UNIVERSITY OF NAIROBI

LIVESTOCK DERIVED BIOGAS AND WOODFUEL FOR CLIMATE CHANGE MITIGATION: COMPARATIVE ANALYSIS IN NAKURU COUNTY, KENYA

By

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DECLARATION

I declare that this dissertation is my original work and has not been presented elsewhere for examination or publication. Where other peoples' work has been used, this has been properly acknowledged and referenced.

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DEDICATION

This dissertation is dedicated to my family; wife Joyce Lokhale, sons Clinton and Cleophas for their prayers, patience and support during my coursework and field research.

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Efforts from individual people and institutions led to the success of this dissertation. I would like to appreciate the following people and institutions for their support towards this study. My supervisors from the University of Nairobi guided me from dissertation proposal to dissertation writing. Mr.Kiogora; Director of Water, Energy and Environment Resources, Mrs. Virginah and other staff of Ministry of Agriculture, Livestock and Fisheries in Nakuru County for their support during the cross-sectional survey. I also recognize encouragement from my classmates.

I thank the Almighty God for protecting my life and giving me strength during my post graduate studies.

ABSTRACT

Increasing greenhouse gases levels and consequently climate change is one of the serious concerns of developing and developed countries. The main greenhouse gases in the earth's atmosphere are Carbon dioxide (CO_2), Methane (CH_4) and Nitrous oxide (N_2O). In Nakuru County about 50.5% of people utilize woodfuel as a source of energy and there are lots of unmanaged livestock manure which both release methane emissions that contribute to climate change. This study contributes towards reducing methane emissions through the use of biogas as strategy for climate change mitigation in Nakuru County; Kenya. The specific objectives of the study were to determine the quantity of woodfuel and biogas used by wood stove and biogas stove user households, to estimate reduced quantity of woodfuel usage and methane emissions from use of biogas in mitigating climate change, and to examine how use of biogas contributes to improvement of household livelihoods.

Multi-stage sampling technique was used to come up with a sample for the cross sectional survey; dairy cattle farmers' households were clustered and purposively sampled. The instruments for survey were questionnaires and interviews. Collected data were coded and analyzed using quantitative and qualitative techniques. Content analysis, descriptive statistics and inferential statistics were also used summarize data and determine significance level.

Mature trees felled for woodfuel by wood stove and biogas stove user households were 14 and 7 per HH per year respectively. The annual demand of woodfuel from forests exceeded the supply by 0.02% per HH per year, translating to felling of 10.5 mature trees instead of 10.3 mature trees per HH per year. This implied that woodfuel use is unsustainable. The use of biogas resulted in reduction of woodfuel usage by 3899.4 Kg/HH/year. This reduction saved 53.3-54.1% of methane emissions annually from being emitted to the global atmosphere. Conserved trees in the forests from reduced woodfuel usage increased carbon sink for Carbon dioxide by 72.6% annually. There was a saving of Ksh.3599.00 per planting season from not buying mineral fertilizers for each biogas user household. Use of bio-fertilizer avoided nitrous oxide emissions from nitrogenous fertilizers.

The findings of the study elucidate the benefits of using biogas digesters as reduced woodfuel usage by 53.3% and methane emissions reduction. Findings of the study are beneficial to livestock farmers, crop farmers, agricultural and climate policy makers.

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LIST OF ABBREVIATIONS/ACRONYMS AND SYMBOLS

AK Amkeni waKenya

C Black Carbon

CAN Calcium Ammonium Nitrate

CEDGG Centre for Enhancing Democracy and Good Governance

CFCs Chlorofluorocarbons

CH_4 Methane

CO Carbon monoxide

CO_2 Carbon dioxide

CO_2e Carbon dioxide equivalent

DAP Diammonium Phosphate

DoE Energy Department

EPA Energy Protection Agency,

FAO Food and Agriculture Organization

GHGs Greenhouse gases

GWP Global Warming Potential

HFCs Hydrofluorocarbons

HHs Households

IEA Institute of Economic Affairs

IPCC International Panel on Climate Change

KENDBIP Kenya Domestic Biogas Programme

Kg Kilogramme

MoP Muriate of Potassium

NGOs Non-Government Organizations

N_2O Nitrous oxide

ppb parts per billion

ppm parts per million

SDGs Sustainable Development Goals

SF_6 Sulfur hexaflouride

SLC Student Learning Centre

SPSS Statistical Package for Social Sciences

USDA United States Department of Agriculture

UNDP United Nation Development Programme

USGCRP United States Global Climate Research Program

CHAPTER ONE

1.0 INTRODUCTION

This chapter presents the background of the study, statement of the problem, hypothesis of the study, objectives of the study, justification and scope of the study.

1.1 Background of the study

One of the serious concerns of developing and developed countries now and in future is increasing levels of greenhouse gases (GHGs) and climate change. The atmospheric concentration of carbon dioxide has increased from 280 to 379 ppm in 2005.The concentration of Nitrous oxide has increased from 270 to 319 ppb in 2015 (Sujuta *et.al.,* 2014).Climate change is shift in climate which is attributed directly or indirectly to human activities that alter the composition of the global atmosphere due to changes in concentration of GHGs and which are in addition to natural climate variability observed over decades or centuries (IPCC, 2013). Heat trapping gases in the atmosphere keep the earth surface warm. Human activities are raising the concentration of GHGs reinforcing the natural greenhouse effect. The main greenhouse gases of great concern emitted to the earth's atmosphere are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), chlorofluorocarbons (CFCs) and sulfur hexaflouride (SF_6). The impacts of climate change include prolonged droughts, melting of snow and glaciers, rising of sea level, more frequent flooding and spread of diseases (Sarvari *et.al*., 2016; Tantrakarnapa *et.al.,* 2008; Kosse *et.al.,* 2016).

The second most important cause of global warming and climate change after carbon dioxide is methane. Methane is a potent greenhouse gas estimated to be responsible for one fifth of anthropogenic climate change. In the past two centuries, rising methane emissions have resulted in steady increases in concentration in the atmosphere. The concentration of methane in the atmosphere was 722 parts per billion (ppb) in the beginning of industrial revolution and increased to an average of 1834 ppb in 2015 (Buddle *et.al.,* 2010; Yao *et.al.,* 2014; IPCC, 2013; Saunois *et.al.,* 2016). The concentration of atmospheric methane has risen by about 154% compared to beginning of the industrial revolution. This is as a result of human activities related to agriculture, fossil fuels, waste management and burning of biomass. In the past decades, methane growth in the atmosphere has been variable. The methane concentration was relatively stable for about a decade in the 1990s but then started to increase in 2007 due to activities of microbes in wetlands, rice paddies and guts of ruminant animals.

Other sources of methane are marine sediments, lakes and guts of termites. Methane contributes to global climate warming due to its heat trapping characteristics and indirectly due to production of other GHGs such as stratospheric water vapor and tropospheric ozone through photochemical reactions (Tarinee *et.al.*, 2013; Saunois *et.al.*, 2016; Meng *et.al*., 2016; Melvin *et.al.*,2016). Positive feedback mechanism of increased methane emission due to global warming is likely to enhance methane release from other sources such as Tundra permafrost areas because higher temperatures boost the activity of methane producing bacteria (Jorgensen, 2009; Stepniewski, 2007). Woodfuel used in developing countries like Kenya for cooking cause global warming and consequently climate change through emissions of GHGs such as black carbon, carbon monoxide, carbon dioxide and methane to the atmosphere. Livestock wastes in most areas of Kenya are disposed openly and generate greenhouse gases such as methane and nitrous oxide. Livestock sub sector is a major contributor to methane emissions and has turned into a focal point of research (Somanathan and Blufftone, 2015; Amare, 2014; Buddle *et.al.*, 2010; Demissie *et.al.*, 2016; Vac *et.al.*, 2013).

Biogas system has the capacity to reduce methane emissions by capturing methane that would have escaped into atmosphere to contribute to climate change and utilize it to provide biogas fuel (Scherr and Sthapit, 2008; Kelleher and Robin Environmental, 2013; Sujata *et.al.*, 2014; Melvin *et.al.*, 2016; Maraseni and Maroulis, 2008; Amegah and Jaakkola, 2016; Moraes *et.al.*, 2016). Biogas digester is used to convert livestock manure into renewable energy in form of methane rich biogas and bio-fertilizer (Beedu and Modi, 2014; Adhikari *et.al*., 2015; Puyol *et.al.*, 2016). The use of biogas for cooking food and heating water in the households displace fossil fuels such as kerosene and reduce woodfuel usage. The use of biogas fuel decreases deforestation, improve soil fertility and enhance good health by improving air quality in the households. Reducing methane emissions does not only have climate benefits but also could improve crop production. Because of methane's high global warming potential of 28 and shortest lifetime of 12 years in the atmosphere compared to CO_2, its reduction offers opportunity to slow climate change efficiently in short time horizon. Atmospheric life of CO_2, N_2O and HFCs is 5-200,114 and 1.4-260 years respectively (Rouf *et.al.* 2015; Saunois *et.al.*, 2016; Glover, 2009; Mohajan, 2017).

Many studies have been carried out on environmental impact, socio-economic and household benefits, and performance of biogas systems (Bacenetti *et.al.*, 2013; Sendegeya *et.al.*, 2010; Praes *et.al.*, 2015; Dubrovskis *et.al.*,2009). Special attention has focused on energy balance and greenhouse gases emissions. Few research studies have been done in relation to the role of livestock manure management in reducing methane emissions (Demissie *et.al.,* 2016; Gromke *et.al.,* 2015; Mengistu *et.al.,* 2016). The objective of the study was to evaluate the contribution of biogas utilization in reduction of methane emissions for mitigation of climate change in Nakuru County; Kenya.

1.2 Statement of the problem

About 50.5% of the population in Nakuru County depends on woodfuel as source of energy. 75.4% and 48.1% of poor and rich Kenyans utilize woodfuel respectively (KENDBIP, 2014). Woodfuel use causes deforestation, poor human health and global warming. There is lots of unmanaged livestock waste in Nakuru County. Both woodfuel and livestock waste release methane contributing to climate change. The number of cattle in Kenya has increased from 13.392 million in 1999 to 18.135 million in 2015.Cattle population in Nakuru County has increased from 263,380 in 2011 to 486,132 in 2015. The world has 1.486 billion heads of cattle as at 2013 (UNDP, 2013; Cook, 2015; Cattle Network, 2015; County Government of Nakuru, 2017). In Nakuru County, the average levels of methane have increased from 3.6 billion to 3.72 billion mol/cm^2 in 2012 to 2016. Average levels of methane emissions in Kenya have increasing trend from 3.42 to 3.54 billion mol/cm^2 in 2012 to 2016 (Giovanni, 2017).

In the beginning of industrial revolution, the level of methane in the atmosphere was 722 parts per billion (ppb) and continued to increase through 2015 reaching an average of 1834 ppb. Atmospheric methane levels have grown by 154% since 1750s as result of human activities related to ruminant livestock production, fossil fuel extraction and distribution, biomass burning, municipal solid and water waste management, lakes and termites (IPCC, 2013; Saunois *et.al.,* 2016). Positive feedback mechanism between increased methane emissions and global warming is likely to reinforce methane release from other sources such as Arctic permafrost and marine regions since higher temperatures boost the activity of methane producing bacteria (Stepniewski, 2007).

The impacts of climate change include prolonged droughts, more frequent flooding and spread of diseases. Residents of Nakuru County face problems such as over-reliance on woodfuel, widespread deforestation of Mau forest complex, indoor air pollution, poor solid waste disposal, high level of unemployment and poverty (CEDGG and AK, 2014). There is need to adopt the use of biogas which reduces methane emissions, provides renewable energy and clean surroundings. Thus use of biogas mitigate climate change over Kenya and the globe at large (FAO, 2012; USGCRP, 2009; Morris, 2010).

1.3 Hypothesis of the study

Null hypothesis: The use of biogas does not reduce methane emissions from woodfuel cooking stove and livestock waste in Nakuru County.

Alternative hypothesis: The use of biogas does reduce methane emissions from woodfuel cooking stove and livestock waste in Nakuru County.

1.4 Overall Objective and Specific Objectives

1.4.1 Overall Objective

The overall objective of the study was to evaluate the contribution of biogas utilization in the reduction of methane emissions for mitigating climate change in the study area of Nakuru County; Kenya.

1.4.2 Specific Objectives

The study addressed the following specific objectives

(i) To determine the quantity of woodfuel and biogas used by wood stove and biogas stove user households.

(ii)To estimate reduced quantity of woodfuel usage and methane emissions from biogas use in mitigating climate change.

iii) To examine how the use of biogas contributes to improvement of household livelihoods

1.5 Justification of the study

Accumulation of greenhouse gases such as methane from different sources such as biomass burning and livestock waste alter the composition of global atmosphere causing climate change (IPCC, 2014). There is increasing trend in livestock numbers, deforestation of Mau forest complex and woodfuel usage leading to increased levels of methane emissions in Nakuru County. Wood supplies are disappearing by 40 % each year in Kenya (Cook, 2015; KENDBIP, 2014; UNDP, 2013; Giovanni, 2017). The findings of study are related to promotion of natural forest conservation resulting from reduced woodfuel use and better agricultural practices. The benefits of promoting biogas use include improving household air quality and health, reducing cost of agricultural production, combating deforestation and enabling households to access sustainable energy source through biogas fuel production (Laxmi *et.al.*, 2014; Al-smairan *et.al.,* 2015; FAO,2012; USGCRP 2009).

This study found that households reduce methane emissions by sustainable livestock waste management through the use of biogas. Biogas system reduces methane emissions by capturing methane from organic wastes such as livestock manure and converting it to biogas fuel. There is destruction of methane when biogas fuel is used in cooking food or heating water as it is converted into carbon dioxide. This CO_2 is not considered to cause greenhouse effect since it comes from biogenic carbon as long as new plants and tree growths take an equivalent quantity of carbon from the atmosphere over the life cycle assessment time of 100 years (Hristov *et.al.,* 2013; Morris, 2010).The use of biogas assists Kenyans and in particular the residents of Nakuru County to attain Sustainable Development Goals(SDGs) and targets such as No.6,7,11,13,15 that is clean water and sanitation, renewable energy, improving air quality and waste management, combating climate change, and sustainable management of forests(Amegah and Jaakkola, 2016).

1.6.0 Scope of the Study

The study evaluated the contribution of biogas use in reduction of methane emissions for climate change mitigation and indoor air quality in Nakuru County; Kenya. The data was collected from households of the dairy cattle farmers who owned more than two cattle and were purposively sampled from 5 clusters. The respondents and interviewees in the study were dairy cattle farmers who were either biogas stove user or, and wood stove user households. Data on quantity of woodfuel and biogas used by the households was collected. The study paid attention to livestock waste especially the cow dung as the raw material for the production of biogas fuel.

1.6.1 The description of study area

The subsections below discuss geographical location, climate and agriculture of Nakuru County.

1.6.1.1 Geographical location

Nakuru County is among the 47 Counties in Kenya as shown in Fig.1. The County is found on the North West of Nairobi and is 160 Kilometres from the capital city of Kenya. It is located in the South Rift region and surrounded by seven counties. It borders Kericho and Bomet to the West, Narok to the South West, Baringo to the North, Kajiado to the South, Nyandarua to the East and Laikipia to the North East. The County is demarcated into eleven Sub-Counties; Subukia, Bahati, Nakuru East, Nakuru West, Rongai, Kuresoi North, Kuresoi South, Gilgil, Naivasha, Molo and Njoro. It has an area of 7496.5 Kilometres squared. It is located between latitudes 1.16^{o} S to 0.22^{o}N and longitudes 35.42 to 35.58^{o}E.The highest elevation within the County is 1859 metres above the sea level.

1.6.1.2 Climate

The County is characterized by equatorial climate. It experiences bimodal rainfall distribution. Long rains occur in April, May to August while short rains are received in October to December. Dry season starts in January to March. Average annual rainfall of the study area is 800mm.The highest and lowest annual rainfall is 1200mm and 700mm respectively. The average maximum temperature of the area is 20^{o}C while the average minimum temperature is 10^{o}C.The coldest months are July and August while hottest months are January to March.

1.6.1.3 Agriculture

Nakuru County has human population of 1,603,325 persons and 409,836 households as per Kenya National Population Household Census of 2009. The main natural resources of the County include Mau forest water tower, national parks, rivers and lakes. The County is industrialized, agriculturally rich and has good biomass potential. In terms of agriculture, the County is characterized by mixed farming that is crop and livestock production. Other livelihoods in the County include fishing, tourism and mining. The County has 159,628 cattle as per Nakuru County Livestock Annual Report 2016 (County Government of Nakuru, 2017). Nakuru was chosen because it has a relatively high human population density and there is plenty of fodder and water thus conducive for livestock farming; a favourable indicator for adoption of biogas plants. Energy sources in Nakuru County include 7.7% electricity, 41.8% paraffin, and 50.5 % firewood (County Government of Nakuru, 2016).The County is faced with problems such widespread deforestation, over reliance on woodfuel, poor solid waste disposal, high level of unemployment and poverty (CEDGG and AK, 2014; KENDBIP, 2014).

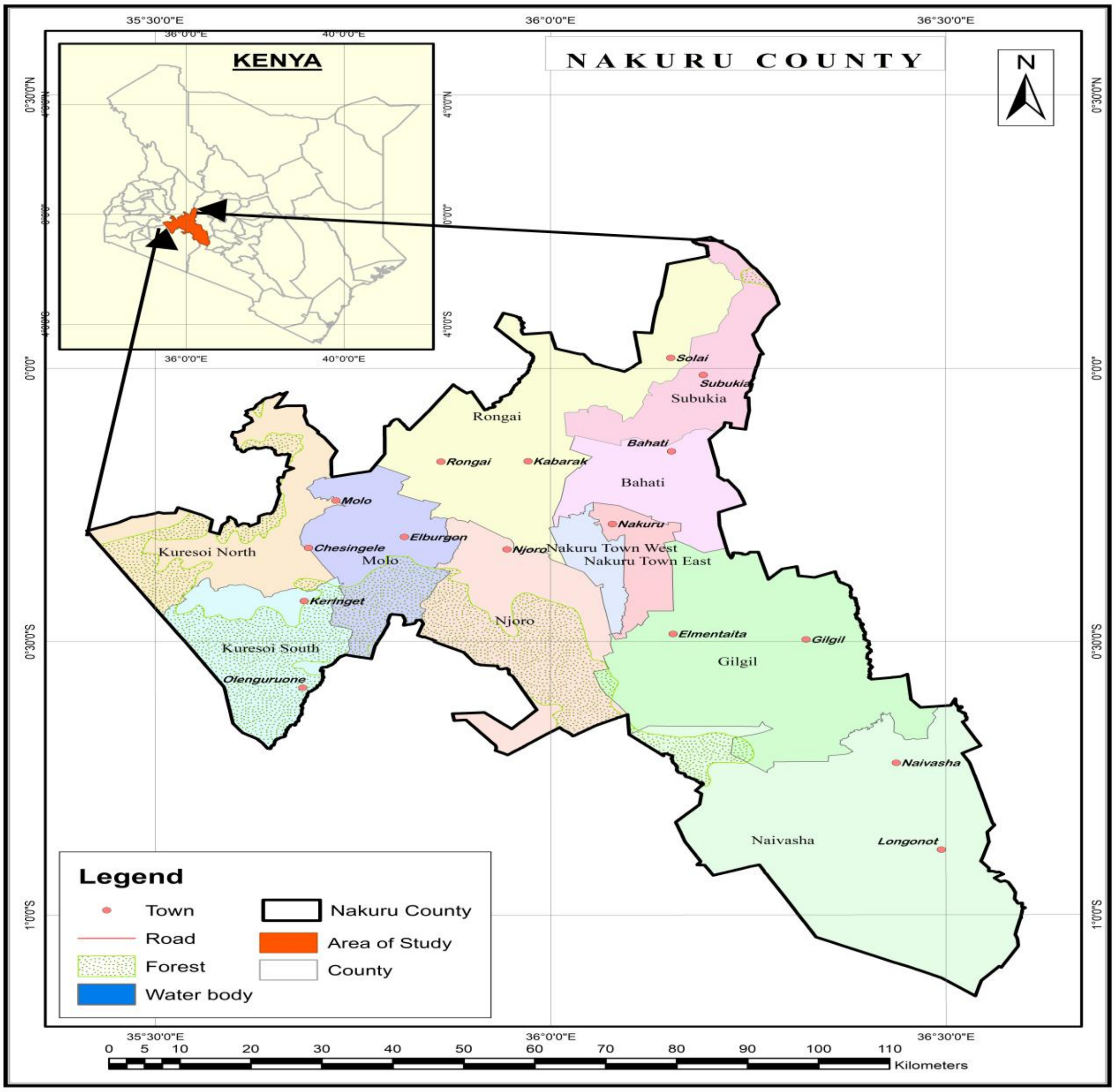

Figure 1: Map of Kenya showing the location of study area of Nakuru County (Author, 2018).

1.6.2 Limitations of the study

The following were the limitations of the study

i) The study required more than 3 months to carry out all its activities exhaustively.

ii) The study used purposive sampling yielding to findings that are non-representative of the population.

1.6.3 Assumptions of the study

The study was conducted under the following assumptions.

i) The dairy farmers interviewed would be capable to recall and give accurate answers on fodder/pasture production yields and climate getting drier in the last 10 years.

ii) The dairy farmers would provide true answers and that incase a different respondent other than the head of the household had better knowledge of the daily management of the farm, their answers were considered.

iii) The monthly woodfuel and biogas usage was constant throughout the year.

CHAPTER TWO

2.0 LITERATURE REVIEW

In this chapter, literature regarding woodfuel and biogas utilization, woodfuel and Methane emissions reduction as means of mitigating climate change, and the contribution of biogas use to household livelihoods improvement was reviewed. Brief description of conceptual framework of the study is also presented.

2.1 Woodfuel and Biogas Utilization

Woodfuel and biogas are utilized for cooking and heating. Biomass such as charcoal, firewood and agricultural wastes are the greatest source of energy in Kenya. Energy sources in Kenya include 68% woodfuel and other biomass, 22% petroleum, 9% electricity and 1% others. About 40% of the world population relies on woodfuel as their energy source (Kemausuor *et.al.,* 2016;IEA, 2013;Government of Kenya,2013;Amare, 2014). Woodfuel has negative health effects on households. High prices of paraffin impact severely on rural poor. Use of biogas will make rural poor people to be self reliant in energy and minimize pressure on traditional biomass fuel. In 1957, Mr. Hutchinson constructed the first biogas plant in Kenya. Since then, Government of Kenya and development partners have built hundreds of biogas digesters across the country (KENDBIP, 2014; Nguu *et.al.*, 2014).

2.2 Woodfuel and Methane Emissions reduction as way of mitigating climate change

Methane emissions are rising at worrying rate. Atmospheric methane concentration has increased by about 1112 ppb since pre-industrial time reaching 1834 ppb in 2015 (Saunois *et.al.,* 2016). The effect of methane on the climate of the earth depends on the time it remains in the atmosphere and its ability to absorb long wave radiation energy. These factors are referred to as global warming potential which is described as the relative radiative forcing of mass of methane gas compared to an equivalent mass of carbon dioxide during a chosen period of years. The period of years can be 20,100 or 500. Global Warming Potential (GWP) of methane is 28 means that one kilogram of methane will have a warming effect equivalent to 28 kilograms of carbon dioxide over 100 years. Radiative forcing of methane is 0.64 WM^{-2} and being positive leads to warming of the climate system (Kosse *et.al.* 2016; Hope, 2001; IPCC, 2013; Mohajan, 2017). Radiations from the sun reach and warm the earth's surface.

The atmosphere allows short wave radiations to the earth and retain large portion of re-radiated long wave radiations thus act as insulator causing global warming. Infrared radiations from earth are re- radiated back to space but a portion is captured by water vapour and other greenhouse gases. Release of GHGs into the atmosphere by human activities is believed to be the main driver for climate change. Methane absorbs and emits efficiently thermal infrared radiations. Increased quantity of methane in the atmosphere has led to global warming because methane molecules increase infrared opacity of the atmosphere and terrestrial radiations cannot go to space resulting to more heat being trapped in the atmosphere (Fayez and Ziad, 2000; Schouten *et.al.*, 2013; Niggli *et.al.*, 2008).

Sources of methane emissions include natural wetlands, rice paddies, municipal wastewaters, municipal landfills/solid wastes, biomass burning, animal waste, human sewage, termites, food wastes, fossil fuels, oceans and marine sediments. Positive feedback effect can happen in Arctic, Subarctic and marine sediments which are highly responsive to temperature rise by reinforcing the release of methane emissions to the atmosphere resulting to further global warming (Stepniewski, 2007; Holmes and Smith, 2016; Gashaw and Teshita, 2014; Al-smairan *et.al.*, 2015; Umeghalu *et.al.*, 2012; James *et.al*., 2016). Biogas is primarily a mixture of gases with large percentage of methane and carbon dioxide produced by methanogenic bacterial decomposition of livestock wastes in the absence of oxygen. The most common organic matter to produce biogas is manure. Liquid manures that can be used for production of biogas include those of dairy cattle and fattening pigs. The biogas systems confine methane that would have escaped into the atmosphere contributing to climate change and utilize it to create clean renewable biogas fuel for cooking and heating. The system also produces digestate which can be used as bio-fertilizer. Production of biogas in particularly designed plants is the most used method to capture and diminish methane emissions. The most common types of biogas plants are fixed dome digester and floating drum digester (Bessou *et.al.*, 2010; Mulinda *et.al.*, 2013; Zusana *et.al.*, 2016; USDA *et.al.*, 2014; Mengistu *et.al.*, 2016;Baig *et.al.*, 2017). Anaerobic digester is designed to help in the decomposition of organic wastes in a closed system with limited oxygen and produce renewable energy source; biogas. Biogas generated is composed of 50-70% methane, 30-40% carbon dioxide, 5-10% hydrogen, 1-2% nitrogen, 0.3% water vapour, traces of hydrogen sulphide and other contaminants (USDA *et.al*., 2014; Gashaw and Teshita, 2014; Chand *et.al*., 2012; Singh and Sankarlal, 2015). Anaerobic digestion is a biological process where acid forming bacteria and methane forming bacteria use organic matter in the livestock waste to produce a mixture of gases known as biogas in oxygen deficit environment. Anaerobic digestion can be explained by a four phase system namely hydrolysis, acidogenesis, acetogenesis and methanogenesis. The yield of biogas depends on parameters such as temperature, retention time, mixing or agitation, solid content, pH and Carbon/Nitrogen ratio (Shin *et.al.,* 2015; Jayaraj *et.al.,* 2014; Yaru *et.al*., 2015; Nguu *et.al*., 2014; Young *et.al.,* 2014; Kumaran *et.al.,* 2015).

Anaerobic digestion and biogas system have potential to produce, confine and destroy majority of methane from livestock wastes providing renewable energy and cleanliness opportunities for low and medium income nations. During cooking and heating, the captured methane by biogas system is converted to carbon dioxide, which is not considered to cause greenhouse effect since it comes from biogenic carbon as long as new grasses and tree growths take an equivalent quantity of carbon from the atmosphere over the life cycle assessment time of 100 years. (Hristov *et.al.,* 2013; Morris, 2010; Hublin *et.al.,* 2014). The use of livestock waste for biogas fuel production could reduce the quantity of methane emissions being emitted into the atmosphere by about 19%. Using biogas from livestock waste leads to reduction of both woodfuel energy use and Methane emissions due to minimal Methane emissions from stored livestock waste and woodfuel burning (Holmes and Smith, 2016; Cheng *et.al.,* 2014; Corre and Conijn, 2016; Bedi *et.al.,* 2015). Climate change mitigation involves human interventions that reduce sources or enhance sinks of anthropogenic emissions of greenhouse gases. This is necessary to slow climate change. Methane is among the GHGs mitigated under Kyoto Protocol (IPCC, 2013; FAO, 2012). There is mitigation of climate change by using biogas because Methane emissions in the atmosphere are reduced and sequestered carbon in the form of conserved forests is increased. Application of bio-fertilizer on the farms avoids the use of nitrogenous mineral fertilizers which emits nitrous oxide; powerful greenhouse gas. Biogas technology plays a role in assisting communities to build resilience to the effects of climate change by increasing the reliability of important services such as energy and waste management. There are synergies and resiliency for agricultural needs when linking livestock manures and nutrients recycling to the arable or cattle farm for food and fodder production (Chand *et.al*., 2012; USDA *et.al*., 2014).

2.3 Contribution of biogas use to household livelihoods improvement

Use of biogas has benefits which include provision of cooking fuel, reducing deforestation, improvement of air quality, saving on cost of mineral fertilizer and saving time in the household (Rouf *et.al.,* 2016; Esfandiari *et.al.,* 2011; Tumwesige *et.al.,* 2011; Sunil *et.al.,* 2015). When biogas is used as source of cooking fuel it reduces both the use of forest trees as firewood and indoor household air pollution from woodfuel smoke. Time is saved from not collecting firewood, during cooking and cleaning of utensils. Slurry from biogas digestion is used as organic fertilizer which saves expenses of purchasing mineral fertilizers. The bio-fertilizer is highly fertile as it contains valuable nutrients such as nitrogen, phosphorus and potassium for crop growth and production. Biogas system is a good source of employment as it creates facilities where temporary and permanent jobs are needed to build and run the biogas digesters (FAO, 2012; Laxmi *et.al*., 2014; Nguu *et.al.*, 2014; Rouf *et.al.*, 2015; Uddin *et.al.*, 2015).

2.4 Conceptual Framework of the study

Figure 2 shows conceptual framework after reviewing relevant literature. The objective of the study was to evaluate the contribution of biogas utilization in the reduction of methane emissions for mitigating climate change in the study area of Nakuru; Kenya. Wood stove uses woodfuel as source of energy while biogas stove uses biogas fuel. The use of woodfuel contributes to climate change by releasing GHGs and decreasing capacity of carbon sinks. Woodfuel usage and biogas usage of dairy farmers' households was used in the analysis of woodfuel usage, methane emissions and cost of fertilizer for wood user and biogas user HHs. There was reduced amount of woodfuel usage, methane emissions and cost of fertilizer after installation of biogas system. Conserved forests due to reduced woodfuel are associated with bringing rains and would reverse unreliable rainfall pattern that is manifestation of climate change. Climate change mitigation is achieved when Methane emissions are reduced from woodfuel burning, Methane is destroyed during burning of biogas fuel and capacity of carbon sinks is increased. To reduce GHGs emissions and increase capacity of carbon sinks, woodfuel stoves should be replaced by biogas stoves. The dairy farmers' households should upscale the use of biogas fuel stoves so as to contribute to combating climate change.

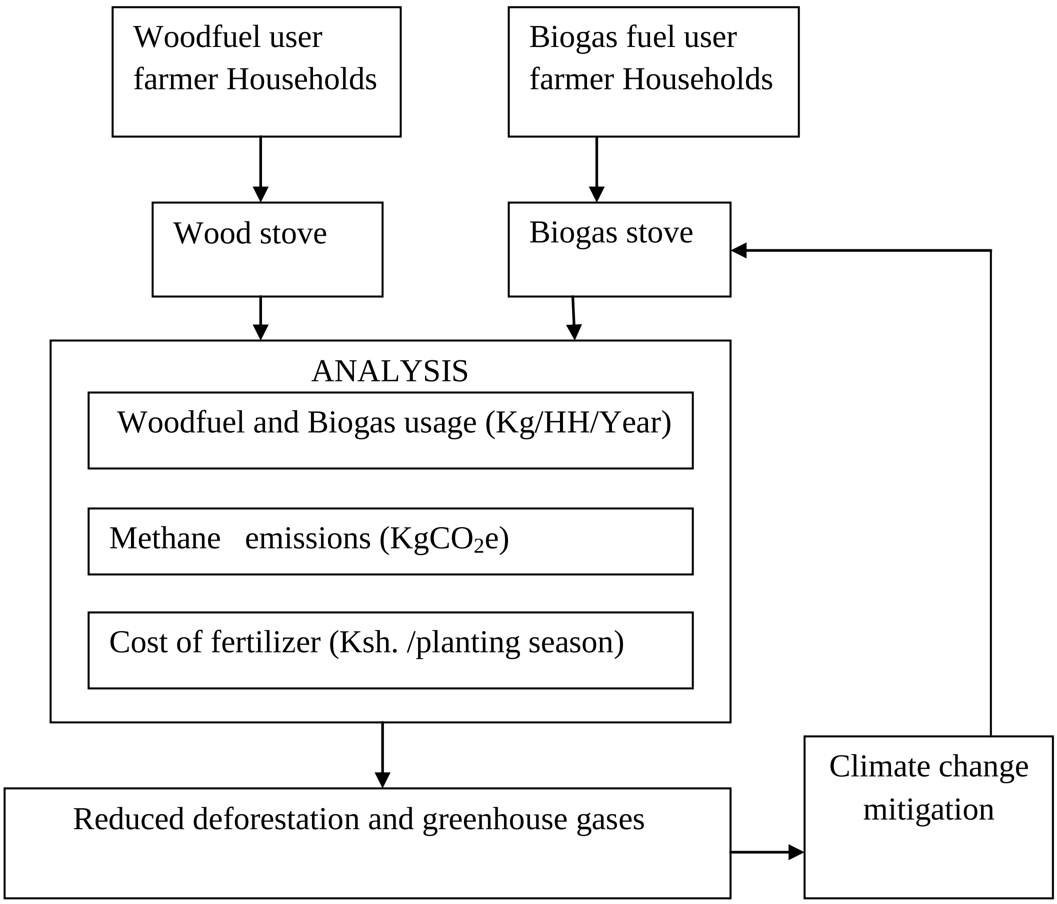

Figure 2: Conceptual framework of the study (Source: Author, 2018)

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CHAPTER THREE

3.0 DATA AND METHODS

This chapter summarizes the data and methods used to achieve the objectives of the study. It presents a description of data collection. It also describes the research design, sampling techniques, population and sample size, instruments of research, reliability and validity of research instruments, steps to achieve each of the research objectives, and data analysis.

3.1 Data

3.1.1 Data collection

Primary and secondary data were collected during the study. Primary data is the type of data which was collected by the researcher fresh at first hand and for the first time thus it is original work of the researcher. Primary data was collected using structured questionnaire and face to face interview. Field assistants were used to administer questionnaire and conduct interview. Questionnaires are forms which are completed through filling in spaces or ticking boxes and returned to the enumerator by respondents. It is a cheaper method and used where literacy rate is high and respondents are supportive. Interviews are forms which are filled through an interrogation of interviewee by interviewer. They are useful for more compound questions, low literacy rate and less accommodating respondents. The data collected during cross-sectional household survey using semi structured questionnaire was demographic information, household characteristics, fodder and pasture production, manure management, energy resources utilization and climate change information. Key informant interview was done purposively using checklist. Key informants were persons with specialized knowledge on a particular topic. Such individuals were local leaders, government officials and elders. The researcher requested the key informants to expound on his or her answers to questions related to the local situation of energy and climate change. This instrument is useful for obtaining in-depth descriptive data on historical beliefs and practices.

Secondary data is type of data which has been collected, passed through statistical processes and it is retrieved from pre-existing sources (Barreiro and Albandoz, 2001). Secondary data collection involved review of research journals from various publications, websites, textbooks, booklets, unpublished documents and policy documents from libraries and internet. Secondary data was also collected from local Non-Government Organizations, Department of Energy and Department of Livestock production in Nakuru County. Field observation focused on collection of data which was not covered by interview or questionnaire. Direct observation involved making direct measurement and is most accurate method for many variables such as woodfuel usage. Data about the neighboring environment of biogas user and wood user households and condition of biogas plants was captured by camera.

Introductory meeting at Nakuru County Livestock Production Office was the start of field work for data collection where the purpose of the study was stated and study sites selected. The agreements reached during the meeting governed field data collection exercise. A total of 10 enumerators were identified for 5 clusters (2 for each of the Sub-County cluster). They were advised on data collection procedures, communication of soft skills and personal conduct during the exercise. Each cluster had 20 or 30 households to be surveyed resulting to 121 dairy cattle farmers participating.

3.2 Methods

3.2.1 Research design

Cross-sectional survey research design was used during the study. Survey is systematic method of collecting data and it is useful in analysis and interpretation of views for group of people from target population. Survey is classified according to instrumentation into questionnaires and interview. One class of survey based on period of time used to carry out survey is cross sectional survey. In this study, cross-sectional survey involved collecting information from dairy cattle farmers, elders, Non-Governmental Organizations (NGOs) and government staff at single period in time. Cross-sectional survey used questionnaires and interview to ask questions about energy resources and climate change. Survey method provided statistically significant findings due to high representativeness of the population (Sincero, 2012).Survey technique has good response rate and longer interview is more likely to be accepted by the interviewee. To build good relations with the community at the beginning of the survey, the researcher met community committee members to inform about the research and its objectives.

3.2.2 Sampling techniques

Sampling is the method through which a sample is selected from a population. We do sampling because it will take more time, is not cost effective and physically impossible to check all objects in a population. Sampling allows one to get a representative picture about the population without studying the whole population. Probability sampling and non–probability sampling techniques were used in the study. Probability sampling is where each data unit of the sample has the same probability of being chosen from the population. Non-probability sampling does not apply the theory of probability in choosing the elements from the sampling population but inclusion of participants is based on convenience of the researcher. Probability sampling is used when researcher is interested in generalizing the results derived from sample to the general population (Barreiro and Albandoz, 2001).

During this study, the researcher was interested in determining woodfuel and biogas usage, estimating reduced woodfuel usage and methane emissions in mitigating climate change and examining contribution of biogas use to improvement of household livelihoods among small scale dairy cattle farmers in Nakuru County. Multi stage sampling technique was used to come up with sample of 121 households for the County as illustrated in Figure 3. It is complex form of cluster sampling in which two or more levels of units are entrenched one in the other. First stage entailed cluster sampling of five sub-counties chosen from Nakuru County. In the second stage, simple random sampling of two wards from each Sub-County was done. The third stage involved purposive sampling of woodfuel and biogas stove user households. Primary sampling units are clusters in the first stage, the ones in the second stage are secondary sampling units and finally, the tertiary sampling units are groups in the third stage. The concepts of clusters, purposive and random sampling were used. Clustering saves cost compared to systematic random sampling where the population is spread over a wide geographical region as sampling is only done in some areas. The population of Nakuru County consisting of households was divided into Subukia, Bahati, Rongai, Njoro and Molo clusters. Then these units were divided in homogenous clusters (at least two wards per Sub-County). From each of these new units, households were purposively sampled (10 or 15 HHs per ward) resulting to 10 or 15 wood stove user HHs and 10 or 15 biogas stove user HHs per Sub-County for investigation.

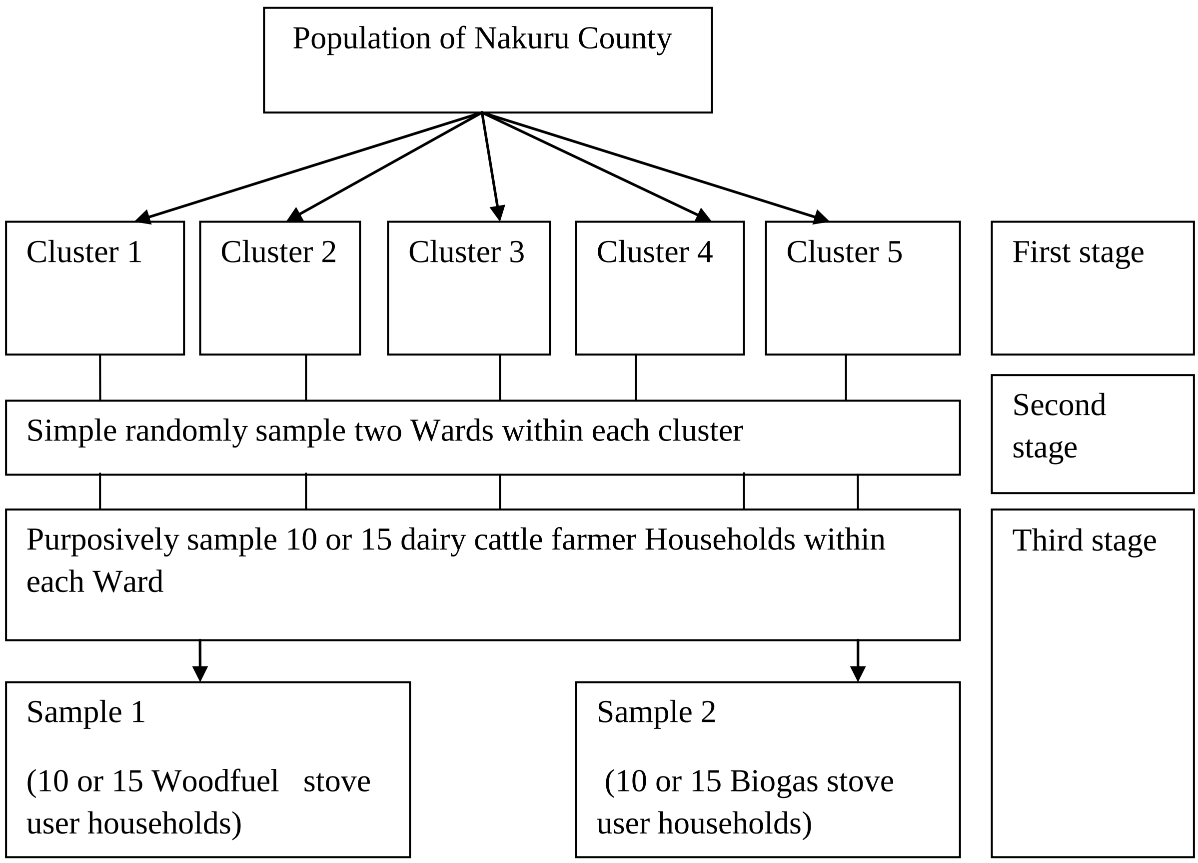

Figure 3: Multi stage sampling of the respondents in the area of study (Source: Author, 2018)

3.2.2.1 Cluster sampling

Cluster sampling was used to select five (5) Sub-Counties that were surveyed. During cluster sampling, the population was divided into (geographical regions) clusters which are homogenous and then some clusters were chosen within the cluster units by simple random sampling. Cluster sampling is useful when the units of the populations are spread over a wide geographical area. The population spread over Nakuru County was clustered into 5 Sub-Counties while the population spread over a Sub-County was clustered into 2 wards. It saved cost compared to simple random or systematic random sampling where the population is spread over a wide geographical region as sampling is only done in some areas. It is cheaper and takes less time and efforts than simple or systematic random sampling. In cluster sampling, the sampling frame is not required as it is expensive to make it (Alvi, 2016).

3.2.2.2 Simple random sampling

Two wards from each of Sub-Counties were sampled using simple random sampling. Simple random sampling is a method where the sample extracted from the population has the equal probability of being chosen, that is, every element of the population has the same likelihood of being selected to be part of the sample. The population of interest was two wards in the Sub- County. A list of all wards in the Sub-County was constructed. Selection of participating wards was through lottery system. Each ward in the list was assigned a number which was then written on a slip of paper. The slips were placed and mixed thorough in a hat. Two slips were picked from the hat to get participating wards. The officers in charge of the selected wards were contacted and investigation was done. This technique has a good representativeness of the population and there is no possibility of sampling biases (Barreiro and Albandoz, 2001).

3.2.2.3 Purposive sampling

Purposive sampling was employed when selecting 121 dairy cattle farmers HHs in the wards who had at least 2 cows and owned or not owned biogas plants. Purposive sampling is sampling techniques that involved choosing a group of dairy cattle farmers because they have specific knowledge on livestock farming and utilization of energy resources such as woodfuel and biogas that the researcher wants to study. With purposive sampling, the researcher trusts that some individuals are fit to the research compared to others. In purposive sampling, the researcher selects the sample and tries to make it representative depending on the purpose of the research (SLC, 2013).

3.2.3 Population and Sample size

Households of dairy cattle farmers were elements of the population. The population of Nakuru County consists of 409,836 households. Sample size is count of observations that constitute a sub-population to be studied in order to make inference to reference population in a survey. A sample of HHs was selected from 409,836 households for survey. Sample size was determined by Arkin and Colton formula developed in 1963 as shown in Equation (1) (CEDGG and AK, 2014; Alvi, 2016; Chand *et.al.*, 2012).

$$n = \frac{NZ^2 \times P(1-P)}{[ND^2 + Z^2 \times P(1-P)]} \quad \text{……………………………………………….Equation (1)}$$

Where

n = Sample size

N = Total number of households

Z= Confidence level of 95%; Z=1.96

P = Estimated population proportion; 0.5

D = Desired error; 0.1

With 50% of 409,836 households in Nakuru County practicing agriculture, the sample size for the survey was found to be ninety six (96). The calculation had 10% desired error and 95% confidence level. To control influences of non-responsive participants, the study sampled 121 dairy cattle farmers from Nakuru County. The surveyed households were 62 wood stove users and 59 biogas stove users. The household survey was conducted from 12th March to 5th April 2018.

3.2.4 Instruments of research

The instruments of research used were structured questionnaires and face to face interview to collect information concerning socio-economic and biophysical characteristics of the study area, woodfuel and biogas energy from respondents and interviewees. Photography was also used as data capture tool.

3.2.4.1 Questionnaire

Questionnaire refers to forms administered to respondents comprising of closed ended questions which are followed by response options and open ended questions to elicit information from respondents. Closed ended questions takes less time, are easily coded and interpreted and useful for quantitative research. In open ended questions, there are no pre-existing response choices incorporated. Respondents can give feedback to open ended questions they way they want to answer them, researcher can investigate the meaning of the feedbacks and ideal for qualitative type of research. Questionnaires are useful when gathering data from large group of participants. The respondents are likely to be more honest with their responses (Sincero, 2012).The questionnaire was developed and utilized in this study (Annex I) and captured broad aspects of respondents. Sections of the questionnaire were demographic information of respondents, household characteristics, fodder and pasture production, manure management, energy resources utilization and climate change information.

3.2.4.2 Interviews

Interview is the conversation that has a structure and purpose between the researcher as interviewer and respondent as the interviewee. Structured interview was conducted by using already designed checklist forms. Interview is a method of data gathering where an enumerator verbally asks questions directly to interviewees. The information obtained through inquiry is recorded by enumerator. During interview, forms are filled in by the interviewer and not by the respondent as was the case with questionnaire. Face to face interview was designed to obtain dairy cattle farmers' knowledge on woodfuel usage, biogas usage, various energy sources, motivation towards biogas production, problems facing biogas plant farmers, and consequences of climate change (Annex 2 and 3). Interviews are useful for exploring individual beliefs, values, understanding, feelings, experiences, and perspective of an issue. Face to face interview provided follow up questions that can be asked to clarify responses from the interviewee thus provide better understanding of interviewee's answers. There is high response rate in face to face interview. Additionally, probing can be done to improve the quality of data (Sincero, 2012).

3.2.4.3 Photography

Non verbal data was collected through photographs. Researcher captured direct observations on the farms and biogas plants using camera. The main data obtained from photography included number of livestock kept, crops planted, biogas system and status of biogas plants (Annex 4).

3.2.5 Reliability and Validity of research instrument

When selecting survey instruments, reliability and validity are important aspects to consider. Reliability refers to the degree to which data collection tool yields consistent findings over many repeated trials. Types of reliability include inter-rater reliability, test-retest reliability and split-half reliability. Validity refers to the extent that instrument's results from a measure accurately represent the concept they are supposed to measure in a quantitative or qualitative study. Use of both quantitative and qualitative data may increase the validity of the evaluation. Types of validity include construct validity, criterion validity, face validity and content validity (Phelan and Wren, 2006; Heale and Twycross, 2015).

Forms designed for interview checklist and structured questionnaires were pre-tested to establish their reliability and validity. Pre-test was used as preamble to full-fledged survey. The pre-test study was carried out from 19th to 23rd February 2018 in Menengai West Ward of Rongai Sub-county; Nakuru County. Pilot study was done in Menengai West ward of Rongai Sub-county where dairy cattle farmers have experienced same socio-economic and biophysical conditions. During pre-testing, questionnaire and interview checklist were subjected to 20 dairy cattle farmers and data was analyzed to find the extent to which it measures the expected results. The responses and analyses were useful in reviewing the initial draft of data collection instruments. The pre-test study enabled refining of questions leading to improved clarity and reduced ambiguity in the structured questionnaire and interview checklists.

3.2.6 Steps followed to achieve research objectives

i) To determine the quantity of woodfuel and biogas used by wood stove and biogas stove user households

Representative of wood stove and biogas stove user households among dairy cattle farmers were contacted and then there was on site household interview. Checklist for household interview contained questions about monthly bundles of firewood used, average weight of firewood bundle, monthly bags of charcoal used, average weight of bag of charcoal and number of hours the biogas stove was turned on per day. Turning on household burner of biogas stove for 1 hour consumes 0.2-0.45M^3 of biogas (Tilley *et.al.*, 2014). The field assistants were used to find the quantity of woodfuel usage by wood stove and biogas stove user households in the selected wards by measuring the mass of woodfuel in Kg used per day using weighing scale. Structured questionnaire was then administered to representative wood stove and biogas stove user households. The structured questionnaire contained questions about demographic information of respondents, household characteristics, fodder and pasture production, manure management, energy resources utilization and climate change information.

ii) To estimate reduced quantity of woodfuel usage and Methane emissions from biogas use in mitigating climate change

The reduced quantity of wood fuel caused by use of biogas was estimated from the difference between average amounts of woodfuel consumed by wood stove user and biogas stove user households using Equation (2).

$RWU = \overline{x_{WS}} - \overline{x_{BS}}$ ....Equation (2)

Where

RWU = Reduced woodfuel usage (Kg/Household/year)

$\overline{x_{WS}}$ = Average annual woodfuel usage for wood stove user HHs (Kg/Household/year)

$\overline{x_{BS}}$ = Average annual woodfuel usage for biogas stove user HHs (Kg/Household/year)

The t-test was performed on the average woodfuel usage of wood stove user and biogas stove user HHs for woodfuel usage reduction to show whether the difference was significant at 95% confidence level.

The quantity of Methane emissions reduction resulting from use of biogas was computed from the difference between Methane emissions produced by wood stove user and biogas stove user HHs in terms of kilogrammes of CO_2 equivalent per year using woodfuel usage, emission factor and Global Warming Potential of Methane. Previous studies found Methane emission factor as shown in Table 1.

Table 1: Emission factor of Methane from previous studies

Authors of studies	Location	Emission factor of Methane (g of Methane /Kg of wood burned)
EPA, (1993)	America	14-25
Pathak *et.al.*, (2009)	India	3.9
Amare, (2014)	Ethiopia	4
Sujuta *et.al.*, (2014)	Nepal	3
Demissie *et.al.*,(2014)	Ethiopia	6-10
Somanathan and Bluffstone, (2015)	Nepal	4.9

Source: Author, (2018)

The Global Warming Potential of Methane for the period of 100 years is 28 (IPCC, 2013).For this study, Methane emission factor of 0.006-0.01Kg of Methane per Kg of wood burned was used. The mass of Methane emissions from burning of woodfuel for the HHs in Kg of CO_2 equivalent was calculated using Equation (3).

$$E_W = \frac{1}{n}\sum_{i=1}^{n} U_i \,(EF_{CH4} \times GWP_{CH4}) \text{...Equation (3)}$$

Where E_W = Methane emissions in Kg of CO_2 equivalent from burning of woodfuel

n = Total number of sample HHs

U_i = Quantity of annual woodfuel usage in Kg by a sample HHs

EF_{CH4} = Methane emission factor for woodfuel

GWP_{CH4} = Global Warming Potential of Methane

For wood stove user HHs, the quantity of Methane emissions produced in Kg of CO_2 equivalent from burning of woodfuel was computed using Equation (4).

$$E_{W1} = \frac{1}{m}\sum_{i=1}^{m} U_w \,(EF_{CH4} \times GWP_{CH4}) \text{...Equation (4)}$$

Where E_{W1} = Methane emissions in Kg of CO_2 equivalent for wood stove user per HHs

m = Total number of wood stove user HHs

U_w = Quantity of annual woodfuel usage in Kg by wood stove user HHs

EF_{CH4} = Methane emission factor for woodfuel

GWP_{CH4} = Global Warming Potential of Methane

For the biogas stove user HHs, the quantity of methane emissions produced was calculated using Equation (5).

$$E_{W2} = \frac{1}{k}\sum_{i=1}^{k} U_b \ (EF_{CH4} \times GWP_{CH4}) \ldots\ldots\ldots\ldots \text{Equation (5)}$$

Where E_{W2} = Methane emissions in Kg of CO_2 equivalent for biogas stove user per HHs

k = Total number of biogas stove user HHs

U_b = Quantity of annual woodfuel usage in Kg by biogas stove user HHs

EF_{CH4} = Methane emission factor for woodfuel

GWP_{CH4} = Global Warming Potential of Methane

The quantity of methane emissions reduction resulting from biogas production and use was obtained by computing the difference between Methane emissions produced wood stove user per HH and biogas stove user per HH using Equation(6).

$$RME = E_{W1} - E_{W2} \ldots\ldots\ldots\ldots \text{Equation (6)}$$

Where RME = Quantity of Methane emissions reduced in Kg of CO_2 equivalent

E_{W1} = Methane emissions for wood stove user per HHs (Kg of CO_2 equivalent)

E_{W2} = Methane emissions for biogas stove user per HHs (Kg of CO_2 equivalent)

iii) To examine how the use of biogas contributes to household livelihoods improvement

Comparison was made on increase or decrease in occurrence of diseases such as eye problems, coughs, chest pains, diarrheal diseases, and headaches before and after installation of biogas among biogas stove user households. An inquiry was done among biogas user households on how much money was saved for not buying mineral fertilizers based on estimates from previous years' expenditure. Time saved (minutes per day per HH) was found by estimating the time saved from firewood collection, cooking and utensil cleaning after biogas installation among biogas stove user households.

3.2.7 Data analysis

The units of analysis were households of dairy cattle farmers. Survey results of different variables in the data set were tabulated during data entry and data cleaning. A coding framework was developed consisting of list of codes used to index data from descriptive responses of questions asked during the survey. The framework labeled and defined values of data. Collected data was entered into spreadsheet using Microsoft Excel computer program and coded. Coding involved reducing the data to numbers. The coded data was exported into computer software program of Statistical Package for Social Sciences version 20.0 for processing. Categorical data included stove user type, gender, diseases status and biogas digester status. Numerical data included mass of woodfuel usage, length of time for turning on biogas and capacity of biogas. Level of measurements such as nominal, interval, ratio or ordinal for quantitative and qualitative data were identified.

Categorical data classified all observations into categories which were summarized by determining how times a category occur. For gender as variable, the number of females who participated in the study was described as the frequency of females among the respondents. Such information was presented using a frequency table. Frequency distribution is organized table of the number of individual respondents are in each category. This helped to know how many observations are in each category and spread of the observations. Status of diseases and biogas digester were presented as proportion or percentages of the total respondents. Proportion is the relative frequency of each category and was computed by dividing each frequency by the total number of respondents. Percentage distribution table showed the proportion of respondents who are represented within each category. Percentages were calculated by multiplying the proportion by 100. Mean and standard deviation were used to describe numerical data. The percentages were used to construct bar graphs and pie charts. Mean woodfuel usage of wood stove HHs was calculated by adding up all the observations of woodfuel usage and then divided by the total number of HHs using wood stove. Standard deviation showed the average difference between each individual woodfuel usage and the mean woodfuel usage. If all data points are close to the mean, then standard deviation is low showing that there is little difference between values. A large standard deviation shows that there was large spread of data.

Quantitative analysis involved generation of generalizable data to establish cause-effect relationships while qualitative analysis entailed studying the experiences, attitudes, opinions, behaviours and reasons behind them. Descriptive statistics was used to describe the collected data in terms of frequency, percentages, mean and standard deviation. Content analysis was used to analyze qualitative data that is respondent's understanding of climate change. Inferential statistics was used to identify statistically significant difference between two groups of data that is woodfuel stove user and biogas stove user households using Levene's test and t-test. Using Statistical Package for Social Sciences software for computing independent sample test of comparing means, Levene's test for equality of variance has the t-test assumption which states that variability of each group is approximately equal. If the p-value of Levene's test was less than or equal to α level for the test(0.05), then the null hypothesis was rejected that is the variability of the two groups is equal implying that the variances were different. When the significance is less than or equal to the α level, then use the row labeled "Equal variances not assumed". When the p-value is greater than α level, then use the row labeled "Equal variances assumed". Quantitative analysis involved the test of hypothesis using t-test. The t-test was used to determine whether or not the average of the two sample groups of stove user HHs was statistically significant. The t-test for equality of means table had columns labeled "t", "df", "Sig.(2-tailed)", "mean difference" and "95% confidence interval of difference" that indicated the observed or calculated t-value, degrees of freedom, two tailed p-value associated with t-test respectively. When p-value was less than or equal to α, then the null hypothesis was rejected which implied that the difference was significant in the woodfuel usage between wood stove and biogas stove user HHs. When p-value was greater than or equal to α, then the null hypothesis was accepted which implied that there was no significant difference in woodfuel usage between the wood stove and biogas stove user HHs.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

This chapter provides summary of results and discussions for the research that was done in Nakuru County. A total of one hundred and twenty one (121) dairy cattle farmers households; 59 biogas stove users and 62 wood stove users were sampled during the study from 5 Sub Counties.

4.1 Demographic information of respondents

Demographic information of the dairy cattle farmers included gender, age, education level and duration of stay in the area of study. Table 2 shows majority of the respondents were female; 66.9% and male were 33.1%. The study focused on biogas which is a cooking fuel associated with female respondents since they are in charge of cooking and males were less interested.

Table 2: Distribution of the respondents by gender

Type of gender	Number of respondents	Percentages of respondents
Male	40	33.1
Female	81	66.9
Total	121	100

Source: Author, (2018)

Most respondents (43.8%) were in the age bracket of more than 60 years. For the age brackets of 51-60, 36-50 and 18-35 years were 30.6%, 16.5% and 9.1% of the respondents respectively as indicated in Figure 4. Respondents who were more than 60 years owned land and biogas plants.

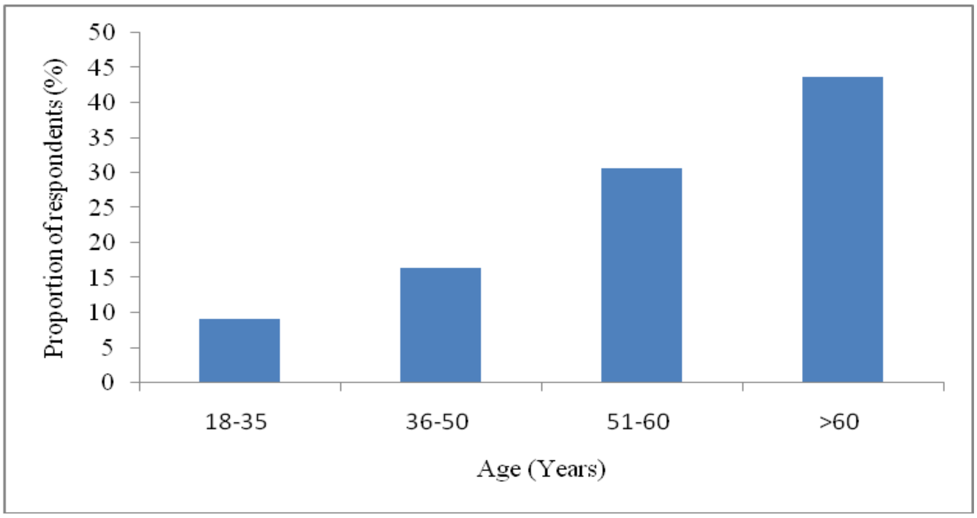

Figure 4: Distribution of respondents by age (Source: Author, 2018)

Majority of the respondents (43.8%) had secondary level of education, next levels were primary education (38.8%), no formal education (4.1%) and finally those with University degree (3.4%) as shown in Figure 5. Most of the respondent (82.6%) were able to read and write as they had primary and secondary education.

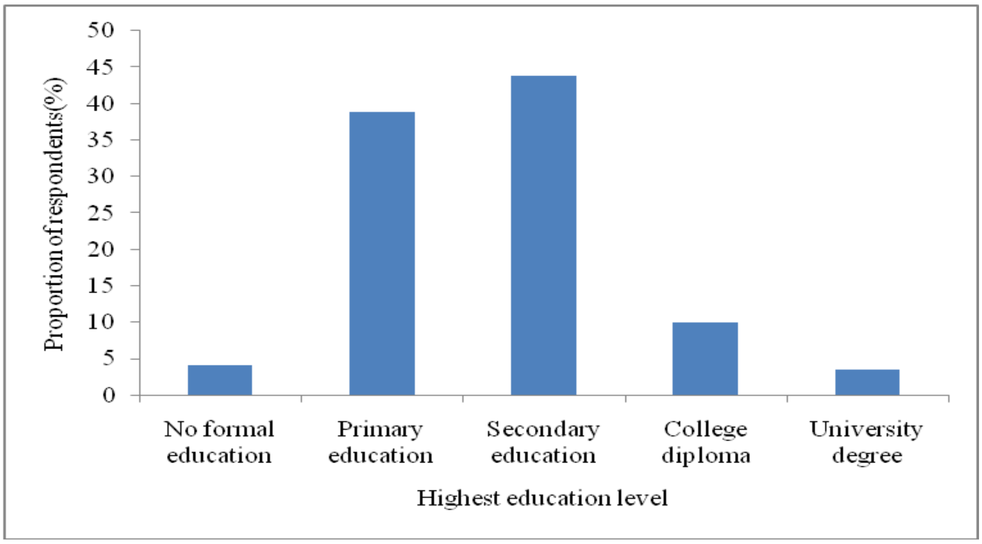

Figure 5: Distribution of respondents by highest level of education (Source: Author, 2018)

With regards to how long the respondents have stayed in the area of study, majority of them (44.2%) have stayed in the area of study for more than 30 years. For durations of 21-30 years, 5-10 years, 11-20 years and less than 5 years of stay were 22.5%, 15.8%, 14.2% and 3.3% of the respondents respectively as in Figure 6. Most of the information collected was from respondents with more than three decades experience. They were able to give accurate view on how climate has changed over the last 30 years.

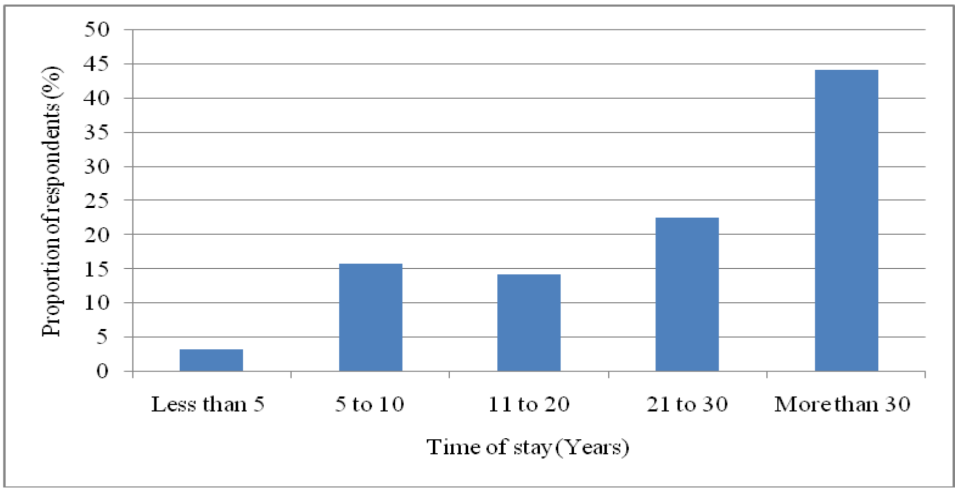

Figure 6: Distribution of respondents by duration of stay in the area of study (Source: Author, 2018)

4.2 Household Characteristics

Details of household characteristics comprised of marital status of HH head, HH head type, sources of livelihoods, people cooked for in the HH and livestock numbers per HH are shown in Figures 7 to 10 and Table 3. Majority of the respondents were married (90.8%) while singles were 9.2 % as indicated in Figure 7. Biogas installation is a long term investment which requires the adopters to be people who have long term perspective.

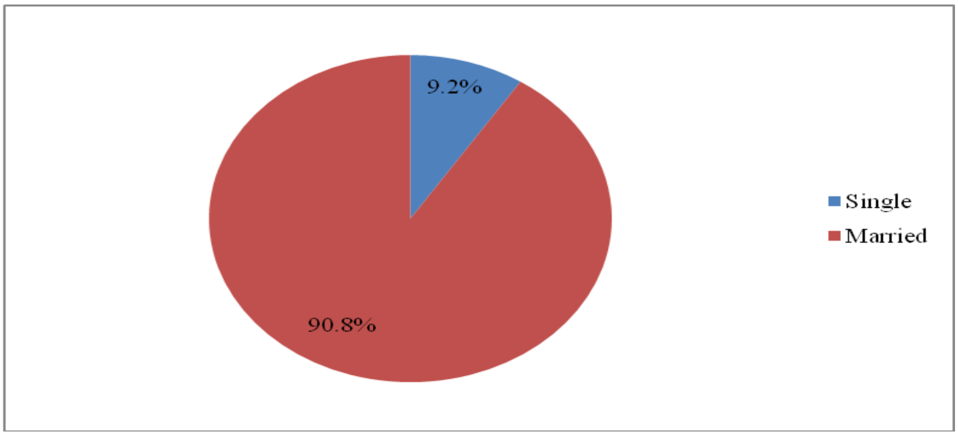

Figure 7: Distribution of respondents by marital status of HH head (Source: Author, 2018)

Male headed HH type (80.8%) was more dominant in the study area than female headed HH type (16.7%).Also there were HHs who were child headed(2.5%) as in Figure 8. Male headed HH type was dominant in the study area because the culture of the respondents accepts patriarchy type of HH leadership.

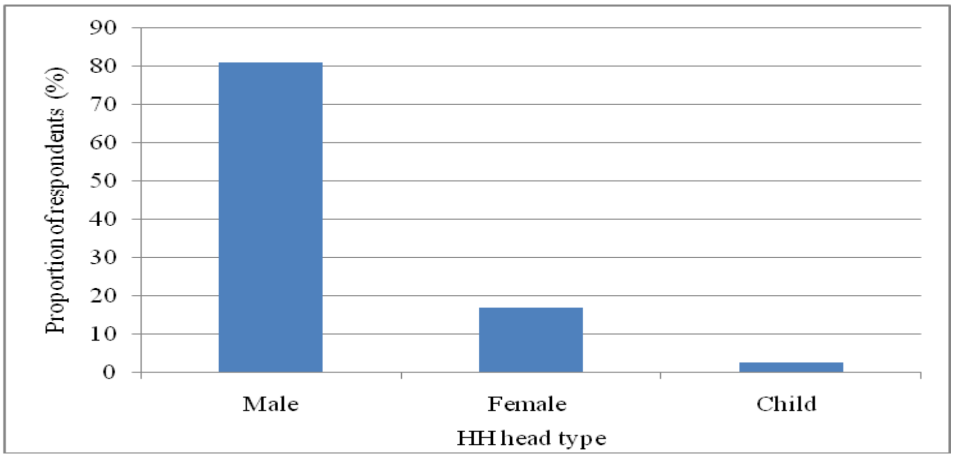

Figure 8: Distribution of HH head by type (Source: Author, 2018)

With regards to sources of livelihoods, majority of the respondents (84.4%) were occupied by farming while public service, trading, private sector and waged labour contributed 8.2%, 4.4%, 1.5% and 1.5% respectively as shown in Figure 9. The area of study has equatorial type of climate which receives bimodal rainfall distribution and has fertile soil favourable for crop and livestock farming.

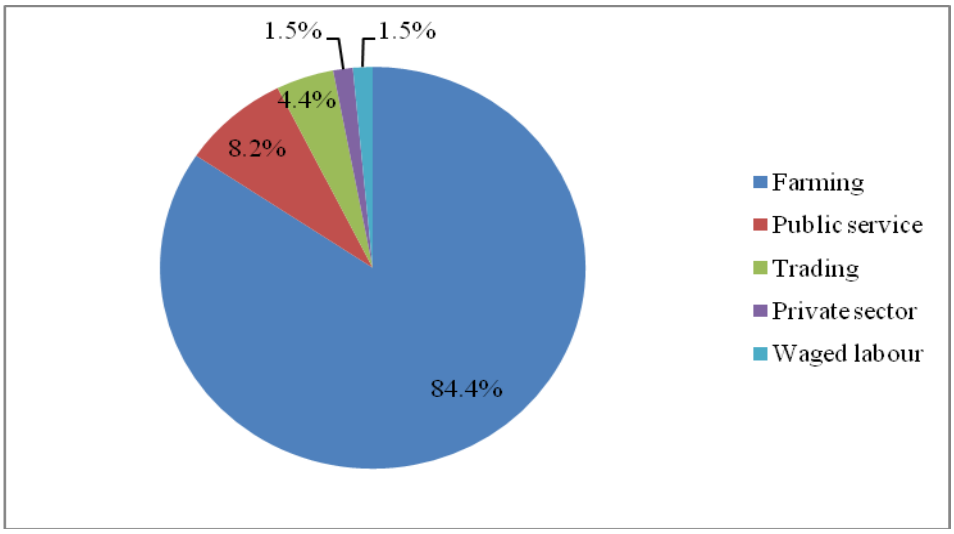

Figure 9: Distribution of livelihood sources of respondents (Source: Author, 2018)

The Figure 10 shows that most HHs (22.8%) cooked food for 3 people. It was followed by 4 people (17.5%), 2 people (16.7%), 5 people (15.5%), 6 and 7 people (11.4% each) and 8 people (2.6%). The least of the respondents cooked for 1 person and 10 people at 0.9% each. Most respondents had small family to cook for. Other members of the family were away in schools or work in distant places.

Figure 10: Distribution of number of people cooked for in the HH of respondents (Source: Author, 2018)

In Table 3, the respondents kept an average of 4 cattle per HH which is more than the least requirement of 2 cattle for installing a biogas digester. Each HH had an average of 6 sheep and goats. 429 cattle produced 1,565,850-2,348,775 Kg of cow dung which translated to estimated production of 37,580.4 – 1,409,265 M^3 of biogas annually. 60 % of total annual dung production was available for biogas production as majority of respondents practiced semi-intensive stall feeding. The livestock waste from cattle and goats/sheep was 1,709,568.7-2,540,400 Kg annually producing 45,419.6 – 141,971.27 M^3 of biogas annually.

Table 3: Estimates of dung and biogas production

Type of livestock	**Average herd size (Livestock /HH)**	**Total Number of livestock**	**Daily dung production per animal(Kg)**	**Annual dung production (Kg)**	**Annual biogas production(M3)**
Cattle	3.94	429	10 - 15	1,565,850 - 2,348,775	37,580.4 – 1,409,265
Sheep / Goats	5.77	525	0.75 - 1	143,718.75 -191,625	7,839.2 -10,452.27
Total		954		1,709,568.7- 2,540,400	45,419.6 – 141,971.27

Source: Author (2018)

4.3 Fodder and pasture production

The fodder and pasture production yields decreased slightly as noted by 35% of the respondents over the last 10 years. A proportion of 23.3%, 20.8%, 10.8% and 10.1% of the respondents noted that the yields of fodder and pasture had increased slightly, decreased significantly, no change and increased significantly respectively as presented in Figure 11.Slightly decreased fodder and pasture yields over the last 10 years pose a challenge to availability of feedstock for biogas production. Adequate feedstock can only be assured through supplementary feeding of the livestock at additional costs.

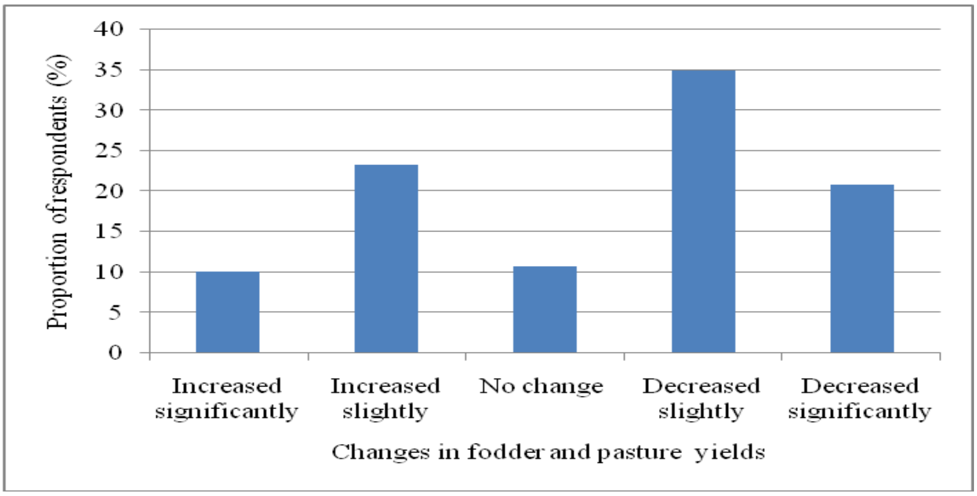

Figure 11: Changes in fodder and pasture yield over the last 10 years (Source: Author, 2018)

Respondents attributed unreliable rainfall (47.6%), increased knowledge on fodder and pasture production (35.2%), low knowledge on fodder and pasture management (8.6%) and Others reasons (4.7%) and poor soil fertility (3.9%) to changes in fodder and pasture yields respectively as shown in Figure 12. Other reasons stand for reduced land for pasture production and high cost of fodder production inputs. Rainfall has become a limiting factor in fodder and pasture production since its pattern has changed to erratic and unpredictable. This has been due to cutting down of trees in the forests and climate change.

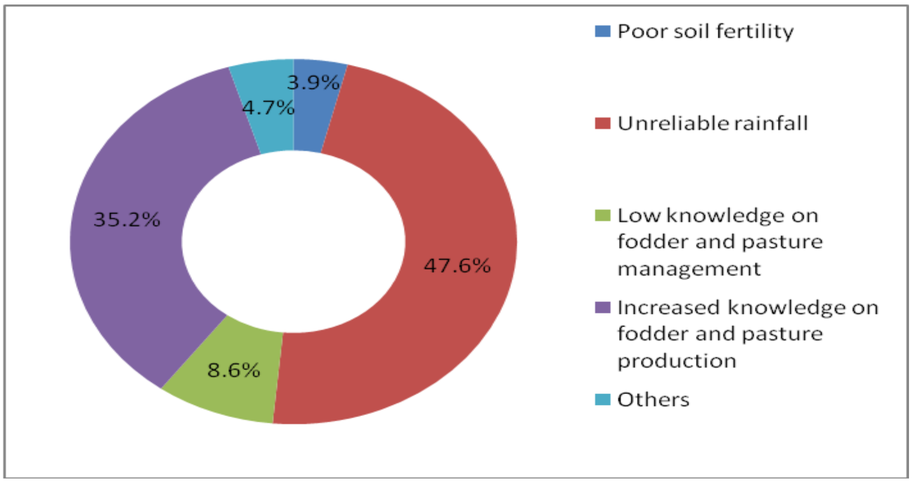

Figure 12: Reasons attributed to changes in fodder and pasture yields (Source: Author, 2018)

4.4 Energy resources utilization

This subsection presents analysis on sources of energy, sources of woodfuel, reasons for using woodfuel as source of energy, sizes of biogas digesters, status of biogas plants, cost of biogas digesters, reasons for using biogas fuel as source of energy, and assessment on the effect of biogas technology in the households. The most used sources of energy among the respondents was woodfuel (35.5%), followed by grid electricity (24.5%), biogas (18.2%), Liquid Petroleum Gas (12.9%), solar (8.3%) and other sources (0.6%) as shown in Figure 13. Other sources were maize cobs and kerosene. The use of woodfuel contributes to deforestation and consequently to climate change. The use of biogas among the respondents was low and it should be up-scaled so as to combat climate change.

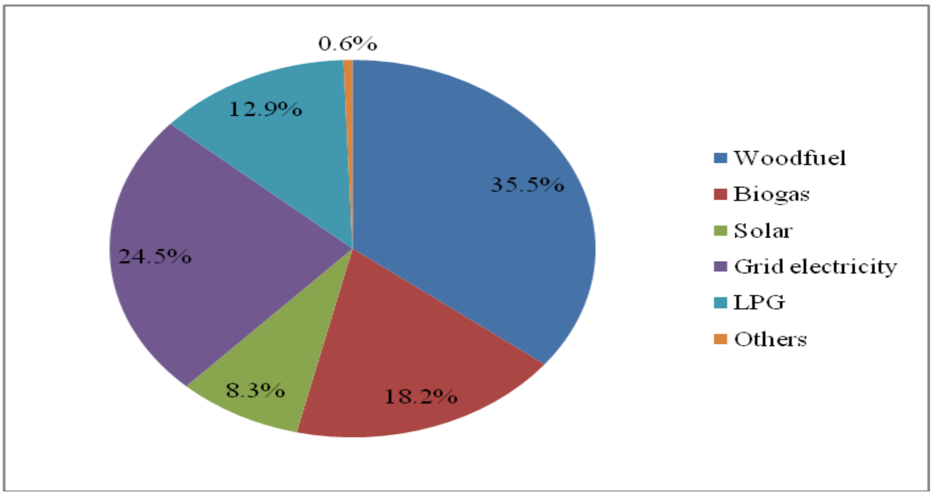

Figure 13: Distribution of energy sources among respondents (Source: Author, 2018)

Majority of the respondents (73.7%) got their woodfuel from farm forests. Also respondents sourced woodfuel from market (21.2%), other sources (4.2%) and private forest (0.9%) as shown in Figure 14. Other sources included sawmills and timber yards. Most respondents sourced woodfuel from farm forests indicates that dairy cattle farmers' HHs practiced afforestation and reforestation. The most common tree species planted in the area of study for woodfuel production were *Eucalyptus spp*, *Cypress spp* and *Grevillia spp.*

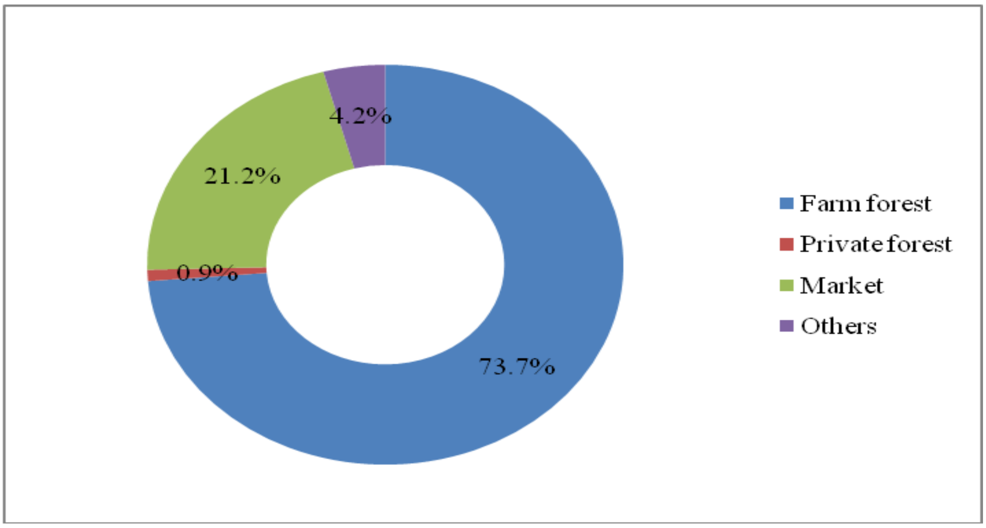

Figure 14: Distribution of woodfuel sources for HHs (Source: Author, 2018)

Woodfuel was available locally and that is why most respondents (53.2%) preferred it as source of energy for cooking and heating. 26.2%, 16.6% and 4% of respondents used woodfuel because it is available at no cost, other alternatives are expensive and packed in small quantities that can be easily purchased respectively as shown in Figure 15.Woodfuel was locally available because most of the respondents got it from their farm forests. The benefit of planting trees is that respondents did not have to travel long distance to fetch firewood.

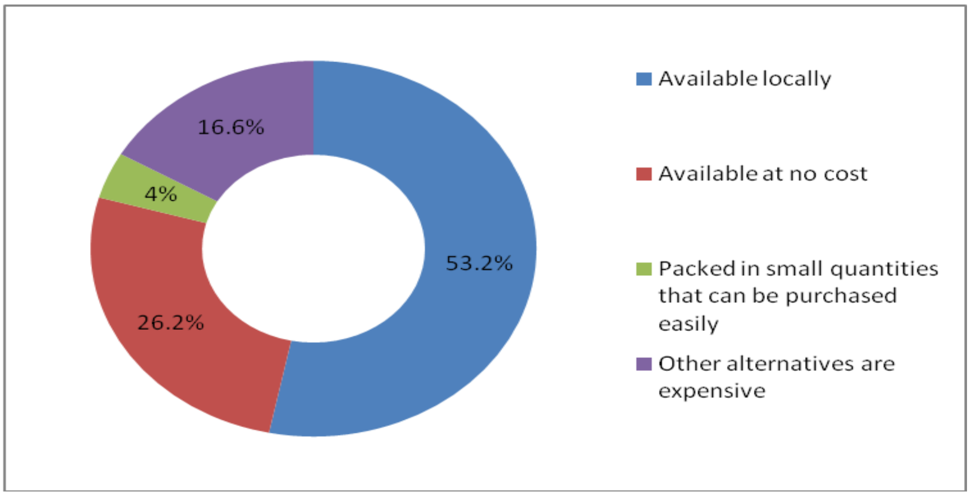

Figure 15: Reasons for using woodfuel as source of energy by respondents (Source: Author, 2018)

Most respondents (25.5%) had installed biogas digester of size 8 M^3 compared to other sizes such as 10 and 6 M^3 (15.7% each), Others M^3 (14%), 4 M^3 (9.7%), 12 and 16 M^3 (7.8% each), and 14 M^3 (3.8%) as presented in Figure 16. Other sizes included 5, 9, 21, 35, 50, 75 and 90 M^3.The size 8 M^3 was the most installed size because the HHs had an average herd size of 4 cows. The most common type of digester installed by the farmers was fixed dome biodigester. The average cost of installing biogas digester was Ksh.84, 362.07 with minimum cost of Ksh.40, 000 and maximum cost of Ksh.250, 000.

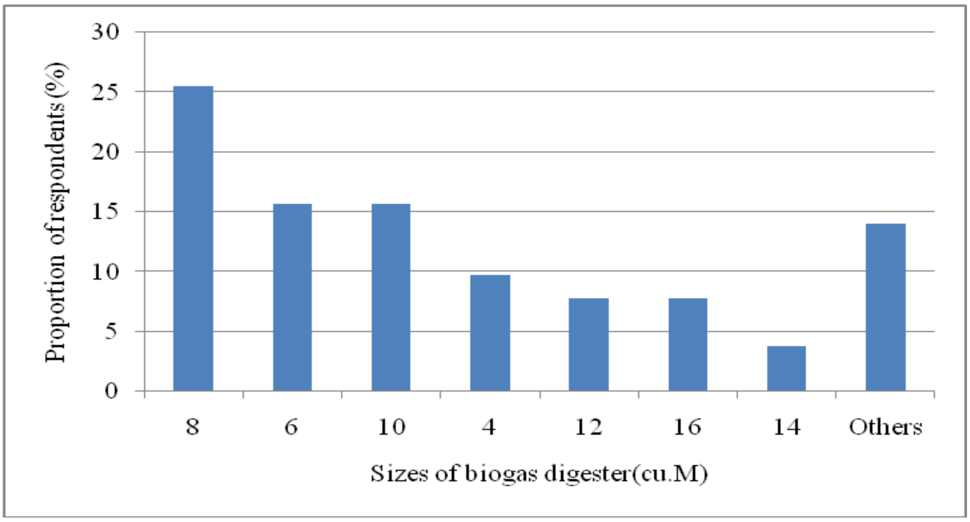

Figure 16: Distribution of biogas digester sizes by capacity (Source: Author, 2018)

Figure 17 shows most of the respondents (93.1%) had their biogas digester functioning while 6.9% had no functioning digesters.

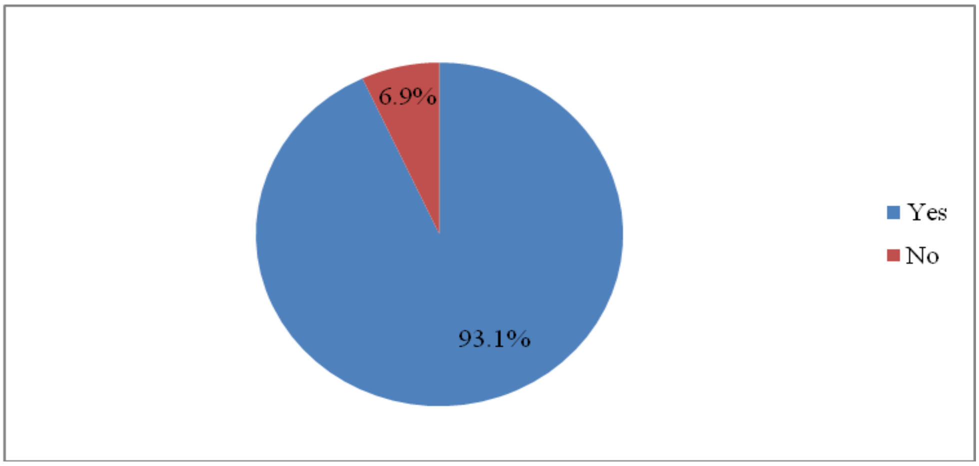

Figure 17: Distribution of the state of installed biogas digesters in the area of study (Source: Author, 2018)

Most respondents (30.8%) were using biogas fuel because it was cheaper than other fuels. Other respondents preferred biogas fuel since it makes kitchen more hygienic (22.3%), has little operation expenses (20.8%), reduced smoke (16.9%) and increases crop yield (9.2%) respectively as shown in Figure 18. If we spread the average cost of biogas plant say Ksh.84, 000 over 20 years, the farmer would be spending Ksh.4200 annually.

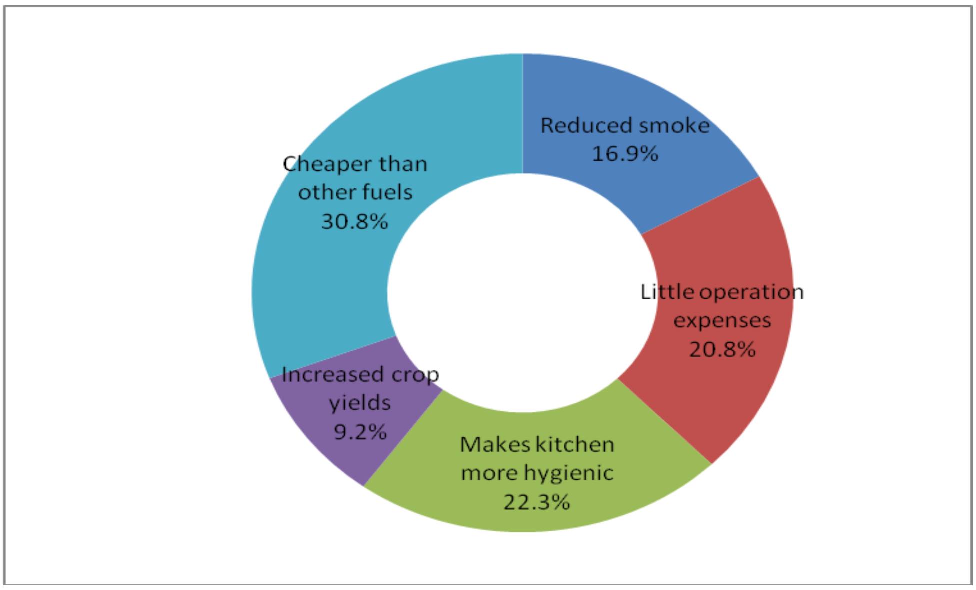

Figure 18: Reasons for using biogas fuel as source of energy for HHs (Source: Author, 2018)

Figure 19 indicates that respondents strongly agreed that in the HH, biogas technology reduced smoke related diseases (74.1%), saved money from not buying mineral fertilizers (55.2%), empowered women and children by saving time in cleaning utensils, cooking and not collecting firewood (55.2%). Also the respondents strongly disagreed (29.3%), agreed (27.6%), disagreed (15.5%), neutral (13.8%) and strongly agreed (13.8%) that biogas technology provided employment to the youths. Smoke related diseases include coughs, eye problems, chest pains and headaches. Mineral fertilizers such as DAP, CAN and MoP were not bought because respondents used bio-fertilizer from biogas digesters. Time was saved because women and children did not fetch firewood from distant forests since biogas fuel was available at their doorsteps. They also spend little time cooking and cleaning utensils because biogas fuel does not form black soot on the utensils. Biogas plants provide employment to the youths as sale persons, artisans and caretakers of the bio-digesters.

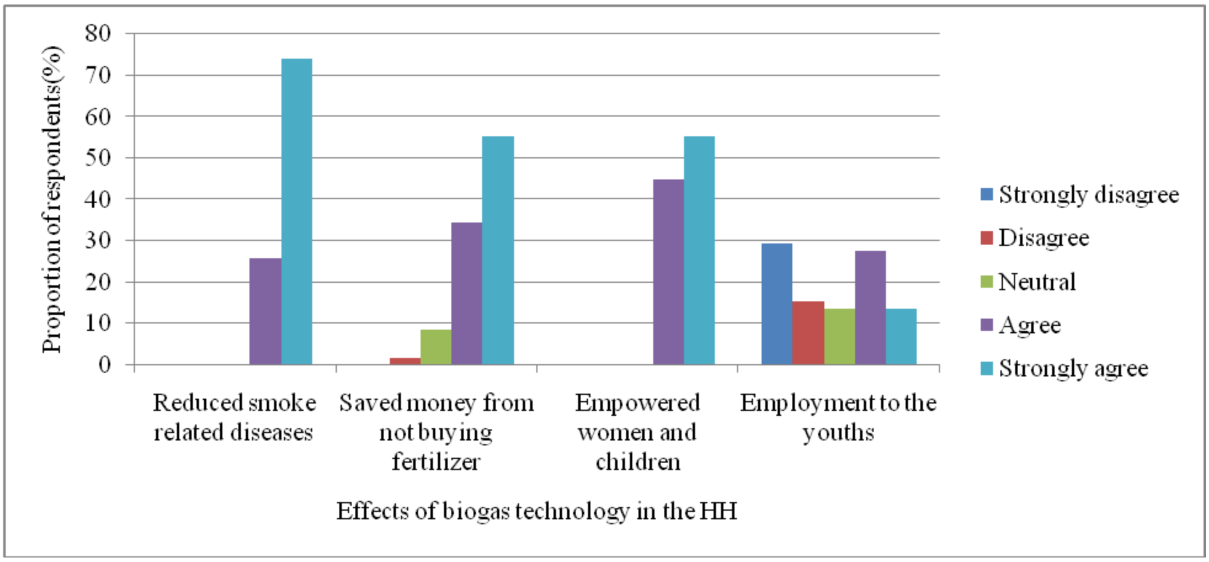

Figure 19: Assessment on the effects of biogas technology in the HH (Source: Author, 2018)

4.5 Climate change information

This subsection presents how respondents linked their understanding of climate change with precipitation variation showing whether or not the climate had been getting drier over the last 10 years and the effects of changes in climate on their lives. In Figure 20, the respondents understood climate change as any change in pattern of weather, seasons or drought (52.1%), variations in mean of rainfall and temperature (29.4%), attributed to human activities such as production of gases that alter global atmosphere (13.5%) and cause emerging diseases and pests (5%). The respondents were not aware of what is climate change. According to International Panel on Climate Change, climate change is a shift in the state of the climate that can be identified by changes in the mean and/or the fluctuations of its properties and persists for decades or longer (IPCC, 2013).The respondents were not aware of what is climate change but knew consequences of climate change.

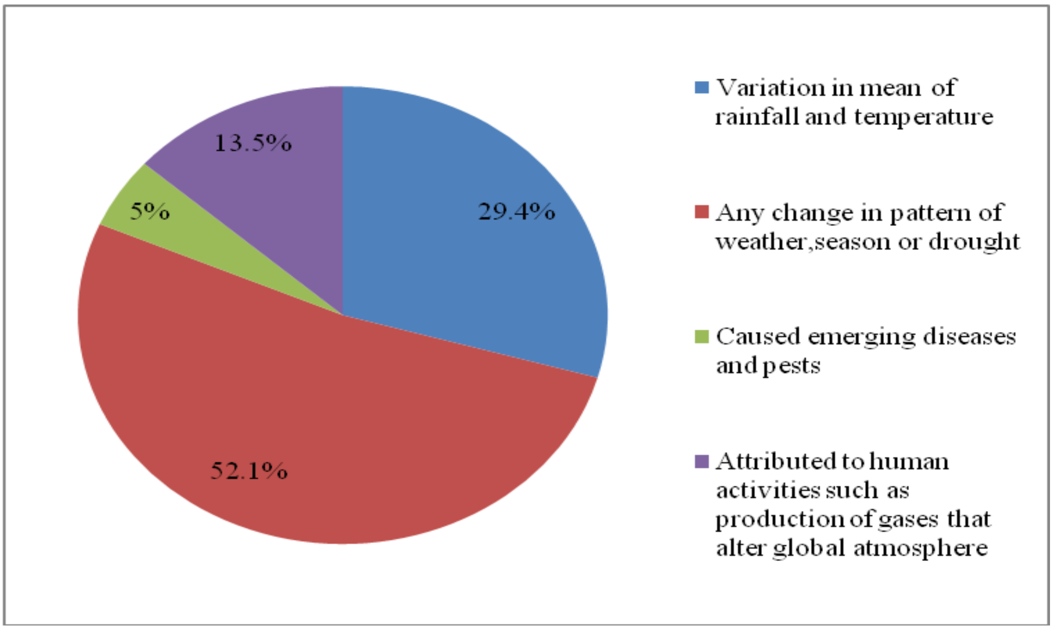

Figure 20: The meaning of climate change among the respondents (Source: Author, 2018)

Figure 21 indicates that 75% of respondents had noted that climate has been getting dry, 12.5% very dry, 7.5% not dry, and 5% extremely dry over the last ten years. With climate getting dry over the last years, the area of study had been experienced increased surface temperatures. Increased surface temperatures are associated with global warming and climate change.

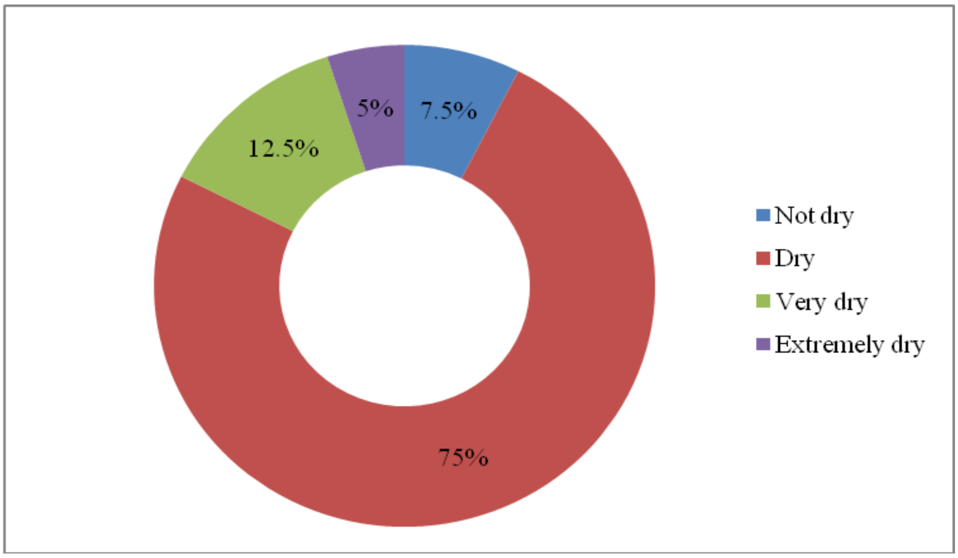

Figure 21: Distribution of respondents by dryness in the area of study over the last ten years (Source: Author, 2018)

According to the findings of this study, the respondents noted that the climate has been getting dry over the last 10 years thus affecting them by causing less feed for livestock (36.4%), less water (34.8%), less food for household (22.8%), loss of livestock (4.8%), other effects (0.8%) and death of people (0.4%) as shown in Figure 22. The most important effect of change in climate was shortage of livestock feeds which affects the livelihood of the respondents; livestock production. Dry conditions were not favourable for fodder and pasture production because high evapo-transpiration reduced soil moisture for plant growth.

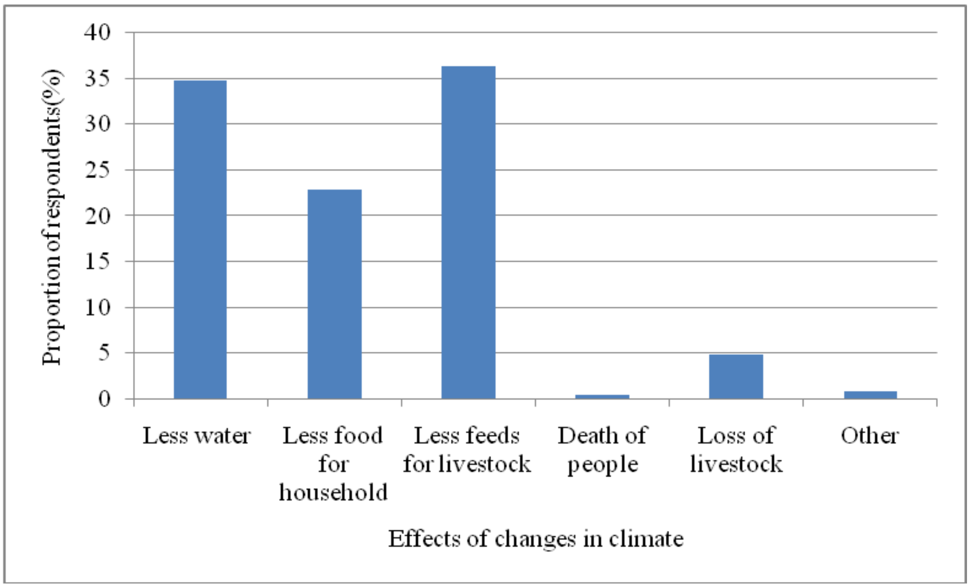

Figure 22: Distribution of respondents by effects of changes in climate (Source: Author, 2018)

4.6.1 Results for determination of quantity of woodfuel and biogas used by households

The average annual woodfuel usage per household for wood stove user HHs was 7,314.5 Kg while for biogas stove user HHs was 3,415.1 Kg. The average quantity of woodfuel usage for both wood stove and biogas stove user HHs was 5,481.4 Kg/year as shown in Figure 23. The sustainable supply of woodfuel from forests was 5,364.8 Kg/HH/year which resulted to a shortfall of 116.6 Kg/HH/year compared to average demand.With average annual woodfuel usage of 7314.5Kg, each wood stove user HHs cut down 14.1 mature trees per year.The average annual woodfuel usage for biogas user HHs of 3415.1Kg translated to cutting down of 6.6 mature trees per HH per year. Both wood and biogas stove user HHs cut down 10.5 mature trees/HH/year from forests for woodfuel production.The forests sustainably supplied 10.3 mature trees/HH/year.The average weight of woodfuel from mature tree was estimated as 520.6 Kg (Chand *et.al*., 2012).Woodfuel production was not sustainable as forests were harvested unsustainably by the HHs. The quantity of biogas used per biogas stove user household was 481.6 M^3 per year.With average methane content in biogas being 60%, each biogas stove user HH destroyed 228.6 M^3 of Methane during cooking and heating annually. Biogas stove user households used 26,487.5 M^3 per year of renewable energy from livestock manure management.

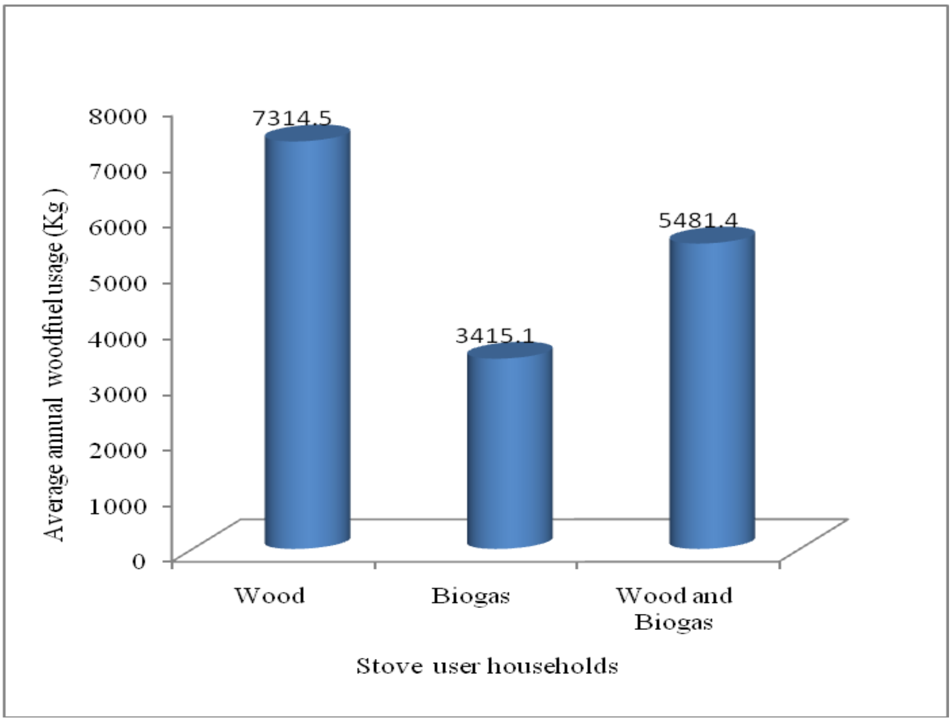

Figure 23: Annual average woodfuel usage by type of energy sources (Source: Author, 2018)

4.6.2 Results for estimation of reduced quantity of woodfuel usage and methane emissions from biogas use in mitigating climate change

The 62 wood stove user households sampled had average annual mass for woodfuel usage of 7314.5 Kg/year with standard deviation of 6217.1. The 55 biogas stove user households sampled had average annual mass for woodfuel usage of 3415.1 Kg/year with standard deviation of 2755.3. The wood stove user households had higher average woodfuel usage than biogas stove user households. The reduced quantity of woodfuel caused by use of biogas was estimated from the difference between average amount of wood fuel consumed by wood stove user and biogas stove user households.

Reduced Woodfuel Usage =7314.5-3415.1(Kg/HH/year)

=3899.4 Kg/HH/year

Woodfuel usage reduced by production and use of biogas was estimated as 3899.4 Kg/HH/year.

The t-test performed on average woodfuel usage of wood stove user HHs and biogas user HHs showed that the difference was highly significant at 95% confidence level. The two tailed p-value associated with the test was 0.000 implied that the difference in averages of the two type of stove users HHs was highly significant at 0.05 level. The use of biogas reduced significantly the quantity of woodfuel usage in wood cooking stove among the dairy cattle farmers' HHs of Nakuru County. The confidence interval was 2164.8 to 5634. Assuming variances are not equal, the t-value was 4.47. There were 86 degrees of freedom associated with the t-test.

The households used woodfuel which contributed to emissions of Methane. For wood stove user HHs, the quantity of Methane emissions produced in Kg of CO_2 equivalent from burning of woodfuel was computed.

$$E_{W\,1} = \frac{1}{62}\sum_{i=1}^{62} 453497.76\,((0.006 \text{ to } 0.01) \text{ x}28)$$

$$= 7314.48(0.006\text{-}0.01) \text{ x } 28$$

$$= 1228.83 \text{ to } 2048.05 \text{ Kg}CO_2\text{e}$$

For the biogas stove user HHs, methane emissions produced was calculated.

$$E_{W\,2} = \frac{1}{55}\sum_{i=1}^{55} 187829.95\,((0.006 \text{ to } 0.01) \text{ x}28)$$

$$= 3415.09(0.006\text{-}0.01) \text{ x } 28$$

$$= 573.74 \text{ to } 956.23 \text{ Kg}CO_2\text{e}$$

The quantity of methane emissions reduction resulting from biogas production and use was obtained by computing the difference in Methane emissions between wood stove user and biogas stove user HHs.

Reduced Methane Emissions = (1228.83 to 2048.05 KgCO_2e) – (573.74 to 956.23 KgCO_2e)

$= 665.09$ to 1091.82 $KgCO_2e/HH/year$

The saved woodfuel usage of 3899.4 Kg/HH/year due to use of biogas fuel has reduced methane emissions by 665.09 to 1091.82 Kg of CO_2 equivalent per HH per year which were to be emitted to the atmosphere as indicated in Table 4.

Table 4: Annual Woodfuel usage and methane emissions per HH

Woodfuel usage for Wood stove user HHs (Kg/HH/year)	Woodfuel usage for Biogas stove user HHs (Kg/HH/year)	Reduced Woodfuel usage (Kg/HH/year)	Reduced Methane emissions ($KgCO_2e/HH/year$)
7314.5	3415.1	3899.4	665.09-1091.8

Source: Author (2018)

Figure 24 shows minimum and maximum methane emissions produced by different types of energy sources used by stove user HHs. Methane emissions production of 1228.83 and 2048.05 $KgCO_2e$ represented minimum and maximum quantity for wood stove user HHs respectively. For biogas stove user HHs, 573.74 and 956.23 $KgCO_2e$ represented minimum and maximum quantity of methane emissions produced respectively. Biogas stoves have significantly lower greenhouse effect to the climate system compared to the wood stoves. Biogas technology is one of the excellent strategy of reducing woodfuel induced greenhouse gases and global warming.

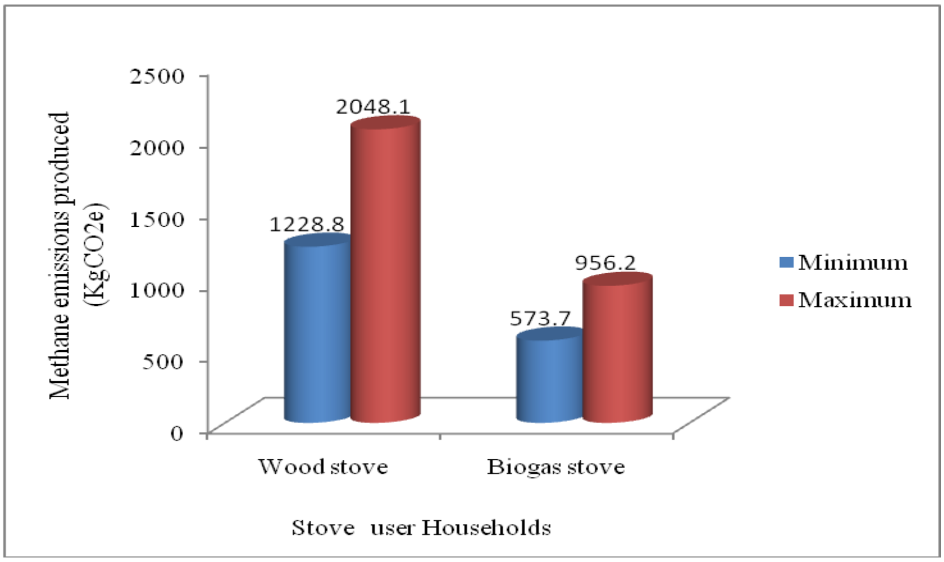

Figure 24 : Methane emissions production by type of energy source (Source:Author,2018)

The biogas digester provided clean renewable energy in form of methane rich biogas. Management of livestock waste through energy conversion of manure contributes to methane emissions reduction during heating of biogas fuel as methane is destroyed. One biogas digester was able to reduce methane emissions by 12.09 to 19.84 Kg of CO_2 equivalents per year. Reduced amount of methane emissions slows down the rate of global warming in the community and Kenya at large. From the study, biogas installation saved 7.5 mature trees /HH/year from being cut down for woodfuel production. The conserved trees provided additional annual carbon sink for 6433.99 to 7018.9 Kg of Carbon dioxide as 1 Kg of wood holds 1.65-1.8Kg of CO_2 (Kaltimber, 2017).Each HHs in the study area should practice afforestation by planting at least 8 trees per year so as to reduce deforestation and sequester carbon in form of conserved trees. This leads to enhanced climate change mitigation since methane emissions from woodfuel is avoided from reduced woodfuel usage and conserved trees in the forests increase the capacity of forests for carbon sink.

4.6.3 Results for examination of how the use of biogas contributes to household livelihoods improvement

Occurrence of diseases such as eye problems, diarrheal diseases, coughs, headaches and chest pains were reduced after installation of biogas. Proportion of respondents who noted decreased coughs, eye problems, headaches, chest pains and diarrheal diseases were 28.9%, 28.1%, 20.7%, 19% and 3.3% respectively as shown in Figure 25. Decreased coughs were highly recognized to have been caused by biogas installation and the least recognized was diarrheal diseases. There were reduced respiratory diseases due to improved air quality resulting from smokeless biogas use in the HHs. There were no pollutants associated with woodfuel combustion.

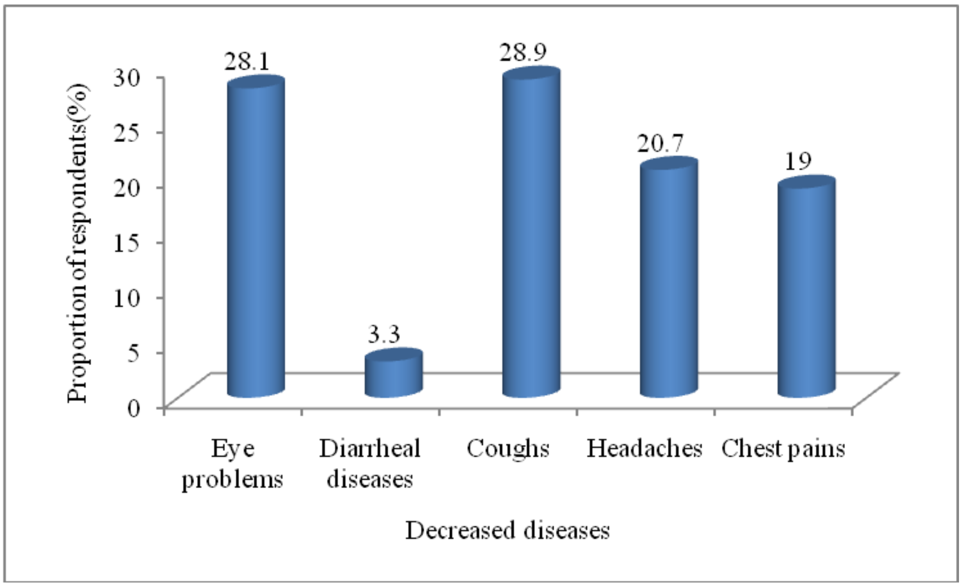

Figure 25: Distribution of respondents by decreased diseases after biogas installation (Source: Author, 2018)

Figure 26 shows majority of respondents used manure from their cattle to improve soil fertility by spreading on the farm (42.4%).They also used it for making biogas (40.4%) and making compost (17.2%). There should be increased capacity building of the respondents on the use of manure to make biogas because biogas production does not only provide biogas fuel but also produces bio-fertilizer for soil fertility improvement.

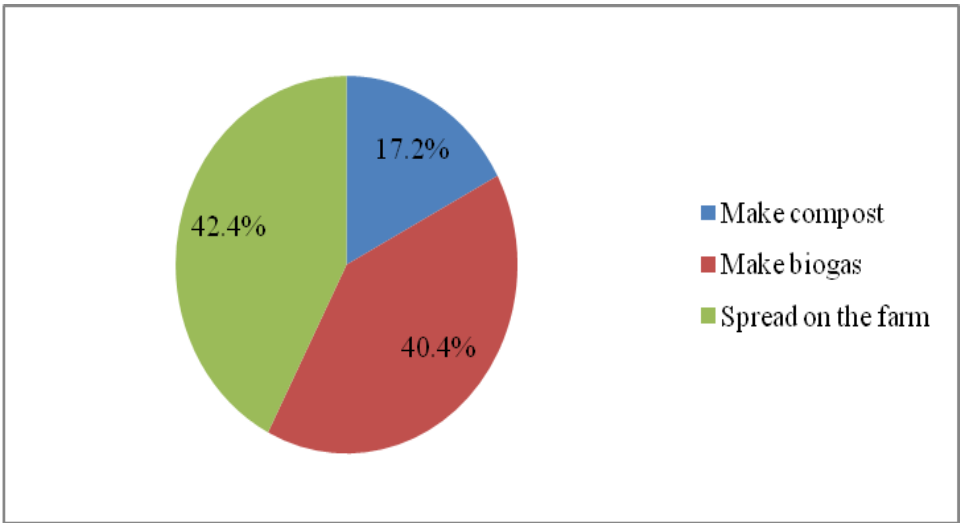

Figure 26: Distribution of respondents by use of manure (Source: Author, 2018)

Figure 27 indicates that the respondents utilized bio-slurry in their croplands (38.7%), kitchen garden (26.9%), others (19.4%) and vegetable farm (15.1%).Others fields where bio-slurry was utilized included Napier grass field, Boma Rhodes field and bananas plantation.

Nitrogen, Phosphorus and Potassium content in bio-slurry are 0.014, 0.011 and 0.008 Kg per Kg dry weight (Pathak *et.al.*, 2009). Money was saved from not purchasing chemical fertilizer (DAP, CAN or MoP) as manure from the cattle was spread on the farm and bio-slurry from biogas digester was used in the croplands. Money saved from not buying mineral fertilizer was estimated as Ksh.3, 539.00 per HH per planting season. The minimum and maximum money saved was Ksh.400 and Ksh.18, 000 per HH respectively.

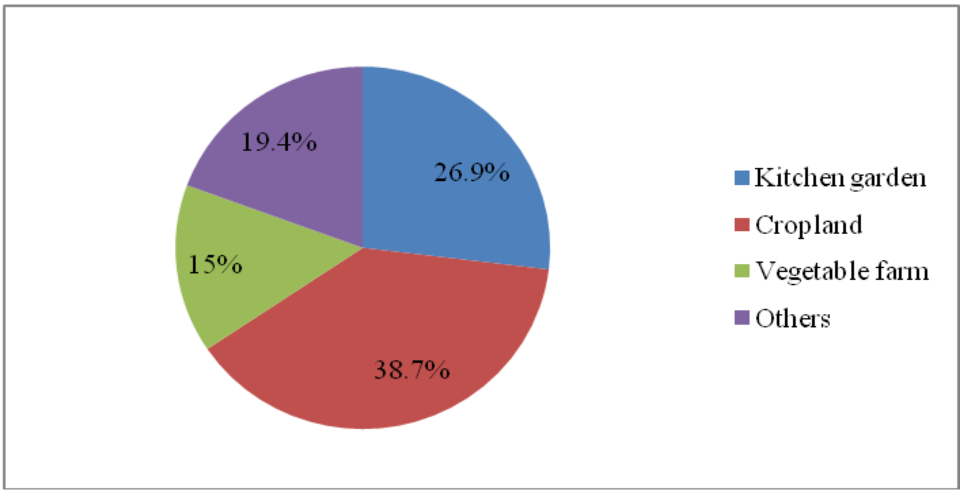

Figure 27: Proportion of respondents by utilization of bio-slurry (Source: Author, 2018)

Table 5 shows the time saved from various types of domestic chores. The time saved from installation of biogas was 3 hours and 40 minutes per day per household. More time was saved from woodfuel collection (1 hour and 58 minutes) than from cooking or cleaning utensils.

Table 5: Time saved from domestic chores after installation of biogas

	Domestic chores	**Average time saved (minutes/day/ HH)**
a	Woodfuel collection	117.6
b	Cooking	61.7
c	Cleaning utensils	40.5
	Total	219.8

Source: Author (2018)

The time saved after installation of biogas was utilized by respondents in crop farming (29.9%), feeding livestock (26.5%), social and religious work (20.5%), cleaning the home (17.9%), child care (3.4%) and others (1.7%) as presented in Figure 28. Others stands for resting. Women and children were empowered as they utilized the saved time from firewood collection, cooking, utensil cleaning after biogas installation in crop farming, feeding livestock, and social and religious work according to their first, second and third priorities respectively.

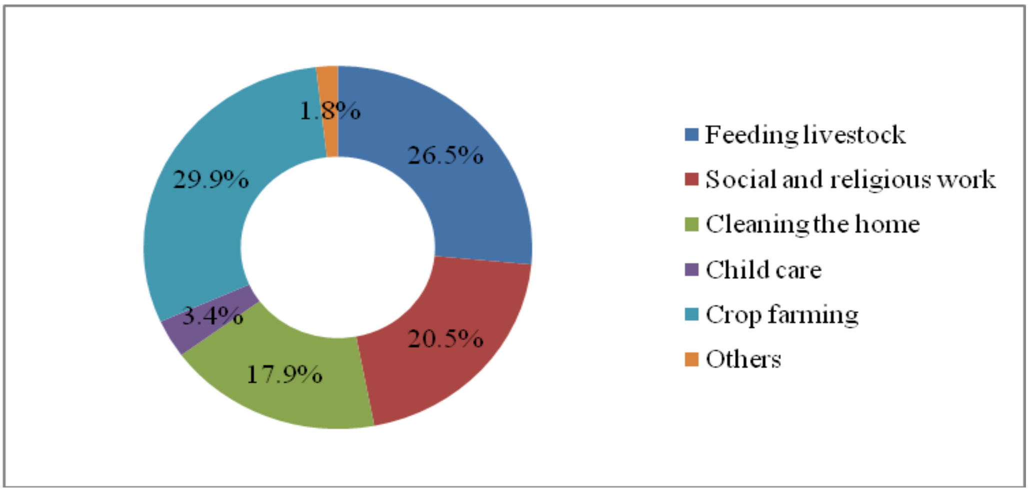

Figure 28: Distribution of respondents by utilization of saved time after installation of biogas (Source: Author, 2018)

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

This chapter presents conclusions and recommendations for the key findings

5.1 CONCLUSIONS

In Nakuru County, the average woodfuel usage for wood stove user HHs was 7314.5 Kg per year while for biogas stove user HHs was 3415.1 Kg per year. Wood stove user HHs used higher amounts of woodfuel per year than biogas stove user HHs by 53.3%. The supply of woodfuel in the study area was found unsustainable by 0.02% per HH per year hence the households harvested the forests unsustainably. The average woodfuel usage for both wood and biogas stove user HHs was 5481.4 Kg per year which resulted to 10.5 mature trees/HH/year cut down for woodfuel production. 10.3 mature trees per HH per year were supplied sustainably by forests. The use of biogas reduced woodfuel usage by 53.3% which saved 7.5 mature trees per HH per year from being destroyed. In the study area, 18.2% of the respondents used biogas fuel in the energy mix. The average biogas usage was 481.6 M^3 per HH per year. The biogas stove user HHs destroyed 228.6 M^3 of Methane per year during cooking and heating. Biogas use promotes clean energy production at HH level by recycling livestock wastes. Therefore upscale in adoption of biogas use in the County would translate to enhanced tree cover of 72.8 % in the County. Enhanced tree cover will bring more rains and increase capacity of forests to absorb Carbon dioxide hence slows down the rate of global warming and climate change.

The study revealed that due to biogas utilization, there was reduction in woodfuel usage by 3899.4 Kg per HH per year. This reduction of HH fuel saved 53.3-54.1 % of Methane emissions from HH per year from being emitted into the atmosphere. The study found that a biogas digester reduced 12.09 to 19.84 Kg CO_2 equivalent of Methane emissions per year from biogas stove and fuel. The biogas utilization is important strategy to save our forests and reduce methane emissions in combating climate change. Reduced woodfuel usage allowed reduction of methane emissions and delayed depletion of 7.5 mature trees per HH per year from forests hence contributing to mitigating climate change. Due to these conserved trees, the forests increased their capacity to absorb Carbon dioxide by 72.7% per year. Mitigation of climate change also involved reduction of methane emissions through direct destruction of 228.6 M^3 during heating of biogas fuel.

The study addressed livestock manure management using biogas technology by converting manure into methane rich biogas which has been used as source of energy for cooking and heating, reduced cost of fertilizer and has many socio-economic impacts. The percentage of members in biogas stove user HHs with woodfuel smoke related diseases had reduced. There was considerable time saved after installation of biogas and the saved time was utilized in crop farming. The livestock wastes from cattle and small stock was 1,709,568.7-2,540,400 Kg annually producing 45,419.6 – 141,971.27 M^3 of biogas annually. Bio-slurry application to agricultural crops from biogas production was cost effective. On average each biogas stove user HH saved Ksh.3539.00 per planting season from not buying mineral fertilizer. The application of bio-fertilizer avoids the use of nitrogenous fertilizers which are the source of nitrous oxide, powerful greenhouse gas. Biogas utilization has reduced the source of greenhouse gases hence climate change mitigation has been achieved. The slightly decreased fodder and pasture yield over the last years was attributed to unreliable rainfall. The climate has been getting dry leading to shortage of livestock feeds hence livelihood of the respondent; livestock production was affected. Livestock wastes from cattle provide greater potential of bioenergy due to lower cost of biogas in the long term. Biogas utilization has contributed to climate change mitigation by reducing Methane (greenhouse gas) emissions from woodfuel, destroying Methane during burning of biogas fuel, increasing the capacity of conserved forests to absorb Carbon dioxide from the atmosphere and avoiding nitrous oxide emissions from nitrogenous fertilizers.

5.2 RECOMMENDATIONS

- There is need to improve understanding of the contribution of woodfuel and Methane emissions to climate change at all tiers of Government; National and County Governments. This can be achieved through conducting trainings and seminars in all counties of Kenya.

- Awareness creation on benefits and problems associated with conventional fuels, unconventional fuels and biogas in the context of climate change should be done.

- To promote the shift from unsustainable energy to green energy sources, we need to upscale biogas development through anaerobic digestion of livestock wastes.

- Woodfuel is becoming scarce and environmentally unsustainable, more attention should directed towards biogas production and utilization which is economically cheaper and does not pollute the global atmosphere.

- The biogas stove users HH generate biogas from cow dung. Farmers should be advised to practice climate smart fodder and pasture production so as maintain sustainable supply of cow dung.

- Government of Kenya through public private partnership should disseminate biogas technology to all levels of community, rural and urban areas of the 47 Counties.

- Stakeholders should find ways of reducing high initial cost of biogas installation.

- Future researchers should study the effects of acaricides on biogas production.

6.0 REFERENCES

Adhikari, B., Khanal, S.N., and Miyan, R. (2015). Quantitative Study of Biogas Generation Potential from Different Landfill Sites of Nepal. *Waste Technology,* Vol.**3** (**1**) 2015. doi:http://dx.doi.org/10.12777/wastech.3.1.1-6.p.1

Alvi, M.H. (2016). A manual for selecting sampling techniques in research. https://mpra.ub.uni-muenchen.de/70218/MPRA paper No.70218.p.11

Al-smairan, M., Al-Harahsheh, S., and Al-Khazaleh, H, H. (2015). Biomass energy utilization in North Eastern Badia of Jordan. *Research Journal of Applied Sciences, Engineering and Technology*. Vol.**10** (**11**), 2015. p.1322-1323

Amare, Y. Z. (2014). The role of biogas energy production and use in greenhouse gas emission reduction, the case study of Amhara National Regional state, Fogera District, Ethiopia. *Journal of Multidisciplinary Engineering Science and Technology* Vol.**1** Issue **5**, December 2014.p.407

Amegah, A.K and Jaakkola, J.J.K. (2016). Household air pollution and the sustainable development goals. *Bulletin of the World Health Organization,* March 2016, 94. DOI:10.2471/BLT.15.155812.p.217

Bacenetti, J., Negri, M., Fiala, M., González-García, S. (2013). Anaerobic digestion of different feedstocks: Impact on energetic and environmental balances of biogas process. *Science of total environment* (2013).http://dx.doi.org/10.1016/j.scitotenv2013.04.058 p. 542

Baig, A.A.M., Khasim,S.S.K., Murthy, G.S.N., Ramu, K. (2017). Design of biodigester for CMR Technical campus hostel using Kitchen waste. *Journal of Mechanical and Civil Engineering*: *International conference on recent innovation in civil and mechanical engineering*.DOI:10.9790/1684-1605 30498103.p.99-101

Barreiro, P.L., Albandoz, J.P. (2001) Sampling Techniques: population and sample. *Management Mathematics for European Schools,* 94342-CP-1-2001-DE-COMENIUS-C21.p.4-5

Bedi, A.S., Pellegrini, L., Tasciotti, L. (2015). Effects of Rwanda's biogas program on energy expenditure and fuel use. *World Development* Vol.**67**, 2015. p.461

http://dx.doi.org/10.1016/j.worlddev.2014.11.008

Beedu, R., Modi, P. (2014). Design of biogas generation plant based on food waste. *International Journal of Current Engineering and Technology*. Special issue **2** (February 2014).DOI:http://dx.doi.org/10.1474/ijcet/spi.2.2014.77.p.417

Bessou, C., Ferchaud, F., Gabrielle, B., Mary, B. (2010). Bio-fuels, greenhouse gases and climate change. A review. *Agronomy for Sustainable Development.* INRA, EDP Sciences, 2010. DOI: 10.1051/agro/2009039.p.8-13

Buddle,M.B.,Denis,M.,Attwood,G.T.,Altermann,E.,Janssen,P.H.,Ronimus,R.S., Pinares-Patiño,C.S., Muetzel,S.,Wedlock,D.N. (2010). Strategies to reduce methane emissions from farmed ruminants grazing on pasture. *The Veterinary journal* **188** (2011). p.11

Cattle Network, (2015). World Cattle Inventory: Ranking of Countries (FAO).www.cattlenetwork.com.p.1

CEDGG and AK, (2014). Nakuru County First County Integrated Development Plan. Popular version, 2014.p.8

Chand, M.B., Upadhyay, B.P., Maskey, R. (2012). Biogas option for mitigating and adaptation of Climate Change. *Rentech Symposium Compendium*, Volume **1**, March 2012.p.5-7

Cheng, S., Li, Z., Mang, H.P., Elisabeth-Maria, H., Gao, R., Wang, X. (2014). Development and application of prefabricated biogas digester in developing countries. *Renewable and sustainable energy reviews* **34**(2014) p.388.

Cook, R. (2015). World Cattle Inventory: *Ranking of Countries*.FAO. p.1

Corre, J.W., Conijn, G.J (2016). Biogas from Agricultural residue as energy source in Hybrid Concentrated Solar Power. *Procedia Computer Science* **83** (2016) p.1131

County Government of Nakuru (2017). Livestock Production Annual Report for Year 2016.Directorate of Livestock Production.p.53

County Government of Nakuru (2016). Nakuru County clean energy policy and sustainable clean energy action plan. Directorate of Water, Energy and Environment Resources. October 2016.p.6

Demissie, S.W., Ramayya, V.A., Nega, D.T. (2016). Design, Fabrication and Testing of biogas stove for 'Areke' Distillation: The case of Arsi Negele, Ethiopia, Targeting reduction of fuel wood dependence. *International Journal of Engineering Research and Technology*.Vol.**5** Issue **03**, March 2016.p 362

Dubrovskis, V., Plume, I., Straume, I. (2009). Investigation of biogas production from mink manure and cow manure. *Engineering for Rural Development*.Jelgava, 28-29.05.2009.p.253

Energy Protection Agency, (1993) A summary of the emission characteristics and non-cancer respiratory effects of wood smoke. EPA Report. EPA-453/12-93.7036.p.3

Esfandiari, S., Khosrokhavar, R., Sekhavat, M. (2011). Greenhouse Gas Emissions Reduction through a Biogas Plant: A Case Study of Waste Management Systems at FEKA Dairy Farm.*2011 2nd International Conference on Environmental Science and Technology, IPCBEE* Vol.**6** (2011).p.V1-445

Government of Kenya, (2013).State of the Environment Report, *National Environmental Management Authority*, NEMA Nairobi.p125

FAO, (2012). Climate Change Adaptation and Mitigation: Challenges and Opportunities in the food security. *Department of National Resource Management and Environment*. Rome, Italy. p.9

Fayez, A.A., Ziad, D.A. (2000). Methane emission from domestic waste management facilities in Jordan-Applicability of IPCC methodology. *Journal of Air and Waste Management Association*. Vol.**50**.**2**, p.235.

Gashaw, A., Teshita, A. (2014). Co-digestion of Ethiopian food waste with cow dung for biogas production. *International Journal of Research (IJR)* Vol-**1**, Issue **7**, August 2014. p.476-478

Giovanni NASA, (2017). Average monthly atmospheric methane 2002-2016.Timeseries.Accessed on 21st April 2017.

Glover, B. (2009). Biogas capture and utilization: An effective, affordable way to reduce Greenhouse gas emissions and meet local energy needs. Ned Stowe and Jesse Caputo (eds). Environment and Energy Study Institute. Issue Brief June 2009, Washington D.C.p.3

Gromke, J.D., Liebetrau, J., Denysenko, V., Krebs, C. (2015). Digestion of Biowaste -GHG emission and mitigation potential. *Energy, Sustainable and Society,* (2015) **5: 3** DOI 10.1186/s 13705-014-0032-6.p.1-2

Heale, R., Twycross, A. (2015) Validity and Reliability in Quantitative studies. http://dx.doi.org/101136/eb-2015-102129.p.2-3

Holmes, D.E., Smith, J.A. (2016). Biologically produced methane as a renewable energy source. In Sariaslani & G.M. Gadds (Eds). *Advances in Applied Microbiology*. p.34-35

Hope, C. (2001). The Climate Change benefits of reducing methane emissions.WP13/2001.*Research papers in Management Studies*. University of Cambridge.p.3

Hristov, A.N., Oh, J., Lee, C., Meinen, R., Montes, F., Ott, T., Firkins, J., Rotz, A., Dell, C., Adesogan, A., Yang, W., Tricarico, J., Kebreab, E., Waghorn, G., Dijkstra, J., and Oosting, S. (2013). *Mitigation of greenhouse gas emissions in livestock production – A review of technical options for non-CO2 emissions.* Edited by Pierre J. Gerber, Benjamin Henderson and Harinder P.S. Makkar. FAO Animal Production and Health Paper No. **177**. FAO, Rome, Italy.p.89

Hublin, A., Schneider, D.R., Džodan, J. (2014). Utilization of biogas produced by anaerobic digestion of agro-industrial waste: Energy, economic and environmental effects. *Waste management and research,* 2014, Vol. **32**(**7**) p.626-627

IEA, (2013). Energy in Kenya: *Energy scenerios workshop*, July 2013.p.7

IPCC, (2013). Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley(eds.). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, p.1450, 52, 57,714.

IPCC, (2014). Climate change 2014: Impact, Adaptation and Vulnerability, Frequently Asked Questions and Cross-Chapter Boxes. A contribution of Working Group II to Fifth Assessment Report of Internal Panel of Climate Change. Field, C.B., V.R. Barros,D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy,S. MacCracken,P.R. Mastrandrea, and L.L. White (eds.). World Meteorological Organization, Geneva, Switzerland.p.183

James,R.H., Bousque,P., Bussmann,I., Haeckel,M., Kipfer,R., Leifer,I., Niemann,H., Ostrovsky,I., Piskozub,J., Rehder,G., Treude,T.,Vielstadte,L., Greinert, J. (2016). Effects of Climate change on methane emissions from seafloor sediments in the Arctic Ocean. *Limnolgy and oceanography* .Wiley Periodical, Inc. doi: 10.1002/lno.10307.p.2

Jayaraj, S., Deepanraj, B., Sivasubramanian, V (2014). Study on the effect of pH on biogas production from food waste by anaerobic digestion. *The 9th International Green Energy Conference*.p.799-800

Jorgensen, P.J. (2009). Biogas-Green energy. 2nd ed. Anna Busch Nielsen & Finn Bendixen (eds). PlanEnergi and Researcher for a Day. p.6 booklet

Kaltimber, 2017 How much Carbon Dioxide is stored in Kg of wood? *Kaltimber.com blog*/2017/6/19.p.1

Kelleher and Robin Environmental (2013). Canadian biogas study: benefits to economy, environment and energy. Technical document. December 2013.p12-13

Kemausuor, F., Bolwig, S., Miller, S. (2016). Modeling the socio-economic impacts of modern bioenergy in rural communities in Ghana. Sustainable *Energy Technologies and assessments* **14**(2016).p.9

KENDBIP (2014). Kenya Domestic Biogas User Survey 2014. Covard Consultants, August 2014.p.2-6

Kosse, P., Blomberg, K., Mikola, A., Heinonen, M., Kuokkanen, A., Lange, R-L., Lübken, M., Wichern, M. (2016). Climate change and greenhouse gas emission within the context of urban waste management. *Water Solutions* **2,** 2016 p.89

Kumaran, P., Hephzibah, D., Sivasankari, R., Saifuddin, N., Shamsuddin, A.H. (2015). A review on industrial scale anaerobic digestion system deployment in Malaysia: Opportunities and challenges. *Renewable and sustainable energy reviews* **56,** (2016) .930-931

Laxmi, T.P., Yajna, T., and Rajan, P. (2014). Climate Change and Community Forestry in Nepal: Local People's Perception. *American Journal of Environmental Protection* Vol. **2**, No. **1** (2014). doi: 10.12691/env-2-1-1.p.1-2

Maraseni, T.N. and Maroulis, J. (2008). Piggery: From environmental pollution to climate change solution. *Journal of Environmental Science and Health Part B*. June 2008.p.2-3

Melvin, A.M., Sarofim, M.C., Crimmins, A.R. (2016). Climate benefits of US EPA programs and policies that reduced Methane emissions 1993-2013.*Environmetal Science and Technology*. May 2016 DOI:10.1021/acs.est.6b00367.p.A-B

Meng, L., Roulet, N., Zhuang, Q., Christensen, T.R., Frolking, S. (2016). Focus on Impact of Climate Change on wetlands ecosystems and carbon dynamics. *Environmental Research Letters*. **11** (2016) 1002011. p.1

Mengistu, M.G., Simane, B., Eshete, G., Workneh, T.S. (2016). The environmental benefits of domestic biogas technology in rural Ethiopia. *Biomass and Bioenergy*, **90** (2016).p. 131-132

Mohajan, H.K (2017).Greenhouse gas emissions, Global warming and climate change. *15th Chittagong Conference on Mathematical Physics, 2017. Jamal Nazrul Islam Research Centre for Mathematical and Physical Sciences (JNIRCMPS).* University of Chittagong, Chittagong, Bangladesh.p.3

Moraes, B.S., Petersen, S.O., Zaiat, M., Sommer, S.G., Triolo, J.M. (2016). Reduction in greenhouse gas emission from vinasse through anaerobic digestion. *Applied Energy* **189**(2017). DOI:10.1016/j.apenergy.2016.12.009.p.21-22

Morris, J. (2010). Bury or Burn North America MSW? LCAs provide Answers for Climate Impacts and Carbon Neutral Power Potential. *Environmental Science and Technol*. Vol. **44**, No. 20, 2010. p.7945

Mulinda, C., Hu, Q., Pan, K.(2013). Dissemination and problems of African biogas Technology. *Energy and power Engineering*, **5**,2013.http://dx.doi.org/10.4236/epe.2013.58055.p. 506-507

Nguu, J., Ndivo, S., Aduda, B., Nyongesa, F., Musembi, R. (2014). Livestock farmers' perception on generation of cattle based biogas methane: The case of Embu West District, Kenya. *Journal of Energy Technology and policy,* Vol.**4**, No.**8**, 2014.p.3

Niggli, U., Schmid, H., Fliessbach, A. (2008). Organic farming and climate change. Technical paper. *International Trade centre UNCTAD/WTO and Research Institute of organic Agriculture (FiBL).*Geneva.p.11

Pathak. H., Jain.N, Bhatia. A., Mohanty .S, Gupta.N. (2009).Global warming mitigation potential of biogas plants in India. *Environmental Monitoring and Assessment* **157**(2009). DOI10.1007/s10661-008-545-6.p.410

Phelan, C., Wren, J. (2006) Exploring reliability in Academic Assessment.UNI Office of Academic Assessment 92005-2006.p.1-2

Praes, M.F.F., Junior, J.L., Orrico, A.C.A., Junior, M.A.P.O., Hermes, R.G., Sorbara, J.O.B., Duarte, K.F., Schwingel, A.W., Sgavioli, S., Domingues, C.H.F., Sunada, N.S. (2015). Biogas production: Litter from broilers receiving direct fed microbial and enzyme blend. *Scientia Agricola.*Vol.**73**, No.**5**.September/October 2016. htttp//:dx.doi.org/10.1590/0103-9016-2015-0195.p.406

Puyol, D., Batstone, D.J., Hülsen, T., Astals, S., Peces, M., Krömer, J.O. (2016). Resource recovery from wastewaters by biological technology: Opportunities, challenges and prospects. *Frontiers in Microbiology*.**7**: 2106. Doi:10.3389/fmicb.2016.02106.p.8

Rouf, M.A., Islam, M.S., Rabeya, T., Mondal, A.K. (2015). The anaerobic digestion of mixed dried fallen leaves by mixing with cow dung. *Bangladesh Journal of Scientific and Industrial Research.* **50**(**3**), 2015.p.163

Rouf, M.A., Islam, M.S., Rabeya, T., Mondal, A.K., Khanam, M., Samadder, P.R., Ara, Y. (2016). Biogas from slaughterhouse waste and optimization of the process. *Bangladesh Journal of Scientific and Industrial Research.* **51**(**3**), 2016. DOI: 10.3329/bjsir.v51i3.29432.p.204

Sárvári, H. I., Tabatabaei, M., Karimi, K., Kumar, R. (2016). Recent updates on biogas production - a review. *Biofuel Research Journal* 10 (2016) 394-402. DOI: 10.18331/BRJ2016.3.2.4 p.394

Saunois, M., Jackson, R.B., Bousquet, P., Poulter, B., Canadell, J.G. (2016). The growing role of methane in anthropogenic climate change. *Environmetal Research Letter*. **11**(2016)120207 p.1-3

Scherr, S.J. and Sthapit, S. (2009). Mitigating climate change through food and land use. *Worldwatch Report 179*. Ecoagriculture Partners and Worldwatch Institute. Washington DC.p.19

Schouten, P.W., Sharma, A., Burn, S., Goodman, N., Parisi, A., Downs, N. and Lemcket, C. (2013). Making small scale classroom greenhouse gas flux calculations using a handmade gas capture hood. *Teaching Science*, Vol. **59**. No.**1**, March 2013.p.48

Sendegeya, A., Ssebuwufu, P.J.M., Silva, I.P. (2010). Benefits of using Biogas in Households: Experience from user in Uganda. *Conference paper, April 2010*.DOI:10.1314/2.1.1306.7208.p.1

Shin, J.D., Park, S.W., Lee, S.I., Kim, H., Lee, R.S. and Kim, M.S. (2015). Effects of digestion temperatures and loading amounts on methane production from anaerobic with crop residues. *Carbon letters.*Vol.**16**, No.**4**, (2015). p**.**265

Sincero, S.M. (2012 Advantages and Disadvantages of Surveys. http://explorable.com/advantages-and-disadvantages of surveys.p.3-4

Singh, T.S., and Sankarlal, P. (2015). A review on advancement in Biogas Technologies. *International Journal of Engineering Research and Technology (IJERT).TITCON-Conference proceedings*, 2015.DOI: 10.13140/RG.2.1.1672.3288.p.750

SLC, (2013). Sampling. https://www.flinders.edu.au/SLC. **5**/2013.p.4

Somanathan, E. and Blufftone, R. (2015). Biogas: Clean energy Access with low cost mitigation of Climate Change. *Policy research working paper 7349*. World Bank Development Research Group, Environment and Energy Team, June 2015. DOI: 10.13140/RG.2.1.2326.8961.p.2

Stepniewski, W. (2007). Alleviation of greenhouse effect by reduction of methane emission from anthropogenic sources. Pawlowski and Dudzinska (eds).*Environmental Engineering*. Taylor and Francis Group, London, ISBN13 978-0-415-40818-9.p.33

Sujuta, M., Prakash, L., Kuwar, T.U. (2014). Global warming mitigation potential of biogas technology in security institution of Kathmandu Valley, Central Nepal. *International Research Journal of Environment Sciences*.Vol.**3** (**10**),October (**2014**).p.68

Sunil, N.M.G., Manasi, S., Bez, P., Bhaskar, K. and Khan, Y.D.I. (2015). Potential of manure based biogas to replace conventional and non-conventional fuels in India. *Management of Environmental Quality: An International Journal*, Vol. **26** Iss **1**.http://dx.doi.org/10.1108/MEQ-04-2013-0034. p.15

Tantrakarnapa, K., Utachkul, U., Aroonsrimorakot, S., Arunlertaree, C. (2008). The potential of greenhouse gas reduction from Clean Development Mechanism Implementation in Cassava starch and palm oil industries in Thailand. *Journal of Public Health*. *Special issue on 60th Anniversary of Faculty of Public Health* p.131

Tarinee, B., Aroonsrimorakot, Bhaktikul, K., Thavipoke, P. (2013). Biogas production and greenhouse reduction from wastewater at Mahidol University, Salaya campus, Thailand. *APCBEE Procedia* **5**(2013) 169-174.p.170

Tilley.E, Ulrich.L, Luthi.C, Reymond.P, Zurbug.C (2014).Compendium of Sanitation Systems and Technologies. *The Department of Water and Sanitation in Developing Countries of eawag, the Swiss Federal Institute of Aquatic Science and Technology*, Sandec, Dubendorf, Switzerland.p.2

Tumwesige,V.,Avery,L.,Austin,G.,Balana,B.,Bechtel,K.,Casson,E.,Davidson,G.,Edwards,S., Eshete,G.,Gebreegziabher,Z.,Glenk,K.,Hailemichael,K.,Mugisha,J.,Kasozi,A.,Leckie, S.,Lemna,B.,Magombe,J.,Mahteme,Y.,Matthews,R.,Melamu,R.,Mwirigi,J.,Naik,L.,Orskov,B.,Pertiwiningrum,A.,Sabiiti,E.,Semple,S.,Subedi,M.,Ssendagire,W.,Sylvia,N.,Turyareeba,P.,Walekwha,P.,Yilma,D., Yongabi, K., Zenk, G., and Smith, J. (2011). Small scale biogas digester for sustainable energy production in Sub Saharan Africa.*1st World Sustainability Forum*, 1-30 November 2011.p.3

Uddin, W., Khan, B., Shaukat, N., Majid, M., Mujtaba, G., Mehmood, A., Ali, S.M., Younas, U., Anwar, M., Almeshal, A.M. (2015). Biogas potential for electric power generation in Pakistan: A survey. *Renewable and sustainable energy reviews* **54** (2016) p.26

Umegahalu, C.E., Chukwuma, E.C., Okonkwo, I.F., Umeh, S.O. (2012). Potential for biogas production in Anambra State of Nigeria using cow dung and poultry droppings. *International Journal of Veterinary Science* **1**(**1**).p.25-26

UNDP, (2013). Kenya National Human Development Report 2013.*Climate change and Human Development: Harnessing emerging opportunities*. UNDP Kenya.p.30

USDA, US Energy Protection Agency and US Department of Energy (2014). Biogas Opportunities Roadmap: Voluntary actions to reduce methane emissions and increase energy independence. *USDA, EPA, DoE report* August 2014.p.13-14

USGCRP, (2009). Climate Literacy: The Essential Principles of Climate Sciences. National Science Foundation. Second Version. March 2009.Washington D.C. p.6

Vac, S.C., Popiţa, G.E., Frunzeti, N., Popovici, A. (2013). Evaluation of GHG emission from animal manure using the closed chamber method for gas fluxes. *Not Bot Agrobo,* 2013, 41(2). p.576

Yao, Y., Su, Y., Wu, Y., Liu, W., R., He, R. (2014). Analytical model for estimating the reduction of methane emission through landfill cover soils by methane oxidation. *Journal of Hazards Materials.* **283**(2015) 871879.http://dx.doi.org/10.1016/j.jhazmat.2015.10.035 p.871

Yaru, S.S., Adegun, I.K., Akintunde, M.A. (2015). Wobbe index determination of cattle dung biogas. *Scientia Agriculturae* **9** (**2**). Retrieved from www.pscipub.com DOI: 10.15192/PSCP.SA.2015.9.2.7682. p.77

Young, S., Sproul, A.B., Bruce, A.G. (2014). Potential for biogas production and emission reduction at Equestrian Centre. *2014 Asia Pacific Solar Research Conference*.p.4-5

Zusana, P., Topisirović, G., Adamovský, F., Lukáč, O., Jeremić, M., Baláži, J., Zarić, V. (2016). Agricultural Biomass: It’s potential in Slvakia and Serbia. Slovak University of Agriculture in Nitra. p. 51

ANNEX

7.1 HOUSEHOLD SURVEY QUESTIONNAIRE

Dear respondent

I am a postgraduate student studying **Climate Change Science** in the University of Nairobi. This questionnaire is intended to collect your views concerning **Energy and Climate Change Mitigation** in Nakuru County; Kenya. As a resident of this area; you have been selected as one of the people to provide accurate and reliable information about issues listed below. Your honest responses gathered will be accorded utmost confidentiality and are great asset to me for academic purposes. Mark boxe(s) with a tick or fill in the space(s) provided.

SECTION 1: LOCATION OF RESPONDENT

Sub county ………………………………………..Questionnaire Number……………………

Ward……………………………………………… Interview date ……………………………

Village…………………………………………….

SECTION 2: DEMOGRAPHIC INFORMATION OF RESPONDENT

1) Indicate your gender? ☐ Male ☐ Female

2) What is your age in years? ☐ 10-17 ☐ 18-35 ☐ 36-50 ☐ 51-60 ☐ >60

3) What is your highest level of education? ☐ No formal education ☐ Primary education ☐ Secondary education ☐ College Diploma ☐ University degree

4) For how long have you lived in this area? ☐ Less than 5 years ☐ 5-10 years ☐ 11-20 years ☐ 20-30 years ☐ More than 30 years

SECTION 3: HOUSEHOLD CHARACTERISTICS

5) What is the marital status of the household head? ☐ Single ☐ Married

6) Who heads the household? ☐ Male headed ☐ Female headed ☐ Child headed ☐ Others (Specify)…………………………………………………………………...

7) What is the major source of livelihood for the household?

☐ Farming ☐ Public service ☐ Trading ☐ Private sector ☐ Waged labour

8) How many people is food cooked for in the household?..

9) How many livestock are kept in the household?

Livestock type	**Cattle**	**Sheep and goats**
Total Number		

SECTION 4 : FODDER AND PASTURES PRODUCTION

10) Since the last 10 years, how has been the trend in fodder and pasture yield in your farm?

☐ Significantly increased ☐ Slightly increased ☐ No change ☐ Slightly decreased

☐ Significantly decreased

11) What do you attribute the change in Question No.10? ☐ Poor soil fertility

☐ Unreliable rainfall ☐ Low knowledge on fodder/pasture management

☐ Increased knowledge on fodder and pasture management

☐ Other (specify)…………………………………………………………………………..

SECTION 5: MANURE MANAGEMENT

12) How do you use manure from the cows? ☐ Make compost ☐ Make biogas

☐ Spread on the farm ☐ Store as liquid slurry in uncovered lagoons

13) If you make biogas, where do you use the bio-slurry from the biogas plant?

☐ Kitchen garden ☐ Cropland ☐ Vegetable farm ☐ Other (specify)……………………..

14) How much mineral fertilizer have you used?

Before biogas use		After biogas use	
Mineral fertilizer used per acre/planting season(50Kg bag)	Cost of fertilizer per acre/planting season (Ksh.)	Mineral fertilizer used per acre/planting season(50Kg bag)	Cost of fertilizer per acre/planting season (Ksh.)

SECTION 6: ENERGY RESOURCES UTILIZATION

15) Indicate the energy sources that you use in your household.

☐ Woodfuel ☐ Biogas ☐ Solar ☐ Grid electricity ☐ Liquefied Petroleum Gas

☐ Others (specify)…

16) If you are using woodfuel, where do you collect it from? ☐ Farm forest ☐ Government ☐ Government Forest ☐ Private forest ☐ Market ☐ Other (specify)………………

17) Why do you use woodfuel for cooking food or lighting?

☐ It is locally available ☐ It is available at no cost ☐ It is packed in small quantities that can be easily purchased ☐ Other alternatives are expensive

18) If you are using biogas, what is the size (M^3) of your biogas plant?....................................

19) When was the biogas plant installed?...

20) How much did it cost to purchase the biogas plant?...

21) Is the biogas plant functioning? ☐ Yes ☐ No

22) Why do you use biogas fuel for cooking, heating or lighting? ☐ It has reduced smoke

☐ It has little operation expenses ☐ It makes kitchen more hygienic

☐ It increases crop yield ☐ It is cheaper than other fuels

23) How much time is saved (minutes/HH/day)?

Activities	**Woodfuel collection**	**Per Cooking**	**Cleaning utensils**
Average time used before biogas installation(Minutes)			
Average time used after biogas installation(Minutes)			
Average time saved			

24) How is the saved time utilized? ☐ Feeding livestock ☐ Social and religious work

☐ Cleaning the home ☐ Childcare ☐ Crop farming ☐ Others (specify)…………

25) What has been the situation of household health for the following diseases before and after biogas installation?

Diseases	Before installation of biogas	After installation of biogas
Eye problems		
Diarrheal diseases		
Coughs		
Headaches		
Chest pains		

26) What is your assessment on the effects of biogas technology in the household? Please mark in the box that best describes your agreement or disagreement on each of the following statements.

Statement	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
There is reduction in smoke related diseases					
Money is saved from not buying mineral fertilizers					
Women and children are empowered since time is saved in cleaning utensils, cooking and from not collecting firewood					
There is employment for the youth as artisans, sale persons, caretakers of biogas plants					

SECTION 7: CLIMATE CHANGE INFORMATION

27) What do you understand by climate change?

………………………………………………...

28) Has weather or seasons been getting drier leading to severe drought in the last 10 years?

☐ Not dry ☐ Dry ☐ Very dry ☐ Extremely dry

29) In what ways has the changes in weather/seasons affected you?

☐ Less water ☐ Less food for household ☐ Less feed for livestock ☐ Death of people

☐ Loss of livestock ☐ Others (Specify)……………………………………………………….

Thank you for participating

JOHN SAMALI EIPA

7.2 CHECKLIST FOR HOUSEHOLD INTERVIEW

TOPIC: ENERGY AND CLIMATE CHANGE MITIGATION

1) How many bundles of firewood do you use per month? ……… Bundles

2) What is the average weight of one bundle of woodfuel? ………Kg

3) What is the cost of one bundle of firewood? Ksh..............................

4) How many bags of charcoal do you use per month? ………….Bags

5) What is the average weight of one bag of charcoal?.....................Kg

6) What is the cost of one bag of charcoal? Ksh………………………

7) How many hours do you take cooking food and heating water using biogas fuel?......

Thank you for participating

JOHN SAMALI EIPA

Student of the University of Nairobi

7.3 CHECKLIST FOR KEY INFORMANTS INTERVIEW

TOPIC: ENERGY AND CLIMATE CHANGE MITIGATION

1. What are the main livelihoods for the people in this area?

2. Mention the sources of energy used in this area?

3. What is the name of the forest where majority of the people in the area collect woodfuel?
4. What is the weight of woodfuel from an average mature tree?

5. What is the cost of woodfuel (bundle), charcoal (bag), LPG cylinder (Kg), Kerosene (Litre), Mineral fertilizer (50Kg) in this area?

6. Why are farmers motivated to produce biogas?

7. State the main problems faced by farmers owning biogas plants?

8. Has the area experienced any change in terms of climate conditions? Explain and give details.

9. What do you think are consequences of climate change in this area?

10. Do you have any organization in this area involved in climate change? If yes, name the organization.

Thank you for participating.

JOHN SAMALI EIPA

Student of the University of Nairobi

7.4 PHOTOGRAPHY

Plate 1: Determining weight of firewood using weighing scale

Plate 2: Biogas production system

Plate 3: Biogas stove with regulator (red in colour)

Plate 4: Bio-slurry being released out of biodigester