THE EFFECTS OF BIOMASS ENERGY USE BY RURAL HOUSEHOLDS IN A DRYLAND ENVIRONMENT – CASE STUDY OF MWINGI DISTRICT

By

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DECLARATION

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

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Date: 8/10/2004

This Research Project has been submitted for examination with our approval as University Supervisors

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DEDICATION

To the stalwarts of my household environment, Liz and Nimu, for the energy they provide to make life what it is.

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LIST OF ABBRVIATIONS AND ACRONYMS

ARI	Acute Respiratory Infections
ASAL	Arid and Semi-Arid Lands
CBS	Central Bureau of Statistics
dbh	Diameter Breast Height
DSOs	District Statistical Officers
FAO	Food and Agriculture Organization
FD	Forest Department
GoK	Government of Kenya
ha	Hectare
HH	Households
ITDC	Indigenous Technology Development Centre
ITDG	Indigenous Technology Development Group
KEFRI	Kenya Forestry Research Institute
KFMP	Kenya Forestry Master Plan
Kg	Kilograms
Km	Kilometres
Kshs	Kenya Shillings
LPG	Liquified Petroleum Gas
m^3	Cubic metre
NASSEP	National Sample Survey and Evaluation Programme
NGOs	Non Governmental Organizations
PSU	Primary Sampling Units
PV	Photovoltaic
SACCO	Savings and Credit Cooperatives
UNHCR	United Nations High Commission for Refugees

ENERGY UNITS OF MEASURE

Source of energy	***Energy Content***
Fuelwood	16.0 MJ/kg
Charcoal	33.1MJ/kg
Crop Residue	13.9MJ/kg
Cow Dung	12.8MJ/kg
Biogas	24MJ/Litre
LPG (Bottled gas)	45.2MJ/kg
Kerosene	39.1 MJ/Litre
Electricity	3.6MJ/Kwh

ABSTRACT

The predominant use of biomass energy in rural households continues to raise serious environmental concerns especially because of its unsustainable utilization. Additionally, its use could contribute to adverse socio-economic impacts, as effects on the environment have related social and economic consequences on people's lives. This is more so in the arid and semi-arid lands where biomass resources are more scant, and the environments more fragile.

This study set out to investigate the environmental and related social impacts arising from this predominant use of biomass energy in rural households in a dryland environment, namely, Mwingi District in Kenya. Like other energy studies, it examined the households' energy demand, and compared this with the sustainable biomass supply available and accessible. Environmental and social impacts arising from the biomass deficit and the actual use of particular biomass types were then investigated. This study also aimed at shifting from the usual energy-environment studies done at national levels, to more local and centralized areas given the site-specific nature of biomass energy. It further examined whether there were any differences in consumption between households purchasing firewood and those collecting it from various sources.

In undertaking this research project, a sample of 60 households from 5 divisions of Mwingi district was sampled. To determine the biomass demand of households, actual weight measurements were taken. Other household practices in the use of biomass were also observed, among them: the type of stoves used, and whether they undertook tree planting. The study then assessed the sustainable supply of biomass available and accessible in the district and compared this with the households' demand to determine the biomass balances.

The study found that current biomass consumption in Mwingi is about 276,000 tonnes as compared to the sustainable accessible supply of 241,000 tonnes. There thus exists a large biomass deficit of about 35,000 tonnes which is bound to rise to 125,000 tonnes in the next 20 years if no interventions are put in place. This exhibited a clear case of unsustainable use of biomass resources in the district, and resulted in negative environmental impacts. Key among these were: Deforestaton; destruction of water catchments and subsequent drying of rivers and water resources scarcity; soil erosion; loss of soil fertility; and air pollution.

Social and economic impacts identified were: 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 insecurity; diseases; and gender inequality.

The study also found out that despite the predominant use of biomass fuels, only a few households undertake tree planting, and even where this is done, the trees are exotic varieties used mainly for fruit and for shade. Additionally, the study found that there are few efforts by households to reduce biomass consumption by using energy-efficient cooking stoves and other energy saving practices mainly due to low energy-conservation awareness among households.

From the identified environmental and social impacts, the research project then proposed some area-specific recommendations to ameliorate the situation. These included: Promotion of use of improved efficiency energy saving cooking stoves for both firewood and charcoal; use of improved kilns in charcoal production; better management of existing vegetation types; agroforestry promotion; promotion of indigenous food crops; energy substitution; and a shift in government policy to enable to foregoing to be actualized.

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1.0 INTRODUCTION

1.1 Background to the Study

Energy is one of the key human requirements and rights because of the services it provides like cooking food, lighting, heating and other social and economic functions. In Kenya and other developing countries, most rural households use biomass for the fulfillment of their energy needs and to facilitate their livelihoods. The use of biomass, as with other actions, produces a reaction on the environment.

The purpose of this project is to study this reaction/impact on both the environment and the communities in drylands, with Mwingi District being the case study. This is important because drylands, which consist of both the Arid and Semi Arid Lands (ASALs) constitute 80% of Kenya and are home to one quarter of the nation's population. On the other hand, rural communities make up about 75% of the national population.

1.2 Statement of the Problem

Kenya's rural households dependence on biomass is comparable to most developing countries and accounts for 96.8% of energy at the household and small cottage industries level, and 80% of total energy consumed in Kenya (Kamfor, 2002). Its use in rural areas is mainly in three forms: firewood, charcoal and farm residues, at 89.4%, 34%, and 29% use by households respectively. Per capita use in rural households for the three types was also determined at 741 Kg/year, 156 Kg/year and 435 Kg/year at the national level (Kamfor 2002). The main energy uses are cooking, water heating and space heating.

The predominant use of biomass has led to a high deficit of 20 million tonnes/year or 57% net biomass supply deficit which is projected to grow to about 63% or 34 million tonnes/year by year 2020 if current trends continued (Kamfor, 2002). These figures are quite alarming and more so considering that the surplus/deficit scenarios are different in specific locations, with some having over 90% deficit. Such a deficit means that use of biomass energy is unsustainable, as consumption is derived from growing stocks and is akin to spending one's capital instead of living off the annual interest.

Such a scenario is particularly worrying in the ASAL and other areas which have fragile environments because use of biomass as the predominant source of energy could have adverse effects on the environment. This being the case, this study seeks to investigate environmental and social effects of use of biomass energy in households in Mwingi, one of the ASAL districts in Kenya, and where the effects of biomass energy have yet to be studied.

In determining environmental and social energy impacts, most studies revolve around determining energy demand which is then compared with sustainable energy supply. Energy balances in terms of surplus and deficit scenarios are then calculated from which impacts are determined in the short, medium and long term, and arising policy measures formulated towards sustainable provision of energy to meet domestic and other social needs.

Energy demand considers actual energy consumption per capita while energy supply considers all biomass supplies including agroforestry, woodlots, live fences, etc. This is in light of the fact that most biomass at the household level is sourced from non-forest sources, unlike earlier energy studies which considered mainly forest supplies and pegged sustainability of use to available forest stock and its regeneration/reforestation. Determination of biomass demand and supply has however been problematic due to the fact that, unlike commercial energy types like petroleum and electricity, it does not enter the formal markets, and is sometimes illegal especially as regards charcoal.

Most of these studies have only been undertaken at the national level. They have also been undertaken infrequently with Kenya having had only two since independence, namely: the Beijer Institute Study in 1980/81, and the Kamfor Company Study in 2000-2002. There are hardly any done at local levels, and there is a resultant lack of data, and an assumption that there is no capacity to intervene at these local points.

Local studies, at least at district level, are however desirable considering the fact that biomass usage impacts, both environmental and social, are better assessed at local levels where they are felt and resultant mitigation measures can be put in place. This is because, household energy consumption is dependent on the area, household sizes, household incomes, food types, availability of local resources and alternative fuels, climate, and they even vary by seasons. Supply of biomass energy on the other hand is dependent on the ecological capacity of an area, major type of vegetation formations and their different yields, and accessibility in terms of geographic factors, infrastructure, topography, land use and land ownership.

Biomass energy usage is thus site-specific in nature and requires a decentralized approach. This is because, the national scenario biomass abundance or scarcity may not be reflective or applicable at local levels. This is mainly because the resources considered at the national level as supply may exist where there is no actual demand. Linkages of environmental impacts from biomass energy use have also not been investigated thoroughly though various linkages have been established. This is especially because biomass cannot be transported over long distances, and ASAL areas have their own peculiar environmental and social conditions.

This study thus aimed at determining the environmental and social impacts at the desired local level. It also endeavored to establish local data on biomass demand, sustainable biomass supply, and resultant balances, so that interventions, if any, are local and homegrown. As such the study also looked at key ways in which the communities mitigate environmental impacts in areas like tree planting and use of efficient stoves.

1.3 Research Objectives

This study aimed at determining the environmental and social impacts of the use of biomass energy by households in Mwingi District and to come up with mitigation and enhancement measures for such impacts.

The specific objectives of the study were:

1. To examine the energy demand, sustainable supply and energy balances in rural Mwingi District;

2. To find out whether the rural households in Mwingi District who use biomass for energy engage in either biomass demand and supply management;

3. To assess the environmental impacts, both positive and negative, resulting from the biomass use and practices by rural households in Mwingi District;

4. To assess the social impacts, both positive and negative, resulting from biomass use by rural households in Mwingi District;

5. To recommend possible area-specific interventions at the local and national policy level to mitigate any adverse effects, and promote positive effects on both the environment and society in view of the important and dominant use of biomass energy, and its subsequent impacts on the environment and society.

1.4 Research Hypotheses

The "biomass gap" theory as paraphrased from the fuelwood gap theory rings true for the Kenyan situation. Arising from it, this study set forth to test the following key hypotheses:

1. There is a significant difference between biomass demand and biomass supply in Mwingi District.

2. There are significant environmental and social impacts if the household biomass demand exceeds sustainable supply in Mwingi District.

3. There is a significant difference in consumption between households who purchase firewood with those who collect firewood in Mwingi District.

4. There is no significant involvement by households using biomass energy in either biomass supply enhancement or demand management in Mwingi District.

1.5 Theoretical Framework

The "fuelwood gap theory", formulated in the 1970's, implied that woodfuels were consumed on a non-sustainable basis. The "gap" indicated that in many countries consumption was larger than the sustainable supply from forest land. It was then concluded that deforestation and forest degradation were largely due to fuelwood harvesting.

When this theory was proposed, data on the origins of fuelwood was scarce and it was assumed that all of it originated from forests. However, with improved data availability on the supply of fuelwood a different picture has emerged. It has become more and more evident that, actually, most of the fuelwood comes from non-forest sources. The fuelgap theory has thus been dismissed by many scientists with some claiming that fuelwood supply from the non-forest sources is more than sufficient to "fill the gap" and as such, fuelwood use is not necessarily linked to deforestation. Most of these scientists see the effects of deforestation and negative environmental impacts as arising from human settlements and agriculture, and the use of biomass arising from these two as secondary.

The fuelgap theory however seems to ring true especially when it is paraphrased to read the "biomass gap" theory. This is because with increasing populations and the over-reliance on biomass energy, biomass consumption has been shown to be much higher than sustainable biomass supply. There is thus a non-refutable biomass gap which is not just linked to deforestation, but to environmental degradation especially in terms of land and air. This is especially so in localized areas and in certain conditions (for example ASAL areas) where the deficit is quite big, not so much because of the high demand, but more so because of the low sustainable supply. This rings true even when both forest and non-forest areas like village lands, agricultural land, agricultural crop plantations homesteads, and trees along roads among others are considered.

1.6 Research Justification

This study is important because there is lack of accurate data on both environmental and social impacts resulting from use of biomass energy in most areas because of their site-specific nature. Universal or national scenarios are thus rarely applicable at local levels though they might give a particular direction. In this case, though the national household energy demand and supply study was recently undertaken, there is a risk of ignoring local conditions as the country dwells on the "whole". In such a scenario, the abundance or scarcity of biomass at the national level may eclipse the given situation in a smaller area/locality, such as a district. This is mainly because the resources considered at the national are based on averaged data that may not show critical situations in a smaller region.

Further, the two national studies undertaken so far in Kenya did not focus on environmental and social impacts *per se*, and any reference to such impacts was only in passing. Further, the national study figures for average per capita may not be representative of particular specific areas like rural dryland areas, or areas with slightly different domestic food preparation habits. This is because both local consumption and supply vary, and so do the overall surplus and deficit scenarios.

It is thus important to undertake studies locally and to come up with distinct intervention measures for the different areas. The study is also important in order to identify the social and environmental impacts at a given locality especially in an ASAL environment. This is mainly because biomass cannot be transported over long distances, and ASAL areas, which have their own peculiar environmental and social conditions, may need slightly different interventions from those proposed nationally.

Mwingi was chosen for the study because of its being a rural ASAL district and having being part of the national survey as part of the larger old Kitui district. In this respect, it was possible to compare the results of this study with those of the national Kamfor study. Mwingi's high dependence on biomass is also expected to continue unless any interventions are put in place, as this is the case throughout Kenya and indeed the developing countries.

1.7 Research Limitations and Assumptions

In undertaking this study, there were a few limitations, which however did not seriously compromise its quality or the recommendations arising from it. These limitations and assumptions include:

1. Some of the data used was secondary data collected two years ago for the national study. A validation sample was however undertaken to ensure the validity of the data.

2. Two different samples of households, taken at an interval of two years were used. The samples were however taken from the sample sampling frame and the same sampling procedure used.

3. The study assumed that all biomass energy consumed is sourced from the district and that all sustainable supplies are also only used in the district.

2.0 THE STUDY AREA

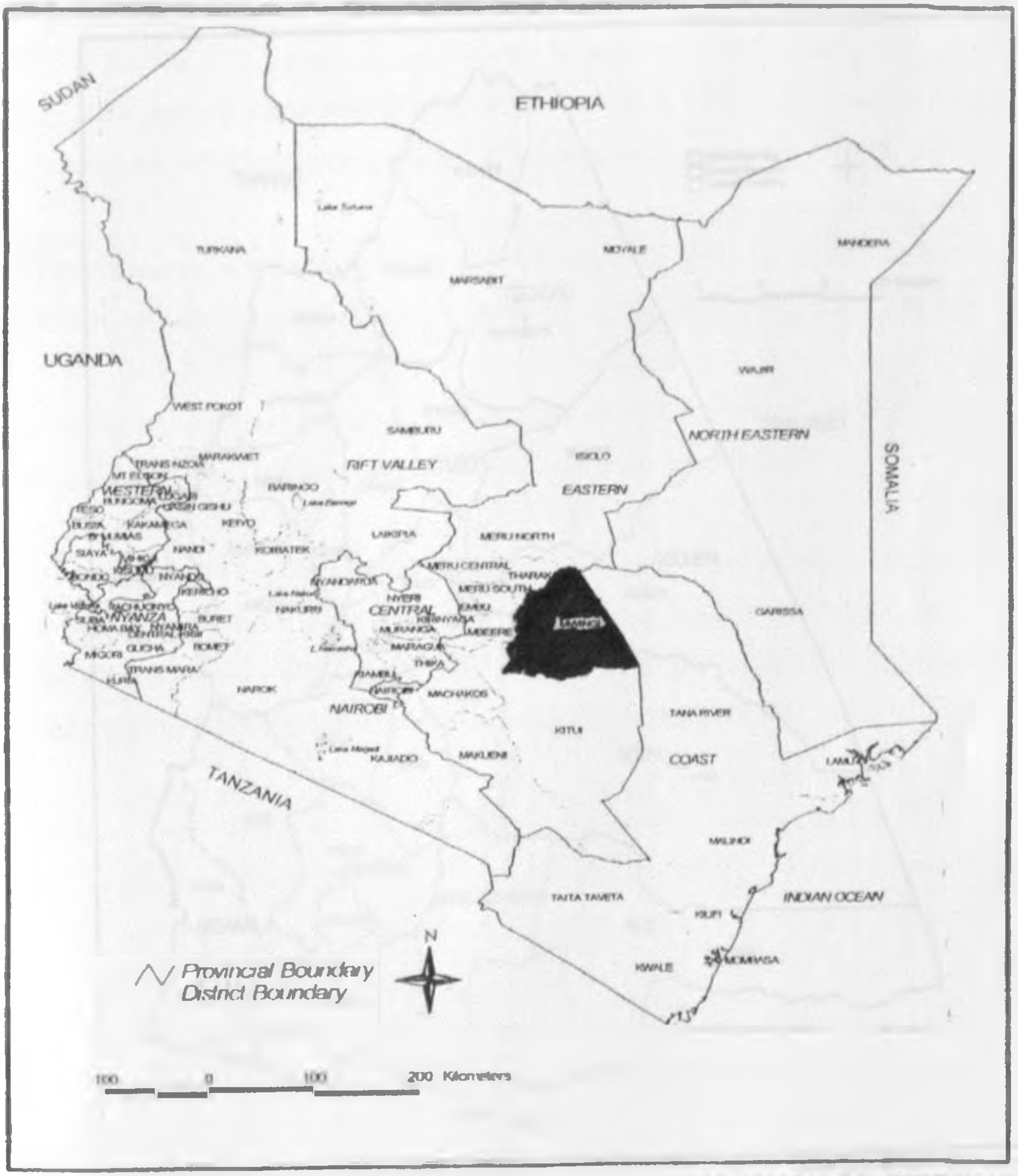
Mwingi is one of the thirteen districts in Eastern Province and lies between latitude 0^{0} 03^{1} and 1^{o} 12^{1} south and 37^{0} 47^{1} degrees 38^{0} and 57^{1} east. The whole district covers a total area of 10,030.30 Km^{2} of which 4,513.6 Km^{2} is arable, while the rest is non-arable (GoK, 2002). The District has red sandy soils, loamy sand soils and patches of black cotton soil. Most soils are of low fertility and prone to erosion, other than for a few areas with moderate to high fertility in the river valleys. There are neither permanent rivers nor large water bodies.

Mwingi's climate is hot and dry for the most part of the year with temperatures ranging between 14 – 34 ^{0} C, and rainfall between 400 – 800 mm. The district is homogeneously inhabited mainly by the Kamba community, and had a population of 303,828 as per the 1999 census, with a 2.4%growth rate. Year 2002 population is estimated at 325,506 with 60,099 households having an average size of 5.3 persons.

Mwingi is a true rural district, with only one main urban centre and hence it has 95% of its population living in rural areas, and the other 5% living in the few small urban centres. Mwingi is thus an ideal case study area as it captures both the rural and ASAL aspects. The average population density for Mwingi is 30 persons per Km^{2} and total livestock population is about 900,000.

There are nine administrative divisions (Central – urban; Migwani, Muumoni, Mui - in highlands; Kyuso, Nguni, Ngomeni, Nuu, and Tseikuru – lowlands) with the driest being Nguni, Kyuso, and Tseikuru. Most divisions practice some form of agriculture though some like Ngomeni are prevalently a livestock zone. The main agricultural crops planted are maize, beans, sorghum, brown millet, pigeon peas, green grams, cotton, castor, sisal and sugarcane while livestock includes cattle, goats, sheep, rabbits, and poultry.

LOCATION OF MWINGI IN KENYA



Prepared by CBS 1999 Pop Census

Figure 2.1: Mwingi District in Kenya
Source: GoK, 2002: Mwingi District Development Plan 2002 - 2007

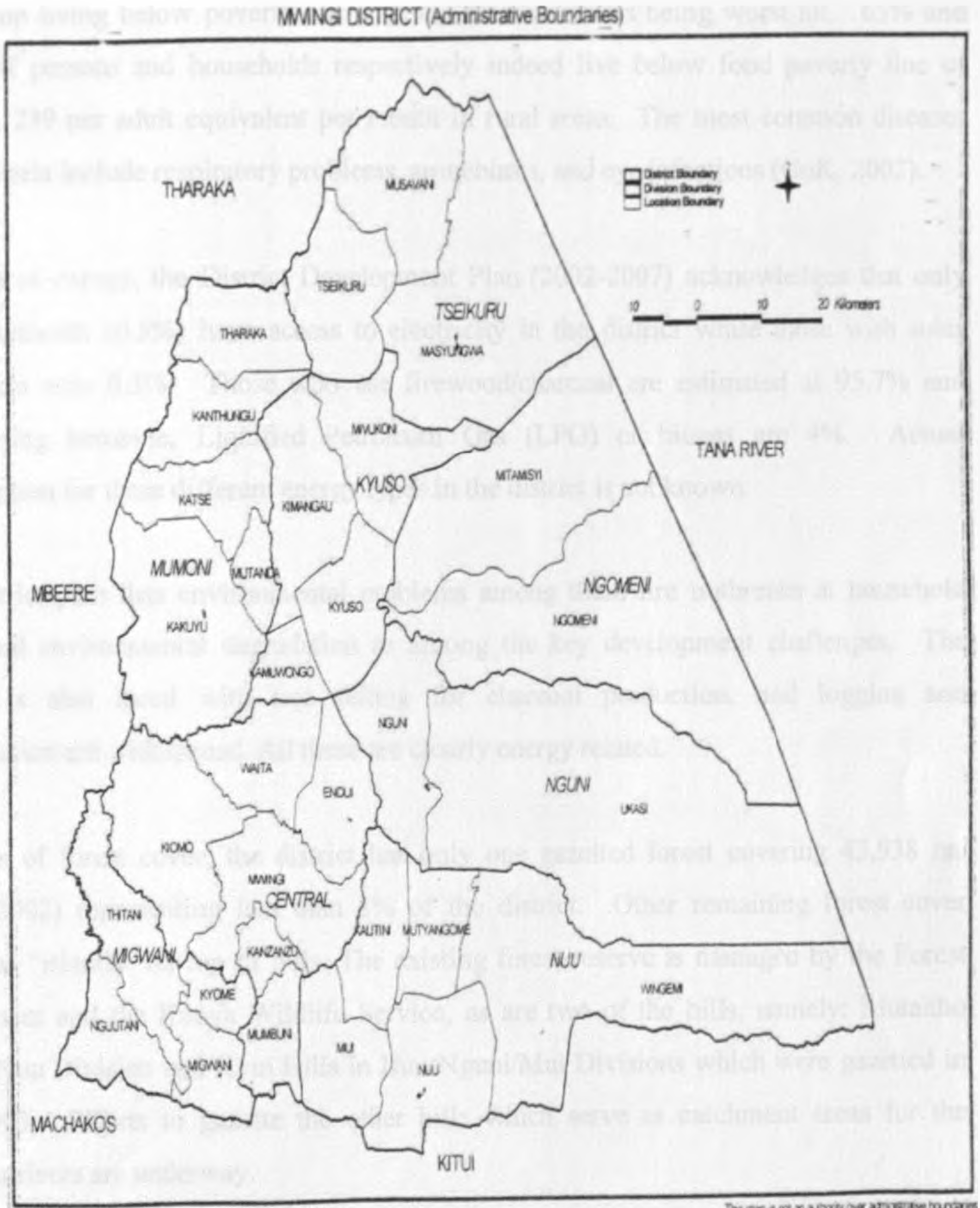


Figure 2.2: Map of Mwingi District
Source: GoK, 2002: Mwingi District Development Plan 2002 - 2007

There is also very high prevalence of poverty in the district at large with 60% of the population living below poverty but with the drier divisions being worst hit. 65% and 58.5% of persons and households respectively indeed live below food poverty line of Kshs. 1, 239 per adult equivalent per month in rural areas. The most common diseases after malaria include respiratory problems, amoebiasis, and eye infections (GoK, 2002).

In terms of energy, the District Development Plan (2002-2007) acknowledges that only 300 households (0.5%) have access to electricity in the district while those with solar power are only 0.3%. Those who use firewood/charcoal are estimated at 95.7% and those using kerosene, Liquified Petroleum Gas (LPG) or biogas are 4%. Actual consumption for these different energy types in the district is not known.

The district plan lists environmental problems among them fire outbreaks at household level, and environmental degradation as among the key development challenges. The district is also faced with tree felling for charcoal production, and logging and deforestation are widespread. All these are clearly energy related.

In terms of forest cover, the district has only one gazetted forest covering 43,938 ha. (GoK, 2002) representing less than 8% of the district. Other remaining forest cover occurs as "islands" on top of hills. The existing forest reserve is managed by the Forest Department and the Kenya Wildlife Service, as are two of the hills, namely: Mutaitho Hill in Nuu Division and Kyui Hills in Nuu/Nguni/Mui Divisions which were gazetted in 2002/2003. Efforts to gazette the other hills which serve as catchment areas for the district's rivers are underway.

Key vegetation types in the district are however found in terms of : Woodland, bushland, dense wooded grassland and sparsely wooded grassland consisting mainly of acacia species; planted tree vegetation mainly on farms in terms of woodlots; farm boundaries consisting of regenerated acacia species; and a few planted species of *Melia volkensii*, *Terminalia* species, *Eucalyptus camaldulensis, Grevillea robusta* and different fruit trees. Increasingly, farm residues have become important sources of biomass energy.

The area estimates of the various vegetation types is as summarized below:

Source/Land-use	Sub-Vegetation Type	Total Area in Ha
Forests and Hills		56,058
Woodlands, Bushlands, Wooded grasslands		553,019
Woodlands	49,271	
Bushlands (including national parks – 24,500 ha)	478,965	
Wooded grasslands	15,854	
Sparse wooded grasslands	9,829	
Farmlands and Settlements		313,102
Others		79,951
Total		**1,003,030**

Table 2.1: Areas of Different Vegetation Types in Mwingi District

Source: District Forests Officer/District Statistical Officer - Mwingi District (2004)

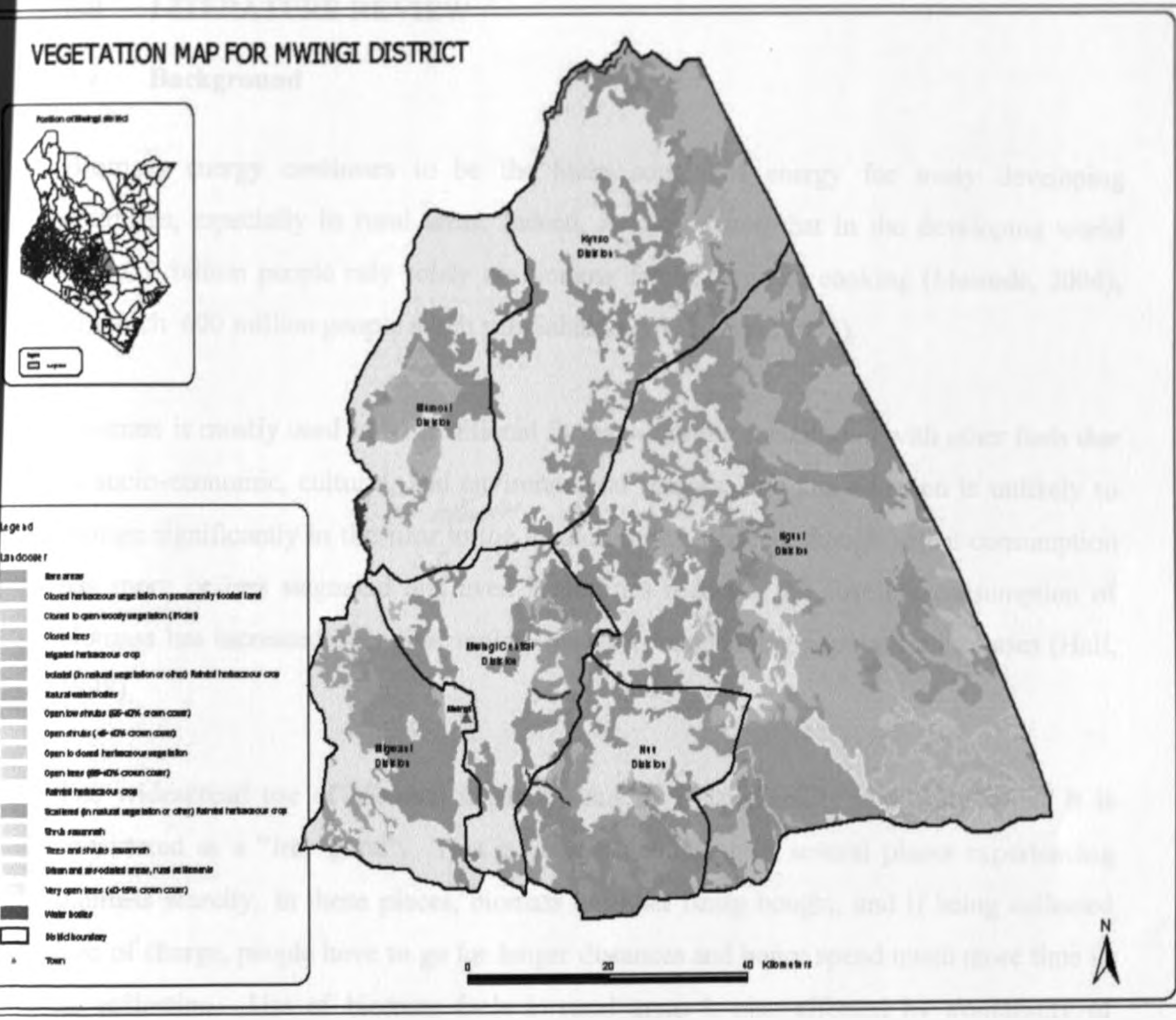


Figure 2.3: Vegetation Map of Mwingi District
Source: GIS Laboratory, International Livestock Research Institute

3.0 LITERATURE REVIEW

3.1 Background

Biomass energy continues to be the main source of energy for many developing countries, especially in rural areas. Indeed, it is estimated that in the developing world alone, 2 billion people rely solely on biomass for heating and cooking (Masinde, 2004), of which 600 million people are in sub-Saharan Africa (EIA, 2003).

Biomass is mostly used in its traditional forms with little substitution with other fuels due to socio-economic, cultural, and environmental reasons, and this situation is unlikely to change significantly in the near to the medium term. Indeed, though actual consumption has more or less stagnated and even sometimes reduced, the absolute consumption of biomass has increased over time mainly due to corresponding population increases (Hall, 1998).

The widespread use of biomass is mainly due to its availability especially where it is considered as a "free good". This is however changing in several places experiencing biomass scarcity. In these places, biomass is either being bought, and if being collected free of charge, people have to go for longer distances and hence spend much more time in its collection. Use of biomass fuels in rural areas is also affected by availability of substitute fuels both in terms of ease of access and the high mark-up costs for the fuels when easily accessible.

It is also well known that traditional biomass energy is usually used very inefficiently and can result in environmental degradation, and serious negative health mainly due to air pollution. There has thus been a strong connection between traditional forms of biomass energy use, environmental degradation, and health hazards, though this is a question that attracts different extreme opinions from scientists, mainly because it has been associated with deforestation.

3.2 Divergent Views on Effects of Biomass Use

There are two differing views on the effects of biomass use to both the environment and to human well being. On one hand are scientists who associate biomass use with environmental degradation, and who claim that its use and the resultant unsustainable harvesting has led to deforestation in what is usually referred to as the "fuelwood gap theory", developed in the 1970s (Montalebart, 1983).

On the other hand are those who dissociate biomass energy use with environmental degradation. These group terms the "fuel gap theory" as too simple an argument, and claim deforestation cannot be caused by biomass use as most biomass for energy is sourced from non-forest sources. For them, deforestation is caused by human settlements and the failure to care for diminishing forest resources. This group includes the Food and Agriculture Organization (FAO) whc in 1997 stated that "wood energy use is not and will not be a general or main cause of deforestation." They go further to argue that demand for woodfuel is a motivation to plant trees in farmlands and woodlots and to develop agroforestry and community forestry, thus promoting rural development and improving living standards.

In terms of air pollution this group of scientists sees biomass for energy use as being carbon neutral and even environmentally friendly when used sustainably. Indeed, in terms of carbon dioxide, the amounts produced are said to be fully compensated for by the amounts withdrawn from the atmosphere during growth of trees (Mbuthi, 1998), and if they could replace fossil fuel, they could reduce atmospheric carbon emissions. They are also said to be advantageous in that they produce no sulphur oxides and have low level of particulates when operated efficiently (Otiti, 2004). As such, the impacts of use of biomass are said to be "more controllable, more reversible and consequently more benign" (Pasztor et.al 1990). Some of these scientists thus argue that use of biomass fuels by households actually has positive environmental effects. They associate biomass energy use with environmental sustainability and climate stabilization. This is however only when it is produced and used sustainably. Sustainable use of biomass can also contribute to moderating greenhouse gas emissions and also developing sustainable forest management systems. This is manly in terms of carbon sequestration through the development of energy plantations.

The Clean Development Mechanism adopted in the Kyoto Protocol to the UN Framework Convention on Climate Change could become an excellent tool to mobilize funds for the sustainable development of forests and to improve the living and economic conditions in rural areas which have not been touched by the present reforms of market liberalization and modernization especially in the tropics where the largest suitable areas for afforestation are found. This view is however contested by others who argue that sequestration in new forests is problematic and is not a long-term solution because trees cease sequestering once they reach maturity (Openshaw, 1997).

On the negative side, bio-energy could cause serious environmental damage if feedstocks are not properly managed and conversion technologies are inadequately controlled (Otiti, 2004). Already in the developing countries, the demand for fuel wood is far greater than supply. In many areas in sub-Saharan Africa fuelwood consumption is running 30 – 200% ahead of average increase in stock of trees (Masinde, 2004). The problem is further exacerbated by the rapid urbanization.

As such, there is a clear link between the use of biomass energy by households has, impacts on the environment, though not necessarily in terms of deforestation. This is more so in fragile environments like drylands, and those localized areas where there are situations of acute biomass scarcity. Indeed, in many areas where there is scarcity of biomass, or where it is found in insufficient quantities, people are quite aware of the potential negative impacts of over-exploitation of natural resources and whenever possible avoid excesses. However, socio-economic issues can override such behaviour (Openshaw,1997).

Shortage of fuel wood has also led many rural people to switch to even lower forms of biomass like dung and light agricultural residues as an alternative energy source. This has a critical opportunity cost in terms of lost soil carbon replenishment as crop residues are returned to the soil, and the humus resulting from their decomposition helps maintain soil nutrients, soil porosity, water infiltration and storage, as well as reducing soil erosion. They thus serve as a form of fertilizer and their use is thus associated with loss in crop production and the cumulative effects on food security and subsistence agriculture. Use of some residues for energy is however feasible using some residues which are unsuitable for compost like jute sticks, or those which are burnt to prevent disease transmission from one season's crop to the next, for example, cotton stalks (Clancy, 1997). Their use is however a reflection of unfulfilled energy demand especially putting into consideration their low calorific value.

Use of biomass also contributes to environmental degradation through air pollution. Annually, biomass burning is estimated to emit 22 million tonnes of methane and 0.2 million tonnes of nitrous oxides (IPCC, 1995). These emissions have significant implications for climate change due to their considerably high global warming potential compared to carbon dioxide (IPCC, 1990). This is compounded by lack of a 'sink' through deforestation, which has far exceeded afforestation (ratio of 8.5:1) in tropics during 1980's (Houghton, 1996). Recent studies have also indicated that topsoil is a far larger carbon sink than the growing vegetative material terrestrially (Theuri, 2004). As such, environmental effects like soil erosion which affecting topsoil can increase green house gas emissions.

Air pollution is however more significant at the local and household level. Such pollution poses a risk to human health, varying according to the intensity and duration of exposure and the health status of the population exposed (Otiti, 2004). Respirable suspended particles in a house measures over 24 hours have been found to range between 1,000 $\mu g/m^3$ to 9,000 $\mu g/m^3$ with peaks reaching 21,000 $\mu g/m^3$ (Wafula, 2000). This range is far higher than that of 100 – 150 $\mu g/m^3$ recommended by the World Health Organization.

Additionally, carbon monoxide from wood smoke is well known and it can cause acute and chronic effect on humans at various concentrations which may be manifest as headaches, dizziness, vision and hearing impairment, asphyxia, cerebral congestion, edema and death. The particulates in wood smoke are of considerable concern because they are quite small, mostly less than 5 microns in diameter, and are thus of respiratable size. As such, they readily penetrate into lungs (Kituyi, 2000, 2004).

3.3 Past Studies

In determining environmental and social energy impacts, most studies revolve around determining energy demand which is then compared with sustainable energy supply. Energy balances in terms of surplus and deficit scenarios are then calculated from which impacts are determined in the short, medium and long term, and arising policy measures formulated towards sustainable provision of energy to meet domestic and other social needs.

Energy demand considers actual energy consumption per capita while energy supply considers all biomass supplies including agroforestry, woodlots, live fences, and others. This is in light of the fact that most biomass at the household level is sourced from non-forest sources, unlike earlier energy studies which considered mainly forest supplies and pegged sustainability of use to available forest stock and its regeneration/reforestation. Determination of biomass demand and supply has however been problematic due to the fact that, unlike commercial energy types like petroleum and electricity, it does not enter the formal markets, and is sometimes illegal especially as regards charcoal.

Other than looking at the various sources, biomass energy supply looks at their productivity which are dependent on the ecological capacity of an area, the total annual yield per annum, and their accessibility in terms geographic factors such as the location of consumption and resources, the infrastructure, slope, land use and land ownership. Accessibility also takes into account the fact that not all available biomass is for energy use.

In Kenya, there is currently no data available on long-term growth rates of forests as no permanent sample plots have been productively maintained in the indigenous forests and woodlands (Kigomo 2002, 1991). However there are various estimates from the Kenya Forestry Master Plan (KFMP) which considered values ranging from 0.5 – 2.8 m^3/ha as reasonable estimates to use for Kenya (KFMP, 1994). Estimates by Kenya Forestry Research Institute (Kigomo, 2002) of productivity of closed forests, based on the available sample plots, gave growth rates ranging between 0.83 - 2.37 m^3/ha/yr for high potential areas (>1000mm annual rainfall), 0.61 - 1.52 m^3/ha/yr for medium potential areas (500 - 1000 mm annual rainfall) and 0.42 m^3/ha/yr for closed forests on hill tops and along riversides in the low potential lands(<500 mm annual rainfall). As forests are gazetted and thus restricted, their accessibility for biomass energy is quite low at about 5% for fuelwood twigs and branches, and for remains from timber harvesting.

For woodlands, bushlands, wooded grasslands and grasslands, there are also limited studies undertaken on the growth and yield of woodlands, bushlands and wooded grasslands vegetation. A survey undertaken by KEFRI and the Forest Department (Wachiori et.al. 2001) covered 6 representative dryland districts with these vegetation types. Based on these studies and available local statistics, it was found realistic to fix productivity of the three woody vegetation types at the maximum yield for sites occurring in high potential land, median growth for the medium potential occurring sites and lowest growth for the low potential occurring vegetation cover (Kigomo, 2002). The estimates are summarized in Table 3.1 below:

Vegetation/Potential	High Potential	Medium Potential	Low Potential
Woodlands	0.97	0.64	0.32
Bushlands	0.64	0.44	0.24
Wooded grasslands	0.48	0.33	0.09
Sparse wooded grasslands	0.10	0.08	0.06

Table 3.1: Productivity of Dryland Vegetation Types in Kenya (m^3 /ha/annum)
Source: Kigomo et. al. (2002)

According to KFMP (1994), woodlands and bushlands consist of 2% timber, 9% pole and 89% fuelwood. Access of wood for fuel from woodlands, bushlands and wooded grasslands is expected to be much higher than from closed forests and an estimated 2% of inventory or 50% accessibility was found by the KFMP as realistic. For Wooded Grasslands and Grasslands, accessibility is even lower considering and also factoring in the small sizes of trees (mostly less that 5cm dbh), and low tree density in the arid wooded grasslands, the accessible wood for fuel would be much less and only 20% of wood energy would be expected from Wooded Grasslands and 10% from the sparsely wooded grasslands and grasslands. Most of these areas are also in the national parks.

Trees on farmlands however have different and variable productivity. A survey by KEFRI (Wachiori, 2001) indicated that farmers cut their trees within 6 to 14 years of planting. A study by KFMP (1994) revealed that the wood biomass growing stock on farms was 9.3 m^3 /ha in 1992 and was expected to grow annually at 0.5 m^3/ha. This implies that the on farm tree stocking could be estimated to be 14.3 m^3/ha in 2004. For the mainly low potential and few medium potential farmlands, this would imply an annual yield of about 1.07 m^3/ha taking into account a rotation period of about 13 years. This is in line with results found from KEFRI studies which gave a yield of 0.82 - 2.00 m^3/ha/yr for low to high potential farmlands (Kigomo, 2002).

Although trees on farm are 100% accessible to farmers, most are planted to supply timber, fodder, fruits, medicines and hedges to mark farm boundaries. As per the KFMP study on wood biomass outside forests, farmlands and settlements consist of 20% timber, 7% pole and 73% fuelwood. Only a certain proportion would therefore be available to meet the energy requirements, and this according to KFMP is about 3% of the inventory, which corresponds to between 70-90% accessibility.

For farm residues, various studies in Eastern Africa by FAO (1983) have come up with a correlation between crop yield and residues used for energy . It has thus determined multiplier factors which are used to convert crop yields of different crop types to their equivalent fuelwood equivalent. Their accessibility has also been determined at 50% available for energy use (FAO, 1983).

Past energy studies have also looked at the issue of gender. This is mainly because household energy is primarily women's responsibility. These studies have dwelt on durations spent collecting firewood, impacts on health, empowerment of women and other social issues. In terms of the environment, past studies saw women as the destroyers of natural resources through their harvesting of biomass for energy. Later studies however saw women as the victims of a biomass energy crisis, and more recently some view women as the saviours of the natural resources (Khamati-Njenga, 2004).

3.4 Past Interventions in Biomass Energy Use

The key interventions taken to manage biomass deficits have been demand management and supply enhancement.

Demand management aims at reducing actual biomass consumption by improving the efficiency of use especially considering the low technologies associated with biomass use. Traditional three stone stoves which are common in rural households have only an efficiency of about 10% while improved technologies using other stoves like the 'kuni mbili' fixed or non-fixed jiko can yield 30% efficiency (Kamfor, 2002).

In terms of charcoal, production has traditionally been through earth mounds or pits with an efficiency of 15% conversion by volume while (use of brick kilns can have a recovery of about 25% to 32% (Kamweti, 1982). The same can be said of use of charcoal cooking stoves with the traditional 'sagiri' having an efficiency of about 18% while the various improved jikos, the most common of which is the Kenya Ceramic Jiko (KCJ) having an efficiency of about 30% (Kamfor, 2002).

Other than energy savings, improved efficiency stoves have reduced indoor pollution. Indeed, the prevalence of Acute Respiratory Infections (ARI) and conjunctivas among children aged below five years and women between 15 and 60 years in households with traditional 3-stone jikos is significantly higher than with households with improved stoves (Wafula, 2000). Since household energy is primarily women's responsibility, they are the direct beneficiaries in such improvements or in cases of diversification of choice of energy carrier. Indeed, a project by Indigenous Technology Development Group, (ITDG) in Kajiado revealed that improved stoves led to improved health of women and children who were previously affected with respiratory diseases (Theuri, 2004).

Demand management has also been achieved by fuel substitution and the climbing of the energy ladder in terms of moving to higher and cleaner energy types, namely; kerosene, LPG and electricity. This has however been slow in many rural areas due to the cost implications in terms of cost of fuels and also the cost of appliances associated with the use of such fuels. The bulk of the rural poor can thus seldom afford them as most of them live below the poverty line of 1$. Energy is however tied to poverty as energy is also seen as having access to sufficient amounts of good quality energy can reduce a households vulnerability in terms of poverty (Theuri, 2004). Access to modern energy in rural areas is however also limited by energy supply systems which are inadequate and unreliable. However, experiences have shown that where there has been a direct government policy to encourage fuel substitution, like in Senegal, uptake has been quite high.

Demand management in Kenya as a whole has taken commendable measures to reduce biomass supply. This has however mainly been in terms of charcoal, where the energy saving jiko, Kenya Ceramic Jiko and other types are well adopted with about 47% of the country using them as shown in the Kamfor study. This uptake is however not true in terms of firewood use as only 4% of households nationally use improved firewood stoves. This is mainly because promotion efforts did not recognize the other roles of traditional stoves like flexibility, space heating, lighting, and insect repellence.

Other measures or plans as concerns charcoal include improving kiln efficiencies for charcoal production as is the case in Mwingi where there are plans to reduce up to 20% wastes in charcoal production (GoK, 2002). In terms of fuel substitution, the government has tried to reduce taxes on both kerosene and LPG, but more has to be done to improve uptake.

Supply enhancement aims at increasing standing stock to sustainably meet demand. This is mainly in form of tree planting and agroforestry practice on farmlands. Supply enhancement has also been in terms of improving management and protecting of the standing stock in forests, woodlands and bushlands. Establishment of tree nurseries for agro-forestry is also among key initiatives undertaken.

3.5 Importance of Local Studies

The characteristics of biomass fuels are site-specific and vary as the environment, geographic, agro ecological and climatic conditions, existence and accessibility of resources changes among areas (Hall, 1998).

Apart from the influence of energy on the environment, environmental factors can also influence the energy system in a certain area. Consequently, scenarios and effective interventions should be adapted to local conditions. This calls for an area-based approach in energy planning which for biomass energy basically means matching demand and supply. Interventions can be demand oriented, supply oriented or a combination of both.

These interventions are however hampered by lack of sufficient data at the local levels because distinct measures for particular areas are yet to be made, as the surplus and deficit situations have only been done at the national levels. Calculations for districts and provinces have only been estimated through the national studies. This, however, is too general, and more data for particular areas needs to be determined so that interventions are undertaken using accurate data on biomass stock, sustainable supply, local demand and consumption, and environmental effects thus making this study very important.

Linkages of environmental impacts from biomass energy use have also not been investigated thoroughly though various linkages have been established. This is especially because biomass cannot be transported over long distances, and ASAL areas have their fragile environmental and social conditions. Energy planning is not a one-time exercise, but a continuous and interactive process. The need for policy vis-à-vis energy, environment and socio-economic factors needs to be formulated especially at local levels. This is more so in terms of biomass energy which has often been regarded as the poor man's source of fuel, and yet given little attention by policy makers and energy planners.

The biomass situation in Mwingi should however not be used as the universal ASAL biomass energy-use environmental impacts example as the energy situation is different in every area and should be tackled as such as current trends suggest. It can however be used as an example to be replicated in other areas. This is because, household energy consumption is dependent of the area, household sizes, household incomes, availability of local resources and alternative fuels, climate, and even by seasons.

4.0 METHODOLOGY

4.1 Background

To investigate the environmental and social impacts arising from the use of biomass energy by rural households in Mwingi District, this study determined the energy consumption/demand in terms of firewood, charcoal, and farm residues. This was then compared with available sustainable biomass supply from forests, woodlands, bushlands, wooded grasslands, farmlands (agroforestry), and agricultural residues. The comparison of demand and supply was then used to determine the energy balances in terms of deficit or surplus biomass energy in the district, and the accruing environmental and social impacts arising from the deficit or surplus scenario established keeping in mind the fragile nature of Mwingi's dryland environment.

The study also looked at biomass energy use in terms of both demand management and supply enhancement. This was specifically in terms of the use of various improved technologies, use of modern fuels, conservation measures in place, and whether there was tree planting at the household level.

4.2 Data Collection

In undertaking this study, both primary and secondary data were used. Secondary data was mainly from literature review and raw data from the old Kitui district collected in the National Households Energy Demand and Supply Study undertaken by Kamfor Company Limited, of which the investigator was involved. Primary data was collected in the field through questionnaire administration to validate earlier data and to increase the sample size. Interviews with key personnel in Mwingi, and observations were also employed.

4.3 Sampling

The sample for the study was drawn from the National Sample Survey and Evaluation Programme (NASSEP) 111 Master Sample Frame used by the Central Bureau of Statistics and which had been developed during the 1989 Population and Housing Census, and updated in year 2000 when a new listing of households was undertaken for the Multiple Indicator Cluster Survey (MICS) in May of that year.

The master sample frame, is a two stage stratified cluster design, where the Enumeration Areas of the population census were the Primary Sampling Units (PSUs). The PSUs were selected using the Probability Proportional to Size method and then segmented into smaller units of about 100 households which constitutute on cluster.

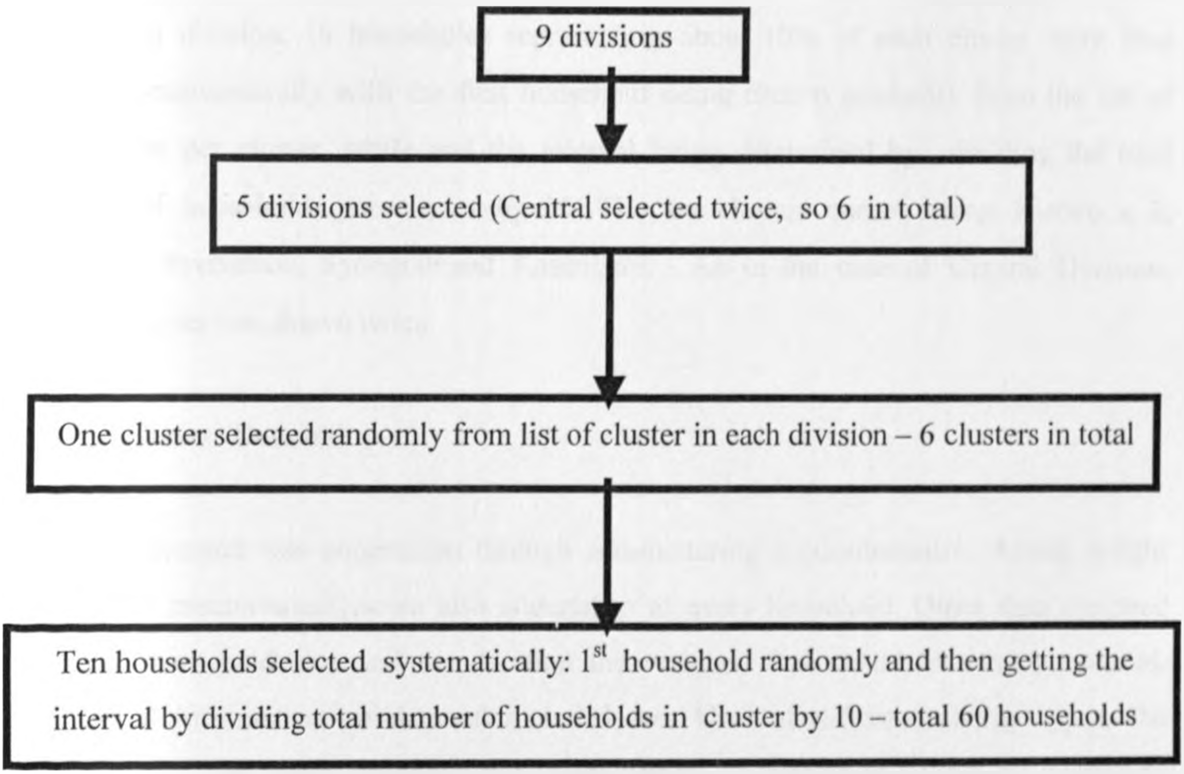


Figure 4.1: Sampling Format

A total of 60 households was chosen for this survey which represents about 0.1% of the total households in the district. 40 of these households were picked from raw secondary data from the Kamfor Study (2002), while 20 other households were selected to validate the earlier data and to increase the sample to the desired 60 households.

In selecting both the Kamfor and validation samples, multi-stage sampling, followed by systematic sampling was undertaken as shown in Figure 4.1 above. As a first step, the 4 divisions (Kyuso, Central, Nuu and Muumoni) and 2 divisons (Migwani and Central) were selected from the nine divisions in the district respectiviely. Central was drawn twice as the sample selection was done with replacement where a sample once selected has a chane of being picked again as shown.

The clusters in each divisions were then put together and one cluster chosen randomly from each division. 10 households representing about 10% of each cluster were then chosen systemantically with the first household being chosen randomly from the list of households per cluster, while and the interval being determined by dividing the total number of households per cluster by 10. The six clusters chosen were: Kisovo x 2, Kithinge, Syomavou, Syongoni,and Kasunguni. As in the case of Central Division, Kisovo cluster was drawn twice.

4.4 Biomass Demand

Biomass demand was undertaken through administering a questionnaire. Actual weight or volume measurements were also undertaken at every household. Other data captured included household size and the duration the weighed fuel would last the household. Additional information on demand included are: Uses of different energy types, the availability of the fuels, preferred fuel types, prices of fuel types, distances walked to purchase or collect, persons collecting/purchasing woodfuel, type of cooking stoves used, availability of energy saving devices, and energy saving awareness, among others.

Energy demand/consumption was calculated as follows:

1. Household biomass consumption per annum for the various biomass fuel types (firewood, charcoal and crop residues) was:

   Weight of fuel type x 365 days/ number of days the fuel lasts

2. Per capita consumption per fuel type was:

   Annual household consumption of fuel type/household size

3. Overall consumption of fuel type for the district was:

   Fuel type per capita x population

4. For charcoal, overall consumption was then converted into wood used to make the consumed charcoal in the district assuming a 15% recovery for pit and earth mound kilns by:

   Wood for Charcoal = Charcoal consumed x 100/15

4.5 Energy Supply

Biomass supply for the study was determined from the different vegetation formations in the district which include forests, woodlands, bushlands, shrub formations, and farmlands.

Available supply was determined by multiplying the yields and areas of the different formation types as shown in Table 4.1 below:

1. Available supply = Area of vegetation type x annual yield

Vegetation type	Areas in Ha	Annual yield in m^3/ha/yr	Total m^3/yr	Total tonnes/yr
Forests	A_1	Y_1	A_1Y_1	(A_1Y_1) 0.7
Woodlands	A_2	Y_2	A_2Y_2	(A_2Y_2) 0.7
Bushlands	A_3	Y_3	A_3Y_3	(A_3Y_3) 0.7
Wooded grasslands	A_4	Y_4	A_4Y_4	(A_4Y_4) 0.7
Grasslands	A_5	Y_5	A_5Y_5	(A_5Y_5) 0.7
Farmlands	A_6	Y_6	A_6Y_6	(A_6Y_6) 0.7
Total	Sum($A_{1:}A_6$)		Sum(A_1Y_1: A_6Y_6)	Sum(A_1Y_1:A_6Y_6)0.7

Table 4.1: Determination of Gross Supply of Biomass

NB: 0.7 tonnes/m^3 is the average density of wood

Areas on vegetation types used are as given in Table 2.1 while for yields, those of medium potential drylands were used as shown in Table 3.1. Conversion of supply from volume (m^3) to weight (tonnes) was done by multiplying the volume by average wood density.

Not all available biomass supply is however usually available for energy use. As such, the gross supply above was adjusted for accessibility. As discussed earlier, it is dependent on legislation, terrain, distances, and social and cultural factors. The accessibility chosen for the various vegetation types was: 70% for farmlands. 40% for woodlands and bushlands, 20% for wooded grasslands and 10% for grasslands.

Vegetation type	Total supply (tonnes/yr)	Accessibility (%)	Total accessible Supply (tonnes/yr)
Forests	S_1	a_1	S_1a_1
Woodlands	S_2	a_2	S_2a_2
Bushlands	S_3	a_3	S_3a_3
Wooded grasslands	S_4	a_4	S_4a_4
Grasslands	S_5	a_5	S_5a_5
Farmlands	S_6	a_6	S_6a_6
Total	Sum(S_1 S_6)		Sum(S_1a_1: S_6a_6)

Table 4.2: Determination of Accessible Supply of Biomass

For crop residues, supply was determined by getting the yields in tones of various main crops grown in the area. These were then multiplied by a conversion factor developed by FAO to give their equivalent in terms of wood fuel. Total supply was then divided by 2 as FAO has determined accessibility for biomass energy of crop residues as being 50% as shown in Table 4.3 below:

Farm Residues	Tonnes harvested	FAO Conversion Factor	Total Available in m^3	Total Accessible in m^3
Maize	X_M	Y_M	X_MY_M	$(X_MY_M)0.7$
Sorghum	X_S	Y_S	X_SY_S	$(X_SY_S)0.7$
Millet	X_{ML}	Y_{ML}	$X_{ML}Y_{ML}$	$(X_{ML}Y_{ML})0.7$
Beans	X_B	Y_B	X_BY_B	$(X_BY_B)0.7$
Total	SUM(X_M : X_B)		SUM(X_MY_M : X_BY_B)	SUM((X_MY_M)0.7 : (X_MY_M)0.7)

Table 4.3: Determination of Accessible Crop Residue Supply

4.6 Energy Balances and Projections

Comparisons of data on demand and supply were then made in tonnes and the balances in terms of deficit/surplus determined. Emerging scenarios showed areas of priority intervention, and the kind of strategic measures necessary at both technical and policy level. The deficits were further projected for the next 20 years under two scenarios: **A:** No intervention Scenario, and **B:** Intervention Scenario. Projections of energy demand took into account the population growth rate, while supply took into account decreasing vegetation rates as populations increased.

4.7 Determination of Impacts and Formulation of Intervention Strategies

Environmental and social impacts were determined from the deficit scenarios, and from field observations, interviews, and the various practices of households captured by the questionnaire. Other data used for determination of impacts was from the District Health Officer, District Forest Officer, and District Statistical Officer. Subsequently, appropriate intervention strategies were recommended.

5.0 FINDINGS AND DISCUSSION

5.1 Use of Different Fuels In Rural Mwingi District

The study found that households in rural Mwingi use different energy types at the household level for their various energy needs. The mean for the different energy types was as shown in Table 5.1 below:

Energy Type	Actual No. of Households	Weighted Percentage use by Households
Biomass Energy		
Firewood	60	100%
Charcoal	15	25%
Crop residues	27	45%
Other Energy Types		
Kerosene	59	98%
Liquid Petroleum Gas	0	0%
Electricity	0	0%
Solar	2	3.3%
Biogas	0	0%
Vehicle Batteries	1	1.6%
Dry cells	38	63%
Total Households	**60**	

Table 5.1: Weighted Percentage Use of Energy Types by Households in Rural Mwingi

Source: Field Work, Gikonyo J.M (2004)

Most of the energy needs at the household level included: domestic cooking, water heating, space heating, lighting, ironing and entertainment. Among the users of the different energy types, the percentage use for the various needs were as shown in Table 5.2 below:

Use / Energy Type	Domestic Cooking	House Heating	Water Heating	Lighting	Ironing	Entertainment
Firewood	100	35	87	10	0	0
Charcoal	100	21	57	0	43	0
Crop residues	100	15	46	10	4	0
Kerosene	5	0	0	100	0	0
Solar	0	0	0	100	0	84
Vehicle Batteries	0	0	0	0	0	100
Dry Cells	0	0	0	26	0	100

Table 5.2: Percentage Use for Various Activities by Households using Particular Fuel Types

Source: Field Work, Gikonyo J.M (2004)

5.2 Biomass Energy Sources

Firewood in rural Mwingi is either collected, purchased, or the combination of the two. Charcoal is either produced on farm or purchased, while crop residues are mainly collected from farms.

Biomass type	Collect only	Purchase only	Mainly collect, purchase a little	Mainly Purchase, collect a little
Firewood	88%	5%	5%	2%
Charcoal	57%	43%	-	-
Crop Residues	100%	-	-	-

Table 5.3: Biomass Sources by Households in Rural Mwingi
Source: Field Work, Gikonyo J.M (2004)

NB: For charcoal, collect refers to that produced on farm

A few households (3.3%) had stopped using crop residues citing that they had sufficient firewood as the primary reason. Though only a small percentage, their reason is quite significant because they point out the fact that use of farm residues is predominantly because of lack of sufficient amounts of firewood. Others (3.2%) had also stopped using crop residues because they are too smoky.

The mean average one-way distance to purchase firewood was 2.4 km with the furthest distance being about 5kms, but with majority of persons (60%) walking within a 1 km radius for purchase of firewood. Households who purchase firewood do it in various forms: whole tree, pieces and sticks, and in cartloads.

Most collected firewood is gotten from woodlots and from neighbours farms, boundary fences and cropland. About 25% of families have small woodlots, with a mean size of 2.2 acres consisting mainly of regenerated species of Acacia.

Source	Percentage
Boundary/Fences	10.%
Cropland	3.4%
Woodlots	13.8%
Neighbours	13.8%
Others - (purchased, and from trust lands i.e. woodlands, bushlands and wooded grasslands and grasslands)	58.6%
Total	**100%**

Table 5.4 Firewood Sources
Source: Field Work, Gikonyo J.M (2004)

Collected firewood is mainly tied in bundles and transported by women (89%) on their backs. The average one-way distance for collecting firewood is I km. Though this is still a short distance, it has increased five fold as compared to that of 220 metres average distance for collecting firewood about 10 years ago. Charcoal is mainly purchased within a 3 km radius.

Collector	Involvement	Hours per week
Adult Female	89%	4.3
Adult Male	43%	43 minutes
Children	23%	2.0

Table 5.5: Summary Findings on Firewood Collection
Source: Field Work, Gikonyo J.M (2004)

Figure 5.1: Woman Carrying Firewood in Mwingi

Figure 5.2: Untied Firewood Bundle in Mwingi Household

Among the charcoal using households, purchase is mainly in the form of sacks and debes, with only a small percentage (10%) procuring charcoal in small 2 litre-size tins.

The key residue used by those using crop residues was maize cobs (92.6%) and occasionally maize stalks (14.3%). Maize is planted by about 87% of the farmers, followed by beans (35%) cow peas (20%) and millet (10%). The average farm holding from the study was 6.4 acres which compares with that of 7 acres in the District Development Plan 2002-2007. Animal dung is not used as biomass fuel though most families have an average of 8 farm animals.

Figure 5.3: Maize Cobs for Use as Biomass Energy in Mwingi Household

5.3 Energy Demand

The Total biomass consumption when firewood, charcoal and crop residues are considered for Mwingi district is 276, 076 tonnes (equivalent to 394,395 m^3)as shown in Table 5.6 below.

For firewood, average household in Mwingi is 3,300 Kg per annum for both purchased and collected firewood. With an average household of 4.87 this gives a per capita consumption of 685 Kg which compares with the national average of 741 Kg for rural households given by the Kamfor (2002) study. The average weight of collected firewood used by a household per day is 9.51 Kg compared to that of 1.47 Kg purchased firewood clearly indicating use of up to five times more for collected firewood in comparison to that purchased. Those purchasing may also have alternative energy sources.

Charcoal consumption per household per annum per annum is 68 Kg giving a per capita annual consumption of 14 Kg as shown in Table 5.6. Consumption was found to be higher in households which produce their charcoal on farm at 1 Kg per day as compared to that of 0.68 Kg per day for those purchasing it.

Fuel Type	Annual HH consumption in Tonnes	Household Size	Per Capita in Tonnes	District Consumption in Tonnes
Firewood	3.335	4.87	0.68	223,597
Charcoal	0.068		0.01	4,575
Wood for Charcoal	0.455		0.09	30,500
Crop Residues	0.328		0.07	21,978
Total Biomass				**276,076**

Table 5.6: Biomass Consumption in Rural Mwingi District
Source: Field Work, Gikonyo J.M (2004)

For crop residues, the average amount used per household was 328 Kg per annum giving a per capita annual consumption of 64 Kg. Actual consumption for households using this fuel was however 2.7 kg. Most of the crop residues were collected in 'own' farms within a radius of 1 Km. Collection was mainly dome by adult females with the average collecting time being 1 hour per week.

5.4 Households Practice in Biomass Use

Only 39% of households plant trees on their farms in rural Mwingi. This low percentage may be because of the relatively small number of farmers who have heard of agroforestry (26.2%), and majority of them heard about it from NGOs and their neighbours. Most tree planting is undertaken by the household heads (71.4%), and children (19%).

Among the tree-planting households, majority plant fruit trees and *Grevillea robusta*. The most common trees are however species of Acacia (brevispica – Mikuswi; mellifera - mithia; seyal – White thorn tree – miongoli, migaa; nilotica – musene; polyacantha – white whistling thorn – migaa). Others are Mikeu (Melia volkensii), and Mithulu (Croton megalocarpus), some of which are regenerated.

Figure 5.4: Common Acacia Tress Preferred for Biomass Use by Households

The source of most planted seedlings is from vendors (47%) and own nurseries (seeds matured on farms – 28%). The average distance traveled to purchase tree seedlings is 17 km at an average cost of Kshs 5 per seedling. The average age of planted trees is about 10 years, with the main reason for tree planting being shade (17%) and timber (3.3%).

The main tree species used for firewood are Acacia species as shown in Figure 5.4. They are also the most preferred species. Most firewood is used while dry, but a small percentage of households still use firewood while it is green or while the rest of the pile continues to dry (8.2%), a clear indication of firewood scarcity. Only about 4% of households claimed to use the whole tree for biomass, and these are the ones who purchase it as such from their neighbours. Others use branches and twigs collected from the ground, or cut from shrubs.

In terms of appliances for firewood use, majority of households (98%) use the three stone jiko (also known as open fire) as shown in Figure 5.5 whose efficiency is about 10%, while only 1.7% use efficiency improved firewood jikos that have improved efficiency of about 30%, the key type in this category one being the "kuni mbili" (two sticks) fixed jiko as shown in Figure 5.6.

Most households (80%) using charcoal use the traditional "sagiri" (Figure 5.7) with an efficiency of about 18% while only a few (20%) use improved jikos in the form of the Kenya Ceramic Jiko - KCJ (Figure 5.8), with efficiencies of about 30%. This is way below the projected national average uptake of the KCJ of 47% reported by the Kamfor (2002) study. Most charcoal is produced from acacia species using earth kilns with an average efficiency of about 15%.

Figure 5.5: Three stone jiko

Figure 5.6: "Kuni Mbili" fixed Jiko Found in Mwingi Household

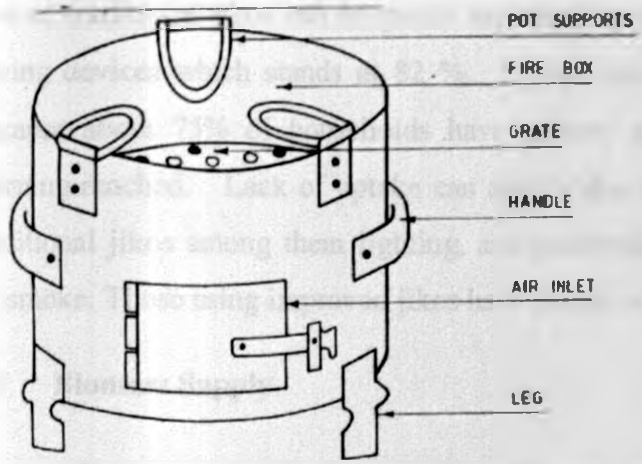


Figure 5.7: Traditional Sagiri Jiko

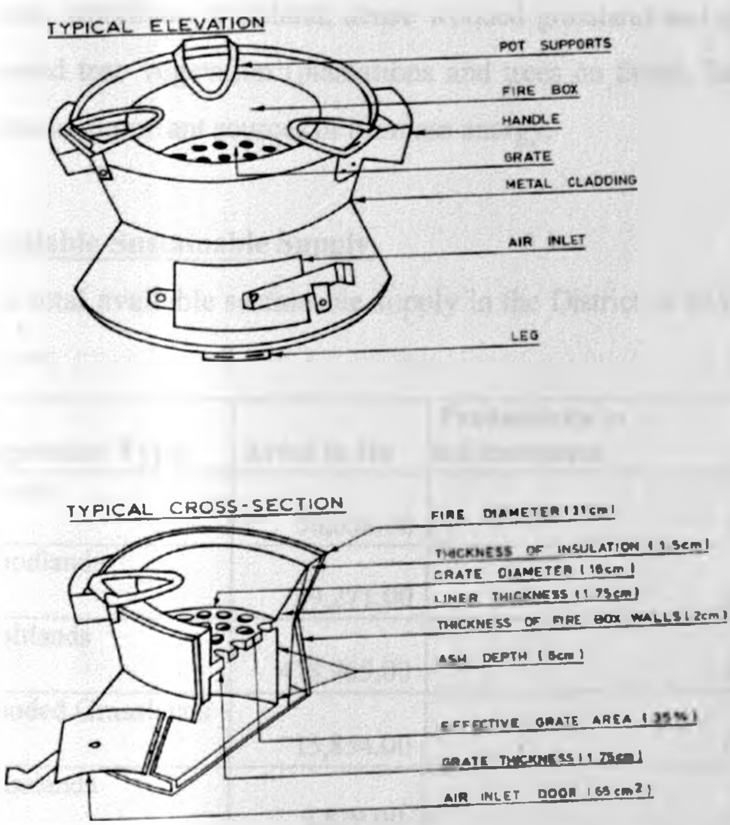


Figure 5.8: Kenya Ceramic Jiko

Use of traditional jikos can be partly explained by the high lack of awareness of energy saving devices which stands at 82 %. It can also be tied to the low education levels because about 75% of households have primary education being the highest level of learning reached. Lack of uptake can also be due to the multiplicity of purposes of the traditional jikos among them lighting, and preservation of thatch from termites and ants by smoke. Those using improved jikos have mainly obtained them from NGOs.

5.5 Biomass Supply

Biomass for energy use by households in Mwingi is sourced from the various vegetation types with the key ones available in the district being natural wooded vegetation (natural forest, woodland, bushland, dense wooded grassland and sparsely wooded grassland) and planted tree vegetation (plantations and trees on farm). Increasingly, farm residues have become important sources of biomass energy.

Available Sustainable Supply

The total available sustainable supply in the District is 625,359 m^3 as shown in Table 5.7 below:

Vegetation Type	Areas in Ha	Productivity in m3/ha/annum	Annual yield(m3)
Forests	56,058.00	0.75	42,043.50
Woodlands	49,271.00	0.64	31,533.44
Bushlands	478,965.00	0.44	210,744.60
Wooded Grasslands	15,854.00	0.33	5,231.82
Grasslands	9,829.00	0.08	786.32
Farmlands	313,102.00	1.07	335,019.14
Total	**923,079.00**		**625,358.82**

Table 5.7 **Available Energy Supply From Various Vegetation Types**
Source: Field Work, Gikonyo J.M (2004)

For Farm residues, available supply in rural Mwingi is 20,920 m^3 firewood equivalent as shown in Table 5.8 below:

Farm Residues	*Yield in Bags	Yield in Tonnes	FAO Multiplier	Fuelwood equivalent in m3
Maize	145,688.00	13,111.92	1.00	13,111.92
Sorghum	44,700.00	4,023.00	1.00	4,023.00
Millet	23,590.00	2,123.10	1.00	2,123.10
Beans	65,968.00	5,937.12	0.28	1,662.39
Total biomass from crop residues				**20,920.41**

Table 5.8 Available Energy Supply From Farm Residues
Source: Field Work, Gikonyo J.M (2004)

* **Yields in bags from District Statistical Officer**

Accessible Supply

The accessible supply for biomass energy in Mwingi is summarized in Tables 5.9 and 5.10 below:

Crop Residues	Fuelwood Equivalent in m3	Accessible Crop residues in m^3	Accessible Crop residues in tonnes
Maize	13,111.92	6,555.96	4,589.17
Sorghum	4,023.00	2,011.50	1,408.05
Millet	2,123.10	1,061.55	743.09
Beans	1,662.39	831.20	581.84
Total	**20,920.41**	**10,460.21**	**7,322.14**

Table 5.9 Accessible Energy Supply From Farm Residues
Source: Field Work, Gikonyo J.M (2004)

Vegetation Type	Accessibility	Accessible supply for biomass in m3	Accessible supply for biomass in tonnes
Forests	0.05	2,102.18	1,471.52
Woodlands	0.40	12,613.38	8,829.36
Bushlands	0.40	84,297.84	59,008.49
Wooded Grasslands	0.20	1,046.36	732.45
Grasslands	0.10	78.63	55.04
Farmlands	0.70	234,513.40	164,159.38
Total		**334,651.79**	**234,256.25**

Table 5.10 Accessible Energy Supply From Various Vegetation Types
Source: Field Work, Gikonyo J.M (2004)

The total accessible biomass supply in Mwingi district is thus the total of Tables 5.9 and 5.10 which comes to 345,112 m^3 or 241,578 tonnes per annum.

5.6 Negative Environmental Impacts Linked to Biomass Use in Mwingi District

Unsustainable Use of Natural Vegetation and Deforestation: There is unsustainable use of the various vegetation types for energy purposes in Mwingi District. Indeed, when the total biomass demand of **276,076 tonnes per annum** (394,395 m^3) is compared with the total sustainable and accessible biomass supply **241,578 tonnes per annum** (345,112 m^3), we note that there is a current biomass deficit of **34,498 tonnes per annum** (49,283 m^3) in Mwingi at the moment.

This represents a 12.5% deficit per annum which is met by over-harvesting and clearing (Figure 5.9) of the various biomass supplies and this is analogous to "living off the nature's capital rather than from nature's interest", if one considers a financial situation.

With the average volume of 8.5 m^3 per ha for a mature acacia woodland (Wickens, 1995), the 49,283 m^3 per annum deficit translates to about 5,789 hectares of an acacia woodland. This is thus not sustainable as consuming the stock means even less sustainable yields further exacerbating the situation.

With growing populations this deficit is expected to grow to 124,800 tonnes (equivalent to (178,285 m^3) representing a 30% deficit by year 2024 if no intervention is made as projected in Table 5.11 below. This is equivalent to 21,000 ha which is nearly half the woodland size in the Mwingi District. The unsustainable use of biomass energy thus clearly leads to deforestation, loss of habitats for species.

Years	**Yr 2004**	**Yr 2009**	**Yr 2014**	**Yr 2019**	**Yr 2024**
Population	326,506	367,613	408,868	449,214	487,518
Consumption tonnes/yr	276,076	310,834	345,717	379,832	412,219
Sustainable supply tonnes/yr	241,578	250,986	261,523	273,880	287,451
Deficit tonnes/yr	**(34,498)**	**(59,848)**	**(84,194)**	**(105,952)**	**(124,769)**

Table 5.11 Projected Biomass Balances to the Year 2024
Source: Field Work, Gikonyo J.M (2004)

Drying of rivers and water sources: The water catchment areas of Mwingi district have been negatively affected due to biomass energy extraction for firewood and charcoal production, some of which is being "exported" to Nairobi and other urban centers outside the district. This is mainly a common phenomenon in the hilltops in the whole of the district as shown in Figure 5.10. It is however most rampant in the Mui hills. Degradation of the water catchment areas has led to drying of the rivers during most of the year as shown in Figures 5.11 and 5.12.

Figure 5.9: Cleared Acacia Woodland in Mwingi

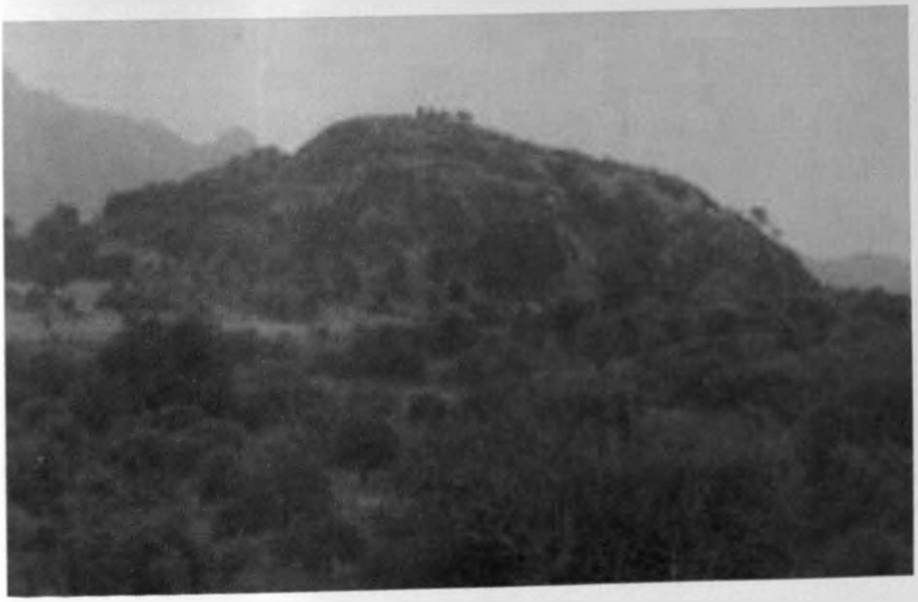


Figure 5.10: Cleared Hill Top in Mwingi

Figures 5.11 and 5.12: Dry River Bed in Nguutani in Mwingi District

Soil Erosion: The excessive pruning, destruction and removal of trees and vegetation leaves the ground susceptible to action from wind and water and results to soil erosion. This is mainly because removal of vegetation robs the soil of its protective cover and binding structure resulting in increased water run-off, and increased dispersal by wind. Increased run-off also results due to decreased infiltration of water into the soil. Soil erosion is mainly prevalent in sheet and gulley form in sloping areas and degraded hills. Erosion thus destroys upland areas, and the resulting sediment goes to the rivers.

Loss of Soil Fertility: Unsustainable use of biomass and the resultant deforestation denies the soil organic carbon which reduces soil fertility and water retention. Soil fertility is also reduced by loss of topsoil and humus through soil erosion.

The drylands of Mwingi also experience accelerated soil fertility loss by the use of crop residues which would otherwise be used to enrich and give nutrients back to the soil. This is more so considering that there is predominant and unsustainable over-use of farm residues for energy purposes as actual consumption is presently 22,000 tonnes (Table 5.6) against the sustainably available 7,000 tonnes (Table5.11).

The use of residues further threatens food security as the farming community does not have resources to buy fertilizers. The crop residues biomass deficit is set to rise to 23,000 tonnes per annum by year 2024 if no mitigatory measures are taken as shown in Table 5.12 below.

Air Pollution: Use of biomass invariably causes air pollution. This is mainly in form of carbon dioxide, carbon monoxide, and methane especially in the production of charcoal. Air pollution is further exacerbated by use of crop residues which give noxious gases, and also considering the inefficient jikos and the unventilated environments they are used in. Actual use of biomass also increases green house gases especially considering that it is used unsustainably, thus contributing to global warming and climate change.

Years	Yr 2004	Yr 2009	Yr 2014	Yr 2019	Yr 2024
Population	326,506	367,613	408,868	449,214	487,518
Consumption	21,978	24,746	27,523	30,238	32,817
Sustainable supply	7,322	7,871	8,462	9,096	9,778
Balances	(14,656)	(16,874)	(19,061)	(21,142)	(23,038)

Table 5.12: Farm Residue Balances and Projections to Year 2024
Source: Field Work, Gikonyo J.M (2004)

5.7 Social Impacts

Other than environmental impacts, use of biomass by households in rural Mwingi district has several social and economic impacts. These are discussed below:

Increased distances for firewood collection: Biomass scarcity has resulted in increased distances to be traveled for collecting firewood by households. The one-way distance for collecting has increased from 220 metres ten years ago, to 1 Km. This is a fivefold increase!

If the unsustainable use of biomass continues, scarcity will rise and the distances for collecting firewood increase. This will mean more drudgery for those involved in the collecting of firewood, with resultant increased periods, fatigue, and ill health, and lost time for other profitable activities like farming.

Increased periods spent in woodfuel collection: As shown in Table 5.5, women in Mwingi district spend an average 4.3 hours per week in collecting firewood, while children spend another 2 hours a week doing the same. Time spent in collecting firewood is always at the expense of other more economically viable activities especially for women who are the main biomass-for-energy collectors as shown in Table 5.4. Children on the other hand would engage in academic pursuits.

The firewood collecting periods are bound to rise with continued unsustainable use, and the resultant increasing scarcity and distances to be walked. The increased periods also imply increased fatigue, requiring even more hours for rest before embarking on other tasks.

Economic impacts: Biomass has always been considered a "free good" by most rural households. However, with increasing scarcity, there are an increasing number of households in Mwingi who now have to purchase firewood (Table 5.3) especially with respect to firewood. The purchase of biomass bears a cost on the household, while the money would otherwise be used in other areas of the household economy like food, clothing, education and business enterprises. In this regard, the less purchased biomass used in a family, the better for its economy. This may be the main reason why households who purchase firewood used five times less quantities than those collecting it.

Cultural impacts: Biomass scarcity has resulted in the dying out of some cultural practices which were associated with biomass use at the household level. Some of these include advice given to youth by elders in the evenings as they warmed themselves around a fire in the evenings. The absence of sufficient biomass has thus resulted to lack of a forum for advising youth, and passing on traditional knowledge and folklore resulting in among other things, moral decadence.

Food insecurity: Use of biomass and the resulting soil erosion and loss of fertility result in reduced food production in Mwingi District. The destruction of the water catchment also impacts negatively on the already low rainfall amounts, further reducing the agricultural output and affecting livestock production. All these lead to food insecurity.

Reduced coking means that protein intake is reduced as well, and this contributes to malnutrition. This is because most foods in Mwingi require cooking to be palatable and digestible. Lack of insufficient biomass for energy thus results to insufficient cooking of meals and skipping of meals.

Diseases: Indoor pollution has health impacts especially on mothers and children. This is mainly in terms of respiratory problems, and eye infections. This was evident in Mwingi where 60,119 and 5,522 cases of respiratory and eye infections respectively were reported in the year 2003 (survey results – Appendix 2). Other diseases linked to the prevalent use of biomass at the household level reported in the same period were malnutrition (568 cases), intestinal worms and amoeba (16,462 cases), diarrhoea (16,264 cases), and typhoid (36 cases). Health officials in Mwingi attributed some of these cases to restricted boiling of water for drinking as a result of lack of sufficient energy amounts and also due to ignorance. Inadequate cooking of food also causes ill health.

Gender issues: Household energy is primarily women's responsibility as shown in Table 5.5. They are thus the group that is most affected by its predominant use, its scarcity and lack of alternatives. They are the one who carry heavy loads (Figure 5.1), walk the increasing distances, spend long periods, and thus suffer the fatigue, backaches, headaches, and injuries from cuts and thorns associated with biomass use. Women and girls are also the ones who light fire and are involved in the cooking of food and are thus the ones who will suffer from the smoke irritation and associated diseases of biomass use. Men and boys on the other hand are rarely involved in biomass collection unless it involves some economic return like charcoal production.

A few rape cases in Mwingi have been associated with biomass collection and use. Its predominant use thus affects women's welfare.

5.8 Mitigation Options

Mitigation of both the environmental and social impacts can be done by reducing the biomass demand by improving energy-use efficiency or through substitution with other energy types, or by increasing the sustainable supply.

Indeed, as recommended in Chapter 6, the overall implementation of these mitigatory measures as proposed would result in removal of the current biomass deficit and actually result into a surplus by year 2014 as shown in Table 5.13 below:

Years	Year 2004	Year 2009	Year 2014	Year 2019	Year 2024
Population	326,506	367,613	408,868	449,214	487,518
Consumption tonnes/yr	276,076	286,224	302,213	314,311	324,321
Sustainable supply tonnes/yr	241,999	272,389.51	308,289.80	350,701.50	400,807.88
Deficit tonnes/yr	(34,076)	(13,834)	6,077	36,391	76,487

Table 5.13 Biomass Balances to Year 2024 After Recommended Interventions
Source: Field Work and Recommendations, Gikonyo J.M (2004)

Demand Management

Demand management includes strategies of reducing biomass consumption. The main ways of doing this would be by promoting use of efficient cooking stoves for both firewood, crop residues and charcoal, and improved kilns in charcoal production.

If these measures were taken up by 100% of the population in Mwingi overnight, the biomass crises in Mwingi district would literally be solved. Indeed, the present biomass demand would decrease from 276,000 tonnes to only 93,000 tonnes resulting in a surplus of 148,000 tonnes up from the current deficit of 34,000 tonnes as shown in Table 5.14 below:

	Present consumption (tonnes)	Intervention	New consumption (tonnes)
Firewood	223,596	Improved stove	74,532
Charcoal	4,575	Improved stove only	2,745
Firewood for charcoal		Improved stove only	18,300
Firewood for charcoal		Improved kilns only	21,961
Firewood for charcoal	30,500	Both improved stove & kilns	10,980
Farm residues	21,978	Improved stove	7,326
Total	**276,076**		**92,838**
Total Supply	**241,578**		**241,578**
Balances	**(34,497)**		**148,739**

Table 5.14: Impact of 100% Uptake of Improved Appliances
Source: Field Work and Projections, Gikonyo J.M (2004)

However, as a 100% uptake is not feasible, a gradual increase of energy efficiency stoves is recommended. As discussed in Chapter 6, for firewood users, a 7% increase in uptake every 5 years would reduce per capita firewood consumption from 684 Kg to 548 Kg in year 2014. The same uptake will reduce farm residues per capita from 67 Kg to 54 Kg in the same period as shown in Table 5.15 below:

	Present per capita (Kg)	Intervention	New per capita (Kg)				
			Year 2004 (if 100% uptake)	Year 200	Year 201	Year 201	Year 202
Firewood	684	Improved stove	***228***	63	607	575	548
Charcoal	14	Improved stove only	***8.4***	1	1	1	9.
Firewood for charcoal		Improved stove only	***56***	8	7	7	6
Firewood for charcoal		Improved kilns only	***67***	9	8	8	7
Firewood for Charcoal	93	Both improved stove & kilns	***34***	7	7	6	6
Farm residues	67	Improved stove	***22.4***	6	5	5	5

Table 5.15 Projected per Capita Consumption to year 2024 if Recommendations are Implemented

Source: Field Work and Recommendations, Gikonyo J.M (2004)

Use of improved efficiency charcoal jikos and kilns by about 10% uptake every 5 years would reduce wood for charcoal per capita from 93Kg to 64 Kg.

At present consumption levels of biomass, the energy requirements of Mwingi District are about 4.4 million GJ. When efficiency of appliances and fuel types is factories in, effective energy in the district is only about 460,000 GJ as shown in Table 5.16 below. If these energy requirement was to be substituted by use of another fuel type, the total demand for biomass would require about 97,000 tonnes of LPG , 1.2 million Kwhs of electricity or about 112 million litres of kerosene considering their conversion of 45.2 GJ per tonne for LPG, 3.6 GJ per Kwh for electricity and 39.1 GJ per 1,000 litres for kerosene. If efficiency is factored in, the energy requirement would be met by 17,000 tonnes of LPG (twenty one 12.5 Kg cylinders each for the 60,000 households), 256,000 kWh of electricity or 31 million litres of kerosene.

		GJ value per tonne	GJ equivalent	Efficiency	Total GJ
Consumption	**per district**				
Firewood per capita	223,597	16	3,577,551	10%	357,755
Charcoal per capita	4,575	33.1	151,436	18%	27,258
Firewood for charcoal	30,501	16	488,011	15%	73,201
Farm residues per capita	21,978	13.9	305,501	10%	30,550
Total Biomass demand	276,076	**Total 1**	**4,034,488**		**415,564**
		Total 2	**4,371,063**		**461,507**

Table 5.16: Conversion of Energy Consumption to Giga Joules
Source: Field Work, Gikonyo J.M (2004)

NB: Total 1 refers to the total while considering charcoal as "charcoal" and Total 2 while considering charcoal as wood for charcoal. Total 2 will be used in the various substitutions.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The hypotheses in this study were tested qualitatively. As such no quantitative tests were done.

From the results of the study, it was evident that there was a significant difference between biomass demand and sustainable biomass supply. With current consumption at 276,000 tonnes and sustainable supply at 242,000 tonnes, there is a current biomass deficit of 34,000 tonnes (12.5% deficit). This is projected to grow to 125,000 tonnes by year 2014 if no interventions are put in place. Accordingly, the first hypothesis was accepted as true:

1. There is a significant difference between biomass demand and biomass supply in Mwingi District.

As discussed in section 5.6 above, it was also evident that there are several environmental and social impacts arising from the unsustainable use of biomass for energy purposes. Accordingly, the second hypothesis was also accepted as true:

2. There are significant environmental and social impacts if the household biomass demand exceeds sustainable supply in Mwingi District.

The study found out that households collecting firewood spent up to five times more than those purchasing it (9.51 Kg/day vs. 1.47Kg/day.). For firewood, those producing their own charcoal were also found to be using about 30% more than those purchasing it (1Kg/day vs. 0.68 Kg/day). From these findings, the third hypothesis was also accepted as true:

3. There is a significant difference in consumption between households who purchase firewood with those who collect firewood in Mwingi District.

The study additionally found that though 39% of households planted trees, they did so for shade or for fruits, and not for biomass energy. In terms of improved efficiency cookstoves, only 1.7% used improved firewood stoves, and only 20% used improved firewood stoves. Charcoal production was also entirely done using the earth mound kiln with low efficiency. Subsequently, the fourth hypothesis of this study was also accepted:

4. There is no significant involvement by households using biomass energy in either biomass supply enhancement or demand management in Mwingi District.

6.2 Recommendations

A discussed in section 5.8 above, the mitigation measures for the environmental and socio-economic impacts will generally involve demand management by substitution and improving technology efficiency in terms of production and end-use, and by enhancing sustainable supply. For these two to work, there also has to be government policy and goodwill.

Promotion of Improved Efficiency Firewood Stoves: Because the 100% uptake is not feasible as shown in Table 5.15 , it is recommended that uptake of improved cookstoves be promoted by about 7% every five years. This is possible with NGO participation and extension services by both government and private players. This will result in improved efficiency cookstoves uptake by households growing from the present 1.7% to 31% in year 2014. This will result to a gradual per capita reduction from 668 Kg to 548 Kg as shown in Table 5.14. As crop residues use the same stoves, their per capita would also reduce from the present 67 Kg to 54 Kg. The thrust of this promotion campaign should be directed to those households already purchasing firewood and those experiencing scarcity. It should also center on women as they understand the difficulties of firewood collection, and are bound to be the biggest beneficiaries in terms of saved time, distances, money, and well-being.

Promotion of Improved Efficiency Charcoal Stoves: Use of improved efficiency charcoal jikos should be promoted by about 10% uptake by households every 5 years. This would increase uptake of the Kenya Ceramic Jiko and other improved stoves from the present 20% to 60% by year 2014. Promotion of these cooking stoves should incorporate local artisans and NGOs to ensure that quality clay liners are produced for maximum efficiency. Strategies should include distributing some free stoves to select households as demonstration centers for energy and charcoal savings.

The use of improved efficiency charcoal stoves would result in a per capita reduction from 14 Kg to about 10 Kg, and per capita wood for charcoal from 93 kg to 66 kg.

Promotion of Improved Charcoal Kilns: All charcoal currently produced and used in Mwingi district is made from earth mound kilns which have an average efficiency of about 15%. This is as compared to improved kilns which yield about 25-32% produced charcoal by volume. Improved production techniques in stacking the earth mound or pit, and in ventilating it and covering it would also increase yields to about 20%.

Uptake of the improved kilns, and improved production techniques while using earth kilns through training would thus result to an average 25%. Charcoal burners should thus be organized into groups for training and a kind of SACCO formed to enable them get and maintain improved kilns. Uptake of kilns would then be raised by about 10% uptake every 5 years so that by year 2024 about 40% of charcoal would be produced at higher yields. This would decrease the per capita wood for charcoal from 93 Kg to about 78 Kg.

Energy Substitution: Despite the overwhelming use of biomass energy in Mwingi, there is need to promote the climbing of the energy ladder. This will mean using cleaner and more efficient fuels like electricity and petroleum at the household level. This would result in less biomass needs and thus increased vegetation cover and accruing environmental benefits. Substitution can however only be taken up slowly due to the cost of the fuels and their associated appliances. This is more so considering the high poverty prevalence of 60% classified as absolute poor. Other areas of substitution would be in terms of promoting solar panels for lighting, and introducing of solar cookers to supplement biomass in terms of cooking.

Better Management of Existing Vegetation: Better management can be achieved by gazetting and rehabilitating the remaining hills which serve as catchments in the district namely: Kea, Endui, Kiomo, Mbaika Nziu, Tharaka, and Kyunga for the forested areas. This will not enhance supply but will have positive environmental benefits and contain further degradation of the hills

Other vegetation types can also be better managed especially by the County Council which owns the bulk of the rangelands by regulating biomass collection and charcoal production, and facilitating regeneration of the existing vegetation through better management. This would increase yields by about 5% every 5 years.

Agroforestry: Only 39% of Mwingi's population plant trees on their farms and these are mainly for shade and for fruits. The concept of agroforestry has only been heard by only about 26% and should thus be propagated by both Government and NGOs. This can be done by encouraging tree planting on hedges and introduction of woodlots on farms. Agroforestry can be easily picked up by farmers if the economic benefits of tree planting can be shown to them, and fast growing trees like *melia volk*ensii and *Eucalyptus* clones can be introduced. These species have been shown to be more profitable than coffee growing even for the higher potential areas and an Internal Rate of Return, IRR, of 66% had been calculated for a seven-year rotation plantation in the National Energy Study by Kamfor in 2002. Other studies have shown that a grown melia tree can earn as much as Kshs 10,000 when split for the manufacture of doorframes or parquet floors.

Promotion of indigenous food crops: This strategy would kill two birds with one stone by enhancing energy supply, and also food security and nutritional value. This is because indigenous food crops such as yams would do well in the dryland environment of Mwingi district and would inadvertently also mean growing of more trees as these are needed to support the yams. The indigenous crops would by themselves also contribute to soil and water conservation (Indigenous Technology Development Centre,1996) because they are only harvested when required. They would thus maintain a vegetation cover throughout the year as they are perennial.

Policy: The implementation of the above recommendation would require some enabling environment through government policy. For example, it would be difficult to train people in better methods of charcoal production or to introduce improved kilns while charcoal making is still considered illegal. The government thus needs to legalize charcoal production and in this way also have a form of localized certification to ensure that the charcoal has been produced from sustainable sources.

The government also needs to reduce taxes on not only the LPG and kerosene fuels, but also the associated appliances for to facilitate their uptake by rural households. This has already been recommended in the Draft Energy policy which calls for a zero-rating of LPG appliances and their standardization. The same should be done with solar energy equipment. Other areas where policy interventions would be required are in the quality control of improved efficiency charcoal stoves where unscrupulous traders have been found using cement instead of clay. This results in the easy cracking of the clay liner leading to several households reverting back to the traditional 'sagiri' stove. This subsequently undermines the uptake of improved efficiency stoves.

Further Studies: More energy studies should be undertaken at the local level, at least at the district level in the other parts of the country as biomass is and will continue to be a major energy source for households countrywide. Mitigatory measures to counter the adverse environmental and social impacts would then be undertaken locally and have better positive impacts.

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8.0 GLOSSARY

Energy Demand: For this study, demand means actual biomass consumption..

Energy Supply: This is the available biomass that can be accessed by the population in the district from the different vegetation types and from agricultural residues. Supplies outside the district will not be considered even though some may still be accessible to the people in Mwingi as interventions will also be formulated at the district level.

Household: A household is defined as a person or a group of persons who reside in the same compound, are answerable to the same head and also pool and share their resources for common provisions. The three important ways of identifying a household are ensuring that:

Woodfuel: Means both firewood and charcoal

Fuelwood: Firewood i.e. All types of wood both indigenous and non-indigenous from trunks, branches and other parts of trees and shrubs which the household uses for the purpose of producing energy.

Charcoal: This is a form of fuel obtained through the pyrolytic conversion of wood in the absence or limited supply of air.

Paraffin: Also known as kerosene and is a hydrocarbon fuel obtained from the distillation of crude oil. It is colourless, inflammable and is commonly used for both lighting and cooking.

Gas (LPG): Liquified Petroleum Gas is a hydrocarbon fraction of the paraffin series. It is lighter than gasoline and is derived from distillation of crude petroleum. It is kept as a liquid under constant pressure and usually sold in cylinders by petroleum companies.

Plantation: Artificially established forest stands by afforestation on land which previously did not carry forests, or where they have replaced an existing forest with new and essentially different species

Appliance: An instrument or tool used to extract energy from a source.

Jiko: Small stove used to burn charcoal, especially for cooking. The normal jiko (sagiri) is a traditional metal stove made from scrap sheet metal.

Kenya Ceramic Jiko: This is a light portable stove which is bell-bottom shaped and has a combustion chamber insulated with a ceramic liner. It uses charcoal

Space heating: Creating warmth or providing heat during cold season or night. Heating may also be used for other purposes.

Kiln: This is a structure in which wood is converted into charcoal. It may be improved in form of bricks or in most cases it is an earth pit or mould where soil is heaped on a stack of wood.

Stack: An arrangement of firewood or other energy type for the sake of determining the volume for sale purposes.

Head load: his is the quantity of wood normally carried on the head from the source to the household consumption area

Tin: Normally the four liter paint can or 2 kg cooking fat containers. Used for selling charcoal in small amounts and weigh about 1 kg of charcoal.

Debe: The size of the 20 litres oil containers or 50 Kg cooking fat. Also used for selling charcoal.

APPENDICES

Energy Demand & Supply for Households Survey in Mwingi District, 2002/2004

Household Composition

Enumerator ____________________

Supervisor ____________________

GEO CODE				CLUSTER NO				H/HOLD			O.U.O
1	2	3	4	5	6	7	8	9	10	11	12

Province .... District ....

City/Town .... Cluster Name...........

Date.......................

Agroecological Zone................................

TO BE ANSWERED BY ALL HOUSEHOLD MEMBERS

SERIAL No.	NAME	RELATION TO HEAD 1 = Head 2 = spouse 3 = son 4 = daughter 5 = Brother/ Sister 6 = Mother/ Father 7 = other relative 8 = Non - relative	AGE IN COMPLETED YEARS If < = 97 code 97	SEX 1 = Male 2 = Female	MARITAL STATUS 1 = Never married 2 = Married 3 = Separated 4 = Divorced 5 = Widowed 6 = other (specify)	ACADEMIC EDUCATION What is the school attendance status of ...... 1. At school 2. Left school 3. Never went to school 4. NS/DK 5. Under 5 years	ACADEMIC EDUCATION What is the highest education level completed by .... see codes in the manual	Occupation of members aged 18years and above See codes in manual
A 01		A02	A03	A04	A05	A06	A07	A08

SOCIO- ECONOMIC INFORMATION

B. INFORMATION ON MEAL COOKED

B01. Do you take the following meals regularly and what is the main type of fuel used?

Taken the following meal		Fuel type used
Breakfast		
Lunch		
Dinner		

Code: 1. Yes 2. No

B02. If No in B01 give reasons for not taking a particular meal

1) ....

2) ....

3) ....

B03. What are your main food /beverages and main fuel type used in the family

Food	Fuel type
1.	1. ....
2.	2. ....
3.	3. ....
Beverages	
4.	4. ....
5.	5. ....

B04. Indicate the approximate time taken to cook the above meals/ beverages in hours/minutes

Meal	Time taken
1.	....
2.	....
3.	....
Beverage	**Time taken**
4	....
5	....

C. INCOME

C01. What was the average household income from wage employment / self employment last year (**Kshs**). Income from **self employment should exclude sales from farm products** (Crop,Livestock and wood products).

Household head ....

Spouse ....

Relative remittance ....

Others (Specify)..................................

C02. Income from crop sales last year in (Ksh.)

Coffee ....

Tea ....

Cotton ....

Maize ....

Pyrethrum ....

Wheat ....

Others (Specify)....................................

C03. Livestock Sales last year in (Ksh.)

Cattle & Products ....

Goat& products................

Sheep& products.............

Chicken & Eggs ....

Milk sales ....

Other (specify)...

C04. Wood product sales last year in (Ksh.)

Firewood..............................

Charcoal...........................

Poles..............................

Whole tree..............................

D. FARM HOLDING CHARACTERISTICS

D01. What is the Size of the farm holding either in

Acres .... or

Hectares ....

D02. Total area under-:

(i) Main Crops (**Specify the area under the respective crops**)

Crop	Area
1.	....
2.	....
3.	....

(ii) Fodder crop ....

(iii) Pasture ....

(iv) Woodland ....

(v) Other (Specify)

1. ....

2. ....

D03 Quantity of main agricultural crops produced last year in Kg

1. ....

2. ....

3 ....

D04. Number of livestock in the household

1. Cows ....

2. Donkeys ....

3. Goats/Sheep ....

4. Pigs ....

5. Poultry

5.1 Local ....

5.2 Broilers ....

5.3 Layers ....

E. HOUSING CONDITION

What materials were used for construction of the main house?

E01. Roof

1. Iron sheet
2. Tiles
3. Asbestos
4. Grass/ Makuti
5. Others(specify)

Circle the response

E02. Wall

1. Mud /Animal dung
2. Stone/ Cement
3. Wood
4. Iron Sheet
5. Others(specify)

Circle the response

E03. Floor

1. Mud
2. Stone / Cement
3. Wood
4. Tiles
5. Others (specify)

Circle the response

E04. Does your household have access to piped water ?

1. Yes 2. No

Circle the response

(EGY) ENERGY: FUEL CONSUMPTION

Please indicate which of the following fuels your household has *used for any activity in the past*. Code appropriately in the boxes provided.

[1] Yes [2] No

egy1	Firewood. If Yes, go to **FW**	**egy1**	
egy2	Wood waste. If Yes, go to **WW**	**egy2**	
egy3	Charcoal. If Yes, go to **CHA**	**egy3**	
egy4	Kerosene. If Yes, go to **KER**	**egy4**	
egy5	Farm residue. If Yes, go to **CPR**	**egy5**	
egy6	Grid Electricity. If Yes, go to **ELE**	**egy6**	
egy7	LPG (Gas). If Yes, go to **LPG**	**egy7**	
egy8	Solar Energy. If yes, go to **SOL**	**egy8**	
egy9	Drycell batteries. If Yes, go to **DRY**	**egy9**	
egy10	Vehicle batteries. If Yes, go to **VEH**	**egy10**	
egy11	Electricity (Own Generator). If Yes, go to **Gen**		
egy12	Candles. If Yes, go to **CAN**	**egy12**	
egy13	Biogas If Yes go to **BIO**	**egy13**	
egy14	Windmill(Wind)	**egy14**	
egy15	Mini-Hydro(MH)	**egy15**	
egy16	Other (Specify) OTH	**egy16**	

Establish whether there is mini hydro and windmill in the locality

(FW) FIREWOOD

fw1 Was firewood used during the last 12 months? fw1

[1] Yes

[2] No

code 1. Yes 2. No

fw1.1 If No, why did you stop?

1. ....
2. ....
3. ....

Give reasons then go to the next fuel type

If Yes, for what purposes ?

code 1. Yes 2. No

fw1.2	Domestic Cooking	fw1.2	
fw1.3	Heating water	fw1.3	
fw1.4	House heating	fw1.4	
fw1.5	Lighting	fw1.5	
fw1.6	For home business	fw1.6	
fw1.7	Other(Specify)	fw1.7	

fw2 How do you obtain your firewood? fw2

[1] Collect/given only

[2] Purchase only

[3] Mainly Purchase / Collect some

[4] Mainly Collect / Purchase some

[5] Other(Specify)

fw3 What unit(s) of measure did you use in purchasing firewood last? fw3

[1] Bundle

[2] Stack (**Indicate the dimensions in cm e.g 20cm by 10cm by 5cm**)

[3] Other (Specify)

fw4 **Ask respondent to show you typical stack/bundle/piece Weigh/measure this stack/bundle/ piece and record the weight (in kg) / measurements in cm.** fw4

fw5 During your last purchase, how many units (given in fw4) of firewood did you buy? fw5

fw6 How much did you spend on this purchase in Ksh.? fw6

fw7 How many days will this purchase last? fw7 fw5 What was the one-way distance travelled in Kilometres to make this purchase? fw8

The following are questions for collected firewood. If the household did not collect firewood during the last 12 months , put [9] from fw9 to fw14.

fw9 What unit(s) of measure do you use in collecting firewood? fw9

[1] Bundle

[2] Stack (**Indicate the dimensionsin cm e.g 20cm by 10cm by 5cm**)

[3] Other, specify

fw10 **Ask respondent to show you typical stack/bundle/piece. Weigh/measure this stack/bundle and record the weight (Kg)/measurement (cm).** fw10

fw11 During last collection, how many units (given in fw10) did you collect? fw11

fw12 How much time was used in collecting firewood by the following members? (hours per week)

fw12.1 Adult male(s) fw12.1

fw12.2 Adult female(s) fw12.2

fw12.3 Children fw12.3

fw13 How many days did this collected firewood last? fw13

fw14 What was the one-way distance traveled in collecting firewood (in Km) fw14

Questions relate to both Collected/Purchased firewood

fw15 What type of firewood appliance(s) do you use ?

1. Three stone 2. Kuni mbili (fixed) 3. Kuni mbili (portable) 4 .Other (Specify)

fw16 From where did you obtain the appliance (s) ? *Please circle*

1.NGOs 2. Enterprenuers 3. Others (Specify)

fw17 When did you obtain the appliance(s) ? ....

fw18 How much did the appliance(s) cost in Ksh.? ....

fw19 Where do you obtain firewood from?

1. Boundary/Fences 2. Crop land 3. Woodlot 4. Roadside 5. Neighbour

6. Trust land 7. Gazeted forest 8. Others

Please circle response(s)

fw 20 What is the mode of firewood transport ?

1. Human
2. Lorry/tractor/Pick-up
3. Bicycle
4. Carts
5. Donkeys
6. Others(specify)

....

Please circle

fw 21 Do you plant trees in your farm ?
1. Yes 2. No

If No, go to **fw29**

fw 22 If yes what tree species do you have and how many per species

....

....

fw 23 What is the age of trees (in years)

....

fw 24 What is your preferred species
1. ....
2. ....
3. ....

Please circle

fw 25 Who does the tree planting ?
1. Head 2. Spouse 3. Children 4. Hired labour

fw26 what is your source of the tree seedlings ?

1. Own nursery 2. Seed vendors 3. Forest Dept.
4. Energy centre 5. Women groups 6. NGOs

fw26.1 What is the one way distance from your farm to the source in Km? ....

fw26.2 What is the cost per seedling in Ksh?

....

fw 27 Who does the tree harvesting ?
1. Head 2. Spouse 3. Children 4. Hired Labour

fw 28 For the planted trees what are the main uses ?

1. Firewood 2. Poles 3. Timber
4. Other(Specify)..........................

fw 29 For firewood which part of the tree do you use ?
1. Stem 2. Branches 3. Twigs
4. Stumps/Roots

Please circle Responses

fw 30 Have you heard about agroforestry ?
1. Yes 2. No.

fw 31 If yes where
1. GOK
2. NGO
3. Farmers
4. Media (specify)
5. Private companies(specify)

1. ....
2. ....
3. ....

fw 32 Are you familiar with Ministry of Energy centres ?
1. Yes 2. No

If no skip to WW

fw 33 If yes how have you benefited from them ?
1. Agroforestry 2. Improved stoves 3. Kiln efficiency
4. Other(Specify)

[illegible]

If Yes, for what purposes ? [illegible]

Domestic Cooking [illegible]

Heating water [illegible]

Lighting [illegible]

For other purposes [illegible]

[illegible]

(CHA) CHARCOAL

cha1	Was charcoal/charcoal briquettes used during the last 12 months? [1] Yes [2] No	cha1	
cha1.1	If No, why did you stop ?		
	If Yes, for what purposes ? *Please code 1. Yes 2. No*		
cha1.2	Domestic Cooking	cha1.2	
cha1.3	Heating water	cha1.3	
cha1.4	House heating	cha1.4	
cha1.5	Ironing	cha1.5	
cha1.6	For home business **(Specify)**	cha1.6	
cha1.7	Other, specify:	cha1.7	
cha2	How do you obtain your charcoal? [1] Produce in the farm [2] Purchase [3] Both	cha2	
	The following are questions for charcoal produced in the farm. If the household did not produce charcoal, put [9] from cha3 to cha7.		
cha3	What unit(s) of measure do you use for produced charcoal? [1] Tin [2] Debe [3] Sack [4] Other, specify	cha3	
cha4	During your last production how many units did you produce?	cha4	
cha4.1	How many units of the produced charcoal were used by the household?	cha4.1	
cha5	**Ask respondent to show you typical Tin/Debe/sack. Weigh this and record the weight in Kg.**	cha5	
cha6	How many days did this stock last?	cha6	
cha7	What kind of kiln(s) do you use ? 1. Earth kilns 2. Improved kilns	cha7	
	The following are questions for purchased charcoal. If charcoal was not purchased by the household, put [9] from cha8 to cha14		
cha8	What unit(s) of measure do you use to purchase charcoal? [1] Tin [2] Debe [3] Sack [4] Other, specify **Ask respondent to show you typical Tin/Debe/sack. Weigh this and record the weight in Kg.**	cha8	
cha9	During your last purchase, how many units (given in cha8) of charcoal did you buy?	cha9	
cha10	How much did you spend during your last purchase ?	cha10	
cha11	How many total days will this purchase last?	cha11	
cha12	What is the one way distance travelled to make the purchase in Kilometres?	cha12	

cha13 Does the price for units you buy vary anytime during the year ? 1. Yes 2. No cha13

If yes, what time of the year ? Price

....

....

cha14 What is the mode of charcoal transport?
1. Human 2. Bicycle 3. Cart 4. Donkey 5. Lorry/tractor/Pick-up 6. Others(specify)

cha15 What type of appliance(s) do you use ? *Please circle the response(s)*
1. Traditional Jiko 2. Kenya ceramic jiko 3. Other (Specify)

cha16 From where did you obtain the appliance (s) ? 1. NGOs 2. Enterpreneurs Others(specify)

cha17 When did you obtain the appliance(s) ? ....

cha18 How much did the appliance(s) cost in Ksh? ....

(KER) KEROSENE

ker1 Was kerosene used during the last 12 last months? ker1
[1] Yes [2] No

Please Code 1. Yes 2. No

ker1.1 If No, why did you stop?
....

If Yes, for what purposes ?

ker1.2 Domestic Cooking ker1.2
ker1.3 Heating water ker1.3
ker1.4 Lighting ker1.4
ker1.5 For home business ker1.5
ker1.6 Other (Specify) ker1.6
ker2 What unit(s) of measure do you use to purchase kerosene ? ker2
1. Bottle 2. Jerrican 3. Litres 4. Other (Specify)
Please specify the volume of the container used
ker3 During your last purchase, how many units of kerosene did you buy? ker3
ker4 How much did you spend during your last purchase? ker4
ker5 How many days will this purchase last? ker5
ker6 What was the one-way distance travelled (in Kms) to make this purchase ? ker6

Ker7 What type of kerosene appliance(s) do you use ? *Please Circle response(s)*
1. Lantern 2. Cooker/Stove 3. Pressure lamp 4. Tin lamp 5. Other (Specify)

(CPR) FARM RESIDUE

cpr1 Was farm residue used during the last 12 months? cpr1
[1] Yes [2] No

cpr1.1 If No, why did you stop?
....

If Yes for what purposes ?

Please code 1. Yes 2. No

cpr1.2 Domestic Cooking cpr1.2
cpr1.3 Heating water cpr1.3
cpr1.4 Ironing cpr1.4
cpr1.5 House heating cpr1.5
cpr1.6 Lighting cpr1.6
cpr1.7 For home business cpr1.7
cpr1.8 Other, specify cpr1.8

cpr2 What type of farm residue do you use ? *Please circle the response(s)*
1. Maize cobs 2. Maize stalk 3. Sorghum stalk 4. Millet stalk 5. Pigeon pea
6. Animal dung 7. Coffee prunning 8. Tea prunning 9. Other(specify)

cpr3 What unit(s) of measure do you use in collecting farm residue ? cpr3
[1] Bundle [2] Sack or bag [3] Other, specify

cpr4 **Ask respondent to show you typical stack/bundle/sack. Weigh/measure this stack/bundle/sack and record the weight (Kg) / measurement(cm)** cpr4

cpr5 During last collection, how many units (given in cpr3) did you collect ? cpr5
cpr6 How much time was used in collecting farm residue last month by the following cpr6
cpr6.1 Adult male cpr6.1
cpr6.2 Adult female cpr6.2
cpr6.3 Children cpr6.3
cpr7 How many days did this collected farm residue last? cpr7
cpr8 What was the one-way distance travelled (in Km) to collect farm residue ? cpr8

cpr9 What is the type of appliance(s) used ? *Please circle the response(s)* cpr9
1. Three stone 2. Kuni mbili (fixed) 3. Kuni mbili (portable)
4. Other (specify)

ADDITIONAL QUESTIONS

Firewood

1. Do you use firewood while green or dry?
2. What tree species so you use for firewood?
3. What is your preferred tree species for firewood?
4. What was the one way distance for collecting firewood ten years ago?

Charcoal

1. What tree species do you use for charcoal?
2. What is your preferred tree species for charcoal?

Awareness

1. Are you aware of energy saving devices/measures
2. If yes, which ones?
3. Which devices do you posses?
4. Which measures do you use for energy savings?
5. From whom did you learn about these devices/measures?
6. Have you experienced any energy savings form these devices/measures?

APPENDIX 2: MWINGI DISTRICT DISEASE PREVALENCE STATISTICS

HEALTH

Disease prevalence statistics. Key diseases associated with biomass use.

Disease	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov.	Dec	Total
Respiratory	5843	5575	6100	5515	6176	7277	7093	4866	3288	4061	3032	959	60119
1.													
2.													
3.													
Eye infections	370	269	395	316	294	710	677	565	452	422	420	425	5522
Malnutrition	37	160	66	71	14	102	35	35	21	19	20	23	565
Intestinal worms	1244	1209	1359	1320	1234	1539	2169	1450	1410	1306	823	1329	16462 ← Amoebiasis included
Amoebiasis			1st qtr			2nd qtr			3rd qtr			4th qtr	
Typhoid			0			14			4			* 18	36
Others:													
Accidents	411	539	734	660	818	611	381	424	515	385	359	416	6253
Skin Diseases	1688	1150	1358	1356	1423	1745	1419	1242	1205	1116	970	1489	16264
Diarrhoea	764	888	955	1318	1260	1275	960	1062	1241	1123	914	1216	13176

Out patient (Respiratory to Amoebiasis)

In-patient given in quarters (Typhoid)

Can some of these diseases be linked with biomass shortages e.g. leading to e.g. boiling of water etc.

In Most Case it's ignorance which leads to the people not boiling water.

Are there rape cases associated with biomass collection.

Yes, there are cases linked to biomass Collection

APPENDIX 3: BIOMASS PROJECTIONS – NO INTERVENTION SCENARIO

Rural	310,180	346,974	382,777	416,231	445,821
Urban	16,326	20,639	26,091	32,984	41,697
Total	326,506	367,613	408,868	449,214	487,518
Pop growth	2.40	2.15	1.9	1.65	1.4
Land area	10,030.30	10,030	10,030	10,030	10,030
Density	33	37	41	45	49
Biomass consumption					
Firewood per capita	0.68	0.68	0.68	0.68	0.68
Firewood for charcoal per capita	0.09	0.09	0.09	0.09	0.09
Farm residues per capita	0.07	0.07	0.07	0.07	0.07
Firewood	223,596.94	251,747.77	279,999.65	307,629.81	333,860.72
Wood for charcoal	30,500.71	34,340.75	38,194.57	41,963.58	45,541.72
Crop residues	21,978.48	24,745.57	27,522.59	30,238.50	32,816.87
Total Biomass	276,076.13	310,834	345,717	379,832	412,219
Biomass supply					
Area "ha					
Forests	56,058.00	54,937	53,838	52,761	51,706
Woodlands	49,271.00	46,807	44,467	42,688	40,554
Bushlands	478,965.00	455,017	432,266	410,653	394,227
Wooded Grasslands	15,854.00	15,220	14,611	14,027	13,466
Grasslands	9,829.00	9,338	8,871	8,427	8,006
Farmlands	313,102.00	336,585	361,828	388,966	418,138
Sub-total	923,079.00	917,903	915,881	917,522	926,096
Productivity					
Forests	0.75	0.77	0.79	0.81	0.83
Woodlands	0.64	0.66	0.67	0.69	0.71
Bushlands	0.44	0.45	0.46	0.47	0.49
Wooded grasslands	0.33	0.34	0.35	0.36	0.36
Grasslands	0.08	0.08	0.08	0.09	0.09
Farmlands	1.07	1.10	1.12	1.15	1.18
		-	-	-	-
Accessible Biomass for Energy					
CF	1,471.52	1,478.14	1,484.80	1,491.48	1,498.19
WD	8,829.36	8,597.59	8,371.91	8,237.96	8,021.71
BL	59,008.49	57,459.52	55,951.20	54,482.48	53,610.76
WDG	732.45	720.74	709.20	697.86	686.69
GL	55.04	53.60	52.19	50.82	49.49
FL	164,159.38	180,883.12	199,310.58	219,615.35	241,988.66
PLT	-	-	-	-	-
Subtotal	234,256.25	249,193	265,880	284,576	305,856
Farm residues	7,322.14	7,871.31	8,461.65	9,096.28	9,778.50
Total	241,578.39	257,064.01	274,341.54	293,672.22	315,634.00

Years	**Yr 2004**	**Yr 2009**	**Yr 2014**	**Yr 2019**	**Yr 2024**
Population	326,506.00	367,613	408,868	449,214	487,518
Consumption tonnes/yr	276,076.13	310,834	345,717	379,832	412,219
Sustainable supply tonnes/yr	241,578.39	257,064.01	274,341.54	293,672.22	315,634.00
Deficit tonnes/yr	(34,497.74)	(53,770)	(71,375)	(86,160)	(96,585)
Deficit (%)	(12.50)	(17.30)	(20.65)	(22.68)	(23.43)
Deficit(tonnes/person)	(0.11)	(0.15)	(0.17)	(0.19)	(0.20)

Assumptions:

1. Current district population growth rate is 2.4%. It is expectedwill to go down by 0.5%, every 10 years as experienced between 1989 and 1999 nationally
2. Areas of natural vegetations will generally decrease, based on past records.Forests will decrease by 2% every five years due to higher protection while other vegetation will decrease by 4% as the have less protection
3. Area of Farmlands will increase at about 7.5 % every five years for food production at the expense of natural vegetation
4. Productivity of different vegetation types will generally decrease as more is exploited for biomass due to the deficit
5. Productivity of farmlands is expected to remain the same over the period due to extansion work by various agencies
6. Farm residue will increase at 7.5% as the the farm area increase
7. Per capita consumption to remain the same

APPENDIX 4: BIOMASS PROJECTIONS – INTERVENTION SCENARIO

BIOMASS DEMAND BALANCES AND PROJECTIONS INTERVENTION SCENARIO

	Yr 2004	Yr 2009	Yr 2014	Yr 2019	Yr 2024
Population					
Rural	312,180	346,974	382,777	[illegible]	[illegible]
Urban	16,320	20,639	[illegible]	32,884	[illegible]
Total	328,500	367,613	408,[illegible]	449,214	487,[illegible]
Pop growth	2.40	2.10	1.8	1.[illegible]	1.4
Land area	10,[illegible]	10,[illegible]	10,[illegible]	10,[illegible]	10,[illegible]
Density	[illegible]	37	41	[illegible]	[illegible]
Biomass consumption					
Firewood per capita	0.[illegible]	0.64	0.61	0.[illegible]	0.[illegible]
Firewood for charcoal per capita	0.[illegible]	0.077	0.[illegible]	0.[illegible]	0.[illegible]
Farm residues per capita	0.07	0.[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
Firewood	223,[illegible]	234,[illegible]	[illegible]	[illegible]	[illegible]
Wood for charcoal	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Farm residues	21,[illegible]	23,[illegible]	24,[illegible]	[illegible]	[illegible]
Total Biomass	278,[illegible]	[illegible]	303,3[illegible]	316,311	324,321
Biomass supply					
Area, Ha					
Forests	[illegible]	54,[illegible]	[illegible]	52,781	51,[illegible]
Woodlands	48,271.00	[illegible]	[illegible]	42,344	40,132
Bushlands	[illegible]	[illegible]	[illegible]	410,[illegible]	[illegible]
Wooded Grasslands	15,[illegible]	[illegible]	14,[illegible]	14,[illegible]	13,[illegible]
Grasslands	[illegible]	[illegible]	9,871	[illegible]	[illegible]
Farmlands	313,[illegible]	[illegible]	361,[illegible]	[illegible]	415,[illegible]
Subtotal	[illegible]	[illegible]	915,[illegible]	917,877	921,[illegible]
Productivity					
Forests	0.75	0.79	0.[illegible]	0.87	0.91
Woodlands	0.[illegible]	0.[illegible]	0.71	0.74	0.78
Bushlands	0.[illegible]	0.[illegible]	0.[illegible]	0.[illegible]	0.[illegible]
Wooded grasslands	0.[illegible]	0.[illegible]	0.[illegible]	0.[illegible]	0.40
Grasslands	0.[illegible]	0.[illegible]	0.[illegible]	0.[illegible]	0.10
Farmlands	1.0[illegible]	1.1[illegible]	1.[illegible]	1.4[illegible]	1.[illegible]
Accessible Biomass for Energy					
[illegible]	1,4[illegible]	1,[illegible]	1,[illegible]	1,[illegible]	1,[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] 741.[illegible]
[illegible]	[illegible]	[illegible]	[illegible] 713.61	[illegible]	[illegible]
[illegible]	1,[illegible]	1,[illegible]	1,11[illegible]	1,125.[illegible]	1,134.[illegible]
[illegible]	110.[illegible]	10[illegible]	1[illegible]	1[illegible]	10[illegible]
[illegible]	184,1[illegible]	[illegible]	[illegible]	271,[illegible]	[illegible] 874.30
[illegible]	-	-	-	-	-
Subtotal	334,[illegible]	[illegible]	[illegible]	341,[illegible]	391,[illegible]
Farm residues	7,[illegible]	7,[illegible]	[illegible]	[illegible]	[illegible]
Total	341,895.66	272,389.61	[illegible]	[illegible]	[illegible]
Years	Yr 2004	Yr 2009	Yr 2014	Yr 2019	Yr 2024
Population	328,500	367,613	408,[illegible]	449,214	487,[illegible]
Consumption (tonnes/yr)	278,076.13	[illegible]	303,313	316,311	324,321
Sustainable supply (tonnes/yr)	241,[illegible]	272,389.51	306,[illegible]	[illegible]	[illegible]
Deficit (tonnes)	(36,[illegible])	(13,[illegible])	[illegible]	35,[illegible]	78,487
Deficit (%)	(12.3[illegible])	([illegible])	2.01	11.[illegible]	23.[illegible]
Deficit (tonnes/person)	(0.10)	(0.04)	0.01	0.0[illegible]	0.16

Assumptions:

1. Current district population growth rate is 2.4%. The growth will be at reduced rates, going down by 0.[illegible]% every 10 years as experienced between 19[illegible] and 19[illegible] nationally
2. Demand is to reduce due to uptake of improved stoves and kilns. This is expected to grow at about 7% for firewood stoves and 10% for charcoal kilns and stoves ever five years
3. Areas of natural vegetations will generally decrease, based on past records Forests will decrease by 2.5% every five years due to [illegible] protection while other vegetation will decrease by 5% as they have less protection
4. Area of Farmlands will increase at about 7.5 % every five years for food production at the expense of natural vegetation
5. Productivity of different vegetation types will increase slightly (5% every five years) as better management is practiced
6. Productivity of farmlands is expected to increase due to extension work by various agencies and promotion of trees on farm
7. Farm residue will increase at 7.5% as the the farm size increase

Consumption	per capita	per district	Actual energy Used	100% demand management (100%)	Per capita (100%)	Year 2009	Year 2014	Year 2019	Year 2024
Firewood per capita	0.6848	223,596.94	22,359.69	74,532.31	0.2283	0.6382	0.6072	0.5752	0.5479
Charcoal per capita	0.0140	4,575.11	823.52	2,745.08	0.0084	0.0120	0.0113	0.0106	0.0099
Firewood for charcoal (improved Jikos only)	0.0934	30,500.7111	5,490.1280	18,300	0.0560	0.0788	0.0753	0.0707	0.0662
Firewood for charcoal (improved kilns)	0.0934	30,500.71	5,490.13	21,961	0.0673	0.0897	0.0858	0.0822	0.0785
Firewood for charcoal (improved Jikos and improved kilns)	0.0934	11,300.43	3,264.08	10,880	0.034	0.0788	0.0723	0.0678	0.0635
Farm residues per capita	0.0673	21,978.48	2,197.85	7,326.16	0.0224	0.0628	0.0597	0.0565	0.0539
Total Biomass demand	-	278,076.13	30,047.67	82,838.73					