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**ASSESSMENT OF ENERGY ALTERNATIVES FOR RURAL
MICROENTERPRISE DEVELOPMENT AND ENVIRONMENTAL
PROTECTION IN THE AGRO-ECOLOGICAL ZONES OF KILIFI
DISTRICT //**

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ENVIRONMENTAL PLANNING AND MANAGEMENT

**Project Submitted in partial fulfilment for the Degree of Masters of
Environmental Planning and Management in the School of Environmental Studies
Kenyatta University**

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*Assessment of energy
alternatives for*

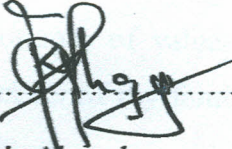


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DECLARATIONS

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

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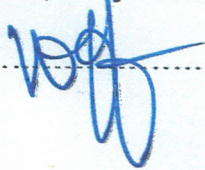
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DEDICATIONS

To my late father Ahmed Mohamed Juma for teaching us (his children), the importance of values and knowledge in all our pursuits and interactions and to all members of my family for their patience, support and encouragement during the study.

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ABSTRACT

Energy, specifically energy services affects social, economic, and environmental aspects of development such as livelihoods, agricultural productivity, health, education, and gender-related issues. Kilifi district in the Coast region of Kenya has very high poverty prevalence (70%). There is dependence on solid biomass for energy and traditional energy end-use technologies. Hence, appropriate energy services for microenterprise development are lacking. This increases the poverty situation and environmental degradation. A household survey, focus group discussions and interviews were used to assess the relative importance of rural micro-enterprises current energy choices, the influence of agro-ecological factors on current energy choices and the environmental impacts of current energy use. The study also determined sustainable energy alternatives for the agro ecological of Kilifi district. The study findings show currently, traditional use of biomass and human energy mainly from women are the main sources of energy for micro-enterprise activities. These findings also show that, agro ecological factors influence both the type and quality of energy sources and microenterprise. Despite this link it appears that, there is no model which uses ecological concepts and principles to assist in designing, developing, and managing sustainable rural renewable energy systems. Rural microenterprise existing energy use impact on the ecological stability and ecosystem services in Kilifi district and beyond which threatens current and future livelihoods. This also undermines human development and well being especially among women. Energy alternatives exists across all agro ecological zones in the district that can offer energy services for microenterprise development and environmental protection but are not being fully utilised. According to this study the district can have between 80.0 billion and 80.1 billion kWh per year of electricity if 10% of its current bioenergy potential is converted to electricity. The study recommends further research on agro ecological approach to sustainable rural communities' renewable energy systems. Development of a Predictive Ecosystem Mapping (PEM) model for Kilifi district so as to improve natural capital (increased soil water retention hence high water table and increased agro-biodiversity).

ABBREVIATIONS AND ACRONYMS

| | | |
|-------|---|--------------------------------------|
| AEZ | - | Agro Ecological Zone |
| CIR | - | Crop Independent Residue |
| DEM | - | Digital Elevation Model |
| FAO | - | Food and Agriculture Organisation |
| GEF | - | Global Environment Fund |
| GIS | - | Geographic Information Systems |
| GVEP | - | Global Village Energy Project |
| HDI | - | Human Development Index |
| HDR | - | Human Development Report |
| KIHBS | - | Kenya Integrated Household Survey |
| KNBS | - | Kenya National Bureau of Statistics |
| LPG | - | Liquefied Petroleum Gas |
| ME | - | Microenterprise |
| MDG | - | Millennium Development Goal |
| ME | - | Microenterprise |
| PEM | - | Predictive Ecological Model |
| TOPB | - | Theory of Planned Behaviour |
| TORA- | - | Theory of Reasoned Action |
| UNDP | - | United Nation development Program |
| UNEP | - | United Nations Environmental Program |
| WDR | - | World Development Report |
| WEC | - | World Energy Council |

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1 INTRODUCTION

1.1 Background to the study

Energy is central to sustainable development and poverty reduction efforts. Energy is not required on its own but for what it can do i.e. energy services. Energy services, the capability derived from energy carriers affects social, economic, and environmental aspects of development including, livelihoods, access to water, agricultural productivity, health, population levels, education, and gender-related issues. In addition, availability of modern energy sources to low income groups form a very useful means of reducing poverty, improving social equality, and human development (Goldemberg *et al* 1995).

Three out of four people in the developing countries live in the rural areas and majority are poor. These rural poor are part of 2.1 billion people in the world who live on less than \$ 2 a day and 880 million survive on less than \$ 1 a day (WDR 2008). The resources that the rural poor depend on for their livelihoods are determined by their agro-ecological situation. These include food, water, shelter and energy. The energy depended upon by the poor include solar energy (for drying crops, cloths e.t.c.) and solid biomass i.e. charcoal, firewood, cow dung and agricultural residues. The use of biomass fuel and lack of access to modern energy sources has negative impacts on the poor's income, health and the bio physical environment.

“It is simply unacceptable that such widespread energy deprivation, with its consequences for nutrition, health, education, welfare and environment, should continue into the next millennium” (WEC/FAO 1999)

Poverty also has implications on human rights such as the right to life and to physical integrity as enshrined in the Universal Declaration of Human Rights, article 3 and the International Covenant on Civil and Political Rights, article 6. The lives and physical well-being of people living in extreme poverty are continuously threatened by lack of food, risk of disease, hazardous work and precarious living conditions. They experience

violence of all types, including attacks, harassment, intimidation, severe discrimination and, in some cases, even death threats. Since the Earth Summit in Rio de Janeiro in 1992 it is increasingly recognised that, improving access to reliable energy of the right, quantity and quality to the poor of the world is essential for promoting their human development, well being and tackling the increasing environmental degradation (Rath *et al*, 2005).

The Millennium Development Goals (MDGs) is currently the main driver of sustainable human development efforts. MDGs include eradication of extreme poverty and hunger, achievement of universal primary education, gender equality plus women empowerment, reduced child mortality, maternal health, and environmental sustainability (UNDP 2007). None of the MDGs can be met without major improvement in the quality and quantity of energy services in the developing countries (Ibid, 2007).

Poverty prevalence in Kenya is 56% and compares very poorly with some of the leading countries in the world with respect to other development indicators (HDR 2006). For example World GDP at purchasing power parity is \$10,000 while Kenya's is \$ 1240 (HDR 2006). More than 80% of the people in the Coast Province of Kenya live in rural areas and majority of them are poor. According to UNDP in its 2006 Human Development Report (HDR) the Coast province ranks 2nd last with poverty incidence of 62%. The Province's life expectancy of 55.1 years is the 3rd lowest among the provinces reviewed. Primary school enrolment was 90.4% and secondary school 19.3% both of which are below national averages. Kilifi district is found in the Coast Province whose poverty situation and the general state of human development is far worse in relation to the Province and the country in general.

Kilifi district has about 70% poverty incidence one of the highest in the country. (CBS 2003). 45% of the poor are male and 55 % are female (Ibid 2005). Ganze the poorest constituency in the country with poverty prevalence of 84% is found in the district (CBS 2005). Kilifi continues to rely on food and non-food assistance during dry spells

to prevent loss of human lives. The most vulnerable persons are those who practice marginal farming, the disabled (10%), the AIDS orphans and the female-headed households (15.8%) (Ibid 2005). In the district literacy levels are very low at 63% with women being the worst affected (GoK 2005). High illiteracy among the women at 76.9% compared to 35% among men means the women have less access to economic opportunities and consequently lower incomes and higher levels of vulnerability to food insecurity and other environmental shocks and stresses.

The overarching theme of MDGs is poverty reduction and within that education and health (UNDP 2007). Therefore, improving incomes is necessary in order to promote the MDGs and enhance the human development situation in Kilifi district. Given that Kenya's industrial base cannot absorb in gainful employment, more than twenty-percent of its employable people (King, 2005; 428-430), micro-enterprise will continue to be a source of livelihood for the poor rural households in Kilifi district.

Micro-enterprise undertaken by rural communities along the Kenya coast can be categorised into on farm and off farm activities. Off- farm MEs include grain and vegetable production, animal husbandry (poultry, goat, bee keeping e.t.c.). The off farm consist of agro based MEs such as food processing e.g. bakeries, honey processing, dairy processing, edible oil processing (e.g. coconut oil), cashew nut processing, fish frying and smoking, fresh juice making and ice-making. Other agro based MEs include grain milling and soap making.. The other off farm MEs include craftwork (wood carving, pottery, knitting, crocheting, weaving and clothes-making / tailoring). There are also off farm MEs dealing with wood and metal fabrication workshops, automobile garages and bicycle repair shops. Consequently Rural microenterprise development and environmental protection offers economic salvation for poorer households a safety net against environmental shocks and stresses. However, access to sustainable energy alternatives among rural communities is critical for microenterprise development (Kirubi 2006). It is within this context the study aimed at assessing energy alternatives for rural microenterprise development in agro-ecological zones of Kilifi district.

1.2 Problem Statement and Justification

Kilifi district continues to have one of the highest poverty prevalence in the country. This means majority of the households lack the income necessary to obtain the minimum calorific inputs required to sustain life. In the district, poor households and their microenterprises obtain energy services from biomass energy through the use traditional technology. This trend is inefficient and produces serious gaseous and particulate pollution. Furthermore, the biomass energy sources particularly wood fuel and charcoal are obtained largely from communal drier savannah woodland and range lands as a 'free good'. This increases degradation of the physical environment and its ecosystem services of which the rural poor depend on for their livelihoods. Therefore the poverty situation and environmental degradation mutually reinforce each other since poverty and environmental degradation have a causal linkage (IFAD 2002).

Kenya's wood fuel consumption is above 68% and fossil fuel 21% (GVEP-Kenya 2006). In Kenya consumption of electricity the most versatile and the most sought after energy form, is low with per capita consumption of 121kilowatt-hours (kWh) (Ibid 2006). Moreover the level of access to electricity nationally is below 15 per cent in the rural areas it is much lower at about 4 per cent (Ibid 2006). The recent massive increase in the world fossil fuel have led to a surge in world food prices and an impending food crisis due to increased diversion of food crops to the production of biofuels. This has also led to an increase in price of fertilizers and local electricity rates the former is a major input in food production and. The net effect is to make access to appropriate mix of energy services for rural microenterprises limited or unaffordable thus worsening the poverty situation in Kilifi district.

Most reproductive work in rural areas such as fetching water, washing clothes, cooking and collecting firewood is done by women and the girl child. This trend apart from reducing time spent on productive activities such as income generating activities, education it also exposes women to hazards including injuries and snake bites. Consequently, lack of access to sustainable energy alternatives in rural Kilifi district

continue to have a negative impact on gender equity, the environment and community well being in general.

1.3 Research questions

- i. How important are rural microenterprise as a source of livelihoods for the poor households in the agro-ecological zones of Kilifi district?
- ii. What are the current energy choices for the rural microenterprises in the agro-ecological zones of the district?
- iii. What is the influence of agro-ecological factors on rural microenterprises current energy choices in the agro-ecological zones of the district?
- iv. What are the environmental impacts of rural microenterprise current energy choices in the agro-ecological zones of the district?
- v. What are potential sustainable energy alternatives for rural microenterprise activities in the agro-ecological zones of the district?

1.4 Research objectives

The overall goal of this research is to assess energy alternatives for rural microenterprise development and environmental protection in the context of poverty reduction, gender equality, environmental sustainability and the Millennium Development Goals in the agro-ecological zones of Kilifi district. In order to achieve its overall goal the study seeks to achieve the following specific objectives: -

- i. To assess the relative importance of current energy choices for rural microenterprise in the agro-ecological zones of Kilifi district.
- ii. To determine the influence of agro-ecological factors on rural microenterprises' current energy choices in the agro-ecological zones of the district.
- iii. To assess the environmental impacts of the existing rural microenterprise energy choices in the agro-ecological zones of the district
- iv. To determine potential sustainable energy alternatives for rural microenterprise activities in the agro-ecological zones of the district.

1.5 Research premises

Premise 1

Current energy choices rural microenterprises impacts negatively on the environment and community well being.

Premise 2

Energy Alternatives exist but have not been fully tapped into.

Premise 3

Rural microenterprise energy choices are influenced by their agro ecological situation.

1.6 Significance of this research

Past studies concluded that household switches to more modern sources of energy as income increases ('Energy ladder theory' Leach, 1988; Leach, 1992). However, more recent studies on energy use in developing countries show evidence contrary to this simple progression i.e. the switch to more efficient fuels and equipment is not a linear or unidirectional process as suggested by the energy ladder theory (Davis 1998, Masera et al 2000, Barnet 2000 quoted in Shonali et al 2003). This study therefore will further highlight how other factors such as agro ecological conditions influence energy choices.

1.7 Justification of this research

The majority of people in Kilifi district and the rural areas of the Coast Province in general depend largely on agriculture for their livelihoods. Therefore promoting agro-based microenterprise is one of the necessary actions if MDG goals of halving poverty and hunger in 2015 are to be met (WDR 2008). Sustainable, affordable energy can make agriculture more productive through diversification into horticulture which is relatively more energy intensive than cereals but brings in more returns to land and creates two times the off-farm employment compared to cereals in processing, packing and marketing.

Household income depends on the time spent in income generating activities such as microenterprise. Therefore it is necessary to increase access to convenient and clean bio energy sources such as electricity and biogas respectively which in turn may provide energy services that end up freeing time from non income generating domestic chores (fetching firewood and water) towards microenterprises.

The agro-ecological zone approach will enable identification of constraints and opportunities posed by the zones' topography and production environment i.e. agro-climate, resource base and socioeconomic conditions. Hence, facilitate the use of energy alternatives i.e. energy choices or energy end use technologies and practices that improve microenterprise development, gender equity and environmental protection.

Given that electricity penetration in rural areas is only 4% this study therefore will provide information that may be the basis for improving access to energy services for microenterprises by identifying viable energy alternatives existing in rural coast of Kenya. Consequently promote the attainment of the Millennium Development Goals.

1.8 Theoretical/Conceptual Framework

The theoretical framework for this study is founded on the Basic Needs theory by Abraham Maslow 1943 and the Attitude-Behaviour Theory i.e. the Theory of Personal/Planned Behaviour (TOPB; Ajzen, 1985) The TOPB is based on the Theory of Reasoned Action (TORA; Ajzen & Fishbein, 1975). There are two general premises that support this theory. First, individuals act rationally and, therefore, use and process available information before acting, and once they establish their intent, the individual is expected to behave accordingly. Secondly, attitudes determine intentions toward the specific behaviour. The basic needs theory is premised on the following; there are certain minimum requirements that are essential to decent standard of living also known as physiological needs. These are food, shelter, health and clothing. They are primary needs and have to be catered for before other needs such as security and shelter, sense of belonging, affection and love, esteem and finally self actualization are pursued. Food is on top of the list.

On the basis of the TOPB one can infer that the rural poor continued to use biomass fuels despite the negative effects on the women health, and gender equity and the environment are influenced by certain attitudes and values. Hence, understanding these attitudes and values is necessary in order to identify local conventions or local institutional constraints and opportunities related to the promotion of gender equity and sustainable environment through sustainable energy alternatives for rural microenterprise development. Furthermore, for the poor, ‘a better life’ first means satisfying the basic human needs, including access to jobs, food, health services, education, housing, running water, waste disposal etc. In providing for these needs, energy is an important element (Goldemberg *et al* 1995). Hence, providing sustainable energy alternatives for rural microenterprises will promote income generation, employment, environmental protection, gender equity and the Millennium Development Goals in general.

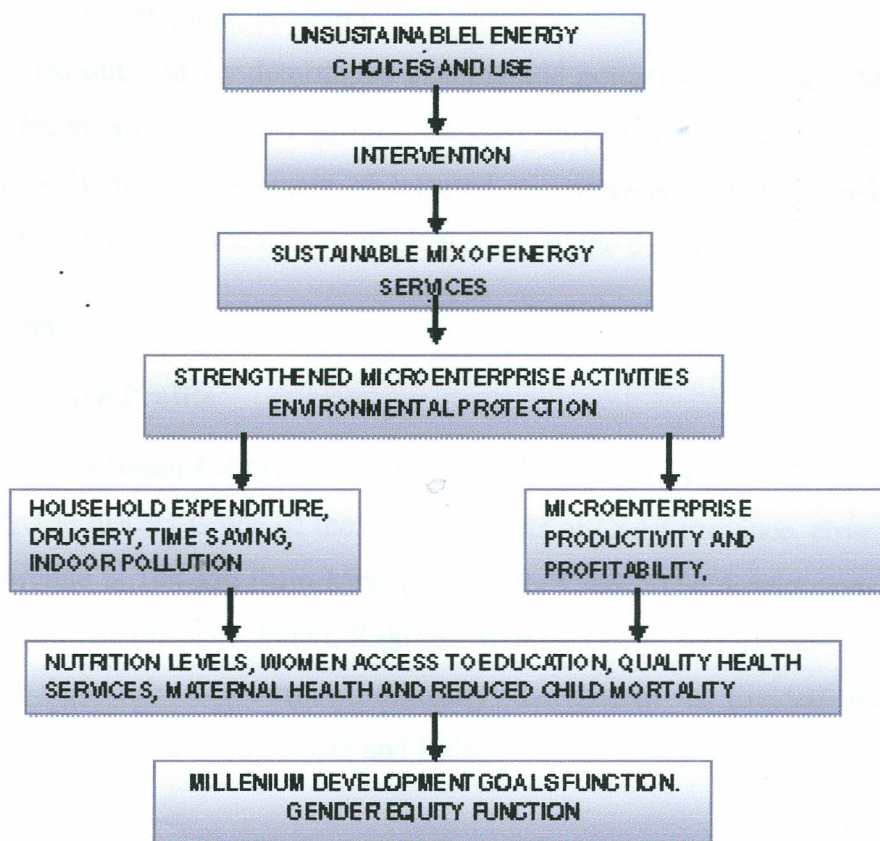


Figure 1-1 The Conceptual framework energy and microenterprise development

1.9 The scope of the study

The study covered all the five agro ecological zones (AEZ) found in the administrative district of Kilifi namely Coconut-cassava CL3, Cashew nut-cassava CL4, Livestock-millet CL5, Lowland ranching CL6 and Coconut-Cassava-Cashewnut CL3-4. Data was collected from government Ministries, and organizations linked to Rural Development, Rural Electrification, Agriculture, Livestock Development, Microenterprise development, and the Environment and Natural Resources.

The study determined which one between wage and microenterprise is an important source of cash income, types of microenterprises and their current energy choices. The study sought to determine how agro-ecological factors i.e. Topography, agro-climatic conditions and social conditions influence current energy choices for microenterprises. Assessment of the ecological, economic and social impacts of current energy choices were also carried out. Finally determined existing and potential bioenergy alternatives and end-use technology that may protect the environment at the same time provide energy services for the development of selected microenterprise leading to increased income and employment in the agro-ecological zones of the district.

The Study Area

The Administrative Profile

Kilifi district lies between *latitudes* $3^{\circ} 16'$ and 4° south and *longitude* $39^{\circ} 05'$ east and 40° east. The district is one of the seven districts of Coast Province, covers 4,878. km². The shoreline is 144 km from Mtwapa to Mida Creek. The district consists of 7 divisions: Bahari, Kikambala, Chonyi, Kaloleni, Bamba, Ganze and Vitengeni. It has 36 locations and 108 sub locations. Politically the district is divided into three constituencies namely: Kaloleni, Ganze and Bahari

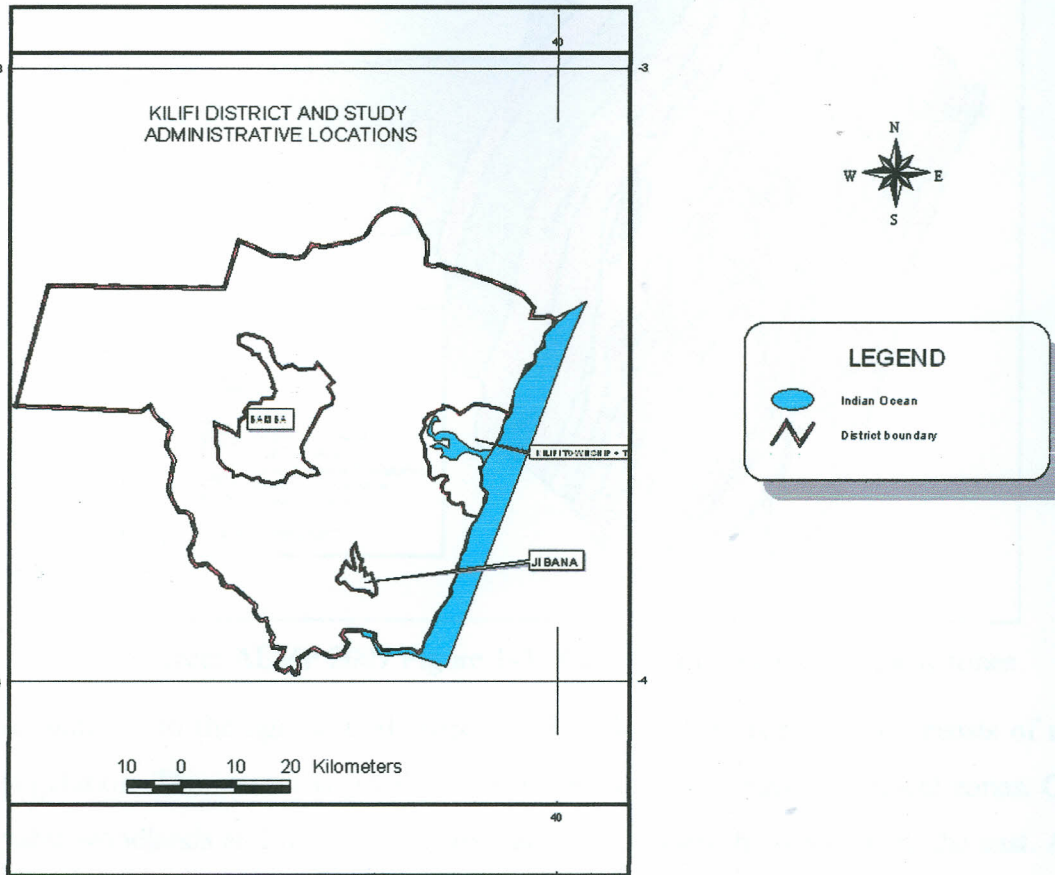
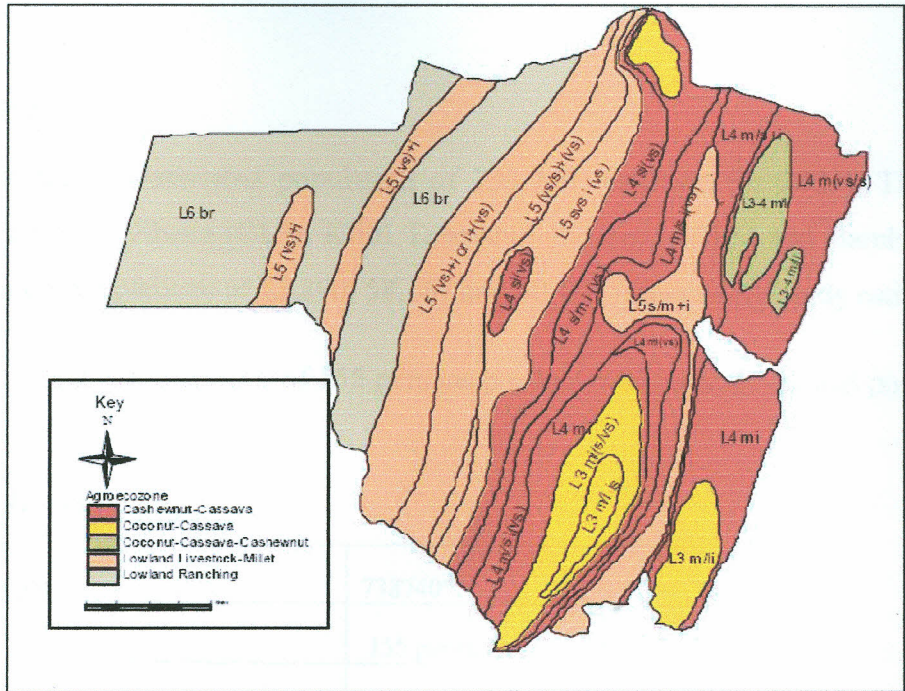


Figure 1-2 Kilifi District and Study Administrative Location

Agro-ecological Conditions

Rainfall is bimodal and varies from 400mm in the hinterland to 1,300 mm in the high potential areas of the coastal plains, with a reliability of about 66%². Temperatures range from minimum of 21⁰C to a maximum of 32⁰ C. Arable land makes up 18.9% of the total land area while water mass and gazetted forests (Arabuko Sokoke) cover 3.4% and 4.8% respectively. Kilifi has 5 agro-ecological zones³: CL3 that has high potential for crop production, CL4 with relatively lower potential for production and CL3-4 zone that falls between the zones CL3 and CL4. CL5 and CL6 zones are regions of lower potential, suitable for dry land farming and ranching (see figure 1-3).



Source: ALMP 2007 Figure 1-3: Kilifi district Agro-ecological zones

In addition to the agricultural crops the flora in Kilifi district also consists of natural vegetation. The natural vegetation in Kilifi varies across agro-ecological zones. Coastal palm woodlands and mangrove groves are found along the coastline in the east. As one moves inland from the shore line Coastal woodlands are found. There are patches of fire induced grassland. The largest proportion of the natural vegetation consists of arid thorn bush land and woodland on the western end of the district.

Geomorphology

The district's soils vary from Triassic sediments of marine and deltaic origin along the coastal line and in Sabaki to sandy soils in the hinterland. The major topographical features in Kilifi district are the coastal plain, the Foot Plateau, the coastal range and the Nyika Plateau. The coastal belt is a narrow belt varying in width between 3km to 20 km. it is not more than 30 m above sea level except for the occasional prominent peaks on the western boundary. The area is also broken by creeks and estuaries. The drainage pattern is formed by seasonal rivers and streams such as Goshi, Ndzovuni, Wimbi and Mtomkuu which drain into Sabaki River and the Indian Ocean Figure.

Demography

The district has an estimated population of 738,740 (estimate for 2009). The Agro ecological zones of Jibana (CL3), Kilifi Township and Tezo (CL5) and Bamba (CL5) have estimated populations of 15,890, 58,167 and 40,169 respectively (study estimates).

The district has a mean density of 155 persons per km² with average annual population growth of 3.05%.

Table 1-1 Demography

| | |
|-------------------------|-----------------------------------|
| Total population | 738740** |
| Mean density | 155 persons per km ² * |
| Population Growth Rate | 3.17% |
| Sex ratio | 90 males per 100 females** |
| Total No. of households | 85696* |
| Average household size | 6.17 |
| Women headed households | 14,296*** |

Source: 2000 Kilifi long Term Strategic Development plan 2001-2015

*KIHBS 2008 ** Study estimates

Kikambala along the coastal plain is the most densely populated with a density of 358 persons per sq km. Bamba is the least dense with only 23 persons per sq km. Women outnumber men such that there are 100 females to every 90 males. The (15-25) age bracket make up about 20% of the population (CBS 2005).

Education

Primary school enrolment was 90.4% and secondary school and 19.3% both of which are below national averages. The district has low levels of education (literacy levels of 63%) hence high levels of illiteracy. However there is High illiteracy among the women (76.9%) as compared to males (35%) (CBS 2003).

Income and Employment

Agricultural sector is the highest employer with over 80% engaged in the sector. Slightly above 6.% are engaged in wage employment (CBS 2005).

Resource Use

Kilifi district residents rely on rain water harvesting mainly through roof catchment and water pans for a considerable proportion of their water needs. Nearly 90% of the households' energy requirements are met by charcoal and firewood (FSM 2008).

Food Security

Kilifi is a food deficit region and food production hinges heavily on the prevailing climatic patterns. In 2005, cereal production in the district was only 20% of the total yearly demand of 92,245 Metric Tonnes. This production can only sustain the residents for two and a half months and therefore Kilifi relies on trade with other districts to meet the food gap (GoK 2005).

Limitation of the Study

The limitations of this study were high illiteracy rates, time, financial resources and secondary data. Poor infrastructure also made travelling challenging in terms of material cost and time. The areas high illiteracy hence it took relatively more time to administer the household questionnaires further put constraints on time. The financial resources constrained the number of questionnaires and therefore the sample size. Like all developing countries obtaining accurate and up to date secondary data was a challenge. For example, the last Population and housing was conducted in 1999 therefore current data regarding the same are projections and estimates.

Definition of terms

Agro-ecological zone: Agro-ecological zone refers to area that is topographically homogenous and its production environment in terms of agro-climate, resource bases and expectedly the socioeconomic conditions also being homogenous.

Biodiversity: the variability among living organisms from all sources, including, 'inter alia', terrestrial, marine, and other aquatic ecosystems, and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystems.

Energy choices: Energy choices refer to end-use energy sources sold to or consumed by a household or microenterprise to provide energy services.

Energy services: Energy services are products or services resulting from the consumption of end use energy sources.

Energy use: Energy uses refer to the different end-use technologies employed to extract the energy services from their sources.

Institutions: rules, laws and organizations and social norms that coordinate human behaviour.

Microenterprise: Microenterprises are very small businesses that produce goods or services for cash income. They are owned and operated by rural households. .

Poverty: At the very least it is the absence of income necessary to obtain the minimum calorific inputs required to sustain life

Primary energy: Primary energy refers to energy carriers: e.g. firewood, coal, kerosene, rivers lakes oceans e.t.c.

Sustainable Energy alternatives: Primary energy alternatives or end use energy technologies that are ecologically economically and socially sustainable.

Useful energy: Energy from energy choices which actually provides the energy service discounting on losses as a result of conversion or due to the effect of the equipment/technology being used.

Bio energy sources: Fuels constituting any plant or animal matter used directly as fuel or a source of primary energy that is converted into other forms of end- use energy.

2 LITERATURE REVIEW

Energy in Human Development

Energy is essential for of basic needs of food, lighting and heating at the household level. Energy is an important driver of any economy hence it is important at the community and national level (Goldemgerg *et al* 1995). More recently it is recognised that improving access to affordable, reliable energy contributes to human development, human well being and promoting gender related issues particularly in the rural areas. Several studies show that, up to a certain point increased per capita consumption of 'modern' or commercial energy such as electricity causes a significant increase to the human development indicator. (Cecelski 2002, Rath 2005, the millennium Project, 2005, Garcia 2006, GVEP-Kenya 2006).

Historically economic development has been linked to increasing per capita energy consumption. Progressive substitution of inanimate forms of energy for human and animal power in agriculture, industry and in the households has been a characteristic of a growing economy (Garcia Jr. 2006).

In 2002, the United Nations indicated that per capita consumption of electricity of just over 1000 kilowatt-hours was needed for a society to experience a medium level of human development. Alan Pasternak looked at a selection of 60 countries in 1997, and found an 84% correlation between Human Development Index (HDI) and annual electricity use per capita in kilowatt-hours (Garcia, 2006).

Energy Chain and Energy Levels

Energy can be looked at from energy levels of the energy supply chain. These levels are primary energy, end-use energy, useful energy and energy services (Pachauri *et al* 2003). Primary energy is the energy contained in energy carriers such as coal, crude oil or, trunks of wood and other biomass collected by householders directly from the environment, before being transported, stored and dried, can also be termed primary energy. End-use energy is the energy bought or obtained by a household or

microenterprise its own use. What households and microenterprise are looking for is not so much fuel or electricity, but rather heat supplied to a cooking pot or the mechanical energy applied to air for air circulation or to water to be lifted to a tank. Therefore, they do not only have to acquire end-use energy, but also equipment, such as heaters, stoves, pumps and lamps (end use technology or gadgets), to transform the end-use energy into heat, mechanical drive and light at the desired location and time. This latter energy is called useful energy. But ultimately, the direct demand is on energy services e.g. a cooked meal or teas, a well-lit retail shop or food kiosk, goods transported from production site to market e.t.c. It suffices to note that, all products and services take some energy to produce, i.e. contain some embodied energy, and are, therefore, energy services in some sense (Ibid 2003).

Rural poverty and energy choices

Numerous literature reviewed acknowledge that there is widespread poor state of human development among the people of the world particularly in the rural areas. Furthermore of those affected women and children are more adversely affected than men (Goldemberg, 1995, Rath, 2005, Cecelski, 2002, GoK 2003, GoK 2007). Since the World Summit on Sustainable Development in 2001 where the Millennium Goals Initiative was launched many studies and reports point out that first, majority of the poor of the world live in the rural areas and depend on ecosystem services for their livelihoods. One of these ecosystem services include traditional biomass fuels such as charcoal, wood fuel, agricultural residues and cow dung.

Subsistence-based societies depend on their physical environment for survival. On a daily basis they collect water, gather fuel, and tend to crops and livestock. By manipulating their natural environment, they carve out their existence from the surrounding natural resources (Fraser 2003).

The use of these sources of energy is a major contributor to rural poverty, illiteracy, poor health, the gender imbalance and environmental degradation (UNEP 2000, 2003 The World Bank 2000).

Access to affordable energy is central to poverty alleviation by way of increasing agricultural productivity, encouraging economic activity, generating employment and income opportunities. The literature reviewed emphasizes that the availability of jobs and productivity increase or economic opportunities are severely limited without access to modern energy services and fuels. Access to modern energy can catalyze the creation of microenterprises and livelihood activities beyond daylight hours and locally owned businesses. (UNDP 2002, 2005, 2006, GET-FAO, 2002, Somali *et al*; 2003).

Rural Microenterprises and sustainable agricultures

Microenterprise development in rural areas offers economic salvation for poorer households by providing them with a safety net against environmental shocks and stresses. Since most of the entrepreneurial activities in rural areas are based on agricultural and natural resource products, the rural poor can broaden their income opportunities by diversifying into higher value enterprises, both on-farm and off farm. The off farm can be value addition to a food and industrial crops (Allderdice *et al* 2000, Kirubi 2006, World Bank 2008). Nevertheless in order to achieve this goal the high value on and off farm agro-based microenterprises of necessity depend on sustainable agriculture.

Sustainable agriculture can be attained only when land is used in a proper way. When land is utilized improperly, productivity rapidly falls and the ecosystem is jeopardized. Proper land use ensures that resources can be used for future generations. Integrated land use management should be directed at an optimal, sustainable use of natural resources. This may include regulation of hydrology, climate stabilization, and preservation of biodiversity such as gene pools, wild-life and plant habitats, as well as appropriate research and education. Proper land utilization improves efficiency in the production process, because relatively few inputs are required to attain the desired output, thus making production more profitable. Forest or permanent tree crops provide natural land cover in the upper watershed. In coastal regions, mangrove forests should also be conserved to protect the coast from erosion. There is a growing awareness that native vegetation savannah, shrubs and trees need to be conserved (Amien 2003).

Rural microenterprises often suffer from the general neglect of rural areas. Infrastructure is usually very limited and characterized by a lack of good roads, inadequate water supply, minimal telecommunications, and electrical distribution supplied only to concentrated population centres (Allderdice *et al* 2000). In so far as modern energy alternatives in relation to the development of rural microenterprise the literature reviewed converge on the view that sustainable energy alternatives are necessary for poverty reduction, social equity and environmental sustainability among the rural communities and the country as a whole (Kirubi 2006, Wanambwa 2006, GVEP 2006).

Energy Policies and Rural Microenterprise

The broad objective of the national energy policy is to ensure adequate, quality, cost effective and affordable supply of energy to meet development needs, while protecting and conserving the environment. The specific objectives are to: (i) provide sustainable quality energy services for development; (ii) utilise energy as tool to accelerate economic empowerment for urban and rural development; (iii) improve access to affordable energy services; (iv) provide an enabling environment for the provision of energy services; (v) enhance security of supply; (vi) promote development of indigenous energy resources; and(vii) promote energy efficiency and conservation as well as prudent environmental, health and safety practices(GVEP-Kenya 2006).

Many energy programs from governments and development agencies are based on poverty reduction, on the assumption that energy creates income generating opportunities. Income generation increases the ability to pay for energy services also increase. However, there is little knowledge about such linkages to underpin these strategies despite there being many examples of best practice where provision of energy services has indeed lead to establishment or growth of small enterprises (Shonali et al; 2003, GVEP-Kenya, 2006).

Electricity supply has not always led to the establishment or growth of microenterprise. This it is argued is due to lack of understanding of the factors underlying the

mechanisms that influence the role of energy in the establishment and growth of small enterprises (Macht *et al* 2007). Furthermore, where modern energy services have lead to use in enterprises, there is lack of understanding of the social and economic impacts, both in the enterprises and in the community. Hence research is needed to understand the linkages between energy services and productive uses (Ibid 2007). This can be done by first, identifying factors that can play a role in shaping these linkages such as those influencing the choice of energy and its use. Factors emanating from the differences in the entrepreneurs themselves, the energy supply characteristics, economic circumstances and other forces or mechanisms at play are also taken into consideration (Ibid 2007).

Recent studies done in Kenya clearly points to this failure or lack of connection between human development objectives of the current economic policies and energy access and its environmental implication. (UNEP 2006, GVEP-Kenya). The Energy Road Map to Achieving MDG Targets; Kenya Sectoral Energy Requirement study report of September 2006 states that; -

“The study finds considerable synergy between the Energy Policy and the Economic Recovery Strategy (ERS) as well as forestry and environmental policies. However, there is little or no integration with other sectoral policies in agriculture and health”.

A series of policy documents aimed at poverty reduction and human development in Kenya starting with the Sessional No 10 of 1965 followed later by the. Poverty Reduction Strategy Paper (PRSP), National Poverty Eradication Plan (NPEP), Economic Recovery for Wealth and Employment Creation Strategy ERS an more recently the Vision 2030. The main objectives of the Sessional paper number 10 of 1965 were to free Kenya from hunger, disease and ignorance. The over arching theme of the recently launched Vision 2030 is poverty reduction and sustainable human development based on three pillars i.e. economic, political and environmental. However

no mention of energy within the context of its central role in the economy, human development, socio equity and sustainability of the environment.

Some literature reviewed that dealt with energy and microenterprise in rural parts of China and India unite on a number of issues. First, impact on poverty and gender relations of energy interventions are strongly affected by "supporting inputs" hence combining a number of interventions, together with improved energy services, appears to have more than proportionate effect. For instance, the choice of energy end-use technology plays a large part in determining, the nature, scale and distribution (between women and men) of energy interventions. Second, the patterns of impacts of energy interventions are often complex, involving both direct and indirect linkages to the reduction of poverty of women and men. Lastly, the vicious circle of energy poverty will often be broken only by combining improved energy services with end uses that generate cash income such as microenterprise development (World Bank 2003, Govinda *et al* 2003, and UNEP 2008) Thus current emphasis of the REP is the electrification of the household and does not cater for other energy needs of the poor households.

If Mrs. Mohlamonyane's time is so constrained by her unpaid employment in pursuing her livelihood, does household electrification represent an opportunity for labour saving and thus time saving? Will the electrification of her dwelling mean that Mrs. Mohlamonyane will "save" the time she currently "spends" on fetching and carrying wood and that she will "invest" this time in "more productive" activities, thus obliquely or directly addressing the question of her extreme poverty and immiseration? Crawford-Cousins, C., 1998, (quoted in Cecelski E.2002)

Agro ecological Approach and Sustainability of Rural Renewable Energy Alternatives

Energy services for microenterprise can be provided by renewable energy sources. Renewable energy sources include the sun, wind, energy from moving water (rivers,

oceans), biofuels and human labour. Renewable energy sources have numerous advantages over non-renewable sources. Apart from being 'infinite', advantages of renewable energy sources include being environmentally more friendly and have been used by human since time memorable (REDP 2009). One of these renewable energy source is biomass

Biomass is a rather simple term for all organic material that stems from plants (including algae), trees, and crops. Biomass sources are therefore diverse, including organic waste streams, agricultural and forestry residues, as well as crops grown to produce heat, fuels, and electricity (UNDP 2001). Among all the renewable energy sources, biomass is the largest, most diverse and readily exploitable resource. Biomass can also deliver energy in all forms that people need (liquid and gaseous fuels, heat and electricity). It is carbon dioxide-neutral and can even act as carbon sinks; and it helps to restore unproductive and degraded lands, increasing biodiversity, soil fertility and water retention (Best and Christensen, 2003). Of priority interest in developing countries is the need to first, improve the current use of traditional biomass and secondly to transform biomass into high-quality low-emission electricity, fuels and gases (Goldemberg and Coelho, 2003).

Reviewing literature relating to agro ecological zones, rural microenterprise, agriculture and rural energy alternatives one key conclusion emerged. That Despite the inter connectedness and interdependence between agro ecological zones , agriculture and rural energy alternatives there is apparent lack of a paradigm that applies ecological concepts and principles to the design, development, and management of sustainable renewable energy systems. a framework that should often incorporate ideas about a more environmentally and socially sensitive approach to renewable energy sources, one that focuses not only on production, but also on the ecological sustainability of the generation system.

Most of the entrepreneurial activities in rural areas are based on agriculture and natural resource products. As has been pointed out previously the rural poor can broaden their

income opportunities by diversifying into on-farm and off farm higher value enterprises. The off farm can be value addition to a food and industrial crops (Allderdice *et al* 2000, Kirubi 2006, World Bank 2008). This means depend on sustainable agriculture production systems. a number of literature reviewed agree that modern and clean energy choices based on renewable energy sources are necessary for rural microenterprise development and the sustainable well-being of rural communities and rural physical environmental. The proposed renewable energy alternatives include wind, micro and small hydro, solar and bioenergy (REDP 2009, Kirubi 2006, Wanambwa 2006, GVEP 2006).

Like agricultural production systems, nature and viability of renewable energy systems for a given area based on renewable energy sources (wind, sun, micro/mini hydro and bioenergy) is influenced by the agro ecological situation of the area. For example, Wind speed a major determinant of wind energy potential for an areas is influenced by topography and agro climate i.e. seasonality, temperature e.t.c. hydro power potential is also influenced by among others stream and river flow, the availability of a suitable head which are all determined by topography, climatic seasonality e.t.c. bioenergy as a viable energy alternative is also influenced by agro ecological factors. Above all, Socio-economic condition is an important aspect of an agro ecological zones answer questions such as how is the renewable energy to be produced, for who and for what purpose is the energy being propose. This in turn will answer the question of type of technology and feasibility of technology transfer.

According to Patzek et al, energy sources renewability and sustainability are concepts that more often than not are taken to mean the same thing. Or sustainability is not regarded as a critical concern.

It is not uncommon for the researchers involved in biomass processing for fuels to claim that there are billions of tonnes of "biowaste" out there, ready to be picked up each year, and processed, providing in effect an almost free, abundant and environmentally benign source of energy for humanity. We will

argue that ecosystems (the Earth Households) are the intricately linked webs of life that know of no waste, see e.g., (Capra, 1996; Patzek, 2004). Quoted in Patzek et al 2006

Whereas Capra was specifically referring to bio waste the same can be said for all other renewable energy resources. The now common closure of hydro electric generation dams on river Tana and the going controversy regarding eucalyptus as a renewable source of energy and its effect on water resources are but only two examples that illustrates this point. Sustainable agriculture which rural microenterprise development closely depends on is guided by agro ecology.

Ecology as a scientific approach has only existed since the late 19th century and relatively more recent is agro ecological research which is less than 50 years old (MacRae et al 1993). The fact that The United Nations Commission on Sustainable Development (UNCSD) is yet to develop a working definition of the term 'agroecology' (American society on agronomy, 2009) perhaps emphasise this point. in addition, the push for renewable energy sources as a means of promoting sustainable development is not more than a decade old. Therefore it is within this context that this literature review also concludes that, there is a knowledge gap i.e. a lack of a model that may provide ecological concepts and principles that will assist in designing, developing, and managing sustainable rural renewable energy systems.

3 METHODOLOGY

3.1 Research design

This study is qualitative covered the three agro-ecological zones out of the five found in the administrative district of Kilifi. However the research design proceeded on the assumption that the microenterprise found in AEZ CL6 will be found in CL5 because in both livestock is a dominant activity in the same way, it was also assumed the microenterprise found in AEZ Coconut-Cassava-Cashewnut (CL3-4) will be found in AEZs CL3 and CL4.. The zones covered were Coconut-Cassava (CL3), Cashew-cassava (CL4) and Livestock-Millet (CL5). The research carried out a household survey using stratified random sampling. Focus group discussions and interviews were also conducted with individuals including officials of government ministries and organisations dealing with rural development, energy, agriculture, microenterprise, and environment issues.

3.2 Sample design

The sampling was done using stratified simple random sampling. The three AEZs CL3, CL4 and CL5 formed the strata. The administrative locations within each of the agro-ecological zones CL3, CL4 and CL5 were then assigned numbers and a number was randomly picked within each zone. A questionnaire was administered to 35 households in each of the three randomly selected administrative locations thus yielding a total sample size of 105 households. for each of the three randomly selected administrative units Two focus group discussion conducted.

3.3 Data collection

Structured questionnaires were administered to households to collected information on sources of income, types of microenterprise and information related to on current and potential energy choices and use. The structured questionnaires was use to collect household characteristic, (gender, education, age). Personal Interviews were used to collect additional data on traditions related to energy choices and use. Direct observations and photographs were also used to collect primary data.

Secondary data was collected from published materials, reports, newsletters, books, records, journals and statistics from government department and parastatals.

3.4 Data analysis

There was field editing followed by central editing of the raw data. The field editing entailed correcting spelling mistakes linked to local words, name of places , local names of trees. The central editing largely dealt with unit conversions and harmonising units of rates i.e. from say consumption per day to consumption pwer week e.t.c. thematic analysis of data from the interviews and focus group discussions was done subsequently, the data was coded and classified. Using SPSS and MS excel the data was then organized into summary tables and graphs. Data from the interviews and focus group discussions was used to explain or validate the results household survey or the variations of the parameters under investigation across the agro-ecological zones in Kilifi district.

4 RESULTS AND DISCUSSIONS

4.1 The relative Importance of Current Energy Choices for Rural microenterprise

Poverty and environmental problems are correlated therefore the study sought to first determine which between wage employment and microenterprise is the important source of cash income the rural household in the study area? Secondly identification and ranking of the current rural microenterprise energy choices was done. This was achieved through a household survey by administering a questionnaire to 105 households using stratified simple random sampling in Jibana, Kilifi +Tezo and Bamba representing agro ecological zones CL3, CL4 and CL5 respectively. Three focus group discussions (FDG) helped to first fill the apparent data gaps arising from the household survey. It was envisaged that, showing the importance of rural microenterprises as source of cash income in the study area, the important type of microenterprise across the agro ecological zones under review and their corresponding energy choice will illustrate the relative importance of current rural microenterprise energy choices.

4.1.1 Sources of cash income

The study found that in all agro ecological zones (AEZs) under review over 94.4% household across all agro ecological zones under review obtained part or all of their cash income from microenterprise activities. CL5 livestock millet zone had highest proportion (42.9%) of households that obtained part or whole their cash income from wage employment. Other sources of cash income in Kilifi district include savings, interests, pension e.t.c. (KNBS, 2008). These sources are nevertheless very insignificant in terms of their contribution in the providing livelihoods.

Table 4-1 Source of household income by Agro ecological zone

| Source of Cash income | CL3 coconut cassava | CL4Cashewnut Cassava | CL5 livestock millet |
|--------------------------|---------------------|----------------------|----------------------|
| Wage Employment Only | 5.6% | 0.0% | 2.9% |
| Microenterprise Only | 69.4% | 83.3% | 57.1% |
| Wage and Microenterprise | 25.0% | 16.7% | 40.0% |
| Total | 100.0% | 100.0% | 100.0% |

The study shows, diversification of sources of cash incomes increases decreasing agricultural potential. The low agricultural potential in CL5 livestock millet compared to CL3 coconut cassava and CL4Cashewnut Cassava means relatively more people have to rely more on wage employment for their livelihoods. In the FGD it emerged that, the wage employment was spatially distant from the household and entailed seasonal or long-term migration (migratory wage labour).

4.1.2 Types of microenterprise

To determine the types of microenterprise and their importance across the AEZs under review microenterprises were categorised into two broad categories i.e. on-farm and off farm microenterprises.

The results as illustrated by figure 4-1 show that, in zone the highest number of respondents (45.7%) indicated that they obtained their cash income from both on farm and off-farm MEs activities. Only 5.7% of the respondents in CL5 livestock millet obtained cash income from off farm activities only. While in CL3 coconut cassava and CL4Cashewnut Cassava relatively higher proportion of respondents indicated that they depended on off-farm MEs for their cash income.

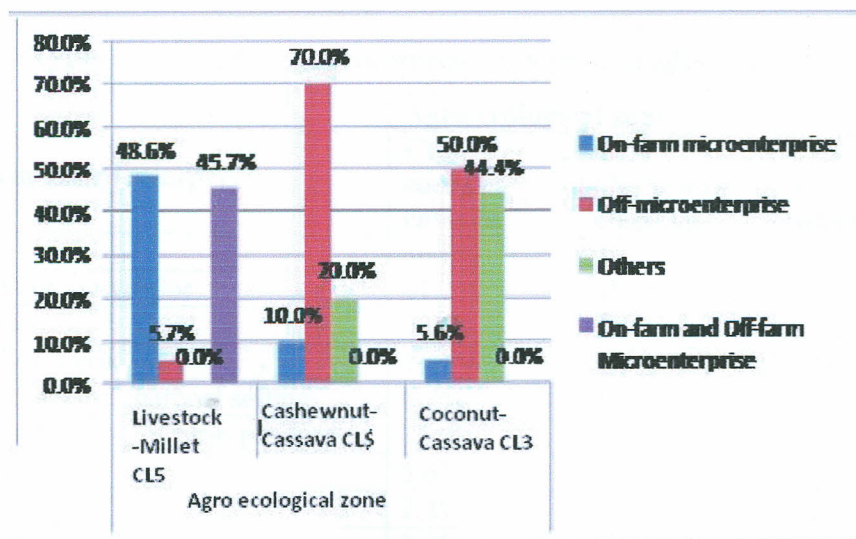


Figure 4-1 Types of Micro-enterprise by Agro ecological zone

Table 4-2 illustrates that, households in CL5 livestock millet have relatively wide variety or mix of on-farm micro enterprises activities compared to CL3 coconut cassava and CL4 Cashewnut Cassava.

Table 4-2 Types of on-farm microenterprise by Agro ecological zone

| Farm based microenterprise | Agro ecological zone | | |
|---------------------------------------|---------------------------|-----------------------------|----------------------------|
| | CL3 coconut cassava | CL4 Cashewnut Cassava | CL5 livestock millet |
| Others | 91.7% | 90.0% | 8.6% |
| Crops | 8.3% | 10.0% | 22.9% |
| Traditional animal husbandry | 0.0% | 0.0% | 17.1% |
| Crop and traditional animal husbandry | 0.0% | 0.0% | 34.3% |
| crops and/or modern poultry | 0.0% | 0.0% | 8.6% |
| apiculture/crops/livestock | 0.0% | 0.0% | 8.6% |
| Total | 100.0% | 100.0% | 100.0% |

Note: Others include respondents who did not give any answer or the questions were not applicable.

Table 4-3 illustrates that In CL5 off-farm microenterprise largely in cooking and selling of food plays an important role in providing households with cash income. In CL3 and CL4 the off-farm microenterprises are more diverse.

Table 4-3 Types of off-farm microenterprise by Agro ecological zone

| Off- farm microenterprise | Agro ecological zone | | |
|------------------------------------|---------------------------|-----------------------------|----------------------------|
| | CL3 coconut cassava | CL4 Cashewnut Cassava | CL5 livestock millet |
| Others | 50.0% | 30.0% | 40.0% |
| Food and/or tea vendor | 11.1% | 36.7% | 54.3% |
| Hardware | 0.0% | 3.3% | 0.0% |
| Retail shop/kiosk | 11.1% | 6.7% | 2.9% |
| fire wood and/or charcoal selling | 0.0% | 3.3% | 2.9% |
| buying and selling of farm produce | 13.9% | 6.7% | 0.0% |
| Tailoring | 5.6% | 6.7% | 0.0% |
| Toddy tapper | 2.8% | 0.0% | 0.0% |
| Transport | 2.8% | 0.0% | 0.0% |
| wood/metal works | 2.8% | 0.0% | 0.0% |
| Entertainment | 0.0% | 6.7% | 0.0% |
| Total | 100.0% | 100.0% | 100.0% |

Note: Others includes the respondents who did not give any answer or the questions were not applicable

These results mean that, majority of the off-farm micro enterprise are agro based. This is particular so in the low potential high poverty CL5 livestock millet where food vending is the most dominant off farm microenterprise. This scenario appears to be consistent with Maslow's basic need theory (see section 1.6) i.e. the relatively high poverty prevalence in CL5 livestock millet means the people spend most of their income on food while the high agricultural potential means people have relatively more incomes hence can afford to buy other things apart from food items only thus supporting a relatively wide variety of off-farm MEs

Furthermore, as agricultural potential decreases diversification of on farm microenterprises and income sources in the household increases. This is perhaps a coping strategy employed by the households to mitigate the often challenging production environment as a result of low and often unreliable rainfall. However the dependence on off-farm micro enterprise in CL3 coconut cassava and CL4 Cashewnut Cassava can perhaps be explained by limited or lack of land for on farm MEs due to the relatively high population density in these high agricultural potential zones.

4.1.3 Current energy choices

Tables 4-4, 4-5, 4-6 and figure 4-2 illustrates the results of the study regarding current energy choices for rural MEs across the AEZs under review. The study found that with regard to energy choices majority of microenterprise in the study area (table 4-2) use traditional biomass energy, human energy and kerosene. Apart from biomass other sources of energy for microenterprise activities included electricity, fossil fuels (kerosene and petrol). Nevertheless, it is only in the agro ecological zone CL3 where respondents indicated they were using agriculture residues.

Table 4-4 use of different energy source across the agro ecological zones

| Agro ecological zone | Others | Biomass only | Fossil fuel only | Biomass and fossil |
|-----------------------|--------|--------------|------------------|--------------------|
| CL3 coconut cassava | 36.1% | 61.1% | 0% | 2.8% |
| CL4 Cashewnut Cassava | 36.7% | 36.7% | 10.0% | 16.7% |
| CL5 livestock millet | 8.6% | 5.7% | 0% | 85.7% |

Note: Others includes the respondents who did not give any answer or the questions were not applicable

Paradoxically, the highest proportion of microenterprise using charcoal a relatively high quality biomass energy source were found in Bamba CL5 an area with the highest poverty prevalence across all the AEZs under review.

Table 4-5 Type of biomass by agro ecological zones and percentage

| Agro ecological zones | Others | Firewood | Firewood and Charcoal | Charcoal only | Agricultural residue |
|-----------------------|--------|----------|-----------------------|---------------|----------------------|
| CL3 coconut cassava | 36.1% | 38.9% | 5.6% | 11.1% | 8.3% |
| CL4 Cashewnut Cassava | 40.0% | 33.3% | 13.3% | 13.3% | 0% |
| CL5 livestock millet | 8.6% | 22.9% | 68.6% | 0% | 0% |

Note: Others includes the respondents who did not give any answer or the questions were not applicable

Majority of the respondents do not have access to electricity. In AEZ CL4 comparatively the highest proportion of households had access to electricity. However, this may be due to the fact that in the area covered in the study Kilifi Township + Tezo is more urban. The electricity is used mainly for lighting and to small extent running fruit blenders and refrigerators. Majority of the respondents obtained their electric from the grid (table 4-6).

Table 4-6 Access to electricity by agro ecological zone an percentage

| Agro ecological zone | Did not indicate | Grid | Generator | Photo-voltaic | No access | generator and photovoltaic |
|-----------------------|------------------|-------|-----------|---------------|-----------|----------------------------|
| CL3 coconut cassava | 25.0% | 2.8% | 2.8% | 8.3% | 61.1% | 0% |
| CL4 Cashewnut Cassava | 16.7% | 40.0% | 0% | 3.3% | 36.7% | 3.3% |
| CL5 livestock millet | 2.9% | 0% | 0% | 0% | 97.1% | 0% |

Figure 4-2 demonstrates that, human energy is important source energy for the rural microenterprise in the different agro ecological zones of Kilifi district more so in the drier and poorer CL5 livestock millet zone.

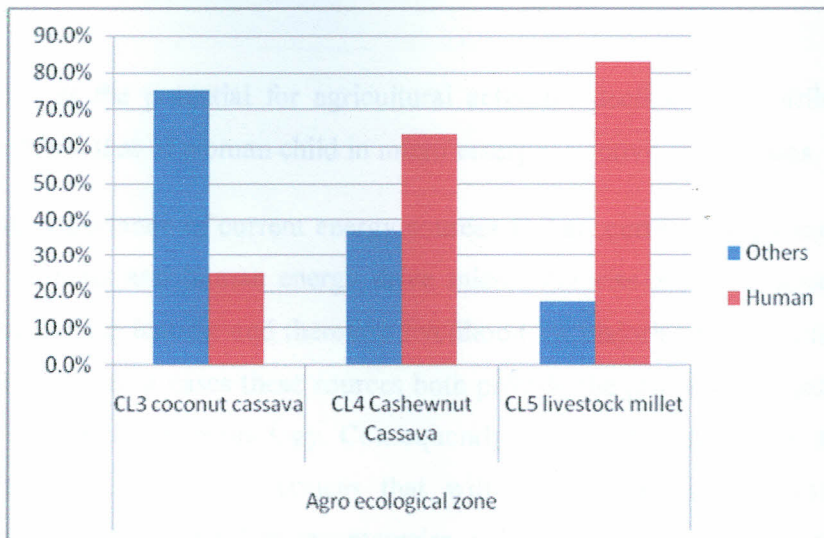


Figure 4-2 Use of human energy by the agro ecological zone

Table 4-7 show that in all AEZs under review the adult woman was ranked first followed by adult man. The woman child was ranked third higher the man child was ranked last across all AEZs under review with respect to human energy contribution for microenterprise activities.

Table 4-7 Ranking of gender-age energy contribution by Agro ecological zones

| Gender-age | Agro ecological zone | Others | 1st | 2nd | 3rd | 4th |
|-------------|-----------------------|--------|------|------|------|------|
| Boy child | CL3 coconut cassava | 97.2 | 0.0 | 0.0 | 0.0 | 2.8 |
| | CL4 Cashewnut Cassava | 70.0 | 3.3 | 10.0 | 16.7 | 0.0 |
| | CL5 livestock millet | 20.0 | 0.0 | 2.9 | 42.9 | 34.3 |
| Girl-child | CL3 coconut cassava | 97.2 | 0.0 | 0.0 | 2.8 | 0.0 |
| | CL4 Cashewnut Cassava | 86.7 | 3.3 | 0.0 | 10.0 | 0.0 |
| | CL5 livestock millet | 14.3 | 2.9 | 45.7 | 34.3 | 2.9 |
| Man-adult | CL3 coconut cassava | 77.8 | 19.4 | 2.8 | 0.0 | 0.0 |
| | CL4 Cashewnut Cassava | 66.7 | 16.7 | 10.0 | 6.7 | 0.0 |
| | CL5 livestock millet | 34.3 | 8.6 | 40.0 | 11.4 | 5.7 |
| Woman-adult | CL3 coconut cassava | 75.0 | 22.2 | 2.8 | 0.0 | 0.0 |
| | CL4 Cashewnut Cassava | 43.3 | 33.3 | 20.0 | 3.3 | 0.0 |
| | CL5 livestock millet | 2.9 | 85.7 | 8.6 | 2.9 | 0.0 |

Relative to other AEZs under study, CL5 livestock millet had the highest proportion respondents (85.7%) who ranked the adult woman as the highest contributor of human energy for microenterprise activities. The adult male was ranked second by 40% of the respondents in the same position with the girl child in terms of contribution to human mechanical energy for microenterprise in CL5 livestock millet. These results

indicate that, as the potential for agricultural activities decline the contribution of woman adult and that of woman child in micro enterprise activities increases.

The relative importance of current energy sources is that, current energy sources i.e. traditional biomass and human energy drive microenterprise activities which is the main source of cash income and therefore livelihood for majority of the household in the study area. In most cases these sources both provide the primary and end use and with traditional end use technology. Consequently, conversion into useful energy is low and absence of energy services that will enhance income generation and employment among the rural microenterprise and environmental protection in the study area.

4.2 The influence of Agro-ecological Factors on Rural Microenterprises Current Energy Choices in the Agro-ecological zones of the District

As has been pointed in the previous section the most important sources of energy for microenterprise in the study area are biomass energy and human energy. The study sought understand the agro ecological factors that influence these energy choices by first, collecting both primary secondary data relating to topography, agro-climatic conditions (temperature, rainfall, and climatic seasonality), resource base and social condition of the study area. In addition, The Focus Group Discussion (FGD) helped to gather data on the peoples' perspectives on which agro ecological factors influence current energy choices and how these factors exert the influence. Interviews were also conducted using Purposeful sampling to the probe and document data relating to institutions (policy, legal environment and institutions) these interviews covered relevant ministry, parastatals and elders. Direct observation and photographs also helped to collect data on how agro ecological factors influence current energy choices.

4.2.1 The Influence of Agro ecological Factors on rural microenterprise current biomass energy choices

Influence of Topography on current biomass energy choices

The study found across AEZs under review Topography appears to influence type and spatial distribution of biomass energy choices for the microenterprise (see figure 4-3 and 4-3). For example, it was observed that valleys considerable influenced on the

location and type of on-farm microenterprise, hence the choice of energy for these microenterprises. This is because in addition to controlling directly the distribution of mesoscale and macro scale climate patterns and it also influences the flow of water through the landscape. These processes have in turn a key influence in natural mechanisms like soil formation, soil erosion and deposition, and the distribution and productivity of ecosystems of which biomass energy sources is but one of them.



Figure 4-3 Topography Influence on distribution of ecosystems CL5

Influence of Agro-climatic conditions on current biomass energy choices

It was observed that the biomass in there variations in the type of biomass across the AEZs under review. Unlike CL5 the biomass energy sources for ME in the relative high agricultural potential zones CL3 Coconut cassava and Cashewnut cassava mainly come from outside the zone. This is due to the fact that CL3 and CL4 have relatively high rainfall potential which is well distributed over the year(see figure 4-4)the agro climatic conditions have led to high agriculture potential leading to high population density.

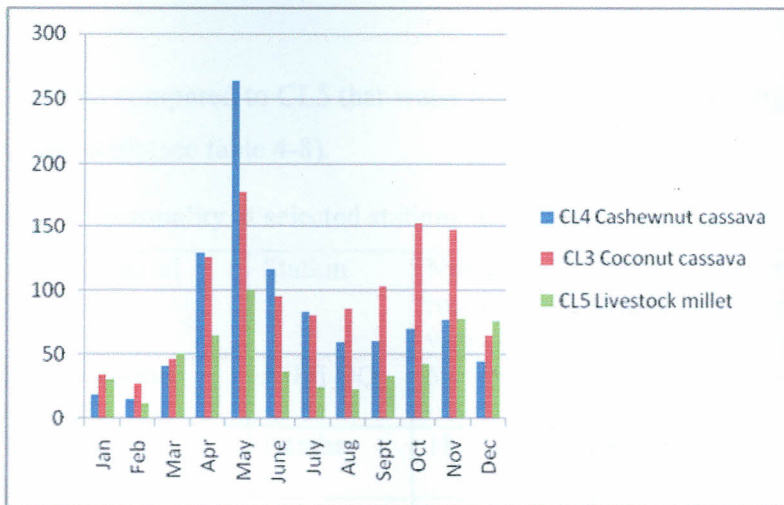


Figure 4-4 Long term annual rainfall distribution by agro ecological zone
Source: meteorological department Nairobi

Consequently, natural vegetation is often cleared to pave way for human settlement and agricultural production (see figure 4-5). This is also the reason why in AEZ CL3 agricultural residues are also one of biomass energy choices for ME.



Figure 4-5 Natural Vegetation Replaced by Agricultural crops CL3

Climatic seasonality influences quantity of biomass energy sources across all AEZs under review. in the relatively high agricultural potential AEZs CL3 and CL4 Climatic seasonality causes rapid plant growth hence accumulation of the biomass unlike in the low agricultural potential CL5. This is because in the CL3 and CL4 there

are fewer dry months compared to CL5 that water availability is the limiting factor in plant growth in the study(see table 4-8).

Table 4-8: Climatic seasonality at selected stations in Kilifi district

| Altitude (m) | Agro ecological Zone | Station | Number of recorded years | Mean annual rainfall | Number of dry months |
|--------------|-------------------------|-----------|--------------------------|----------------------|----------------------|
| 8 | CL4Cashewnut Cassava | Kilifi DO | 53 | 954 | 9 |
| 244 | CL5 livestock millet | Bamba | 18 | 677 | 10 |
| 256 | CL3 coconut cassava | Chonyi | 33 | 1150 | 9 |
| 226 | CL3 coconut cassava | Kaloleni | 15 | 1090 | 7 |
| 204 | CL5 livestock millet | Mariakani | 34 | 856 | 9 |

Source: Meteorological department Nairobi

The study found that climatic seasonality affects quality biomass energy sources across all agro ecological zones under view. Quality of biomass energy source is indicated by its ability to light up quickly, burn longer and the amount of smoke produced and all these are influence by moisture content among other things. Consequently, due to the different climatic seasonality across the agro ecological zones under review quality of biomass will be different. Therefore, the quality of biomass as influenced by its moisture content is relatively higher in CL5 Given that rainfall amount is lower and the number of dry months is higher compared to CL3 and CL5 zones.

Climatic seasonality also has influences the availability of agricultural residues that are use as source of biomass energy source. This energy source is most abundant during harvest. For example, the cashew nut processing microenterprises use the cashew nut shells as a source of energy (see figure 4-6).



Figure 4-6 Use of cashew nut shell as fuel for cashew nut processing microenterprise

Influence of the Resource base on Rural Microenterprise Current Energy Choices

Kilifi district has 310400 hectares or 3104 sq km of arable land which is 65% of the total land in the district. Only 16.4% of the total land in the district or 25.3% of the arable land (GoK 2009). This means the bulk of the arable land is unutilized or lies fallow which provide shrubs that may be used sources of biomass .energy for microenterprise

Gazetted forests constitute another important resource base as far as biomass choices for the microenterprise activities are concerned. The total coverage of these forests is 20,000 ha or about 4.2% of the total area of Kilifi district. Comparatively, Kilifi district still has great reservoir of biomass energy source particularly firewood in view of the fact that almost 75% of arable land is not utilized or is under-utilized.

Influence of the Social Condition on rural Microenterprise Current Biomass Energy Choices

It was observed that population and human settlement influence rural microenterprise current biomass energy choices. AEZs CL3 coconut cassava and CL4 Cashewnut Cassava have relatively higher populations compared to AEZ CL5 livestock millet (see table 4-9.)

Table 4-9 Population 1969-2030 by agro ecological zone or Administrative Unit

| Agro ecological zone or Administrative unit | 1969 | 1979 | 1989 | 1999 |
|---|----------|------------|----------|------------|
| CL3 Jibana | 7903 | 9423 | 10625 | 13704 |
| CL4 Kilifi T/ship +Tezo | 23358 | 30783 | 38200 | 47138 |
| CL5 Bamba | 11843 | 26107 | 31999 | 35852 |
| Kilifi | 213900 | 301905 | 401042 | 544303 |
| Mombasa | 247073 | 341148 | 461753 | 665,018 |
| Kenya | 10942705 | 15,327,061 | 21443636 | 28,686,607 |

Source: Kilifi district development plans 1974-1978, 1989-1993, 1994-1997, 1997-2001 Kenya housing and population census 1989, Kenya housing and population census 1999

Table 4-10 Continuation of Table 4-9

| Agro ecological zone or Administrative unit | 2009 | 2015 | 2019 | 2029 |
|---|----------|----------|----------|----------|
| CL3 Jibana | 15890 | 17365 | 18969 | 22591 |
| CL4 Kilifi T/ship +Tezo | 58167 | 65988 | 71777 | 88572 |
| CL6 Bamba | 40169 | 43005 | 45006 | 50425 |
| Kilifi | 738740 | 887324 | 1002634 | 1360797 |
| Mombasa | 957761 | 1192096 | 1379370 | 1986573 |
| Kenya | 38376021 | 45697074 | 51338207 | 68678603 |

This led to the clearing of natural vegetation which was initially made of humid forests was cleared for housing and farm land. Thus biomass energy particularly that collected free of charge comes from residues of the main agricultural areas such as the coconut palms (coconut frond, husks, shells) and off cuts from cashew nut trees.

Table 4-11 Population Density by Agro ecological zone

| Agro ecological zone or Administrative unit | 1969 | 1979 | 1989 | 1999 | 2009 | 2019 | 2029 |
|---|------|------|------|------|------|------|------|
| CL3 coconut cassava (Jibana) | 225 | 262 | 366 | 422 | 454 | 542 | 652 |
| CL4 Cashewnut Cassava (Kilifi township+ Tezo) | 66 | 259 | 307 | 394 | 513 | 663 | 857 |
| CL5 livestock millet (Bamba) | 39 | 48 | 59 | 76 | 98 | 127 | 163 |
| Kilifi | 45 | 63 | 84 | 114 | 155 | 210 | 285 |
| Mombasa | 876 | 1209 | 1637 | 2357 | 3395 | 4890 | 7042 |
| Kenya | 19 | 26 | 37 | 49 | 66 | 89 | 119 |

Source: Source: Kilifi district development plans 1974-1978, 1989-1993, 1994-1997, 1997-2001 Kenya housing and population census 1979, Kenya housing and population census 1989, Kenya housing and population census 1999 compared to the other

Population density influences the demand for environmental goods and services such as land for food production, land for settlement, water and energy. In the hierarchy of

needs food is at the top, hence availability of land that provides of biomass energy sources is inversely related to land demand for food and settlement.

AEZs under review, CL5 livestock millet has a relatively low population density (table 4-11) and the price of firewood and charcoal is significantly low (see table 4-12). Charcoal making is a major microenterprise in this zone. The popular tree for making charcoal are the acacia species particularly *Acacia Senegal*.

The study also sought to compare prices for selected energy choices in different The prices of firewood and charcoal across the AEZs under review shows that prices in CL3 and CL4 are higher compared to those found in Bamba (see table 4-12). This is further indication that the demand for these energy sources in CL3 and CL4 outstrips the supply.



Figure 4-7 charcoal selling in CL5 livestock millet zone

Table 4-12 Prices for selected energy sources by Agro ecological zone by selling units

| Agro ecological zone | Unit | Price in Kshs | | |
|-----------------------|----------------------------------|---------------|----------|----------|
| | | Charcoal | Firewood | Kerosene |
| CL3 coconut cassava | 45 kg bag/3 tonne load/Litre/KWh | 500.00 | 100.00 | 70.00 |
| | kg/Bundle/125 ml | 20.00 | 150.00 | 90.00 |
| CL4 Cashewnut Cassava | 45 kg bag/3 tonne load/Litre/KWh | 500.00 | 3500.00 | 80.00 |
| | kg/Bundle/125 ml | 20.00 | | 15 |
| CL5 livestock millet | 45 kg bag/3 Ton load/Litre/KWh | 200.00 | 1500.00 | 100.00 |
| | kg/Bundle/125 ml unit | | 20.00 | 18.00 |
| Mombasa | 45 kg bag/3 tonne load/Litre/KWh | 600.00 | 4000 | 66.00 |
| | kg/Bundle/125 ml | 25.00 | | 15.00 |

Influence of Households' characteristics on rural microenterprise biomass energy choices

In the study area majority of those engaged in microenterprise activities conducted all or part of their activities within the household (see table 4-13). Bamba in Agro ecological zone CL5 livestock millet leads with 80.0% of the surveyed household having all or part of their microenterprise activities within the household. While agro ecological zone CL4 Cashewnut Cassava and CL3 coconut cassava had 63.3% and 33.3% respectively had part or whole of their micro enterprise activities carried out within the household. During the household survey and the FGDs the study also determined whether or not households separated energy for microenterprise activities from that geared for domestic activities. According to the results majority of the household indicated that they did do not (figure 4-8).

Table 4-13 Location of the microenterprise activities by agro ecological zones

| Agro ecological | Others | Entirely within household | Partly within household | not in the household | Total |
|-----------------------|--------|---------------------------|-------------------------|----------------------|-------|
| CL3 coconut cassava | 58.3% | 25.0% | 8.3% | 8.3% | 100% |
| CL4 Cashewnut Cassava | 26.7% | 50.0% | 13.3% | 10.0% | 100% |
| CL5 livestock millet | 8.6% | 62.9% | 17.1% | 11.4% | 100% |

The category 'others' includes those house hold where the data for microenterprise activities was inconsistent like for those who obtained their cash income from wage employment only

These results mean that domestic activities will also have implications for ME activities. In addition the fact majority draw a distinction between energy for ME activities and that for domestic activities it is reasonable to infer that, for the most part agro ecological factors that influence household energy choices for domestic activities will also influence ME energy choices and their activities in general.

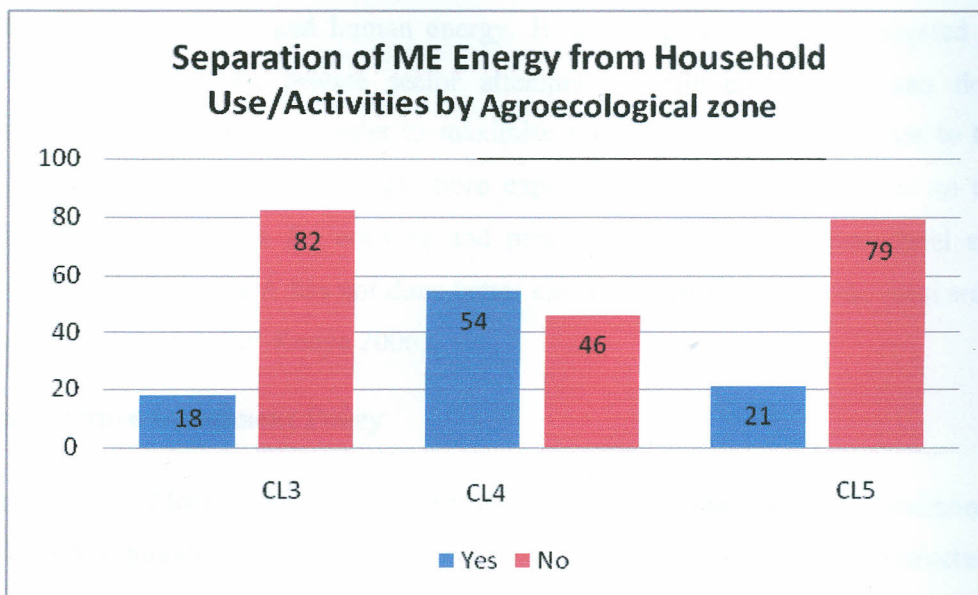


Figure 4-8 Separate household energy use from that for Microenterprise activities

An important aspect of the microenterprise activities being located within the household is that it allows for the poor households to gather together and ‘optimise’ labour and other household capital assets including land, savings, and human energy e.t.c.

Influence of Institutions on rural microenterprise on biomass energy choices

Analysis of the data from household survey, focus group discussions and interviews the study found there are institutions in the study area that influence energy choice. These institutions range from the formal such as policies, laws to informal ones such as traditions, values and attitudes.

Energy Policy and legal environment

The study found out that past and present energy policy and legal environment has contributed to the dependence on current biomass energy choices and lack of access to convenient and clean energy sources for MEs and poor households in general. the policies

and legal measures aimed at addressing the situation such as the rural electrification program notwithstanding. The current policy emphasis that financing of the commercial energy sector through private sources as opposed public funding has made rural microenterprise and the rural poor in general to depend on traditional biomass energy sources and human energy. However, privatisation has created an environment where the private sector attempts to stifle competition and flout regulation where possible in order to maximise profits. Thus, making access to the more convenient sources of energy more expensive increases the reliance on the traditional biomass fuels for cooking and process heating in most household and microenterprise. The REA has not done better electricity penetration in the rural areas is only 4% of the (GVEP-Kenya 2006).

Infrastructure Investment Policy

It appears that, Most of the public investments essential to improving the livelihoods of the rural population in Kilifi district such as in energy, rural infrastructure, agricultural services and human health and education have been biased towards areas with high agricultural potential. In Kilifi district, there is currently no emphasis on microenterprise. For example in the 1997-2001 planning period, of the 149 projects earmarked for the period none was energy. In the planning period 2002-2008 despite energy being ranked 1 the targets were 34 (GoK 2003). These targets covered trading centres, divisional headquarters, health facilities, markets and schools. In addition these projects entailed extension of grid lines (Ibid 2003).

Electricity connection, payment modes and delivery standards

The study also found that, existing electricity payments modes connection and delivery standards lack flexibility which is suitable for most of the rural microenterprise operators. Most energy pricing and payment practices informed by western styled standards have assumed monthly payments. Given that majority of the household in the study area are poor and that their MEs are predominantly agro based, modern energy will continue to be out of reach because the incomes are not monthly and often seasonal in line with agricultural production systems found in the area.

Energy planning

Energy planning in Kenya lacks organised attempt to approach it in an integrated and holistic way for purposes of policy formulation or analysis in the country (GVEP-Kenya 2006). The current energy planning procedure does not consider the energy sources and the consuming sectors (ibid 2006). In addition despite the rapid increase in the demand for energy there has not been a corresponding increase in the supply. This situation is further aggravated by political and policy realities that continue dependence on crude oil for energy supply and energy security. This in turn has led to erratic and ever increasing costs. Furthermore, energy planning so far tends to follow the blue print approach which disregards or assume adequate knowledge of regional socio-economic and cultural environment.

Despite biomass energy sources being a major source of energy for ME and domestic activities in general establishment of protected zones has neither succeeded in ensuring supply of biomass to rural community nor conserve forests and their biodiversity. A classic example in this regard is the ongoing Mau forest debate and controversy is. Such protected zones, most of which were originally community owned forests with indigenous and exotic plants were taken over by governments. The fact that forest and forest resources were taken away from people, thereby taking away a vital natural capital, without providing alternative played a key role in failure of protectionist programs.

Energy legislation

The main law governing the energy sector and provide the legal framework for its development the Energy Act 2006. Part III section 66 to 77 of the Act is of particular relevance in the development, promoting access to modern and convenient energy sources in the rural area. To achieve this goal the Act provides among other things the establishment of the Rural Electrification Authority.

The Forest Act 2005 is part of the legal environment that influence biomass energy sources because its main objective of the act is to provide for the establishment, development and sustainable management, including conservation and rational utilization of forest resources for the socio-economic development of the country. The

Act allows controlled use of products from the gazetted forests found in the district is part of government land thus access to biomass is controlled if not restricted under section 49 part V of the Act;

Land tenure systems

The term land tenure is a derivative of Latin *tenere*, which means, "to hold". Land tenure describes the method, by which individuals or groups hold, transfer or transmit property right in land. Property rights may include a variety of rights commonly referred to as a bundle of rights (e.g. to farm, to transfer to build on or obtain firewood or other sources of biomass energy). Land tenure systems found in the study area include, government land, community land, individual ownership and group ranches. These different tenure systems influence in one or another current biomass energy choices.

Government or public land tenure refers to the phenomenon of the government as a private landowner. In Kilifi district government land includes, forest reserves, national parks, townships and other urban centres, alienated government land unalienated government land. In the national parks there is no any consumptive use allowed. In the gazetted forests there is controlled sue of biomass energy resources and other products through the issuance of permits. However in un-alienated government land there is widespread use of the resources found therein including biomass energy sources. A considerable proportion of the land in the study area except that found within the 10 mile coastal strip existed as Community or Trust till early 1970's during which adjudication sections were done declared, the tenure changing to either private or group ranch . The individual tenure is common in the relatively high potential Jibana CL3 and Kilifi Township + Tezo CL4. While in the low agriculture potential arid and semi-arid i.e. in the CL5 and CL6 the most common tenure is group ranch. The study found that This instrument was also used for registering land in areas which, the people did not particularly favour individual ownership of land as opposed to communal ownership..

The study found that, the traditional tenure system is the *de facto* tenure system that largely influences access to current energy choices in the study area. Given the existing statutes on land are relatively 'recent' and for the most part have been

imposed from above and little or nothing has done to 'domesticate' the statutes in line with the socio-cultural environment of the area. The main objective of the traditional tenure system is guaranteeing access land and its related resources to individuals or families and invests relevant rights of control over allocation and use to relevant political entities. Under customary or communal ownership law, land rights including those of access and use were guaranteed except for the right of alienation (Mkangi, 1983).

Regarding access biomass energy sources and specifically firewood the traditional system did not provide for exclusive control by any individual. Indeed this is true for all environmental resources such as grazing water and vegetables.

'Huku kwetu hakuna mipaka ya kuni, maji, mboga ama malisho, isipokuwa zile sehemu zilizo gawanya' (personal interview)

'In our area there are no binderies when it comes to firewood, vegetables, water and for animal grazing in adjudicated areas'

The introduction of 'modern' or individual tenure system and the exclusive control that comes with private ownership curtailed the free access to biomass energy sources and other environmental services which existed in the traditional tenure system. This is because the individual tenure system appears to give room for the individualistic values which has been hitherto masked by the collectivistic values inherent in the traditional land tenure system.

In addition, the privatisation of land has also curtailed access to biomass energy sources and other environment due rise in land transactions. These transactions have led to transfer of ownership to individuals or organisation from outside local communities who do not necessarily adhere to the collectivistic ownership of environmental services inherent in the traditional land tenure system of the local communities. .

Traditions, Values and attitudes

The study revealed that in the study area i.e. traditions, attitudes and values influence the type of plants to be used as a source of energy and those due to one reasons or

another cannot be used for this purposes. The most common plants that are used for firewood include the following, "Mhowe", "Mkone", "Mkulu" (*Brachylaena huillensis*), "Mtsome". These are mainly shrubs. Big trees are never cut done to provide firewood. Such trees are used for other things such building houses making furniture. These trees found in the area and include "Mvule" (*Milicia excelsa*), "Mbambakofi" (*Azelia quanzensis*), Mrihi. However the off cuts from such big trees are dried and used for firewood.

It emerged from the study that there are traditions and attitudes that discourage the use of some trees for fire wood. One such tree is the *Bavu bavu* which if used for firewood is believed to cause severe chest and respiratory complications. *Mtsonga Mahana* is another tree not used for firewood because it is believed to cause leprosy among the Warabai. However among the Wagiriama this tree is used for firewood. Why there are these differences regarding taboos related to same trees is perhaps a subject for another research.

The majority of the population in the study area of Mijikenda origin (over 90%), and in that sense the districts can be regarded to be virtually one cultural entity (CBS 1994). Seven of nine Mijikenda ethnic sub-groups are distinguished, (Giriama, Kauma, Chonyi, Jibana, Kambe, Ribe, Rabai). The Mijikenda tribes originated from an area called Singwaya in the southern Somali hinterland, and migrated towards the coastal area at the turn of the 17th Century. Initially, they settled in nine, individual, fortified hill-top villages called *Kayas*, along the ridge inland from the southern Kenyan coast. As populations grew larger, people left to settle in the nearby lowlands and beyond (Spear, 1971). These forests still exists to date and continue to provide a source of biomass energy sources however access to these sources is controlled by very strict tradition and taboos.

The traditional method of grain storage influences the choice and use of biomass energy source. The location of the traditional granaries 'uchaga' is such it is usually located where near or above the fire pace where the heat and smoke from the wood fuel fire can to keep the produce dry and hold off pests and other vermins.

During the FGD and interviews it became apparent that, communities in the study area are patriarchal in orientation. Hence, household decisions especially that have bearing on the household income are done by or sanctioned by men. In this context therefore, Men are more likely to take decisions on behalf of households and in terms of their own economic and social priorities. For example, women may value smoke reduction on health grounds and to reduce the drudgery entailed in fetching water and firewood. Men, on the other hand, valued fuel savings (money saving) above other considerations. In addition, because of their different and unequal roles in the division of labour, women and men have different needs and may have different priorities. This means that they may make different tradeoffs between time and energy.

The study found that attitudes influencing current energy choices is due to real or perceived advantages such as their affordability and availability(see figure 4-9). These results mean that there are challenges towards the transition to more convenient and clean energy sources particularly in view of their initial high capital cost. The challenges are due to first, the decisions that require investments are made by men despite main users of this type energy source are expected to be women and the girl child. Secondly, the convenient energy sources and clean biomass energy sources must be seen to have advantages that far outweigh those obtained from use existing energy choices if the energy transition is to take place.

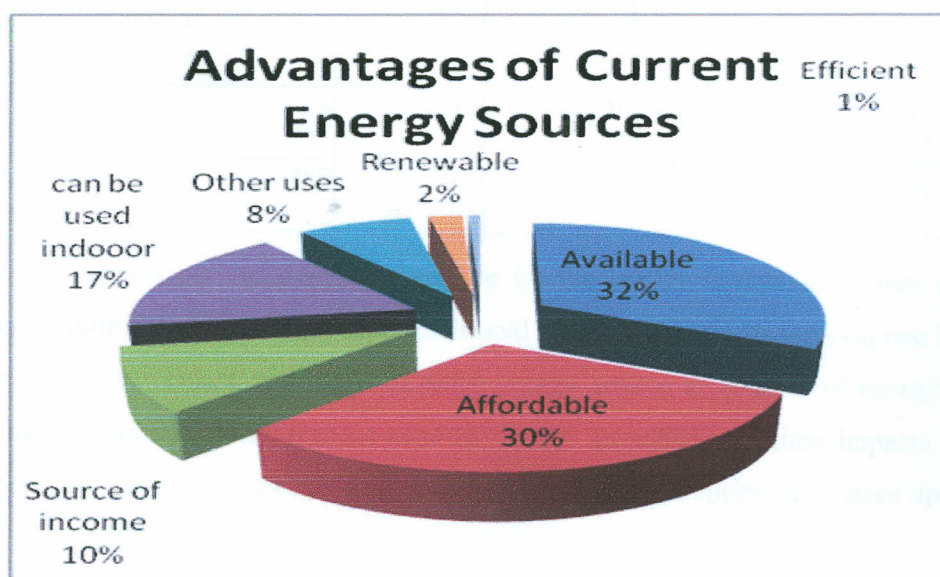


Figure 4-9 Advantages of the current energy sources

Tables 4-14 show that limited access to energy services that promote income generation or employment is not among the disadvantages associated with current use of biomass and human energy. These results are consistent with an analysis of 72 Community Action Plans across all agro ecological zones in Kilifi done by Kilifi District development Program. In its report it emerged that communities in the district rank energy relatively low compared to other basic infrastructure needs (KDDP 2001). This means communities across the agro ecological zones appear not to view energy services as an important input in production related needs.

Table 4-14 Challenges from Current Energy Use by AEZ and percentage

| | Reducing Quality (firewood and charcoal) | Collection is time consuming | Reduced Supply in rainy season | Not clean with Adverse health impacts | Inefficient (takes long to cook with) |
|-------------------|--|------------------------------|--------------------------------|---------------------------------------|---------------------------------------|
| Coconut-cassava | 0 | 0 | 5.6 | 5.6 | 11.1 |
| Cashewnut-cassava | 0 | 40 | 16 | 4 | 0 |
| Livestock-millet | 18.8 | 12.5 | 2.1 | 14.6 | 12.5 |

Table 4-15 Continuation of table 12

| | Biomass expensive | Expensive (electricity, kerosene, gas) | Price fluctuation | land ownership | Risk of Bites or injuries during collection | Total |
|-------------------|-------------------|--|-------------------|----------------|---|-------|
| Coconut-cassava | 0 | 0 | 0 | 5.6 | 72.2 | 100 |
| Cashewnut-cassava | 4 | 16 | 20 | 0 | 0 | 100 |
| Livestock-millet | 0.0 | 0.0 | 4.2 | 8.3 | 27.1 | 100 |

Energy has a derived demand therefore for the energy transitions to take place the communities' attitude regarding traditional biomass energy choices on one hand and towards convenient and clean biomass energy source as sources of energy services that will improve their income need to change. In addition, if their impacts are to be felt (for example of electrification schemes) the communities must have appropriate

end use gadgets and skills. Generally any policy or legal instrument, tradition, mores dealing with land and its related resources will influence the current energy sources.

4.2.2 The Influence of Agro Ecological Factors on Rural Microenterprises Current Human Energy Choices

Influence of Topography on Rural Microenterprise Human Energy Choices

The study also found that, most of biomass particularly firewood is transported using human labour. This implies a relatively high cost of human labour if this energy source is transported through steep slopes or deep valleys. Transportation by vehicles, carts, and donkey is rare.

It was observed that across all the AEZs under review more often than not the terrain is dissected by hills an exception to this is in coastal plain which cover of Kilifi Township +Tezo CL4. Where for instances the there is steep slopes on farm activities such as farm preparation and weeding use human energy because tractors are inappropriate even where in an unlikely event that one can afford to pay for such services.

Influence of Agro-climatic conditions on current human energy choices

The study on the basis of interviews and secondary data estimated maize self sufficiency (Maize is the staple food) and labour demand for crop production MEs and household activities (see figure 4-10) In all AEZ under review climatic seasonality influences the production cycle hence labour demand and supply for on farm microenterprise activities e.g. crop production. Study found the in crop production, the main activities are land preparation, planting, weeding and harvesting. Weeding was found to be the most labour intensive task and may be twice per crop season depending among other things the type of crop. Figure 4-10 illustrates that the peak labour coincides with the lowest household food reserves. In AEZ CL5 at the start of the production cycle food reserves are completely depleted unlike in the wetter CL3. Furthermore in AEZ CL5 rainfall is low and often unreliable hence tasks such planting and weeding is repeated due to crop failure.

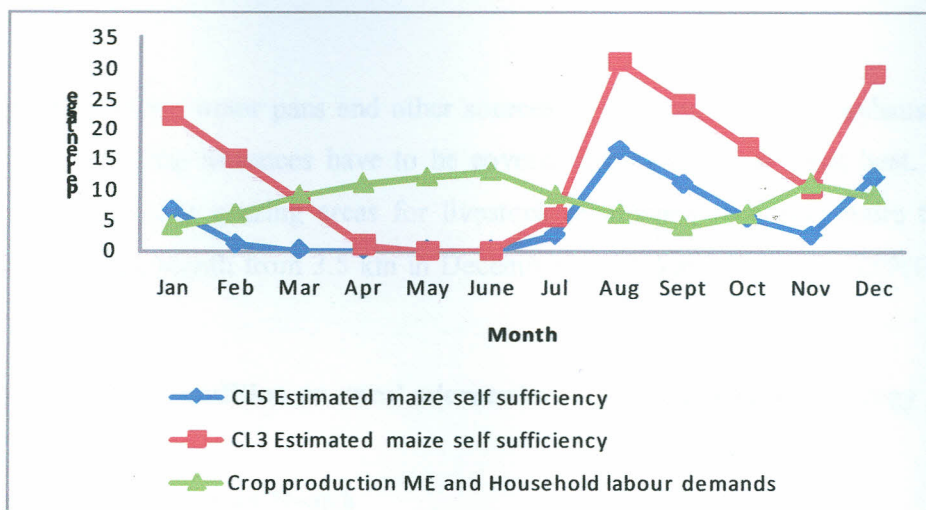


Figure 4-10 Household maize self sufficiency and labour demands in by AEZ (Source: Geist 1981, Hoorweg et al 1995, Waaijbergen 1994, GoK 2009, and field interviews)

Rainfall also affects human energy by through its influence on disease prevalence especially malaria. Kilifi district and most of the Coastal region of Kenya malaria is endemic. The most prevalent diseases include Malaria, Pneumonia and diseases of the digestive system (GoK, 2005). Disease such as malaria and some of the diseases of digestive system of tend to increase during rainfall seasons. The highest prevalence of some of these diseases occurs at the peak of the rain season (see figure 4-4) during which food reserves are at their lowest.

Looking at the human labour demands for crop production across AEZ, maize (food) sufficiency and the influence of climatic seasonality on disease prevalence one can conclude that climatic seasonality has more adverse influence on human labour in the dry CL5 AEZ compared to the wetter CL3 and CL4 AEZs.

The study found that in microenterprises involving livestock there are three major tasks supervising (or pasturing), watering and milking. Of these, supervising and milking do not need much labour Watering, on the other hand, is a gruelling, energy-consuming task for which labour requirements is high in the dry seasons or during dry spells. As surface water dries up, wells have to be dug in dry riverbeds and have to be maintained. As the dry season progresses the wells have to be dug deeper and deeper. Demand for water at the same time increases as more and more cattle return from

outlying areas where water pans and other sources of standing water are exhausted. This means that long distances have to be covered during times of great heat. For instance, Distances to grazing areas for livestock lengthened recording more than double that of last month from 3.5 km in December to 7.9 km in January 2009(GoK 2009).

Influence of Social condition on rural microenterprise current human energy choices

Influence of Nutrition and Health

The findings of this study show that, there a wide food gap in Kilifi districts. This food gap impacts on the supply human energy. In 2005 and 2008 cereal production was 18450 and 24180 Metric Tonnes respectively (CBS 2005, GoK 2009). The 2005, cereal production in the district was only 20% of the total yearly demand of 92,245 Metric Tonnes (Ibid 2005). Based on the 2005 demand and projected 2009 population, the study estimated that despite the 2008 31%increase in cereal production over 2005 this can only meet 23% of the Kilifi district residents' current annual cereal demand. Human and animal energy (animate) are the most basic forms of energy. This energy form like all animate energy source nutrition is necessary. Nutrition provides the body with energy, growth and repair plus the capacity to protection or recovers from disease. The high poverty prevalence in the district aggravates the food gap and its impacts on human energy and health.

The rate of cases of stunted, wasted and underweight under-five children in the Kilifi district is 34.9%, 5.7% and 25.4% respectively (CBS 2005). This indicates poor nutritional condition in the district which has short and long term influence on the human energy in the district. The short term influences include reduced supply and productivity due to ill health, time spent seeking medical care for oneself and children (women being the major contributors of human energy). The long term influence may include future human energy supply.

As illustrated in figure 4-10 the food gap the drier AEZ CL5 has lower maize sufficiency compared to the wetter AEZ CL3. Table 4-16 shows that, as one moves

from the wetter AEZ CL3 drops from to the drier AEZ CL5 the proportion of women respondents in the age group 51-60 drops from 15.8% to 9.1%.

Table 4-16 Respondents by Agro ecological zone, gender and age group

| Agro ecological | | Age group | | | | | |
|------------------------|--------|-----------|-------|-------|-------|-------|----------|
| | | 10-20 | 21-30 | 31-40 | 41-50 | 51-60 | Above 60 |
| CL3 Coconut cassava | Female | 10.5 | 21.1 | 31.6 | 21.1 | 15.8 | 0.0 |
| | Male | 20.0 | 40.0 | 26.7 | 0.0 | 13.3 | 0.0 |
| CL4 Cashew nut Cassava | Female | 11.8 | 29.4 | 29.4 | 23.5 | 5.9 | 0.0 |
| | Male | 7.7 | 23.1 | 23.1 | 15.4 | 23.1 | 7.7 |
| CL5 Lowland ranching | Female | 4.5 | 18.2 | 45.5 | 22.7 | 9.1 | 0.0 |
| | Male | 0.0 | 0.0 | 38.5 | 38.5 | 23.1 | 0.0 |

While this may not be conclusive this reduced life expectancy is perhaps a consequence of the long term adverse impacts of poor nutrition on women and girl child health. This is plausible given that the adult woman and the child woman are the greatest contributors of labour in AEZ CL5. This means that where women and the girl child are an important source of human energy their nutrition become a major influencing factor.

It has been observed earlier that, influenced by agro-climatic seasonality the district has high prevalence of diseases such as malaria, pneumonia and gastroenteritis. These diseases may hinder efficient utilization of food at individual or household level hence impacting on the human energy choices. Under-five mortality rate is high (0.141) whereas life expectancy is 56 years²⁵ as compared to 55 nationally. Similarly, HIV/AIDS incidence rate, estimated at 10 percent, has resulted in high mortality of youth in 15-35 age bracket (Ibid 2005), this HIV/AIDS situation further strains health facilities in the district and the productive labour force.

Influence of Household characteristics

Given that human energy is an important source of energy in the study area it follows that, household size, its structure in terms of gender and age of the members of the household also influence energy choices for microenterprise activities. In the study area adult and the child woman are greatest contributors of human energy for

microenterprise activities. Therefore, it is plausible to infer that, the more women there are in the house hold the more 'energy' for microenterprise activities.

Influence of Institutions on rural microenterprise on biomass energy choices

Influence of policy and legal environment

According to this study existence and enforcement of any policy or legal instrument that reduce poverty, promote women and the girl child education, prevent or discourages child labour will ultimately have considerable bearing on rural microenterprise current human energy choices. In addition policy or legal instruments that improve access to quality and affordable medical services will also influence rural microenterprises current human energy choices. The high prevalence of some diseases and relatively insufficient or hindered access to health facilities and services negatively influences human energy supply. There are 2 hospitals, 2 nursing homes, 5 health centres and 21 dispensaries, which are insufficient to effectively serve the entire population. Only 40% of the households have access to health facilities within 5 km (GoK 2005).

Influence of Traditions, Values and attitudes

In the focus group discussion it emerged traditionally, many of the tasks connected with crop cultivation or livestock herding were more or less allocated by gender. Some of these tasks include collection of firewood which is a task assigned to adult woman and the child woman. This may explain the study findings that women and the girl child are the leading contributors of human energy.

4.3 Environmental impacts of the existing rural microenterprise energy choice in the agro-ecological zones of the district

Interviews, Observation and photography was the main approach use to determine and record the Environmental impacts of current energy choices the three key elements of environment i.e. the ecological impacts, economic impacts and socio-cultural impacts.

4.3.1 The Ecological impacts of the current energy choices

Across all agro ecological zones under review, the study documented different ecological impacts. These impacts varied across the AEZs under review. For example, in the high potential AEZs CL3 and CL4 threat to water resources appear were less

severe(see figure) compared to that in agro ecological zone CL5 and CL6(see figure 4-13 and 4-14). Water is critical for both humans and livestock lives and it is obtained mainly from seasonal rivers and water pans. Therefore, siltation and sedimentation of water channels and pans reduce their water holding carrying and capacity respectively.



Figure 4-11 Water resources in CL3 Coconut cassava zone



Figure 4-12 Water resource in CL5 Livestock millet zone



Figure 4-13 Damage to infrastructure Kombeni river Mazera/Kaloleni Road 2006 the same river in dry season

Impact on Biodiversity

The reduction of tree and vegetation cover as firewood collection and charcoal making also contribute significantly to the loss of biodiversity. These impacts include species loss, habitat loss, declines in the variety of genes within a species, and overall declines in the number of species. For example, according to the local communities the use of the acacia species in the production of charcoal negatively the some birds as owl “Nyuni” and wood pecker that nest in cavities of old or damaged trees. These birds are natural enemies of rodents and other harmful insects (Deudney et al, 1984).

The use of acacia species found in agro ecological zones CL5 and CL6 for charcoal production impact on wildlife. For instance acacia are also the primary source of food for mega herbivores such as giraffes and elephants. Hence use of these trees for charcoal tends to force the mega herbivores to turn to secondary sources of food including maize and other agricultural food crops contributing to degradation of biodiversity and human/wildlife conflicts respectively.



Figure 4-14 Charcoal selling in the agro ecological zone CL5 and impact of Acacia

It is the conclusion of this study, that use of charcoal has the greatest and direct impact on biodiversity in the agro ecological zones CL5 and CL6. Figures 4-16 and 4-15 illustrate this impact.

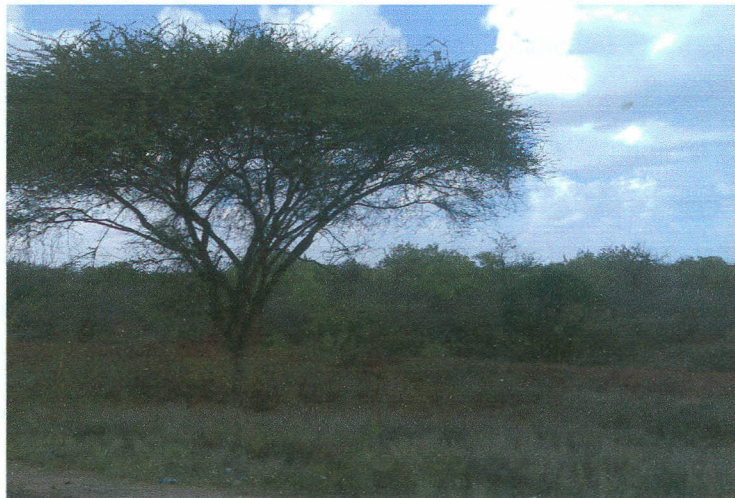


Figure 4-15 Acacia trees in protected area CL5

4.3.2 The Economic Impacts of the current energy choices

Impacts on the sustainability of current agricultural production systems, household income and employment

The current use of biomass and human energy sources render energy services required for *inter alia* value addition microenterprises inaccessible and unaffordable. For instance, energy services such as refrigeration in Bamba CL5 among other things do

not allow for development of some value addition microenterprises. Energy services such as refrigeration may facilitate the production of the high value yogurt from the milk produced in the area.

Lack of energy services such as refrigeration as a result of current use of biomass and human energy leads to livestock microenterprise incurring losses. These losses are in the form of livestock deaths and incomes. The latter is due to serious decline in the prices of livestock during drought. In March 2009 Livestock market prices were Ksh1, 000 for goats and Ksh4, 500 for cattle (GoK 2009). These prices were 29.4% and 38.9% below their respective long-term averages, indicative of increased stress levels (Ibid 2009). During such droughts, refrigeration means animal husbandry MEs may have the capacity to slaughter and store the carcasses or transport the same to market offering better prices hence obtain higher incomes.

Current use of biomass energy sources by MEs threatens employment by threatening environmental services in the study area. These environmental services provide the resource base for microenterprises which are a major source of employment and income. The threat to environmental services is due to the combined effect of the ecological impacts i.e. the impacts on soil, biodiversity, atmosphere, marine and water resources. Water is important for sustenance not only of human life but also of the productivity of animals hence soil erosion leading to siltation of seasonal rivers and pans the main sources of water, negatively impacts on the development of livestock microenterprises..

Bee keeping or apiculture is an important ME particularly in AEZ CL5. Its productivity depends on flowers from the surrounding vegetation (agricultural and non-agricultural) and water. In addition, the apiculture in the study area employs traditional hives that hang on trees in the surrounding forests. Therefore cutting of trees for firewood and charcoal has impacts on beekeeping and related microenterprises. The impact on biodiversity resulting from harvesting and current use of biomass energy choices have economic impacts in that The plant biodiversity provides plant based MEs with raw material and products.. For example use of hard woods which include some *Acacia* spp the preferred trees for making charcoal threatens artefacts making MEs. Other examples MEs threatened by use of some

acacia species for charcoal production and firewood include MEs dealing with the harvesting, marketing and processing of gum Arabic which is obtained from *Acacia Senegal*. This gum Arabic is used locally and exported for mainly to India and the Arabic nations to make varnish and incense.

Table 4-17 Raw and processed products of the cashew tree and their uses

| Raw | Products | Description and Uses |
|-------------------|------------|---|
| Nuts | Kernels | Raw nuts are processed into kernels by boiling, cracking, decorticating and roasting. |
| Cashew tree latex | Cashew gum | Similar to gum Arabic and may be used as liquid glue for paper, in the pharmaceutical cosmetic industry, as an agglutinant for capsules and pills, as a stabilizer of juices, beer and ice cream, as well as for clarification of juices, and in the making of cashew wine. |
| Apple | Prunes | Cashew prunes, produced by boiling the cashew apple in molasses, is very similar to dehydrated prunes or dates. |
| Apple | Juice | Cashew fruit is pulped by grating or pounding and the juice is pressed out and strained. Cashew juice has five times more citric acid than orange juice and is thus a good source of preservation acid medium when mixed with other fruit juices or vegetables. |
| Apple | Wine | The juice from the cashew fruit can be processed into wine using the conventional method of producing fruit wines. The alcoholic content averages 18%. |
| Apple | Pulp | The fibrous pulp obtained after extracting juice from the cashew apple can be used as animal feed or dried and processed into diet fibre biscuits. |
| Shell | CNSL | Extracted from the cashew shell, Cashew Nut Shell Liquid (CNSL) is used in the manufacturing of paints, varnishes, resins and brake linings. |
| Shell | Fuel Wood | After extraction of the shell liquid, the spent shells are used as a processing fuel. |

In CL3 Coconut-Cassava and CL4 Cashew nut cassava zones harvesting of green branches for firewood from tree crops poses threat to their productivity. The reduction in productivity may be due to reduced leaf areas and disease. The latter resulting from the harvesting of green branches which may expose the fruit trees to infection by among others bacteria, fungal e.t.c.

Cutting down of cashew nut tree for firewood denies the area other potential income generating opportunities. The cashew nut provide the base for microenterprises dealing in the production, processing and marketing of raw and roasted cashew nuts in AEZs CL3 and CL4. This trend in addition to threatening present microenterprise employment from the production and marketing of raw and roasted nuts but also development of other future microenterprise and products from the chew tree (see table 4-17).

4.3.3 Socio cultural impacts of the current energy choices

The study showed that dependence of biomass and human energy choices for the microenterprises have socio cultural impacts in the study area by affecting the social fabric of the community and well being of the individuals and families. These impacts include impacts on nutrition, maternal and child health, impact on socio equity and impact on the integrity of family and the community in general.

Impacts on Health

Results of this study previously have shown that women and the girl child are the leading contributors of human energy in the study area. Therefore, lack of alternatives to human energy has significant impact on the health and nutritional status of poor women and girls. For example, in March 2009, Households in agro ecological zone CL4 had to walk longer distances, an average of 9 km compared to the normal 1.5km at this time of the year in search of water and to purchase food stuff (GoK 2009). This leads to among other things reduction in water consumption, particularly for personal hygiene. This in addition to the time and labour costs involved in collecting water women's health is once again negatively affected. During the same period of March 2009, distances to grazing areas for livestock reached 5.1 km. However, in many parts of AEZs CL4, CL5 livestock had to cover up to 6km and 9km respectively in search of both pasture and water (Ibid 2009).

Use of human Energy from women in the absence of labour-saving appropriate technology, poses yet another risk to pregnant women and their unborn babies. The burden of this syndrome is carried mainly by many poor women and girls across the different agro ecological zones, which are already the most socio-economically

disadvantaged segment in Kilifi district and in the region. Consequently, it has serious implications for the health and development status of entire nations.

Impacts on to social equity

Current use of biomass and human energy sources results in limited or lack of appropriate energy services that may promote employment opportunities and increased incomes. Lack of appropriate energy services is also a serious obstacle to raising the social status of women and other oppressed groups. These circumstances not only burdens poor women in these ways, it also has high opportunity costs, as it diminishes their capacity to undertake other productive activities. They consumes enormous quantities of their time and labour meeting basic needs for fuel, food, fodder, and water and not for more productive or life-enhancing activities. The education particularly of the girl child is also interfered with because peak labour demand often coincides with school calendar (see figure 4-10).

In Kilifi district, size of the poor households is relatively larger than that of the non-poor household (KIHBS 2008). Perhaps the demand for labour may be one of the factors perpetuating the need for large families. This may contribute to high birth rates that further deplete the health of poor women by keeping them trapped in the cycle of childbearing and rearing. This further limits their participation in change processes and development programs.

Impacts on the integrity of the family and the community at large

Figure 4-12 compares sex ration across AEZs under review and the administrative district of Mombasa. The figure illustrates that as one moves from the more rural o more urban areas the sex ratio increases. The figure also shows that in the two rural areas of CL3 and CL5 the latter has a lower sex ratio than the former. These results depict the rural to urban migration. The migration is influenced by the difference in expected and not actual income (Todaro, 1986). These results means that, Apart from the gender division of labour women have to fill in the labour gaps further explaining why adult women are ranked the highest with regard to human energy contribution for ME activities.

As pointed out previously the low levels of education and poor training across all agro ecological also means that many of those migrating into Mombasa and other major towns usually work as casual labourers or as unskilled labourers. In addition, given the high urban unemployment many a times the migrant do not get employment. This has significant implication on the household incomes where they come since wages are proportionately lower compared to those received by skilled workers. Consequently, households are increasingly female headed leading to dysfunctional family units thus impacting negatively on the integrity of the family and the community in general.

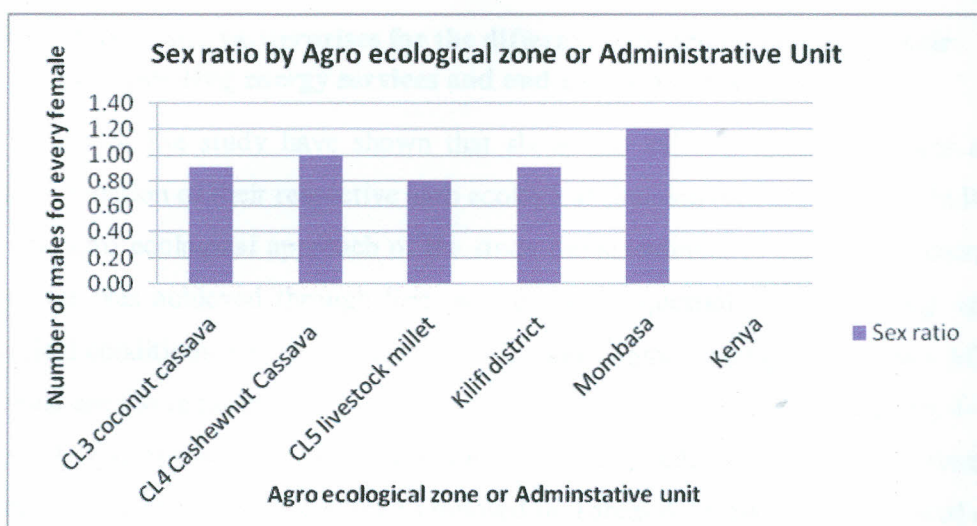


Figure 4-16 Sex Ratio by Agro ecological zone or admin

Increase in Conflicts and Social tension

It immersed from the interviews and that threat or actual occurrences of conflicts do occur as a consequence of current use of biomass energy sources. This is due to real or perceived scarcity of the biomass energy choices. The conflicts have been both inter and intra community. The intra community has been witnessed mainly in areas where communal land has been changed into individual tenure. These conflicts are more in a form of hostility and not violence especially in the CL3 and CL4 due to the relative scarcity of biomass energy sources compared to CL5 and CL5.

Conflicts between the state and the people however, as has been witnessed in the forest reserves have had a more violent nature. These conflicts are in a form of

harassment of women collecting firewood in the protected zones. Such protected zones, most of which were originally forest and forest resources were taken away from people, thereby taking away a vital natural capital, without providing alternative plays exacerbates these conflicts and their accompanying negative social impacts.

4.4 Potential sustainable energy alternatives for microenterprise development in different agro ecological zones

4.4.1 Selected microenterprises for the different agro ecological zones, their corresponding energy services and end-use energy required.

The results of the study have shown that show that existing microenterprises are largely a function of their respective agro ecological situation (see section 4.1). In line with the agro ecological approach of the study the assessment of sustainable energy alternative was achieved through first, answering the question; 'Does existing agro ecological conditions offer opportunities for the development and growth of new MEs and what are the required energy services? The results are summarised in tables 4-18 and 4-19. The overarching theme this study is poverty reduction and environmental protection Therefore end use energy proposed in Tables 4-18 and 4-19 are based on conviction that end use from renewable energy sources offer the best environmental protection.

Apart from providing the listed energy services, the end use energy sources identified in Tables 4-18 and 4-19 offer numerous advantages for microenterprise activities over current biomass and human use. These advantages include improving working conditions, creating market place attraction, lighting allows entrepreneurs to extend their working day and thus increase their income by serving customers in the evening or operating workshops past sundown. Street lighting helps to extend selling hours for street vendors. Electricity and biogas are more convenient, cleaner and relatively safer than traditional means of heating/cooling, cooking, and lighting, which benefits both workers and consumers.

Lights, fans, radios, televisions, and other electrical appliances can draw people to a common location, creating new market place attraction. As pointed out not all energy services can be met efficiently by electricity hence other end use energy is necessary.

Examples of energy services that cannot effectively be met by electricity include land preparation, planting and weeding which call for human based or machine based mechanical energy.

Table 4-18 Selected microenterprise for agro ecological zones CL3 and CL4 energy services and end use energy

| Type of micro enterprise | Microenterprise | Required Energy services | End-use energy |
|--------------------------|---|--|--|
| On-farm | Horticulture | <ul style="list-style-type: none"> • Land preparation • Planting, Weeding and harvesting • Water supply • Refrigeration • Drying (preservation) | <ul style="list-style-type: none"> • Electricity • Biogas • Human labour • Solar energy |
| | Dairy | <ul style="list-style-type: none"> • Water supply • Milking • Refrigeration/cooling | <ul style="list-style-type: none"> • Electricity • Biogas • Human labour |
| | Tree and vegetable nursery | <ul style="list-style-type: none"> • Water supply | <ul style="list-style-type: none"> • Electricity • Human labour |
| | Soap making | <ul style="list-style-type: none"> • Soap bars and tablet • Packing | <ul style="list-style-type: none"> • Electricity • Biomass/biogas • Solar energy |
| | Hardware | <ul style="list-style-type: none"> • Lighting | <ul style="list-style-type: none"> • Electricity |
| | Retail shop/kiosk | <ul style="list-style-type: none"> • Refrigeration | <ul style="list-style-type: none"> • Electricity |
| | Cloth making | <ul style="list-style-type: none"> • Sewing | <ul style="list-style-type: none"> • Electricity |
| | Value addition to Coconut palm products | <ul style="list-style-type: none"> • Coconut milk canning • Packing of frozen fresh shredded copra • Cleaned coir • Coir mats and twine • Coconut husk particle board (cardboards from coconut husks) | <ul style="list-style-type: none"> • Electricity • Biomass/biogas • Electricity • Biogas |
| | Transport and communication | <ul style="list-style-type: none"> • telecommunication & internet services • movement of goods, people and services | <ul style="list-style-type: none"> • electricity |
| | wood/metal fabrication and repair | <ul style="list-style-type: none"> • Metal welding • Metal turning/cutting • Wood turning | <ul style="list-style-type: none"> • Electricity • Biogas/biomass |
| | Marketing of farm produce | <ul style="list-style-type: none"> • Transport and communication | <ul style="list-style-type: none"> • Electricity |
| | Animal feeds manufacture | <ul style="list-style-type: none"> • Feed milling and Mixing • Process heat | <ul style="list-style-type: none"> • Electricity |

Table 4-19 Selected microenterprise for CL5 and CL6, energy services and end use energy

| Type of microenterprise | Existing and potential microenterprise | Energy services | End use energy |
|-----------------------------------|--|---|---|
| On farm | Production of Cereal and pulses | <ul style="list-style-type: none"> • Land preparation • Planting, Weeding and harvesting • Shelling • Drying (preservation) | <ul style="list-style-type: none"> • Electricity • Biogas |
| | Beef production | <ul style="list-style-type: none"> • Water supply • Refrigeration | <ul style="list-style-type: none"> • Electricity • Biogas |
| | Poultry (free range) | <ul style="list-style-type: none"> • water supply | <ul style="list-style-type: none"> • Electricity |
| | Wildlife conservancies | <ul style="list-style-type: none"> • Water supply | <ul style="list-style-type: none"> • Electricity |
| | Tree and vegetable nursery | <ul style="list-style-type: none"> • Water supply | <ul style="list-style-type: none"> • Electricity |
| Off-farm | Food and/or tea kiosks | <ul style="list-style-type: none"> • Cooked meals | <ul style="list-style-type: none"> • Electricity • Biogas |
| | Abattoir and meat processing | <ul style="list-style-type: none"> • Water supply • Refrigeration • Process heating • Meat packing • Transport | <ul style="list-style-type: none"> • Electricity • Biogas/biomass |
| | Processing of grains | <ul style="list-style-type: none"> • Grain milling, | <ul style="list-style-type: none"> • Electricity • Biogas |
| | Animal feed manufacture | <ul style="list-style-type: none"> • Process heating • Feed milling and mixing | <ul style="list-style-type: none"> • Electricity • Biogas |
| | Hardware | <ul style="list-style-type: none"> • Lighting | <ul style="list-style-type: none"> • electricity |
| | Retail shop/kiosk(provisions) | <ul style="list-style-type: none"> • Refrigeration | <ul style="list-style-type: none"> • electricity |
| | Cloth making | <ul style="list-style-type: none"> • Sewing | <ul style="list-style-type: none"> • electricity |
| | Coconut palm products | <ul style="list-style-type: none"> • coconut milk canning • coconut meal packing • cleaned coir | <ul style="list-style-type: none"> • electricity |
| | Communication and communication | <ul style="list-style-type: none"> • telecommunication & internet services • movement of goods, people and services | <ul style="list-style-type: none"> • electricity • biogas |
| wood/metal fabrication and repair | <ul style="list-style-type: none"> • Metal welding • Metal turning/cutting • Wood turning | <ul style="list-style-type: none"> • Electricity • Biogas | |

4.4.2 Potential Bio energy Alternatives and end-Use Technology for the different Agro ecological zones of Kilifi district

As pointed in the previous section that renewable energy alternatives offer better prospects for microenterprise development and environmental protection. The environmental protection must first, ensure a stable resource base and avoid overexploitation including maintenance of biodiversity, atmospheric stability and ecosystems. Second, should promote income generation and employment on a continuing basis. Thirdly, must mitigate or reverse the social impact of the current energy choices and use such as promoting fairness in distribution and opportunities among all persons by enhancing health, education and gender equity. In other words these energy alternatives must be ecologically, economically and socially sustainable. Looking at its agro ecological situation this study take the position that, bio energy sources offer greater prospects for promoting microenterprise development and environmental protection in Kilifi district compared to other renewable energy sources.

Bio energy sources based on the agro ecological conditions has many advantages over other renewable found in the district. These advantages include being carbon dioxide-neutral and can even act as carbon sinks. Bioenergy can help to restore unproductive or degraded lands, increasing biodiversity, soil fertility and water retention. The end use technology for converting bioenergy sources into desired end use energy such as electricity, producer gas and biogas is readily available and relatively cheap.

The energy level approach or energy supply chain analysis further strengthen the assertion that some if not all bio energy sources offer better opportunities for the promotion of microenterprise development and environmental protection. For example, biomass as a primary energy source can deliver end-use energy all forms that people may need. These energy forms include liquid or gaseous fuels, heat and electricity, yet environmentally more friendly thus biomass can serve as an alternative to crude oil. However, biomass has serious environmental implications in the traditional stove because it provides the end use energy source for heating or cooking (see 4.3). It against this background the study sought to assess first the existing and

potential bioenergy sources - agricultural residues, forests resources, biogas from domestic ruminants, and biodiesel from coconut palms- and their theoretical energy potential. Second, possible conversion technologies and potential end use energy in form of electricity.

The energy equivalent of these bioenergy sources was taken based on what would be obtained if they were subjected to the most energy efficient transformation processes. However the reality is that not all may be available as fuel. For example, some agro residues may be used to provide fodder among other things. In addition, the actual availability of bioenergy sources would also depend on the efficiency of collection, mode of transportation and storage. Considering these, in the computation of bio energy sources only 50% is accounted for fuel.

Agricultural residues

The study results show based on the area and crops being cultivated across all the AEZ in Kilifi district the district has good potential for producing energy from agricultural residues. For example, Coconut is one of the main tree crops grown in the all the agro ecological zones of the district. In AEZ CL5 and CL6 where agro climatic conditions are less than ideal the people plant coconut palms by advantage of the influence of topography on the movement of water, soil formation and soil fertility (see figure 4-3). The residue from the coconut palm can be used as a source of biomass energy include frond or leaves, husks and shell (see figure 4-18).

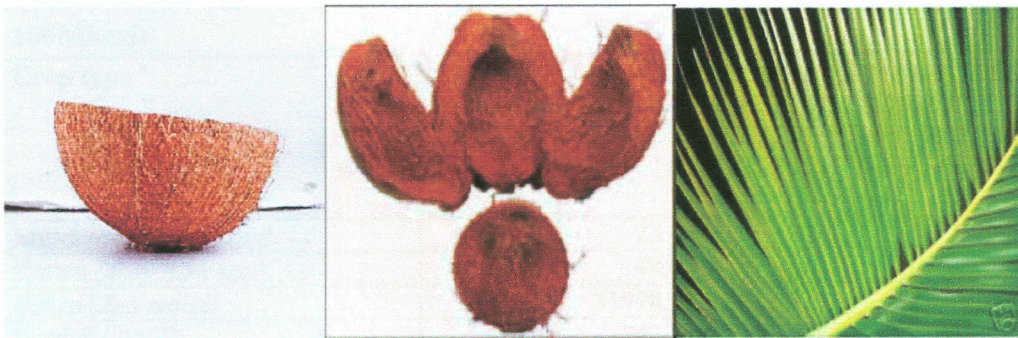


Figure 4-17 Coconut shell, husk and frond

Coconut shells have a very high energy density due to their extremely high specific gravity of 1.1. A coconut shell can be burned directly as fuel or it can be easily

processed into charcoal and combustible gases. Whereas 10 kg of wood makes only 1 kg of charcoal, 10 kg of coconut shells, makes 3 kg of charcoal and 5.5 kg of combustible gases. This makes the coconut shell a very valuable source thermal energy for cooking and process heating.



Figure 4-18 Coconut husks a potential bioenergy outside a homestead in CL4

Table 4-20 summarise the computation of energy amount from agricultural residues of main crops found in Kilifi district, ratio of the main product to the by-product for each crop grown, along with their energy equivalents.

Table 4-20 Energy from Agro-residues in Kilifi district (energy units in 106Mkcal)

| Crop type ^a | Land under crop in Ha | Current yields in Tonne | (CIR) ^b in Tonne /Ha | Residue (CDR) ^b per Tonne of crop | Total CIR in Tonne |
|---------------------------------------|-----------------------|-------------------------|---------------------------------|--|--------------------|
| Millet (<i>pennisitum spp</i>) | 32.0 | 23.4 | 0.0 | 1.30 | |
| Cotton (<i>gospium spp</i>) | 70.0 | 49.0 | 3.8 | 2.20 | 266.0 |
| Maize (<i>Zea maize</i>) | 31351.0 | 31978.0 | 0.0 | 2.30 | |
| Paddy* (2007) | 416.0 | 242.6 | 0.0 | 3.20 | |
| Sorghum (<i>Sorghum vulgare</i>) | 312.0 | 227.8 | 0.0 | 2.63 | |
| Cassava* (<i>Manihot esculenta</i>) | 4424.0 | 35867.0 | 0.0 | 0.75 | |
| Pigeon peas (<i>Cajanus cajan</i>) | 65.6 | 2.0 | 0.0 | 2.50 | |
| Cashew nut | 9980.0 | 1460.7 | | 3.00 | |
| Coconut (<i>Cocos nucifera</i>) | 14776.0 | | | | |
| Coconut Husks and pith | | 22164.0 | | 0.53 | |
| Coconut Shell | | 22164.0 | | 0.22 | |
| coconut fronds | 14776.0 | | 4.0 | | 59104.0 |

Table 4-21 Continuation of Table 20

| Crop type ^a | Total CDR in Tonne ^b | Total residue from the crop Tonne | Energy equivalent (Mcal/Tonne) ^c | Total energy (Mcal) | Total energy in kWh (Mcal=1163 kWh) |
|---------------------------------------|---------------------------------|-----------------------------------|---|---------------------|-------------------------------------|
| Millet (<i>pennisitum spp</i>) | 30.4 | 30.4 | 3.50 | 106.3 | 123612.9 |
| Cotton (<i>gossypium spp</i>) | 107.8 | 373.8 | 3.00 | 1121.4 | 1304188.2 |
| Maize (<i>Zea maize</i>) | 73549.4 | 73549.4 | 3.00 | 220648.3 | 256614017.1 |
| Paddy* (2007) | 776.4 | 776.4 | 3.00 | 2329.3 | 2709027.1 |
| Sorghum (<i>Sorghum vulgare</i>) | 599.0 | 599.0 | 3.50 | 2096.5 | 2438265.3 |
| Cassava* (<i>Manihot esculenta</i>) | 26900.3 | 26900.3 | 4.40 | 118361.1 | 137653959.3 |
| Pigeon peas (<i>Cajanus cajan</i>) | 5.1 | 5.1 | 3.00 | 15.2 | 17619.5 |
| Cashew nut | 4382.1 | 4382.1 | 5.35 | 23444.2 | 27265645.3 |
| Coconut (<i>Cocos nucifera</i>) | | | | | |
| Coconut Husks and pith | 11746.9 | 11746.9 | 1.00 | 11746.9 | 13661668.0 |
| Coconut Shell | 4876.1 | 4876.1 | 4.50 | 21942.4 | 25518964.7 |
| coconut fronds | 0.0 | 59104.0 | 1.50 | 88656.0 | 103106928.0 |
| Total | | | | 490467.7 | 570413895.3 |

^a Ministry of Agriculture and Livestock Coast Province 2008

^b source Biomass resource atlas of India

^c source Ramachandran et al 2005

*2007 figures

Area under cultivation for the dominant crops in Kilifi district obtained from 2008 annual report of the Ministry of Agriculture and livestock Coast province. This gives the theoretical energy potential in Kilifi district obtained from agricultural residues to be 2640805 kWh per year.

Agriculture residue appear to offer good prospects towards addressing the challenge of ensuring sustainable biomass supply or convenient energy sources to meet growing energy demand at the same time avoiding the competition for land between food and fuel. Furthermore, increasing the production of food and industrial crops increases not only the supply of energy but also food and raw material which are critical for microenterprise growth and development.

Forests bioenergy sources

Table 4-22 summarises the computation of energy from forests sources. Accordingly the results of the study show by tapping 50% of bioenergy potential from forests the

bioenergy potential from this sources is between 182 Million kWh and 630 Million kWh per year. The biomass potential of forests is dependent on the type of forest and its distribution cover. Computation requires inputs such as forest types (i.e. Deciduous, Evergreen, etc.); respective spatial extent, annual productivity (tonne/hectare) and energy equivalent (kcal/tonne) (Ramachandra et al, 2001) and outputs would be annual Bioenergy—by forest type wise, by district e.t.c. Total Bioenergy from forests (Bio_{forest}) is computed by

$$Bio_{forest} = \text{Bioenergy from forests (kcal)} = \text{Forest area} * \text{Productivity} * (\text{Energy equivalent}) \text{ (Ramachandra et al, 2005)}$$

Table 4-22 Bioenergy potential from forest sources in Kilifi district

| Vegetation type | Area covered in Ha | Case | Biomass (tonnes/ha/year) | Biomass (tonnes /year) | Energy equivalent in Mcal/tonne | Total potential energy in kWh 1Mcal=1163 kWh |
|------------------------|--------------------|------|--------------------------|------------------------|---------------------------------|---|
| Dense deciduous forest | 20,000 | High | 13.5 | 270000 | 4.0 | 1256040000 |
| | | Low | 3.9 | 78000 | 4.0 | 362856000 |
| | | Low | 0.9 | 0 | 3.4 | 0 |
| Total | 20,000 | High | | | | 1256040000 |
| | | Low | | | | 362856000 |

Biogas

Biogas is produced during the anaerobic digestion, or fermentation organic matter by bacteria. The products of this process are methane gas and carbon dioxide. Feed stocks for biogas production are water and Organic Matter, bacteria, anaerobic conditions, heat and water. The organic matter is the food source for methane producing bacteria. Cow and other livestock's dung and also human excreta are used to produce gases. Biogas can be produced using manure as the only organic source, but the gas production can be greatly increased by adding certain types of food wastes with the manure. Energy crops such as corn silage can also be added to increase gas production.

Depending on the source of organic material biogas can be produced using the following two methods. The slurry based dung digesters uses relatively small amounts of dung feed stock. The second method is the high-rate digester for biomethanation of fibrous and semi-solid organic wastes, the TEAM (TERI Enhanced Acidification and

Methanation) process (see figure 4-20). The latter has a capacity of about 50kg green leafy vegetables per day. The TEAM process can generate good quality biogas and manure from the organic wastes (Müller 2007).

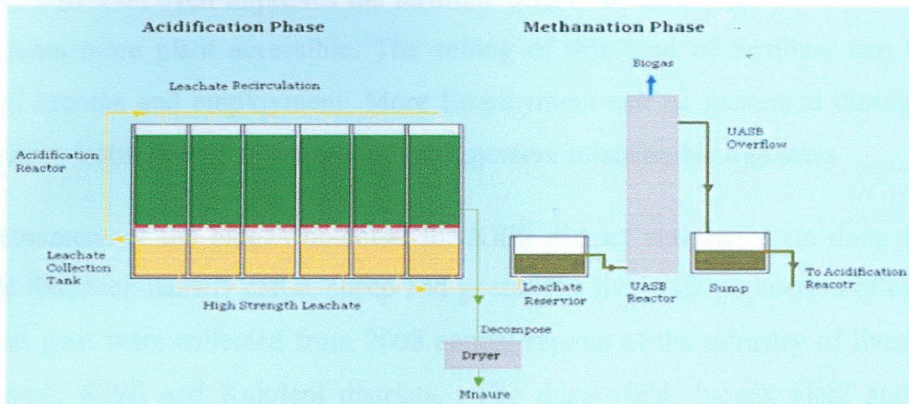


Figure 4-19 Schema of TEAM digester with six acidification reactors and a UASB unit Source: Müller 2007

Biogas can be used for various applications, such as for cooking, lighting, electricity production and for drying fruits and vegetables. The required gas quality depends on the corresponding application. Dewatering of biogas is recommended for all applications, whereas desulfurization is mainly done before usage in an engine (Müller 2007). Hydrogen sulphide is a very aggressive gas responsible for fast corrosion. Biogas used for electricity production in a block heat and power plant has therefore to be treated by desulfurization (Ibid 2007).

Biogas production in the study area will have a number of economic and social advantages. The biogas can be used in fuel powered drier which gives increased control over drying conditions and produces a higher quality product. It is operational all year round, and produces a higher rate of drying than solar driers Therefore fuel powered driers, using bio gas and producer gas can be of particular use Microenterprise dealing with dehydrated mangoes, desiccated coconut and other microenterprise activities in the study area value addition activities in all agro ecological zones.

The production of biogas out of biodegradable solid waste can replace fossil fuel in cooking and light applications (low-tech) or for the production of electricity and heat (high-tech block power and heat plant). Thus, the use of locally available energy resources is, at least on the long-run, more economically compared to imported fuel.

Degraded organic material can be applied as a fertilizer for agricultural purposes. The anaerobic digestion even improves the fertilizer quality by killing germs and making the nutrients more plant accessible. The selling of this kind of fertilizer can be a source of income and employment. More Employment can be generated during the construction, installation, Operation and management of anaerobic digesters

This assessment of the biogas potential for Kilifi district was based on dung from domestic livestock namely cattle, sheep and goats. The livestock population of cattle, sheep and goat were collected from 2008 annual reports of the ministry of livestock development Kilifi and Kaloleni districts. The dung yield, biogas yield and the energy equivalents for each animal are given Table 4-23. Total bio energy from livestock ($BiO_{livestock}$) is computed by:

$(BiO_{livestock}) = (Biogas * Energy Equivalent)$ Where, $Biogas (m^3) = Biogas\ yield * Dung * 1000$ and $Dung (tonnes) = Dung\ yield * Population * 365$ (for annual energy computation).

Table 4-23 Dung Yield by livestock type, Biogas Yield and Energy Equivalents for Kilifi district

| Livestock type | Number ^a | Case | Dung yield (kg/animal /day) | Dung yield(kg/year) | Biogas yield (m^3/kg) |
|----------------|---------------------|------|-----------------------------|---------------------|---------------------------|
| Cattle | 246731 | High | 7.5 | 6.8E+08 | 0.042 |
| | | Low | 3 | 2.7E+08 | 0.036 |
| Goat | 121858 | High | 0.1 | 4447817 | 0.042 |
| | | Low | 0.1 | 4447817 | 0.036 |
| Sheep | 30666 | High | 0.1 | 1119309 | 0.042 |
| | | Low | 0.1 | 119309 | 0.036 |

Sources ^aMinistry of Livestock development annual report 2008 (Kilifi and Kaloleni districts)

Table 4-24 Continuation of Table 23

| Livestock type | Biogas yield per year(m3) | Energy Equivalent (kcal/m3) | Potential annual energy yield in kcal | Potential annual energy yield in kWh (kcal = 0.001163 kWh) |
|----------------|---------------------------|-----------------------------|---------------------------------------|--|
| Cattle | 2.8E+07 | 5340 | 1.51E+11 | 176176553.2 |
| | 9726136 | 5340 | 51937566347 | 60403389.7 |
| Goat | 186808 | 5340 | 997556396.8 | 1160158.1 |
| | 160121 | 5340 | 855048340.1 | 994421.2 |
| Sheep | 47011 | 5340 | 251038622.5 | 291957.9 |
| | 4295 | 5340 | 22935962.16 | 26674.5 |
| Total | High | | | 177628668 |
| | Low | | | 61424485 |

Assuming 50% of the dung in the district is collected for energy production, existing annual bio gas potential is between 30.7 Million and 88.81 Million kWh or between 1807 and 5224 BOE (barrel of oil equivalent). Biogas improves living conditions for rural poor, mainly for women responsible for cooking and fire wood collection. Biogas generates less air pollution by the combustion instead of wood or animal dung. By the usage of biogas less fire wood needs to be collected, hence time is saved for this chore and can be invested in other self improvement enterprises.

Biodiesel energy sources

Biodiesel a generic name for methyl or ethyl esters made from any tri-glyceride oil molecule. Tri-glyceride oils include all plant oils such as canola, mustard, sunflower, safflower, soybean, corn oil, palm oil etc. Used cooking oils can also be turned into biodiesel as well as can fats and tallow. A chemical process called "transesterification" is used to "crack" the glycerol molecule and replace it with an alcohol molecule. A catalyst is used such as sodium hydroxide (Caustic Soda) and an alcohol such as methanol or ethanol.

Biodiesel has a number of distinct advantages over fossil fuel. Apart from being renewable it basically cycles carbon instead of releasing stored carbon into the atmosphere. Therefore, the amount of carbon that is stored by the plant during its growing cycle is the same as what is released during combustion. This fact gives a distinct production advantage in that photosynthesis occurs naturally hence the energy

requirements are provided free by the environment. This results in a net energy benefit. Life cycle analysis has shown that for every 1 unit of energy required in the production of biodiesel, there are at least 2.5 units of energy contained in the fuel. Another advantage is that the technology required extracting and process biodiesel already exists and easily accessible.

Biodiesel from Coconut Oil

The results of the study show that production of biodiesel from coconuts offer good prospects for microenterprise development and environmental protection in Kilifi district. First coconut production is widespread in all agro ecological zones in Kilifi district and particularly in agro ecological zones CL3, CL4 and CL3-4. Hence, the electrification of a village using coconut oil is sustainable in the long-term because coconuts, can be readily available and renewable. Second, extracting the coconut oil can be a basis for microenterprise and the additional costs of the processing are primarily wages paid to people in the village rather than as a flow of capital from the village to the outside world. This also produces employment in the village, allowing more people to be able to afford the electricity generated. Third, the equipment to make coconut bio-diesel is inexpensive to purchase and simple to operate.

The coconut oil is in the copra, or white "coconut meat", as seen in Figure 3. A typical coconut will have 0.25 kg of copra, including water, meal and coconut oil. Drying removes the 50% of the mass that is water, leaving 0.18 kg of dry copra, 67% of which is coconut oil, or .12kg. The most efficient extraction that can be done in a village using hand operated presses is 75% of this oil, or 0.09 kg/coconut. Coconut oil has a density of 890 kg/m³, or .89kg/litre. Thus, 0.1 litre of coconut oil can be produced from each coconut. The coconut oil chemically changed into bio-diesel through the process of transesterification and uses methanol as a reactant and lye as a catalyst. This is a standard procedures used to convert other vegetable oils into bio-diesel. The mixture is 1:5, methanol to coconut oil, with a yield of about 0.8 bio-diesel and 0.2 glycerine, which can be used to make soap. The sale of the glycerine should more than compensate for the additional cost of processing.

Table 4-25 summarises the results of the computation of the existing theoretical potential of coconut biodiesel in Kilifi district.

Table 4-25 Biodiesel from Coconut (*Cocos nucifera*) in Kilifi district

| Crop type ^a | No of trees | Raw' Copra of in kg at 0.36 kg/nut | Dry copra (50% of raw copra) in kg | Coconut in kg Oil (67% of dry copra) | Oil yield in litres (75% extraction) at .89 kg/litre |
|------------------------|-------------|------------------------------------|-------------------------------------|--|--|
| Coconut | 2831978 | 122341450 | 61170725 | 40984386 | 46049872 |

Table 4-26 Continuation of Table 24

| Crop type ^a | Glycerine (20% coconut oil) | Biodiesel (80 % of coconut oil) in litres | Energy equivalent in Mcal/litre | Total energy in kWh (Mcal=1163 kWh) |
|------------------------|-----------------------------|---|---------------------------------|-------------------------------------|
| Coconut | 9209974.3 | 36839897 | 37.38 | 1.60154E+12 |

The assessment was based on 2831978 coconut palm trees based on a census carried by ABD-DANIDA and Coast development Authority (2007). Assuming 50% of the annual production of coconuts in the district is utilised for biodiesel production, existing annual biodiesel energy potential from this source is 800.8 Billion kWh or 471 Million BOE.

Despite enormous potential this source of biodiesel is being threatened by disease and pests (see figure4-21) and competing uses or industry. The most detrimental of these competing uses or industries is the logging of coconut trees for timber (see figure) the timber is used for building construction and for making furniture.



Figure 4-20 Rhinoceros beetles (*Oryctes rhinoceros*) damage on coconut palms

The results show that if 50% of the selected bioenergy source are utilised the existing total bioenergy potential in Kilifi district is between 800, Billion to 801 Billion kWh per year or 472 million BOE (see Table 4-27). Biodiesel from coconuts contributes the bulk 99.9% of this potential. Ironically to date there is virtually zero production of biodiesel coconuts in Kilifi district nor in Kenya as a whole.

Table 4-27 Bio energy potential of Kilifi district from selected sources Bio energy source

| Energy in | Case | Agricultural residues | Forests | Biogas energy | Coconut Biodiesel | Total existing Bioenergy potential |
|-----------|------|-----------------------|----------|---------------|-------------------|------------------------------------|
| kWh/year | High | 2.85E+08 | 6.30E+08 | 8.90E+07 | 8.00E+11 | 8.01E+11 |
| | Low | 2.85E+08 | 1.82E+08 | 3.07E+07 | 8.00E+11 | 8.00E+11 |
| BOE/year | High | 1.68E+05 | 3.69E+05 | 5.22E+04 | 4.71E+08 | 4.72E+08 |
| | Low | 1.68E+05 | 1.07E+05 | 1.81E+04 | 4.71E+08 | 4.72E+08 |

Energy potential assessed data obtained from ABD-DANIDA, GoK ministries of Agriculture, livestock and Natural Resources.

Mzungi ((*Moringa oleifera*))

The study found that some plants used for other purposes are also potential alternative sources of biodiesel. The Moringa tree or local name ‘mzungi’ is a source of vegetable for the communities in the study area. The Moringa tree can produce 1,000 to 2,000 litres bio-thesel per ha year and starts producing within a year. It is highly drought tolerant having Minimum water requirements under rain-fed at 250mm.

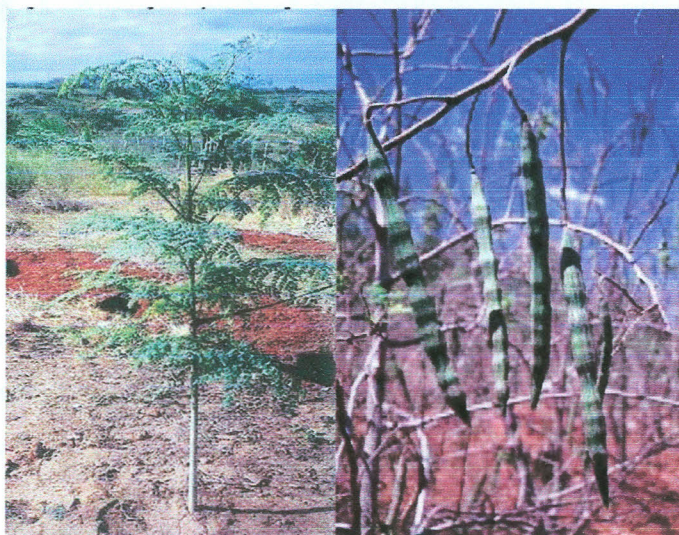


Figure 4-21 Moringa tree and pods

Apart from the production of biodiesel from its seeds the leaves of the Moringa tree have relatively high nutritional value (ref for Moringa health). Community in the study area use the Moringa tree leaves as vegetable albeit of last resort. Some communities use the green pods as vegetable.

Production of biodiesel from the Moringa tree has the net effect of promoting microenterprise development and environmental protection. The extraction of the oil produces oil cake which together with the leaves is an excellent stock feed. Moringa has enormous potential to improve human health, increase livestock's weight gain (oil cake used during fattening of the beef animals) and milk production. In addition the growth of related microenterprise such as the marketing of the oil cake increases income and employment in the rural economy. The environmental protection on the other hand is drought tolerance and its quick growth rate these give the combined advantages of real landscape changes and the production of large, continuous and reliable quantities of biodiesel.



Figure 4-22 Green Moringa seed pods a vegetable at Mackinnon Market in Mombasa

Another important advantage of using Moringa tree for biodiesel production may address the ethical questions of producing crops suitable for human consumption or land traditionally producing grain for bio-fuel production.

According to the study Cultivation of chosen fuel wood species, which can be harvested during a short period of time, could meet the energy demand of growing population and the plantations raised to meet the energy demand of a region is called energy plantation. The species are so chosen that they provide plenty of biomass, are fast growing, have good survival rate (high tolerance or adaptability, pest resistant and drought resistant) and produce large volumes of wood. Multipurpose species are mostly preferred. Leguminous species such as *Leucaena leucocephala* is preferred. This plant has high MAI (Mean Annual Increment) and also coppices vigorously. The energy value of the wood is 17.5-19.3 MJ /kg. The heating value of fuel wood is related to lignin or carbohydrate composition and extractive content will also help maintain the soil fertility in addition to meeting the fuel wood requirements.

In the CL3 and CL4 agro ecological zones *Azadirachta indica* can be grown. Apart from trees, fast growing shrub and bushes are also used. Other fuel wood species for the CL3 and CL4 are: *Acacia auriculiformis*, *alliandra calothyrsus*, *Casuarina equisetifolia*, *Derris indica*, *Gliricidia sepium*, *Gmelina arborea*, *Guazumaulmifolia*, *Leucaena leucocephala*, Mangroves, *Mimosa scabrella*, *Muntingia alabura*, *Sesbania bispinosa*, *Sesbania grandiflora*, *Syzygium cumini*, *Terminalia atappa*, *Trema species*, *Ailanthus altissima*, *Albizia lebbek*, *Alnus acuminata*, *Cajanus cajan*, *Cassia siamea*, *Grevillea robusta* and *Pithecellobium dulce*.

Fuelwood species for agro ecological zones CL5 and CL6 are *Acacia brachystachya*, *Acacia cambagei*, *Acacia cyclops*, *Acacia nilotica*, *Acacia saligna*, *Acacia senegal*, *Acacia tortilis*, *Adhatoda vasica*, *Albizzia lebbek*, *Anogeissus latifolia*, *Azadirachta indica*, *Cajanus cajan*, *Cassia siamea*, *Eucalyptus citriodora*, *Pinus halepensis*, *Prosopis chilensis*, *Eucalyptus occidentalis*, *Pinus halepensis*, *Prosopis cineraria*, *Prosopis tamarugo*, *Tamarix aphylla*, *Zizyphus mauritania*, *Eucalyptus grandis*, *Acacia auriculiformis*, *Leucaena leucocephala*, *Terminalia catappa*, *Tectona grandis*, *Anogeissus leiocarpus*, *Pithecellobium* and *Guazuma ulmifolia*. Table 4-28 gives name and calorific values of selected fuelwood species.

Table 4-28 Table 6: Calorific Values of some Fuel wood species

| Species | Calorific value (cal/kg) |
|------------------------------|---------------------------------|
| <i>Acacia nilotica</i> | 4,793-4,945 |
| <i>Adina cordifolia</i> | 3,855 |
| <i>Albizia sp.</i> | 4,300-4,400 |
| <i>Lagerstroemia sp.</i> | 4,577 |
| <i>Shorea robusta</i> | 4,400-5,050 |
| <i>Tectona grandis</i> | 3,700-5000 |
| <i>Terminalia paniculata</i> | 4,600-4,900 |
| <i>Terminalia tomentosa</i> | 4,923 |
| <i>Xylia xylocarpa</i> | 4,905 |

Source: Ramachandar et al 2005

The utilisation and regeneration of existing resources in energy plantation can be combined with agro forestry involving plantation of trees having nitrogen fixing potential, waste land reclamation and social forestry. Planting of trees and shrubs can provide firewood for use in bioenergy scarce regions in a couple of years. The agricultural output can also be increased by releasing cow dung and by providing soil conservation. Planting of fodder trees, combined with more scientific management of cattle, can contribute directly to rural incomes.

Algae

Some strains of algae which consume CO₂ and produce oil. Tests on diatom algae found that a 1000 square meters pond over a twelve month period 7,600 litres of algae oil was produced. • Algae: 9,000 to 18,000 L/ha. In comparison, the same size area when sown with high yielding canola plants was only capable of producing 190 litres of oil. The researchers concluded that 200,000 hectares of algae ponds would be capable of producing 3.8 billion litres of oil. Oil producing algae can be grown in partly saline which found in some parts of Kilifi i.e. along the shore.

Saline and brackish water is common - normally it poses a problem for fresh water supplies. Several technologies, however, can take advantage of saline water for energy production. These include solar ponds and algae production. Solar ponds use the salt water in such a manner that heat from sunlight is effectively locked in the pool and can be used for a number of process heat applications or electricity production.

The ability of the pond to store solar thermal energy is unique and overcomes the resource variability that is a drawback of traditional solar development. Salt water algae grow prolifically under cultivated conditions and can be pressed to extract biodiesel feed stocks or dried and burned for power production. However neither technology has been demonstrated beyond pilot levels.

Bio energy end use conversion technology

Results of the study show that overall Kilifi district has relatively good bioenergy potential (see table 4-25). However, there is need to promote energy conservation of the bio energy into clean and convenient end use energy such as biogas and electricity. These end use energy sources can provide energy services that would promote microenterprise development and environment protection in the different agro ecological zones

Improved Cooking Stove

Given the agro ecological conditions in Kilifi district and particularly the socio conditions of in terms of income, education there is need to first, improve the current use of traditional biomass. This means promoting the use of cooking stoves that produce little or no smoke and preserve more heat than ordinary traditional cooking stove (see figure4-24). The installation is relatively low and can be produced locally.



Figure 4-23 Improved cooking stove

Bio energy conversion technologies

Gasification is one of the processes of converting biomass energy sources into convenient energy sources. Biomass gasification involves partial combustion of biomass under controlled air supply, leading to generation of producer gas constituting the combustible gases H₂ (20%), CO (20%) and CH₄ (1–2%). The energy value of producer gas is about 5.0 MJ/m³. The producer gas can be used as fuel for internal combustion engine for mechanical and electrical applications. Wood, fuel wood, dried cow dung and other organic elements are put in a big tank and combusted in low air pressure. Smoke formed is cooled and small solid particles are removed. Filtered cooled smoke is used to run engine. Another benefit of using gasifier is household waste is disposed cleanly. Bio-diesel can be used to fuel a diesel generator to make electricity. Alternatively, the biodiesel can be burned directly in a modified diesel generator. coconut oil be burn directly in a diesel generator but this option has difficulties. The coconut oil at room temperature is too viscous to be processed by the fuel pump and fuel injection system of the diesel engine. Therefore, the coconut oil is preheated to approximately 70°C reducing the viscosity to that of conventional diesel fuel. Biogas contains moisture and hydrogen sulphide, so before it is used in an engine the moisture must be condensed out, and the hydrogen sulphide removed to reduce maintenance problems. Biogas can be used produce thermal energy, or it can be used to power a gas or diesel engine to run a generator to produce electrical energy.

The district can have between 80.0 billion and 80.1 billion kWh per year of electricity if 10% of the bioenergy potential of Kilifi district is converted to electricity (table 25). Table 4-27 show energy services for domestic and microenterprises and the corresponding annual power demand for 60-household village based on a load of 108 kW for a 12 hour day. This result show that, electrical energy potential for Kilifi can provide indicated energy services for approximately 169,000 such villages for 365 days.

Table 4-29 Energy services for selected micro enterprise for a 60 household village

| Energy Service | Load per unit | Total Load (kW) | Total load in kW for a 12hr/day | Total load in kW/year |
|------------------------------|------------------|-----------------|---------------------------------|-----------------------|
| Lighting | 9 ^a | 9 | 108 | 39420 |
| Drinking water pumping | 6.5 ^a | 6.5 | 78 | 28470 |
| Grain milling | 9 ^a | 9 | 108 | 39420 |
| Irrigation Pumping 7.5 (1) | 7 ^a | 7 | 84 | 30660 |
| Irrigation Pumping 7.5 (2) | 7 ^a | 7 | 84 | 30660 |
| Irrigation Pumping 10 (3) | 9.5 ^a | 9.5 | 114 | 41610 |
| 5 Sewing | 0.2 ^b | 10 | 120 | 43800 |
| 5 Weaving | 0.2 ^b | 10 | 120 | 43800 |
| 10 Poultry | 0.2 ^b | 20 | 240 | 87600 |
| Oil extraction | 7.5 ^b | 7.5 | 90 | 32850 |
| Pea nut butter making | 0.5 ^b | 0.5 | 6 | 2190 |
| Artisan/metal works | 2 ^b | 2 | 24 | 8760 |
| 5 Shops ^b | 0.2 ^b | 10 | 120 | 43800 |
| Total energy required | | 108 | 1296 | 473040 |

Sources: ^aRavindranath et al 2004

^bWEDS Development Service

Human energy conversion technologies

As been pointed out human especially woman labour is one of the important sources of energy domestic and for micro enterprise activities in the different agro ecological zones of Kilifi district. Human labour provides over most of human based mechanical energy especially in the on-farm microenterprise activities. Therefore, where possible it is necessary to replace human labour or improve its efficiency i.e. doing more using less energy. This can be achieved by improving access to appropriate technology. Technology allows man to perform tasks that would otherwise have been difficult or impossible.

5 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary of findings

The findings of the study are that whereas there are variety of energy choices for microenterprise activities the most important are biomass and human energy. The biomass consists of firewood, charcoal and agricultural residues are the most important energy choices for microenterprise. Human energy is another important source of microenterprise activities in the different agro ecological zones of Kilifi district. The choices of human energy are determined by gender and age. The adult woman followed by the child woman provides most of this energy. The use of modern and commercial energy sources such as electricity and kerosene fuels is very limited. The main use of electricity and kerosene is lighting.

According to the study agro ecological factors influence the location, quality and quantity of biomass energy sources for microenterprise activities in the AEZ reviewed. In addition, agro ecological factors influence types of microenterprise, food availability (nutrition) disease prevalence hence human energy demand and supply. The study findings show that institutions- the rules, laws and organizations and social norms that coordinate human behaviour- an aspect of social condition have the greatest influence on rural biomass and human energy sources. Institutions for example determine division of labour between women and men. The study also finds that based on the climax vegetation equation (Major 1951) inspired by Jenny's soil equation (1941, 1958) a model showing the influence of institutions on biomass energy sources can be illustrated.

Climax Vegetation (V) = f (cl, pm, r, o, t) where Cl= climate pm= parent material r= relief o= organism and t= time (Major 1951)

Let institutions (I) = f (tr, a, v, lw, pl,). Where tr =traditions a = attitudes v = values, l = laws, pl =policies. Therefore If type of biomass energy (\square) is a function of institution on climax vegetation this can be represented as $\square = f [(V,) (I)]$ or $(\square) = f[(cl, pm, r, o, t) (tr, a, v, lw, pl, i \dots)]$

This model needs further research but in its present state it can provide policy makers with a framework for understanding how agro ecological factor influence rural biomass energy choices. Since it appears that, in the medium to long term, firewood and charcoal will remain key energy sources for most households in rural and urban areas due to economic, political and structural reasons.

The findings of the study show that, current use of biomass and human energy has negative ecological, economic and socio-cultural impacts. Furthermore, these impacts have causal linkages and mutually reinforce each other with respect to their contribution to poverty, lack of social equity, environmental degradation and inability to Millennium Development Goals in Kilifi district.

The study finding show that if 50% of the selected bioenergy source are utilised the existing total annual bioenergy potential in Kilifi district is between 800, Billion to 801 Billion kWh per year or 472 million BOE (see Table 4-25). Biodiesel from coconuts contributes the bulk 99.9% of this potential. The district can have between 80.0 billion and 80.1 billion kWh per year of electricity if 10% of its bioenergy potential is converted to electricity. This electrical energy can power 169,000 60-household villages based on a load of 108 kW for a 12 hour day per year. Thus provide energy services mix such as water pumping, grain milling, welding, lighting oil extraction and tailoring. Apart from providing the stated energy services bioenergy sources have a number of advantages over other renewable. These include improving soil fertility, soil water infiltration and water table, food production and nutrition in the district.

5.2 Conclusions

The study concludes that given the current use of biomass and human energy sources energy services required for rural microenterprises development will not be available or expensive thus perpetuating the poverty situation. This scenario continue to negatively impact on the environment and community well being.

Looking at the electrical energy potential Kilifi district has enormous potential for producing convenient and clean energy sources that hardly utilised. Only 1.1% of this energy potential can provide the 2015 projected 887324 Kilifi population with 1000kWh per capita electricity

consumption to put the district into the middle income bracket thus achieving one of the key Millennium Development Goals.

If this energy transition is to occur hence microenterprise development and environmental protection it is critical that the influence of agro ecological factors energy choices and type of microenterprise must be given its due consideration. This means that the bioenergy production is conceptualised, planned and implemented putting into consideration among other things the socio economic and cultural conditions (population, institutions, education, incomes e.t.c.) prevailing in the different agro ecological zones Kilifi district. this includes first high illiteracy and poverty especially among the women who own most of the microenterprises and also provide most of the labour for their activities. second, energy has a derived demand therefore to obtain the required energy services the women must have access to appropriate end use gadgets and operating skills.

5.3 Recommendations

This study makes the following recommendations:

- i. Further study/studies need to be undertaken so as to gain an understanding as to why there is apparently no utilisation of bioenergy sources for generating electricity despite the existence of enormous potential in Kilifi district
- ii. Research need to be that aim at using ecological concepts and principles to develop a model that will assist in designing, developing, and managing sustainable rural renewable energy systems.
- iii. Decentralized renewable energy systems appear to be a viable energy alternative for microenterprise development and environmental protection in the different agro ecological are. Therefore, there is need for a study to that seeks to identify both the opportunities and constraints related to the establishment of decentralised community renewable energy system projects
- iv. The development of Predictive Ecosystem Mapping (PEM) for Kilifi district and rural coast region as a whole. The PEM will provide the basis for the improvement of the

natural capital such as increased soil water retention , improvements in water table (with more drinking water in the dry season), reduced soil erosion combined with improved organic matter in soils, leading to better carbon sequestration, and increased agro-biodiversity.

- v. The study recommends institutional reform that aim at promoting stronger social organisations at local level, new rules and norms for managing collective natural resources, and better connectedness to external policy institutions. This will among other things utilization of legal and policy opportunities such as constituency development fund, local authorities transfer fund among others to put up agro ecological-based decentralized renewable energy systems.
- vi. The study recommends research on the potentials of small scale biodiesel production and also on biodiesel management technologies to reduce negative environmental risks for instance groundwater and soil contamination. The aim of which is the promotion of small scale rural based biodiesel production enterprises and the introduction of biodiesel blended with conventional diesel i.e. B20 (20% biodiesel) or B2 with a gradually shift to B100 (or 100% biodiesel) when production is stable. However
- vii. The study recommends the development Bio energy atlas for Kilifi district, the coast region and indeed for all Agro ecological zones of the republic of Kenya. This bio energy atlas will provide data of all agricultural crops their crop dependent and crop independent residues and their corresponding energy equivalents.

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APPENDICES

Appendix i Household questionnaire

Questionnaire No.....Interviewer..... Date.....
 Location.....
 Agro-ecological zone.....

Q1. Interviewee information

Gender -----
 Marital status -----
 Age Below 18 18-55 55 and above
 Education Not beyond primary secondary tertiary

I. To determine the relative importance of current energy choices in the different agro ecological zones of the district.

Household characteristics

| HH member | Sex | Age | Education | Professional training |
|-----------|-----|-----|-----------|-----------------------|
| | | | | |
| | | | | |
| | | | | |
| | | | | |

Q1. What are the sources of your cash income?

| | |
|-----------------|--|
| Wage employment | |
| Microenterprise | |
| Others | |

If others please specify-----

Q2. With respect to Q2 Name/list the microenterprises

Q3. With respect to Q2 please specify type of wage employment

Q4. Is the microenterprise located within the household? Yes No
 If no, are any activities of the microenterprise carried out in the household? Yes No

Q5. Do you have access to electricity? Yes No

Q6. With respect Q8 indicate the source of your electricity

| | | | |
|------|-----------|---------------|----------------------------|
| Grid | Generator | Photo-voltaic | generator and photovoltaic |
| | | | |

Q7. What are the main sources of energy for your microenterprise activities?

Q8. With respect to Q7, if biomass (fuel wood, charcoal, agricultural residues, cow dung e.t.c.) is included indicate among the sources of energy for your micro enterprise, this source of energy obtained?

| | |
|---------------------------------------|--|
| Purchased | |
| Collected free of charge | |
| Purchase and collected free of charge | |
| Other | |

Please specify others-----

Q9. What is your total monthly energy bill for the microenterprise in Kenya shillings?

| | |
|-------------------|--|
| Not more than 500 | |
| 1000-2000 | |
| More than 2000 | |
| Other | |

If other please specify-----

Q10. If collected free of charge, how many hours do you spend to collect your daily/weekly/monthly energy requirement?

Q11. -----

Q12. Besides collection of biomass energy sources, does your microenterprise use human energy? Yes No

Q13. In relation to human energy stated in Q11 rank in order of contribution. (*Indicate by numbering from 1-3 in order where one is the greatest contributor*)

| | |
|---------------|--|
| Woman (adult) | |
| Man (adult) | |
| Man (child) | |
| Woman (child) | |
| other | |

Please specify others-----

Q14. With regards to the purchasing/collection of the energy choices listed in Q7 do you separate/distinguish between that destined for in microenterprise and that for domestic/household activities? Yes No

II. To assess of the agro ecological factors that influences current energy choices in the different agro ecological zones of the district.

Q15. (a) Are there any challenges you face with respect to your using the energy choices stated in Q7? Yes No

(b) If yes kindly elaborate

Q16. Are there any advantages/benefit obtaining with respect the energy sources listed in Q7 and/or their use the

Q17. Are there any traditions related to energy choices and use? Yes No

Q18. with respect to Q16 if yes kindly elaborate

III. To determine the environmental impacts of rural microenterprise current energy choices in the different agro ecological zones of the district

Q19. What are the impacts on human health associated with current energy choices and use?

Q20. What are the impacts on the environment the current energy choice and use?

Q21. What are the impacts on the plant resources the current energy choice and use?

Q22. What are impacts on wildlife the current energy choice and use?

Q23. What other impacts associated with the current energy choice and use?

IV. To determine potential sustainable alternative energy choices and use for rural microenterprise activities in the different agro ecological zones of the district

Q24. Do you know of any existing potential alternative energy sources in the area?

Q25. In relation to Q20, what factors constrain access or use of these energy sources?

Q26. In relation to Q21, How can these constraints be overcome?

Q27. In your opinion, suggest alternative strategies, measures and investment options for improving access to energy in general.

Appendix ii Tool for Focus Group Discussion

I Exploring the relative importance of current energy choices in the different agro ecological zones of the district

- Q1. What are the main sources of your cash income?
- Q2. Name/list the microenterprises
- Q3. Name /list types of wage employment
- Q4. Where are most of the microenterprise located and why?
- Q5. What are the main sources of energy for your microenterprise activities?
- Q6. Where do people obtain biomass (fuel wood, charcoal, agro residues, cow dung e.t.c?)
- Q7. Who contributes the most energy in microenterprise activities?
- Q8. What the challenges faced in using biomass energy sources?

II Exploring the agro ecological factors that influences the current choice in the different agro ecological zones of the district.

- Q9. Are there any advantages/benefit of using biomass and human energy sources?
- Q10. Are there any traditions related to energy choices and use?

III. Exploring the environmental impacts of the rural microenterprise current energy choices in the different agro ecological zones of the district

- Q11. What are the impacts on human health associated with current energy choices and use?
- Q12. What are the impacts on the environment the current energy choice and use?
- Q13. What are the impacts on the plant resources the current energy choice and use?
- Q14. What are impacts on wildlife the current energy choice and use?
- Q15. What other impacts associated with the current energy choice and use?

IV. Exploring potential sustainable alternative energy choices and use for rural microenterprise activities in the different agro ecological zones of the district

- Q1. Do you know of any existing potential alternative energy sources in the area?
- Q2. What factors constrain access or use of these energy sources?
- Q3. How can these constraints be overcome?
- Q4. In your opinion, suggest alternative strategies, measures and investment options for improving access to energy in general.