression equation formed from the analysis was:

$$Y = 76.765 - 14.205\ X_1 + 12.00\ X_2$$

Where Y = Wood fuel consumption

X_1 = Household income

X_2 = No. of family members

The *F* value of 7.863 was greater than F table value of 2.6802, thus the null hypothesis which states that there is no relationship between level of income, family size, distance travelled to collect wood fuel and wood fuel consumption in Mukaro location, Nyeri County was rejected and the alternative hypothesis accepted.

Having accepted the alternative hypothesis that there is a relationship between household income, number of family members and wood fuel consumption, the direction of the relationships were defined in the regression equation above. The equation showed that there was a negative relationship between wood fuel consumption and income. The study found out that the households consuming a lot of wood fuel fall in the low income brackets since wood fuel is cheaper energy compared to the other sources of energy.

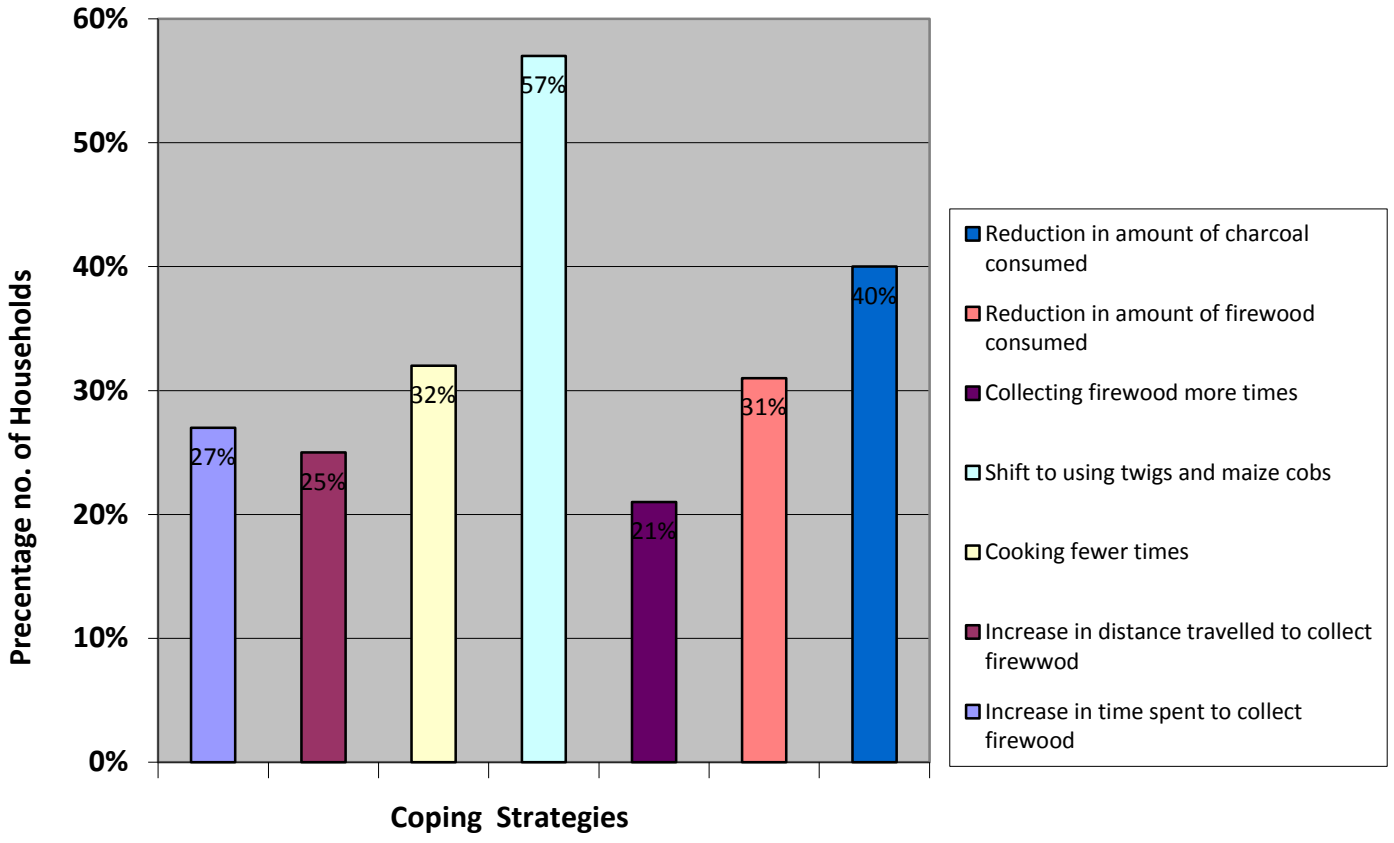
The positive relationship between wood fuel consumption and number of family members was expected and confirmed observations made by the researcher in the rural households. The study

found out that larger households were consuming more wood fuel as their energy demands were higher. These households were using more wood fuel to make large meals. A common characteristic of these large households was that they had more children under the age of eighteen years. This meant that they had to make constant meals and also warm a lot of bathing water, putting their energy demand at a relatively higher level than households that only consisted of adults.

Household Coping Strategies

There was a general acceptance by households that wood fuel was increasingly becoming scarce. 36% of the sampled households had adopted at least one or a combination of strategies in response to reduced wood fuel availability. Households had begun adjusting to reduced wood fuel supply in a number of ways. Figure 5.7 shows the percentage number of households that had adopted each type of coping strategy.

Figure 5.7 Household Coping Strategies



5.4.1 Increase in time and collecting firewood more times

27% of the households were spending more time in collecting firewood while 21% said they were collecting firewood more times in a week than before. The study found out that the number of collecting times had increased from an average of 2 times a week to 3 times a week. The study discovered that this was not a strong indicator of reduced wood fuel availability as most households would easily shift to other strategies as opposed to spending a lot of valuable time searching for wood fuel. Also households that engaged a lot in collecting firewood involved younger members of the family to assist in collecting firewood in order to minimize on time spent.

5.4.2 Increase in distance

As a result of depletion of nearby sources of wood fuel, households had began travelling far to source for firewood. 25% of the households said they were travelling far to acquire firewood. The study found that that the distance had increased from an average of 200 meters to 1.68 kilometers. For years households had harvested firewood from the same sources without making any effort to replace the trees. In any case even for the households that had made some effort to plant trees the rate of tree harvesting was more than the replacement rate. This meant that households had to travel further to collect firewood. The firewood suppliers who were interviewed admitted that they could not get firewood within a radius of 1 km and had to travel far to obtain firewood for sale. The scenario was the same for charcoal suppliers who had to travel more than 50 kilometers to obtain charcoal. However, the study also noted that despite the fact that some households were travelling further to collect fire wood, the same households would retreat back sometimes to source for twigs near their homesteads when they lacked time to travel far. Given the sustained increase in distance to source firewood and charcoal the study has concluded that this is a strong indicator of wood fuel scarcity in Mukaro location, Nyeri County.

5.4.3 Cooking fewer times

32% of households interviewed had reduced the number of times they cooked in a day in order to economize on the amount of wood fuel used. Households that had adopted this strategy were making one big meal either during lunch or dinner, then warm what has been left over for the next meal. Not only were households cooking lesser times in a day but also reducing the

number of times they cook foods that take long to be ready. For example households were avoiding cooking meals such as '*githeri*' which took long to cook. This was because such meals consumed a lot of wood fuel. In instances where a household was to prepare such a meal they looked for wood fuel in advance.

5.4.4 Use of twigs and maize cobs

When faced with wood fuel shortages rural households sometimes resort to using cheaper and less efficient sources of energy. This coping strategy was heavily adopted by households. 57% of the sampled households had shifted to using twigs and maize cobs as a response to reduced wood fuel availability. This was a strong indicator that mature trees could not meet the wood fuel demand of the area. The study found out that households that had available firewood still used maize cobs after the harvest season and postponed use of wood. Maize cobs were commonly used to boil foods and warm water. However they were unpopular with households because of their tendency to smoke. When households lacked the time to source for split wood they would resort to using dry twigs. Twigs were used as an alternative to split wood. Twigs were also unpopular because a household required a big bundle to make a meal and they burned out fast forcing one to keep feeding the fire with more. Dry maize stalks had also become a popular alternative for some households though most women indicated that they also burned out quickly and therefore one has to use much of them. Plate 5.3 shows a pile of dry maize stalks that a woman had just collected to use in making an evening meal.

Plate 5.3 Dry maize stalks

5.4.5 Reduction in wood fuel use

Some households made deliberate efforts to reduce the amount of wood fuel used. The study found out that only households with elderly persons were using wood fuel to warm their houses. It was not common to find a household that had lit fire purposely for warming the house. Wood fuel was being used mainly for cooking while restricting use for other purposes like warming the house and warming bathing water. 31% of the sampled households had made deliberate efforts to reduce the amount of firewood they consumed in a day while 40% of the households using charcoal had reduced the amount of charcoal they consumed. The study discovered that the reduction on the amount of charcoal consumed was also necessitated by the increased prices. Reduction in the amount of wood fuel used could be an indicator of reduced wood fuel supplies. It showed that households preferred to reduce the amount of wood fuel consumed rather than spend a lot time collecting firewood or spend more money purchasing charcoal.

Hypothesis 3

H0: There is no difference in coping strategies adopted by households in the various sub-locations within Mukaro location, Nyeri County

H1: There is a difference in coping strategies adopted by households in the various sub-locations within Mukaro location, Nyeri County

Just like hypothesis one, the data collected for testing this hypothesis was in categorical form and thus Chi square test was used. Under this hypothesis the observed contingency table was a 9 x 9 contingency table.

Table 5.14 Observed Contingency table

Coping strategies/ Sub location	**A-Kinunga**	**B-Gatitu**	**C-Gitathini**	**D-Mununga-ini**	**E-Muthua-ni**	**F-Riamukurwe**	**G-Chorongi**	**H-Mathari**	**I-Ruringu**	Totals
Use of twigs (1)	2	4	2	6	8	5	7	18	3	55
Use of maize cobs (2)	0	3	3	6	8	1	0	15	2	38
Use of dry stalks (3)	0	1	0	2	4	0	0	3	0	10
Reduction in energy consumption (4)	1	1	0	2	2	9	12	9	19	55
Planting trees (5)	0									
Increase in firewood collection times (6)	2	0	0	1	1	2	7	6	0	19
Reduction in cooking times (7)	0	1	0	0	4	5	6	5	11	32
Increase in time spent to collect firewood (8)	2	1	0	5	3	1	7	8	0	27
Increase in distance travelled to collect firewood (9)	0	2	0	5	3	1	4	9	1	25
Totals	7	13	7	28	34	24	43	73	37	266

Table 5.14 shows the observed contingency table where the rows represented nine strategies that households had adopted in coping with decreased wood fuel supplies while the columns represented the nine sub locations under study. The expected contingency table had values less than 1 and at least more than 25% of the expected values were less than 5. Therefore, re-binning was applied by combining rows which were closely related to each other in order to fold the rarely populated cases into more commonly populated cases. The rows which had data on increase in firewood collection times, increase in time spent to collect firewood and increase in distance travelled to collect firewood were combined, use of maize cobs and use of dry maize stalks were also combined. The coping strategy on planting trees was eliminated due to small frequencies in all columns (sub locations). The sub locations (columns) with few samples and also few frequencies we combined. The result of re-binning was a 5x 6 contingency table shown under table 5.15

Table 5.15 Re-binned Observed Contingency table

Coping strategies/ Sub location	**A+B+C+ D**	**E**	**F**	**G**	**H**	**I**	Totals
1	14	8	5	7	18	3	55
2+3	15	12	1	0	18	2	48
4	4	2	9	12	9	19	55
6+8+9	18	7	4	18	23	1	71
7	1	4	5	6	5	11	32
Totals	52	33	24	43	73	36	261

The re-binned observed contingency table 5.15 gave the expected frequency shown under table 5.176with higher frequencies hence meeting the requirements of an expected contingency table

Table 5.16 Expected Contingency table

Coping strategies/ Sub location	**A**	**B**	**C**	**D**	**E**	**F**	Totals
1	11.0	6.95	5.06	9.06	15.4	7.59	55
2	9.56	6.07	4.41	7.91	13.4	6.62	48
3	11.0	6.95	5.06	9.06	15.4	7.59	55
4	14.1	8.98	6.53	11.7	19.9	9.79	71
5	6.38	4.05	2.94	5.27	8.95	4.41	32
Totals	52	33	24	43	73	36	261

RESULTS:

The calculated Chi square statistic was 92.6, the degrees of freedom 20 while the probability level was very small. The predetermined alpha was 0.05. From the Chi square tables, at 20 df and alpha 0.05, the Chi square value was 31.40. Since the calculated Chi square statistic 92.6 was greater than the table value, 31.410, the null hypothesis was rejected and the alternative hypothesis accepted.

From the results, the study concluded that there was a difference in coping strategies adopted by households in the various sub-locations within Mukaro location, Nyeri County. This was visible from the various households interviewed. Different sub locations adopted different coping strategies for various reasons. For example, in Gitathi-ini sub location most women were members of the Green belt movement, a non-governmental organization that encouraged households to plant trees. For this reason, the sub location had a higher number of households planting trees than other sub locations. In Mathari sub location households had shifted to using sawdust as a coping strategy simply because it was available cheaply at five shillings a bag as opposed to other sub locations where it was not available. In Mununga-ini sub location households had shifted to using twigs since the mature trees were no longer available. From the study Mununga-ini was notably having few households with on farm sources of firewood. Most of the households were purchasing firewood from the shopping centre or from neighboring sub locations.

5.5 Environmental and Socio-economic Effects of Coping Strategies

Statement 4

Household responses to reduced wood fuel availability do not have any environmental or socio-economic effects in Mukaro location, Nyeri County.

Hypothesis four was qualitative in nature and thus could not be tested using quantitative techniques. The statement was analyzed qualitatively. Table 5.17 shows the results of the responses of households regarding change of vegetation.

Table 5.17: household responses on change in vegetation

	1. Strongly disagree	2. Disagree	3. Do not know	4. Agree	5. Strongly agree
There has been change in vegetation cover as a result wood fuel use	0%	24%	3%	52%	21%
Vegetation cover has reduced as a result of wood fuel use	0%	26%	3%	51%	20%

5.5.1 Environmental effects of household responses*:*

Reduction in vegetation cover and land degradation

Over 50% of the households agreed that vegetation cover had reduced due to reliance on wood fuel as a source of energy. From the interviews, households pointed out that the tree cover had reduced partly due to harvesting of trees for energy as well as for construction purposes. Other factors like clearing land for agriculture also contributed to the reduction in vegetation cover. The interviewer posed the question "has vegetation cover changed in the last one year" to all 138 households being sampled whether the household in question was using wood fuel or not. 51% of the households simply agreed that vegetation cover had reduced as a result of wood fuel use while 19.5% of the respondents strongly agreed. Generally, 71% of the sampled households agreed, whether merely agreeing or strongly agreeing that vegetation cover had reduced due to wood fuel use as well as other factors like construction and clearance of land for agricultural activities. The strategies that households had adopted had both negative and positive effects on the environment but the study noted that the negative effects were more than the positive effects.

Distance to source: one of the strategies that households had adopted in coping with decreasing wood fuel supplies was sourcing further from their homesteads. 28% of the households using firewood indicated that they were travelling a longer distance to access firewood. For the 72% of households that were not travelling longer to access firewood they continued to rely from the same sources near their homesteads. Given that households continued sourcing for wood fuel from the same sources meant that they continued depleting the environment. Sourcing of energy

from new frontiers poses an environmental challenge to the new area since the same problem is transferred. If depletion of the resource is not addressed this will spread the wood fuel scarcity problem to new areas while aggravating the problem where it already exists. From the interviews and general observation most households had not adopted tree planting as a solution to wood fuel scarcity but instead continued to fuel the demand without looking at the supply side. Some households had a preference for a certain tree species but had no choice but to use what was available (which they considered of lower quality) due to unavailability of the preferred tree species. Such preferred tree species were already harvested and most took long to grow thus were unavailable for use as wood fuel. This had contributed greatly to reduced vegetation.

Shift to use of maize stalks and maize cobs: use of maize stalks and maize cobs as fuel denied tilled land of manure. The maize stalks and cobs would have otherwise been left at the shamba to rot creating manure.

Reduction in amount of wood fuel used: On average 35% of the households in the area had made efforts to reduce on the amount of wood fuel consumed. This had a positive impact on the environment by reducing the demand to cut down trees.

5.5.2 Socio-economic effects of household responses*:*

The study found out various socio-economic effects related to the coping strategies adopted by households.

Change in distance travelled: Distance to source of firewood had increased thereby meaning that households had to spend more time to get their energy supplies. The woman of the household who was tasked with the duty of fetching firewood was now forced to allocated extra time to travel a longer distance as opposed to spending time in more productive activities like farming.

Change in firewood collection times: 23% of households using firewood admitted that they were collecting firewood more times in a week than before. Most households were not collecting firewood more than once in a day but would collect more times in a week than

before. As the need to collect firewood more times increased and distance travelled to source the same increased, some households involved younger members of the household to assist in collecting firewood. 13% of the households using firewood had involved younger members of the family to assist in collecting firewood. This had a social effect on the younger members of the family who were in school; who instead of using such time to study had to assist in searching for fire wood. Such a coping strategy deprived households' time that could be used for other economic activities.

Change in cooking times: For most households the number of meals per day was three however, out of 138 households interviewed 32 households had changed the number of meals from three to two per day. This represented 23% of the sampled population. Though the percentage of population adopting such a strategy was less than 50% it was important for various reasons: meals are compulsory and for a household to adopt such a strategy would mean they have exhausted other options. Secondly, such a strategy has direct implications on the health status of the family. For some households meals which took long to cook were not cooked as often, this compromised on the nutritional status of the household. Such a response affected the dietary patterns of the households and would have a negative social effect.

Shift to use of twigs and maize cobs: The study observed that use of maize cobs caused indoor pollution due to smoking. In some instances, when households used maize cobs and sawdust, they had to wait outside the house until the smoke subsided. Most of the rural kitchens were characterized by black soot hanging from the roof tops, an indication of indoor pollution. Indoor pollution has negative health consequences for the households.

CHAPTER SIX: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

This chapter gives a brief summary of the study findings, highlights the major findings and draws conclusions. From the findings the chapter gives recommendations for policy makers as well as for further studies.

6.2 Summary of Findings

This study gives results of analysis on energy consumption by rural households in Mukaro location, Nyeri County. The research aimed at identifying the sources of energy the households were using, establishing the relationship between wood fuel consumption, level of income, family size and distance travelled to access wood fuel. The study also sought to establish the various strategies that households had adopted in coping with reduced wood fuel availability and the effects such coping strategies had on the environment as well as the socio-economic status of the households. The study sampled 138 rural households in Mukaro location using simple random sampling and analyzed the data using quantitative and qualitative methods.

The study found out that the major source of energy for households in Mukaro location, Nyeri County was wood fuel used significantly for cooking; 69% of the households interviewed were using wood fuel. Firewood was the leading source of energy for the households followed closely by charcoal. Other sources of energy included electricity, LPG, paraffin, solar and sawdust.

The results of the analysis showed a negative relationship between wood fuel consumption and income explained by the fact that households with low incomes tended to consume more wood fuel since it was cheaper compared to other sources of energy. The study also found a positive relationship between wood fuel consumption and number of persons in the households. This was more so because the energy demand for large households was more than small households.

The study identified various factors that determined wood fuel consumption. These factors were synonymous with challenges that households faced while sourcing for wood fuel. They were increased distance to source of fuel wood, increased cost of purchasing wood fuel and reduced fuel wood availability. To tackle these challenges households had adopted various coping strategies. The most common coping strategy was shift to using twigs and reduction in amount

of wood fuel used. Other strategies adopted included planting fast growing trees, use of sawdust, use of energy saving jikos, travelling longer distances to obtain fire wood, cooking fewer times and collecting fire wood more times in a week.

Some of these coping strategies had negative effects on the environment as well as the socio-economic status of the households. The study found out that continued reliance on wood fuel was having negative effects on the environment as households continued harvesting mature trees with minimal replacement thus contributing to reduced vegetation cover. Households were also spending more time collecting fire wood and travelling longer distances as opposed to utilizing that time in more economical activities like farming. The researcher observed signs of indoor pollution which was worse with use of twigs and sawdust which smoke a lot before burning. Some households chose to cook fewer times; such a strategy would have a potential negative impact on their nutritional status

6.3 Conclusions

From the findings of the study, the following conclusions were made;

a. Wood fuel will continue being the leading source of energy for the rural population in Mukaro location, Nyeri County unless major interventions are done to shift the households to '*green energy*'.
b. Wood fuel scarcity is a problem that is growing and unless policy changes are implemented it will become a major challenge in the future. Households shall continue to face the same challenges of increased distance to source, high costs, use of less efficient fuels among others as long as wood fuel supplies continue to decrease.
c. Majority of the households in Mukaro location, Nyeri County have low incomes thus low purchasing power which is an impediment to adopting better energy sources like LPG, solar and biogas.
d. The task of sourcing for wood fuel has remained with women depriving them of time for more economic activities.
e. The environment is being depleted continually by reliance on wood fuel as a source of energy at a rate faster than it's able to rejuvenate.

f. Rural households were facing various socio-economic challenges as a result of dependence on wood fuel.

g. There is need for creation of relevant renewable energy policies which can assist rural households shift to more efficient fuels.

6.4 Recommendations

The study recommends the following:

6.4.1 Recommendation to Policy makers

Agroforestry: Farmers should be encouraged to plant fast growing trees like Grevilea and Calliandra which blend in well with crops in the farm without affecting crop yields. These trees also tend to have a lot of twigs and thus can be harvested without necessarily cutting the whole tree. Though in some areas tree planting especially of Grevilea tree was encouraged by a local NGO, more households need to be encouraged to plant the same. These trees can be provided to the farmers at a subsidized price to entice farmers to plant them. The study also recommends campaigns to encourage tree planting in the area.

Promotion and use of energy saving jikos: the study observed that households had not fully adopted energy saving jikos. Some households had also reverted to using the three stone jiko once the energy saving jikos had worn off. Households need to be sensitized on the need to use energy saving jikos to reduce the amount of wood fuel consumed. The government in conjunction with the private sector can invest in a program to provide energy saving jikos at subsidized prices.

Use of 'green energy': This involves using solar, biogas and wind energy. Households can be encouraged to switch to these sources of energy. The study identified some challenges that hindered households from shifting to these sources of energy. Key among them are high installation costs, low awareness of the benefits of these sources of energy and lack of craftsmen who can install the solar and biogas equipment. Thus to encourage households to adopt solar and biogas, the government with the assistance of the private sector can:

I. Subsidize the installation cost of solar and biogas
II. Train and provide human capacity to install and maintain the solar and biogas equipment

III. Structure a credit facility for households that would want to install biogas and solar yet lack the initial capital required.
IV. Create awareness through field visits and campaigns on media among the rural households on the benefits of solar and biogas use.

More involvement of the Private sector: the study found out that there were few private sector institutions involved in energy issues in Mukaro location, Nyeri County. There was minimal interaction between NGO's and the government in assisting the households tackle the energy challenges they were facing. The private sector can be encouraged to invest in renewable energy programs. Such joint programs can be beneficial to the households in terms of offering financial assistance and capacity building.

Income diversification: Rural households rely mainly on rain fed farming as their source of income. Such type of farming is seasonal thereby exposing households to '*seasonal cash*'. Also most of the farming is small scale hence the incomes are low. This incapacitates the households from adopting efficient energy solutions like LPG, solar and biogas. Rural households can be encouraged to be involved in business enterprises, industries or even formal employment in order to diversify their income and increase their purchasing power.

Energy policy:

I. The energy policy documents in Kenya have given much attention to Electricity and Petroleum energy while giving minimal attention to Biomass energy. There is need for policy makers to give equal attention to biomass energy since it is a major variable in the energy matrix.
II. The gender factor has not been well articulated in the energy policy. There has been mention of the need to include gender issues in energy policy formulation since household energy especially wood fuel has been linked with women. Such policies need to be stated clearly and implemented to relieve the woman of the burden of providing wood fuel to the family.
III. The existing energy policy looks at energy solutions at a national level. There is need to develop programs that are specific to the low income rural population.

6.4.2 Recommendations for Further Research

Biogas and Solar: More research needs to be done to establish details on the low uptake of biogas and solar by households in the County with an objective to give recommendations on improving the situation.

Energy trees: The study recommends more research to be done on the appropriateness and benefits of energy trees in Nyeri County. These trees grow fast and could possibly provide a solution to increasing wood fuel supplies and vegetation cover.

Energy technology: Further research can be done to identify energy technologies that are best suited for the County which can assist households overcome the energy challenges they are facing. This will ensure that technologies adopted are relevant and can be implemented at the local level.

Socio-economic effects of wood fuel use: To some extent households were aware of the environmental impact reliance on wood fuel had caused over the years. However, the study identified room for more research to be done on the socio-economic effects of wood fuel use. This can assist further in creating awareness among the households on the need to shift to more efficient fuels. It can also create awareness on the possible health effects of heavy dependence on firewood as a source of energy.

References

ADB 2007. 'Biomass (traditional & improved biomass)', in ADB/FINESSE training course on renewable energy and energy efficiency, viewed on 5 May 2012 www.afrepren.org/adb

Alabi A.T 2007. Techniques of data presentation, interpretation and analysis, Department of educational management, University of Ilorin, Ilorin, viewed 06 October 2012

Amous & Ebbd 1999. *The role of wood energy in Africa*, FAO, Rome.

Bhagavan, M. 1996. *Energy utilities and institutions in Africa*, Zed Books, London.

Bowonder, B. 1984. *Energy use patterns in rural areas and environmental degradation in developing countries*, Elsevier B.V, Hyderabad.

Brouwer, I.D., Hoorweg, J.C. & Liere, M.J. 1997. *When households run out of fuel: Responses of rural households to decreasing fuelwood availability, Ntcheu district, Malawi* World Development, Vol. 25, No. 2, pp. 255-266, Elsevier Science Malawi.

Carr, M. & Hartl, M. 2010. *Lightening the Load, Labour-saving technologies and practices for rural women*, Practical Action, London.

Central Bureau of Statistics (CBS) 2004. *Economic survey 2004*, Author, Nairobi.

Damte, A.K. & Mekonnen, A. 2012. *Coping with fuelwood scarcity: Household responses in rural Ethiopia*, Environment for development discussion paper series vol. EfD DP 12-01, Ethiopia.

FAO 1995. *Forest, fuels and the future: Wood fuel for sustainable development*, Forestry topics report no.5, Author, Rome.

FAO 1997. *Regional study on wood energy today and tomorrow in Asia*, Author, Rome.

FAO 2005. State *of the world's forests*, Author, Rome.

FAO 2007. *State of the world's forests*, Author, Rome.

FAO 2011. *Wood energy* viewed on 2 August 2011 http://www.fao.org/forestry/energy/en/

FEMA 2007. *Energy security and sustainability in Africa*, Trade Autoprint, Nairobi.

Forestry Department 2004. *Forests bill 2004*, Ministry of Environment, Natural Resources and Wildlife, Nairobi.

Gikonyo, J.M 2004. *An investigation on the effects of use of biomass energy by rural households on the dryland environment and community – a case study of Mwingi district* ,

project paper presented to the department of Geography and Environmental resources University of Nairobi.

GVEP 2006. *Energy road map to achieving MDG targets Kenya sectoral energy requirements*, GVEP Kenya, Nairobi,

Hosier, R. 1985. *Energy use in rural Kenya household demand and rural transformations*, The Beijer Institute and the Scandinavian Institute of African Studies, Stockholm, http://www.energy.go.ke

Joyce C., Neill, A., Watson, V.& Fisher J. 2008. *Tables and graphs*. Assessment resource banks: English, Mathematics and Science, viewed on 25 August 2011, http://arb.nzcer.org.nz/supportmaterials/tables.php

Kamfor Company Limited 2002. *Study on Kenya's energy demand, supply and policy strategy for households, small scale industries and service establishments*, Author, Nairobi

Kammen, D. 2007. *Energy (Biomass) Gender & development*, A lecture on energy and society, 16 September 2007

Karekezi, S. & Mackenzie, G. (eds.) 1993. *Energy options for Africa: Environmentally sustainable alternatives*, Zed Books, London.

Kaumbutho, P.G. and Simalenga, T.E. (eds.) 1999. *Conservation tillage with animal traction*, A resource book of the animal traction network for Eastern and Southern Africa (ATNESA), Harare.

Kenya Forest Department 1994. *Kenya forestry beyond 2000: An overview of the Kenya forestry master plan*, MENR, Nairobi.

Kenya Institute for Public Policy Research and Analysis (KIPPRA) 2010. A *Comprehensive study and analysis on Energy Consumption patterns in Kenya: A synopsis of the draft final report*, report prepared for the Energy Regulatory Commission (ERC), Nairobi, viewed on 10 May 2013 http://www.cofek.co.ke/ERCStudy_ExecSummary_02082010.pdf

Kenya National Bureau of Statistics (KNBS) 2010. *The 2009 Kenya population and housing census*, vol. 1A, Author, Nairobi.

Kenya National Bureau of Statistics (KNBS) 2007. *Statistical abstract 2007*, Author, Nairobi.

Kgathi (ed.) 1997. *Biomass energy policy in Africa; Selected case studies*, Zed Books London.

Kirkman, T.W., 1996. *Statistics to Use*, viewed on 02 Feb 2013 http://www.physics.csbsju.edu/stats/

Ludeki, J. 2006. *Environmental management in Kenya: A framework for sustainable forest management in Kenya- Understanding the new forestry policy and forests act, 2005,* Nairobi

Mbuthi, P. 2005. *Poverty and linkages: Energy access for the rural poor*. Nairobi

Muchiri, L. 2008. *Gender and equity in bioenergy access and delivery in Kenya,* DFID, Nairobi.

Mugenda, O. & Mugenda, A. 1999. *Research methods: Quantitative & qualitative approaches*, Acts Press, Nairobi.

Mugo, F. & Gathui, T. 2010. Biomass energy use in Kenya, A background paper prepared for the international institute for environment and development (IIED) for an *International ESPA workshop on biomass energy*, 19-21 October 2010, Parliament House Hotel, Edinburgh, Practical Action, Nairobi.

Mutua, J.M. 2006. *Biomass energy consumption in dryland towns: A case study of emerging urban settlements in Kitui district*, project paper presented to the University of Nairobi, unpublished project paper, Nairobi.

Nassuna, S. 2007. *The Impact of indoor air pollution on public health*, IRDI, Uganda.

Nyoike, P.M. National industrial energy conservation-Perspectives from Kenya in Karekezi, S. & Mackenzie, G. 1993. *Energy options for Africa: Environmentally sustainable alternatives*, Zed Books, London.

Nzamba, W.O. 2007. *Factors Influencing the Adoption of Solar Energy Technology in Katulani Sub-location, Kitui District*, project paper presented to the University of Nairobi, unpublished project paper, Nairobi.

O'Keefe, P., Barnes, C. & Ensminger, J. (eds.) 1984a. *Wood, energy and households: perspectives on rural Kenya*, The Beijer Institute and the Scandinavian Institute of African Studies, Stockholm.

O'Keefe, P., Raskin, P. & Bernow, S. (eds.) 1984b. *Energy and development in Kenya: opportunities and constraints,* The Beijer Institute and the Scandinavian Institute of African Studies, Stockholm.

Omosa, M. 1987. *The Fuel crisis in rural Kenya: a socioeconomic analysis of the causes and effects of the fuel-wood scarcity in Bura Irrigation settlement scheme, Tana river district*, thesis presented to University of Nairobi

Preacher, K.J. 2001. *Calculation for the chi-square test: An interactive calculation tool for chi-square tests of goodness of fit and independence* viewed on 02 Feb 2013 http://quantpsy.org

Republic of Kenya 2002(a). *National Development Plan 2002-2008,* Author, Nairobi.

Republic of Kenya 2002(b). *Nyeri District Development Plan 2002-2008,* Author, Nairobi.

Republic of Kenya 2003, *National Atlas of Kenya,* Survey of Kenya, Nairobi.

Republic of Kenya 2004. *Sessional Paper No.4 on Energy,* Ministry of Energy, Nairobi.

Republic of Kenya 2005. *Nyeri District (Kieni) Vision and Strategy 2005-2015,* Author, Nairobi.

Republic of Kenya 2006, Arid Lands Resource Management Project (ALRMP) II *Annual Environmental Audit 2006*, ALRMPII, Nairobi.

Republic of Kenya 2008. *Renewable Energy*, viewed on 22 February 2011. http://www.energy.go.ke

Republic of Kenya 2011. *Kenya County Fact Sheet*, Commission on Revenue Allocation, Nairobi

Republic of Kenya 2011b. *Scaling-up Renewable Energy Program (SREP) Investment plan for Kenya, Draft May 2011*, Nairobi

Appendices

Appendix 1: Questionnaire

Introduction

This questionnaire is part of a research being carried out on energy consumption by rural households in Mukaro location, Nyeri County. The researcher is a student of University of Nairobi, Department of Geography and Environmental Studies. You are requested to kindly help in filling the questionnaire to the best of your knowledge and ability. The responses will be treated with confidentiality. Your co-operation is highly appreciated.

BACKGROUND INFORMATION

1.1 Code of Respondent _____

1.2 Date of administering questionnaire_____

1.3 Name of respondent (optional)_____

1.4 Gender (*tick appropriately*) _____Female ( ) Male ( )

1.5 Sub location _____

1.6 Number of family members in the household_____

1.7 Position of the respondent in the household _____

2.0 ENERGY CONSUMPTION

Sources of Energy	Indicate **source** of energy used in the last 1 year (may indicate more than 1)	**Uses** of the source of energy e.g cooking, heating	**Quantity used:** Daily Kg used for firewood and charcoal Kilowatt for electricity p.m	**Cost** per bundle of firewood, sack of charcoal, Electricity bill p.m	**Source** of energy e.g forest, non forest, town	**Distance** to source of energy	**No. of times** travelled to obtain energy daily
Firewood							
Charcoal							
Electricity							
Solar							
Biogas							
LPG (Liquefied Petroleum Gas)							
Others (Specify)							

3.0 CHALLENGES FACED IN ENERGY CONSUMPTION AND COPING STRATEGIES

Change in prices		**Has the price changed in the last one year (YES/NO)**	**From KES**	**To KES**	**As a result of change in price, have you increased or decreased your energy consumption**	**Are you spending more or less in purchasing**	
	Firewood						
	Charcoal						
	Electricity						
	LPG						
Change in distance		**Has the distance travelled to collect firewood/charcoal changed in the last one year (YES/NO)**	**From (Meters/ KMs)**	**To (Meters/ KMs)**	**If Yes, has it led to an increase or decrease in your energy consumption**		
	Firewood						
	Charcoal						
Change in time spent and collection times		**Has the number of collecting times changed in the past one year (YES/NO)**	**From (times of collection)**	**To (times of collection)**	**How many members of the family are involved in collecting firewood each day**	**Has the number of family members involved changed**	**If Yes, from how many to how many (indicate if they are older or younger members)**
	Firewood						
Change in cooking times		**Has the number of cooking times changed as a result of wood fuel availability**	**From how many**	**To how many**			

Change in tree species		**Do you prefer any tree species**	**If Yes, give reason**	**Have you changed the tree species you were using before**	**To quality that is lower or higher**	**Why?**	
Household Income (tick appropriately)	0 – 5,000 ( )	5,000 - 10,000 ( )	10,000 - 15,000 ( )	15,000 - 20,000 ( )	20,000 - 25,000 ( )	25,000 - 30,000 ( )	Over 30,000 ( )

4.0 ENVIRONMENTAL AND SOCIO-ECONOMIC EFFECTS

Please rate how strongly you agree or disagree with the following statements by ticking on the appropriate box

1. Strongly disagree 2. Disagree 3. Do not know 4. Agree 5. Strongly agree

	1. Strongly disagree	2. Disagree	3. Do not know	4. Agree	5. Strongly agree
1.There has been change in vegetation cover as a result wood fuel use					
2.Vegetation cover has reduced as a result of wood fuel use					
3.Time spent on collecting fire wood has increased over time					
4.Distance travelled to collect firewood has increased over time					
5.We are spending more in purchasing charcoal than before					
6.We are spending more money in purchasing firewood than before					
7.We are cooking fewer times now					
8.We have shifted to using twigs and cow dung					
9.We are collecting firewood more times in a day than before					
10.We have reduced the amount of firewood used in a day as a result of scarcity					
11.We have reduced the amount of charcoal used in a day as a result of scarcity					
12.We have not adopted any strategy to cope with the challenges faced in sourcing for wood fuel					

Appendix 2: Interview Schedule for Energy Suppliers

Interview date:

I. Introduction

A. I am a student of University of Nairobi, Department of Geography and Environmental Studies. I am carrying out a research on Energy consumption among rural households in Mukaro location, Nyeri County. I thought it would be a good idea to interview you to get a better understanding on energy supply to households. The responses will be treated with confidentiality.

B. I would like to ask you some questions about your background

C. The interview should take about 15 minutes

II. Body - Let me begin by asking you some questions about you

a. General demographic information

1. what is you level of education
   Primary, Secondary, college/university level
2. what is your monthly income less than 10,000, 10,000-50,000 and over 50,000
3. Number of persons in your family?

b. Energy supply

1. Which type of energy do you supply?
2. Who are your customers?
3. Where do you source it from?
4. What is the distance travelled to obtain wood fuel?
5. What is the price you sell at?
6. Has it changed in the last 1 year?
7. By how much?
8. How much do you sell in day?
9. What are the challenges you face in sourcing the energy and selling it?

III. Conclusion

I appreciate the time you took for this interview. Is there anything else you think would be helpful for me in my research?

Appendix 3: Interview Schedule for Officials in Government Organizations and Non-Governmental Organizations

Interview date:

I. Introduction

A. I am a student of University of Nairobi, Department of Geography and Environmental Studies. I am carrying out a research on Energy consumption among rural households in Mukaro location, Nyeri County. I thought it would be a good idea to interview you to get a better understanding on energy supply to households. The responses will be treated with confidentiality.

B. I would like to ask you some questions about your background

C. The interview should take about 15 minutes

II. Body - Let me begin by asking you some questions about you

a. General information

1. what position do you hold in this organization
2. what role does this organization play in energy consumption or supply

b. On energy

3. What are the sources of energy you have identified households using in the area
4. What are some of the challenges you have identified that households face in sourcing for energy and especially charcoal and firewood
5. What are the coping strategies that you have identified households using
6. As an organization are there interventions or measures you have put in place to assist households in sourcing for energy and in particular charcoal and firewood
7. Have you as an organization identified any socio-economic and environmental challenges as a result of charcoal and firewood consumption
8. What measures have you taken to assist in overcoming the socio-economic challenges as well as environmental challenges

III. Conclusion

I appreciate the time you took for this interview. Is there anything else you think would be helpful for me in my research?

Appendix 4: Tables

Table 2.3 Population of sub-locations within Municipality division
(Source: KNBS, 2010)

Sub-location	Male	Female	Total	Households	Area in Sq Kms	Density
Majengo	13353	11665	25018	8168	6.5	3848
Kihuyo	1073	1079	2152	558	4.8	449
Karia	1586	1678	3264	912	3.5	927
Thuguma	4360	4515	8875	2852	17.9	496
Githiru	1141	1211	2352	640	5.0	468
Muthuaini	1765	1776	3541	939	6.2	576
Kihatha	876	911	1787	483	3.3	549
Riamukurwe	1715	1782	3497	894	6.9	505
Gatitu	1046	1083	2129	650	5.1	420
Kamakwa	6843	7281	14124	4886	5.9	2388
Marua	1077	1194	2271	610	4.7	487
Mathari	4080	3943	8023	2094	38.7	207
Ruringu	6295	7087	13382	4785	3.3	4092
Chorongi	2670	2844	5514	1446	8.1	677
Kinunga	640	657	1297	370	2.2	585
Mununga ini	1377	1644	3021	776	4.5	670
Muruguru	1282	1398	2680	725	5.7	470
Gitathini	1326	1323	2649	706	2.8	957
Total Mukaro)	**52505**	**53071**	**105576**	**32494**	**135.0**	**782**
Kiganjo	2196	1251	3447	924	5.4	636
Gachika	1270	1364	2634	680	7.0	375
Kirichu	2187	2301	4488	1329	9.7	464
Nyaribo	1595	1533	3128	985	10.6	294
Total (Kiganjo)	**7248**	**6449**	**13697**	**3918**	**32.7**	**418**

Table 5.18 Data used for testing hypothesis 2

	Qty of wood fuel used	Distance travelled to collect firewood (In mtrs)	Household income	Family size
1	105	100	1	2
2	84	200	2	4
3	175	100	2	7
4	56	100	1	3
5	210	200	1	5
6	84	300	2	6
7	140	200	2	3
8	252	200	2	7
9	161	50	2	3
10	42	100	3	2
11	77	200	1	3
12	175	100	1	6
13	55	100	3	3
14	40	100	2	2
15	75	100	1	3
16	52	1000	2	5
17	42	100	1	1
18	140	100	1	4
19	77	1500	3	4
20	91	50	2	6
21	90	500	1	2
22	91	2000	3	4
23	28	200	1	1
24	77	100	2	2
25	105	150	1	6
26	280	4000	2	6
27	89	100	2	3
28	28	50	6	3
29	294	200	1	4
30	35	200	1	3
31	47	100	3	7
32	88	3000	1	2
33	63	200	1	2
34	140	100	2	8
35	140	500	1	2
36	168	1000	1	5
37	56	300	2	5

38	5	0	2	1
39	126	500	3	6
40	84	500	1	4
41	140	3000	1	4
42	110	3000	2	5
43	94	5000	2	4
44	58	5000	3	4
45	91	2000	4	8
46	49	500	5	6
47	105	3000	1	6
48	45	1000	3	4
49	81	1500	3	4
50	75	3000	2	4
51	63	500	1	6
52	35	500	2	3
53	80	1500	3	5
54	84	1000	4	4
55	91	500	2	5
56	66	500	2	3
57	98	3500	4	5
58	77	500	2	4
59	105	500	1	5
60	105	5000	2	5
61	107	1500	3	5
62	7	500	2	1
63	107	500	3	4
64	70	1000	3	2
65	133	200	2	6
66	88	50	2	6
67	158	3000	2	3
68	70	1000	2	5
69	70	2000	1	2
70	119	200	1	8
71	88	100	2	2
72	189	50	3	4
73	210	200	2	5
74	88	1000	1	4
75	88	100	2	8
76	168	200	1	3
77	168	50	2	4
78	74	5000	3	4

79	74	200	2	3
80	35	100	2	2
81	70	200	1	5
82	252	200	2	4
83	91	4000	2	3
84	15	50	6	2
85	105	200	1	1
86	84	500	1	5
87	70	500	2	2
88	10	50	2	3
89	70	2000	3	3
90	35	50	6	4
91	90	1500	5	4
92	7	3500	3	4
93	123	500	2	5
94	96	1500	1	8
95	108	1000	3	5