METHANE GAS EMISSIONS BY ENTERIC FERMENTATION FROM CATTLE PRODUCTION IN KENYEWA LOCATION OF KAJIADO COUNTY IN KENYA: A STUDY ON POTENTIAL CLIMATE CHANGE MITIGATION STRATEGIES

BY
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DECLARATION

This research project is my original work and it has never been submitted for examination or degree award in any other University

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To my beloved daughters, Precious and Kezia, for their prayers and words of inspiration.

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ABSTRACT

The study focused on the enteric fermentation contribution to the methane emissions as part of the global anthropogenic greenhouse effect by cattle in Kenyewa Location. The study used cattle numbers and IPCC default values to compute levels of enteric methane emissions from cattle production in Kenyewa in order to get its right perspective. In this endeavour five specific questions were addressed and these included the level of enteric methane emissions in Kenyewa Location, the existing technological options in enteric methane mitigations, viability of existing technological options in enteric methane mitigations, level of participation of the Maasai in Kenyewa Location and, potential for participation in climate change mitigation strategies. These questions were addressed with the objective of determining the levels of methane gas emitted from enteric fermentation by cattle in Kenyewa location of Kajiado County and the existence of technological options for reducing enteric methane gas emissions. In order to guide in achieving the objectives the study hypotheses were that enteric methane emissions from cattle production were minimal and thus insignificant to global anthropogenic greenhouse effect that there were no existing technological options for reducing enteric methane gas emissions in Kenyewa Location.

To address the study questions, meet the objectives and test the hypotheses the study adopted a multistage sample survey. This involved purposive selection of the study area with all the homesteads (manyattas) in Kenyewa constituting the study population but only those that had designated heads, 395, constituted target population. The target population was then stratified based on administrative sub-location units to give two strata which were then sampled in terms of the homestead by simple random method. From each homestead only the head of the homestead was interviewed and this covered a total of 200 homesteads. The sample survey was used to acquire primary data of varied sizes and sources, 200 questionnaires targeting heads of manyattas, 2 key informants meetings, 1 focus group discussions, 50 photographs, 200 field observations and, 200 GPS points obtained from field survey in Kenyewa Location. The primary data were supplemented by secondary data from different sources required for sampling frame, sample size determination and to support primary data for analysis. The acquired data sets were used to generate information for answering the stated research questions and test the study hypotheses in order to meet the objectives of the study.

Data were checked, arranged, coded, edited, mined, sub-files created and entered into SPSS program version 20 software for analysis. The generation of the required information involved the use of statistical tools, both descriptive and inferential. The descriptive tools used provided accurate description of sample data and included frequency distribution, tabulation and graphing, cross tabulation as measures of central tendency dispersions and measures of association and differences. The inferential statistical tools were used to measure the statistical significance of the observed sample distributions. The study used t-test, ANOVA, chi-square and, Kruskal Wallis for measures of differences, while for correlations measures, both Spearman's rank correlation and Pearson's regression coefficient were used. The regression measures were based on Pearson's Linear regression, time series and for temperature trend, time series sequential plot and, time series long term mean variance autocorrelation all of which time domain measures were used. In all inferential statistical measures, significant tests were at α 0.05 given degrees of freedom.

Data analysis results, at the time of the study, indicated that Kenyewa Location of Kajiado County produced a total of 220,428 Kg of enteric methane, a contribution to global anthropogenic greenhouse effect of 5,510,700 Kg CO_2-Eq. There were some viable technological options for reducing enteric methane emissions in Kenyewa Location. The level of participation of Maasai in Kenyewa to climate change mitigation activities was insignificant but there was potential for adoption of other climate change mitigation strategies. In conclusion, enteric methane levels from cattle production in Kenyewa Location were minimal but cumulatively a contributing factor to global warming and climate change. Something was being done and more could be done to mitigate enteric methane emissions in Kenyewa Location. This study recommended creation of awareness by National Environmental Management Authority (NEMA) on effects of enteric methane emissions. The government of Kenya was obliged to do capacity building on activities that lead to mitigation of enteric methane emissions through extension services and offer subsidy on cattle production inputs. Future research could be done on a more accurate measurement of enteric methane levels by Tier 2 and 3 methods and other viable climate change mitigation strategies. This study can be replicated on a larger sample to make comparison between cattle in relation to climate change on extensive and intensive systems of production.

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LIST OF ACRONYMS

AMREF	African Medical and Research Foundation
ASALs	Arid and semi-arid areas
CEA	California Environmental Associates
CEC	Commission of the European Communities
CEH	Centre for Ecology and Hydrology
CO_2	Carbon dioxide
CO_2 – Eq.	Carbon dioxide Equivalent
CH_4	Methane
EPA	Environmental Protection Agency
FAO	Food and Agriculture Organization of the United Nations
FAS	Foreign Agricultural Service
Gg	Gigagram
GHGs	Greenhouse gases
GPS	Global positioning system
GoK	Government of Kenya
$GtCO_2$-eq	Gigatonnes of carbon dioxide equivalent
HBS	Heinrich Böll Stiftung
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature and Natural Resources
LLGHGs	Long-lived Greenhouse Gases
KALRO-ARILRI	Kenya Agricultural and Livestock Research Organization-Arid and Range Lands Research Institute
Mt CO_2e	Million tons of carbon dioxide equivalent
NAS	National Academy of Sciences
N_2O	Nitrous oxide
NEMA	National Environmental Management Authority
NOAA	National Oceanic and Atmospheric Administration
OECD	Organisation for Economic Cooperation and Development
Ppb	Parts per billion

RF	Radiative forcing
RS	Royal Society
SPPS	Statistical Package for Social Scientists
TARDA	Tana and Athi Rivers Development Authority
Tg	Teragram
UK	United Kingdom
UNFCCC	United Nations Framework Convention on Climate Change
UNEP	United Nations Environmental Programme
UNICEF	United Nations International Children's Emergency Fund
U.S/USA	United States of America
USDA	United States Department of Agriculture
WB	World Bank
WMO	World Meteorological Organization
WWF	World Wide Fund for nature
Yr	Year

CHAPTER ONE

1.0. INTRODUCTION

1.1. Study Background

Methane is the second most important anthropogenic greenhouse gas in the earth's atmosphere (WMO, 2013; CEH, 2008). The level of methane in the earth's atmosphere is increasing and this trend will continue due to rising population growth rates and higher incomes (Rowlinson *et al.* 2008). Sixty per cent (60%) of the global methane emissions, as observed by IPCC (1992) is as a result of human activities such as energy coal mining, landfills, livestock production, rice cultivation, oil and natural gas systems among others. Human activities lead to emissions of greenhouse gases (GHGs) which amplifies the natural greenhouse effect (OECD/AIE, 2007). Methane, whose approximate global warming potential per molecule is 25 times greater over a 100-year and 72 times greater over a twenty-year time-frame than carbon dioxide plays an unmistakable role in global warming and climate change (WMO, 2013). Climate change is not a new phenomenon in the Earth-atmosphere system for there are indications in the palaeoclimatic records, proxy or recorded data, of climate eras marked by interchanging between ice ages and warm periods (RS and NAS, 2010; IPCC, 2007).

Livestock production, the main economic activity in the arid and semi-arid areas (ASALs), has been identified as one of the major causes of environmental degradation, air pollution, decreased biodiversity and climate change (FAO, 2006). In the work of UNEP (2012), livestock production and cattle production, in particular, was squarely blamed for anthropogenic greenhouse emissions (methane, nitrous oxide and carbon dioxide). Cattle produce methane especially in the intense dairy sector that has a high concentration of livestock waste. Little focus has been made on the other methane sources within the livestock production systems other than the emission from waste and yet studies have shown that the level of methane emission from enteric fermentation was more than from the waste (David, 2015). Cattle produce enteric methane in the course of the ordinary digestive process at the anaerobic conditions of their fore-stomach (rumen). Cattle start emitting enteric methane at their fourth week of age and the amount released increases with age (Anderson *et al.*1987). There are varying statistics on the amount of methane a cow generates.

Goopy *et al.* (2015) clarified that this figure differs from one cattle type to another and also from region to region. Well founded emission default values for Kenya, provided by IPCC indicate 40 Kg and 31 Kg of enteric methane per head per year for dairy and non-dairy cattle respectively (GoK, 2012). Kenya, to start it off, managed to quantify its emissions in the year 2010 in which agriculture sector accounted for thirty per cent of Kenya's greenhouse gas emissions out of which ninety per cent was from the livestock sub-sector (GoK, 2013). This study, using these default values sought to determine enteric fermentation methane contribution by cattle in Kenyewa Location of Kajiado County to the global greenhouse effect.

The Kenya National Climate Change Action Plan contents that Kenya, like most of the other developing countries, releases minimal greenhouse gas emissions (GoK, 2013). Nonetheless, Nzau (2013) noted that the country is very vulnerable to the impacts of climate change. Though Kenya is struggling with adaptation measures, it will still take part in climate change mitigation strategies. Cattle production offers an opportunity for reduction in enteric methane emissions that lessens global warming. The Maasai have indigenous methods of improving production of their cattle. When production improves, lesser cattle are required to meet a certain level of demand (IPCC, 1992). This leads to reduction in enteric methane gas emissions (Herrero *et al.* 2011; CEA, 2014). The traditional methods of improving cattle production, therefore, lead to mitigation of enteric methane gas emissions. There are modern interventions in the cattle industry in Kenyewa Location that also reduce enteric methane gas emissions. This study sought to determine existence of technological options for mitigation of enteric methane emissions in Kenyewa Location of Kajiado County.

Technological interventions, whether traditional or modern, ought to be viable in order to guarantee sustainability. This study determined the viability of the existing technological options for enteric methane emissions reduction. Enteric methane emissions mitigation is only achievable when cattle numbers decrease while sustaining a particular level of output. There was a need to further determine the level of participation of the Maasai in Kenyewa Location of Kajiado County to climate change mitigation strategies and potential for adoption of other recommended climate change mitigation strategies. This study sought to redress this deficiency.

1.2. Statement of the Problem

This study sought to estimate the methane emissions levels by enteric fermentation from cattle production in Kenyewa Location of Kajiado County and contribution to global anthropogenic greenhouse effect. When cattle feed, some portion of the digested energy, estimated at about 6 per cent is translated into methane and hence cannot benefit the cow for maintenance, growth or production (IPCC, 1992). This enteric methane is emitted either through the mouth and nostrils by eructation and exhalation or through the cow dung (Johnson and Johnson, 1995). Enteric fermentation methane emissions are affected by cattle numbers and default emission factors. A study was done in Kenya to give the sources and levels of agricultural emissions for the years 2000 and 2010 (David, 2015). The resulting statistics gave estimates from enteric fermentation and manure management, among others. In that study, amounts of enteric fermentation methane from cattle, sheep and goats were lumped together (appendix VII).

This study used cattle numbers and IPCC default values to put the levels of enteric methane emissions from cattle production in Kenyewa Location in its right perspective. The computed enteric fermentation methane showed how minimally Kenyans in Kenyewa Location are contributing to the problem of global anthropogenic greenhouse effect and encouraged them to continue agro-industrializing as they gradually prepare to start mitigation of climate change. Nevertheless, enteric methane emissions from cattle, however scanty, cannot be under rated because the amount of heat that a particular mass of methane traps is higher than that which can be trapped by the same level of carbon dioxide (Lines-Kelly, 2014). Cattle industry is a cause of global warming and climate change and of all mankind, cattle keepers are the least resilient to impacts of climate change (Morton, 2007).

Climate change is a global phenomenon and responses to it have been international coordinated approaches by the nations of the world. Some of the international forums held were Kyoto Protocol, Climate Summit at Copenhagen and in Cancan (Remling, 2011). According to David (2015), Kenya's major Climate Change mitigations interventions include National Climate Change Response Strategy (2010) and National Climate Change Action Plan (2013-2017). Despite immense efforts internationally (Mc Michael *et al.* 2003) and nationally (David, 2015), enteric methane levels are still increasing in the earth's atmosphere.

Adaptation to climate change is on-going all over the world, but climate change is still confronting humanity. Therefore, both adaptation to and mitigation of climate change are important (Lebel et al. 2012). In the fight against climate change through mitigation, everyone has a role to play. Local climate change mitigation strategies can complement national and international efforts. For many years, increasing demand for cattle products in Kenyewa Location and beyond has been satisfied through increase in cattle numbers (IPCC, 1992). Cattle herders in Kenyewa Location keep cattle in a harsh environment but have traditional methods of herd and range management for improving production.

Kajiado County’s extension officers and cattle industry stakeholders notably Kiboko Zoological Investigations and Efficacy Trial Centre, Tana and Athi Rivers Development Authority’s (TARDA’S) Emali Livestock Multiplication Project and Kenya Agricultural and Livestock Research Organization–Arid and Range Lands Research Institute (KALRO-ARILRI) Kiboko are involved in training on modern methods of cattle keeping. When production increases, lesser animals are required to meet a given level of demand hence reducing enteric methane. This study sought to identify the existing technological options for reducing enteric methane emissions. Cattle are important economically, socially and politically. Technological options for enteric methane mitigation should increase productivity, be affordable, consistent with Maasai culture and systems of production and, lead to decrease in cattle numbers for a particular level of output. The study sought to determine the viability of existing technological options for enteric methane mitigation.

Climate change mitigation strategies in cattle industry involve manipulation of feeds and feeding, supplementation, breeds and breeding, disease prevention and control and aggressive marketing of steers and culls. This study sought to determine the level of participation of the Maasai in Kenyewa Location in climate change mitigation strategies. There is usually very large potential for enteric methane mitigation in areas with numerous cattle numbers. In Kenya, ASALs have the highest technical potential for enteric methane mitigation. Kenyewa herders live in the ASALs within a unique set up of exposure to knowledge in cattle production. This study sought to determine the potential for adoption of other recommended technological options for reducing enteric methane gas emissions in Kenyewa Location.

1.2.1. The Research Questions

The specific research questions answered in this study were:

1. What is the approximate amount of enteric fermentation methane emitted from cattle production in Kenyewa Location of Kajiado County?
2. What are the existing technological options for reducing enteric methane emissions in cattle production in Kenyewa Location of Kajiado County?
3. Are the identified technological options for reducing enteric methane emissions in cattle production in Kenyewa Location of Kajiado County viable?
4. What is the level of participation of the Maasai community in Kenyewa Location of Kajiado County in climate change mitigation strategies?
5. Is there any potential for adoption of other recommended climate change mitigation strategies in Kenyewa Location of Kajiado County?

Answers to the above questions were used to meet the following objectives.

1.3. Research Objectives

1.3.1. General objective

The study sought to determine the levels of methane gas emitted from enteric fermentation by cattle in Kenyewa location of Kajiado County and the existence of technological options for reducing enteric methane gas emissions.

1.3.2. Specific Objectives

More specifically the study sought to determine:

1. The amount of enteric fermentation methane emitted from cattle production in Kenyewa Location of Kajiado County and contribution to global anthropogenic greenhouse effect.

2. The existing technological options for reducing enteric methane emissions in cattle production in Kenyewa Location of Kajiado County.

3. The viability that leads to sustainability of existing technological options for reducing enteric methane emissions in cattle production in Kenyewa Location of Kajiado County.

4. The level of participation of the Maasai community in Kenyewa Location of Kajiado County in climate change mitigation strategies.

5. The potential for adoption of other recommended climate change mitigation strategies in Kenyewa Location of Kajiado County.

1.4. Study Hypotheses

In order to address the objectives of this study by qualitative testing of hypothesis, several hypotheses were postulated namely:

1. Enteric methane emissions from cattle production in Kenyewa Location of Kajiado County are minimal and thus insignificant in global anthropogenic greenhouse effect.
2. There are no existing technological options for reducing enteric methane emissions from cattle production in Kenyewa Location of Kajiado County.
3. The existing technological options for reducing enteric methane emissions from cattle production in Kenyewa Location of Kajiado County are not viable.
4. The level of participation of the Maasai community of Kenyewa Location of Kajiado County in climate change mitigation strategies is insignificant and below the minimum requirement of seventeen.
5. There is no potential for adoption of other recommended climate change mitigation strategies in Kenyewa Location of Kajiado County.

1.5. Study Justification

Cattle production leads to methane gas emissions in two ways, by enteric fermentation and the cow dung. According to David (2015) and GoK (2013; 2015), methane emissions from enteric fermentation in cattle are higher as compared to those from cow dung (appendix VII) but little focus has been made on this particular source of methane gas. Cattle were given a priority focus of attention because they emit more methane compared to their other domestic ruminant counterparts (UNEP, 2012). This is because globally, cattle are bigger in size and higher in numbers compared to sheep and goats (shoats). The global figures indicate that there are 998.3 million head of cattle in the world today (FAS/USDA, 2017).

Kajiado County had 174,290 dairy and 581,020 non-dairy cattle in the year 2016 (Kajiado County Livestock Office). Though methane sources are known, there is no consensus on exact amounts from the various sources (Cicerone and Oremland, 1988). This study sought to estimate the amount of enteric methane produced by cattle in Kenyewa Location and its consequent contribution to the greenhouse effect.

International climate change forums have focussed on carbon dioxide more than any other greenhouse gas (CEC, 1996). Despite immense efforts to reduce carbon dioxide emissions, climate change continues to threaten humanity. Even though the level of atmospheric concentration of carbon dioxide is high, methane traps thermal infra red radiation (heat) more readily and as such has a higher global warming potential (GWP) than carbon dioxide (Lines-Kelly, 2014). Thorpe (2008) noted that six hundred teragram (Tg) of methane is emitted every year into the atmosphere so the amount of enteric methane released from cattle production in Kenyewa is an addition to already increasing methane levels. Fortunately, Methane gas leaves the atmosphere after about twelve years which is far shorter than residence period of carbon dioxide (Lines-Kelly, 2014). Therefore, technological options to reduce methane emissions are quicker in slowing global warming compared to those that reduce carbon dioxide emissions.

Kenyewa Location has close proximity to key stakeholders in the cattle Industry in Kajiado County. Therefore, herders in Kenyewa Location have a unique blend of traditional knowledge and modern science in cattle production. This study sought to determine the existing technological options for reducing enteric methane gas from cattle production in Kenyewa Location for these form a foundation for further improvement. The way modern interventions are introduced and the viability of the technology is very crucial. Involvement of the local community ensures sustainability of the process. This study sought to determine the viability of the existing enteric methane mitigation strategies. Cattle production provides a platform for participation in climate change mitigation. The government, relevant stakeholders and the civil society should step up all activities that have a bearing on enteric methane gas mitigation. Kenyewa Location could offer untapped potential for climate change mitigation. This is not only due to being a cattle production area but also having herders who are well acquainted with cattle production skills and have already benefited from improved methods of cattle production.

This study sought to determine the potential climate change mitigation strategies. Kenya government has prioritized strategies on adaptation to climate change. When Kenya is ready to start the implementation of mitigation measures, this study is an authentic guide for the planners, policy makers, extension officers, ranchers and herders. As is the case with Kenyewa, no society in Africa should be compelled to implement climate change mitigation strategies, for Africa's contribution to global emissions is minimal (Tadesse, 2010). Nonetheless, Climate change mitigation strategies in Kenyewa Location will not only give positive contribution to Kenya's commitment to reduce its greenhouse gas emissions but also yield localized benefits of improved productivity and resilience in cattle production.

1.6. Scope and Limitations of the Study

Methane gas sources in cattle production are two-ford, enteric fermentation and manure management. This study focussed on the enteric fermentation methane which is a more serious source. Fermentation process takes place in an anaerobic condition of rumen (fore-stomach) of all ruminants, domestic or wild resulting in generation of great quantities of different gases but this study focussed on one of them, methane. Livestock husbandry in general results in methane gas emissions but this study's focus was on was on enteric methane emissions in cattle production. Cattle enteric methane is released mainly through eructation but smaller portions are also released through the nostrils and flatulence. Calves below four weeks do not belch and so this study dealt with mature cattle in the sample area, Kenyewa Location and, Kajiado County. The estimates of total methane emissions per year, total methane emissions per hour, methane per cattle per year, methane per cattle per hour and, methane emissions over the ruminating period each day were calculated. This study further attempted to determine the contribution of cattle in the sample area, in the entire Kenyewa Location and in Kajiado County at large, to global anthropogenic greenhouse effect.

Cattle production is a source of livelihood for millions of poor people worldwide. Some cattle keepers do not own land and have no formal education or training. Cattle keeping are the economic activity dominant in the dry lands of Africa. It is in the ASALs of Kenya that cattle are kept in large numbers. This study was done in Kenyewa Location, Kajiado County in Kenya.

Cattle are kept under intensive or extensive systems but this study was done in an extensive system of production. Adaptation and mitigation are indispensable responses to climate change. This study sought to determine what was being done or could be done to achieve enteric methane mitigation. Mitigation measures can be through reduction of greenhouse gases or improving their sinks but this study dealt with reduction of greenhouse gases.

This study was limited to technological options in enteric methane emissions mitigations. Cattle keepers in the ASALs of Kenya depend entirely on nature for survival of their cattle so tend to maximize their herds. Reduction of cattle numbers is a method of enteric methane mitigation that has no cost implication and does not require any special skill. This study did not cover this kind of a response to climate change because for to majority of cattle keepers in Kenyewa, herd reduction is unpopular due to socio-cultural reasons. In periods of drought, a lot of cattle die due to lack of pasture for maintenance of the herds. Surprisingly, as soon as it rains and there is hope for sufficient herbage, cattle keepers quickly restock their farms. Meat and milk are the major cattle products and a source of delicacy in Maasai land. This study did not consider reduction in consumption of cattle products, a strategy that also has health benefits, as a response to climate change in Kenyewa Location. As is evident in most the meat outlets in the area, beef is packed as a take away meal. This growing trend in consumption of cattle products is expected to increase with increase in population growth rates and growing incomes. The Maasai prefer to counter the effects of cholesterol levels associated with red meat using traditional herbs other than cut down on beef production.

1.7. Operational Definitions

Cattle: Domesticated ruminant mammals of the genus Bos, either dairy or non-dairy, above four months of age, domesticated for meat, milk or traction.

Cattle production: Breeding, raising, growing and finishing activities of cattle either for beef, dairy or dual-purposes.

Climate change: change in the state of the climate that can be identified (for instance, using statistical tests) by changes in the mean and/or variability of its properties, and that persists for an extended period, typically decades or longer.

Climate Change Mitigation: an anthropogenic intervention that reduces the sources of greenhouse gases (abatement).

Emission factor: is an estimate of the amount of methane produced by cattle in Kg per head per year.

Enteric fermentation: a digestive process by which plant material consumed by cattle is broken down by bacteria in the rumen under anaerobic conditions producing methane as a by-product.

Global warming: the gradual increase, observed or projected, in global surface temperature caused by anthropogenic greenhouse gases.

Greenhouse gas (GHG): is any gaseous compound in the atmosphere which traps heat from infrared radiation, absorbs and re-emits it thereby keeping the planet's atmosphere and earth's surface warmer than it otherwise would be.

Livestock: domestic animals, such as cattle, sheep and goats kept for subsistence use or for cash.

Methane (CH_4): chemical compound of one atom of carbon and four atoms of hydrogen.

Methane emissions: methane gas released into the atmosphere from natural or anthropogenic sources.

Pastoralism: an economic and social system common in dry land areas in which 50 per cent or more of household gross revenue comes from livestock or livestock related activities.

Ruminant: a hoofed mammal that possesses a complex and unique digestive system that enables it to use energy from fibrous plant materials better than other herbivores.

Technological options: Measures that are taken to make cattle production more productive.

CHAPTER TWO

2.0. LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK

2.1. Introduction

The literature review was conducted to get a better understanding of enteric methane gas emissions from cattle production in relation to climate change. This was necessary in order to provide insights into the current thinking, methods and trends of investigation, emerging issues, key findings and recommendations on the subject matter. The literature review was organized topically to give both theoretical and empirical perspectives. The topics covered in the literature review included: climate change, greenhouse gases and climate change, methane and greenhouse effect, methane sources and levels, estimating methane emission from cattle sector and technological options to reduce methane emission from enteric fermentation. The topic on technological options to reduce methane emission from enteric fermentation covered three-fold set of intertwined issues namely: what is being done to reduce enteric methane emissions, viability criteria of technological options to reduce enteric methane emissions, community participation in climate change mitigation strategies and what can be done to mitigate enteric methane.

2.2. The Review

2.2.1. Climate Change

Climate change is a very current global issue but lacks a universally agreed upon definition as many scholars and organizations have over the years provided many varying definitions that result in uncertainties on precise meanings and measurements (U.S. EPA, 2002; IPCC, 2007, 2013, 2014; NOAA, 2007; Rowlinson, 2008; RS and NAS, 2010 *et cetera*). U.S. EPA (2002) defined climate change ’as the long-term fluctuations in temperature, precipitation, wind and other elements of the earth’s climate system’ while IPCC (2007, 2013, 2014) defined climate change as the ‘change in the state of the climate that can be identified (for instance, using statistical tests) by changes in the mean and variability of its properties, and that persists for an extended period, typically decades or longer’.

These two definitions focus on the scientific meaning as compared to the definition provided by the UNFCCC (IPCC, 2007) that defined climate change as a ‘change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods’ (IPCC, 2007) which puts the human-induced climate change. Abeygunawardena (2003); Kurukulasuriya (2003); Bobadoye *et al.* (2014) and GoK (2013) stated that climate change is a reality.

In his guidebook, Odingo (2001) noted that climate change affects both human and the natural systems. According to Mwiturubani and Wyk (2009) climate change also affects survival but Tedasse (2010).observes that it also affects the environment. According to Peters *et al.* (2012) and Matere *et al.* (2013) climate change affects livelihoods. Harris et al. (2015) observed that climate change affects life. RS and NAS (2010) argue that climate change, whether due to natural or anthropogenic factors causes mayhem. This study disagrees with that argument and concurs with Harris et al. (2015) that natural greenhouse effect supports life by providing warmth but anthropogenic greenhouse effect disrupts life and livelihoods.

In the work of Odingo *et al.* (1994), an estimate was made that the mean global surface temperature rose by 0.4-0.6 Degrees Celsius in the course of the last century. An increase in global surface temperatures is echoed by RS and NAS (2010). Their finding was that since 1900, the global average surface temperature has gone up by about 0.8 Degrees Celsius (RS and NAS 2010). Climate scientists in the United States of America have observed an increase in temperature and varied precipitation (U.S. G C R P 2014). The report says that temperatures have increased from 0.8-1.1 degrees Celsius since 1895. Moreover, precipitation has generally increased over the years but some areas have recorded a decrease in precipitation. The trend in Africa was given by WWF (2002) who noted that during the twentieth century, temperatures have gone up by about 0.7 Degrees Celsius. Rainfall has decreased over a large part of the semi-arid region south of the Sahara but increased in the East and Central Africa. The scenarios in South Africa, as observed by UNICEF (2011), indicated that average annual temperatures are going up. Moreover, rainfall patterns differ such that some parts of the country recorded more rainfall while the others had less rainfall.

According to IPCC, temperatures in Kenya have risen by one Degree Celsius (1^0C) since 1960 and warming is expected to continue to rise (Christensen *et al.* 2007). Mc Sweeney *et al.* (2008); Christensen *et al.* (2007) noted that Kenya is warming at a rate of about 1.5 times the global average and rainfall has an irregular and unpredictable pattern. In addition, the frequency and magnitude of floods is on the increase. Drawing from Odingo (2001); IPCC (2007), the mountain glaciers are melting and retreating as observed in Mount Kenya and Mount Kilimanjaro at the Kenya Tanzania border. Climate Change in Kajiado County is real. (GoK) 2013 observed that erratic rains, flash floods, extreme temperatures and prolonged droughts are common in the area.

Global warming is unequivocal with the evidence of a warmer earth being widespread, from the ocean beneath to the atmosphere above (Harris *et al.* 2015). The evidence is summarized as warming of the atmosphere and ocean surfaces as well as decrease in the levels of snow and ice (Odingo, 2001; IPCC, 2013; RS and NAS, 2010). These scholar and organizations further noted an increase in the sea level, diminished arctic sea ice and, escalated concentration of greenhouse gases. Climate change is a global issue but its negative impacts are felt more by the developing countries despite their small contribution towards the problem (Abeygunawardena, 2003; UNEP, 2006; Tadesse, 2010; HBS 2010). The vulnerability to climate change is attributed to lack of capacity, low developments and high population growth rates among other factors (Tadesse, 2010; King'uyu *et al.* 2012).

2.2.2. Greenhouse Gases and Climate Change

Greenhouse gases are classified into two, long-lived and short-lived greenhouse gases (IPCC, 2007). This is in order to distinguish those that are reactive from those that are stable chemically. The former description refers to the so-called short-lived greenhouse gases whose concentration in the atmosphere tends to vary from time to time. The latter, referred to as are long-lived greenhouse gases are capable of staying in the atmosphere long enough to have an impact on climate (WISP, 2010; Ramanathan, 2014). They include Carbon dioxide, methane and Nitrous Oxide among other gases (IPCC, 2013). Carbon dioxide is the most important anthropogenic greenhouse gas (WMO, 2013). This study focussed on the second most important anthropogenic greenhouse gas in the earth's atmosphere, methane and chose to deal specifically with enteric methane from cattle production in Kenyewa Location in relation to climate change mitigation.

Developed countries produce high levels of greenhouse gas emissions that are significant in the global anthropogenic greenhouse effect compared to developing countries. U.S.A and Europe emit fifty one (51) per cent of the total global greenhouse gases into the atmosphere (Awuor *et al.* 2008). Canada's greenhouse gas emissions from anthropogenic sources were 720 megatonnes of carbon dioxide equivalent while South Africa recorded 114,305 Gigagrams of carbon dioxide equivalent (Ominski *et al*. 2007; Witi and Stevens, 2014). This is not a good comparison because of the difference in years during which quantification of the emissions was done. Nonetheless, it is clear that Canada's emissions were higher than that of South Africa. In Kenya, a national greenhouse gas emissions inventory was done in 1994 and 2010. In 2010, Kenya estimated its greenhouse gas emissions at 61.53 million tonnes of CO_2 equivalent (GoK, 2012). Though quantification of emissions was done at varied years, Kenya's emissions are lower than those of South Africa. The United Kingdom quantified its emissions in 2005, giving its findings in million tonnes of carbon dioxide equivalents. The findings were that fuels' production and consumption (oil, gas, coal and electricity) gave the highest level of emissions (Gill *et al*. 2009). In the work Nelson *et al.* (2014), energy sector was the key contributor of greenhouse gas emissions in South Africa.

In Kenya, agricultural sector took the lead in greenhouse gas emissions (GoK, 2012). This Kenyan inventory also depicted that greenhouse gas emissions for all sectors from the year 2000-2010 were increasing. There was a similarity in the three countries and this was that waste contributes the least to greenhouse gas emissions. There was common challenge confronting all these nations in their endeavour to determine levels of GHGs in the various sectors and this was the availability of accurate data. From these few examples, it is clear that countries in Africa produce lesser emissions compared to the developed countries. This is despite the fact that there are industries and urban areas in Africa just like in those developed countries. In addition, cattle production, a source of enteric methane, is done in Africa as well as in the developed countries. Nonetheless, Africa's contribution to Climate Change is small, being estimated at four (4) per cent of the global emissions (Odingo, 2001; WISP, 2010). This study sought to test the hypothesis that enteric methane emissions from cattle production in Kenyewa Location are minimal and thus insignificant in global anthropogenic greenhouse effect.

2.2.3. Methane and Greenhouse Effect

Methane gas has very unique characteristics. It is a simple molecule composed of one carbon (C) atom and four hydrogen (H) atoms, thus the chemical formula CH_4 (Moss *et.al* 2000; SI, 2013). It was Migeotte who noticed methane in the atmosphere for the first time (Migeotte, 1948). As regards colour and smell, Wittenberg (2008) and Lines-Kelly (2014) noted that the gas is 'colourless' and 'odourless'. According to Migeotte (1948), methane gas is flammable. A contrasting opinion that methane is inflammable was given by Broucek (2014). This study agrees with Migeotte but disagrees with Broucek, because all methane sources, regardless of origin can ignite a fire. Methane gas has very serious effects on the environment. It is chemically and radioactively 'potent' even though it is a trace greenhouse gas, having a contribution to global warming rated second after carbon dioxide (CEC, 1996; UNEP, 2012).

Methane also contributes to depletion of ozone layer (Broucek, 2014). Even though the level of atmospheric concentration of carbon dioxide is high, methane traps heat more readily and as such has a higher global warming potential (GWP) than carbon dioxide (CEC, 1996; Lines-Kelly, 2014).This means that the amount of heat that a particular mass of methane traps is higher than that which can be trapped by the same level of carbon dioxide. Different scholars and organizations have given contrasting figures for the global warming potential of methane. These are 62 and 25 for CEC (1996) and 25 (Lines-Kelly, 2014; Brander, 2012) respectively. According to IPCC (2007) methane is about 20 times as potent as CO_2 over a one hundred year timeframe and 60 times more potent over a twenty year timeframe. This is unlike the issue of Data Summary which reported an estimated global warming potential per molecule of methane as 25 times greater over a 100- year timeframe and 72 times greater over a twenty- year timeframe than carbon dioxide (WMO, 2013).

Although the figures of the globing warming potential are different, a clarification has been made by IPCC (2007) and WMO (2013) that the values depend on what horizon the estimate is made. IPCC and WMO quote different figures for similar horizon estimates and as such create confusion. This study estimated enteric methane emissions in Kenyewa Location of Kajiado County and converted the figure to carbon dioxide-equivalent using a GWP of 25. There arises another disagreement regarding the stability of methane gas. SI (2013) contents that methane is a short- lived greenhouse gas.

WMO (2013) and IPCC (2007) were categorical that methane is a long-lived greenhouse gas. Methane gas emission levels have been increasing at different rates. Annual global methane emissions were about 582 teragrams (Tg) of methane, the bulk being from human activities (IPCC, 1992). Scharpenseel *et al.* (1990) estimated the increase in methane concentration in the atmosphere at 40-90 Tg CH_4 y^{-1}. This is an annual increase of one per cent (Odingo *et al.* 1994). The scenario in the developed countries is not any different.

In the year 2015, methane emissions in the United States of America amounted to about 600 million metric tons of carbon dioxide equivalents (U.S EPA, 1990). According to Witi and Stevens (2014), methane emissions in South Africa in the year 2010 amounted to 51,545 Gg of carbon dioxide equivalents. No good comparison can be made because the years that these countries quantified methane emissions differ. Nevertheless, it is clear that United States of America produces higher levels of methane emissions compared to South Africa. Kenya has not given the quantities of methane emissions independently. Total emissions in the years 2000, 2005 and 2010 gave 46.51, 53.94 and 61.53 Mt CO_2 e respectively (GoK, 2012). From these findings, it is evident that Kenya releases relatively low emissions compared to South Africa and United States of America. Nonetheless, the level of emissions has been increasing from the year 2000 to 2010. This study chose to deal with a small section of emission of greenhouse gases, methane gas emissions by enteric fermentation from cattle in Kenyewa Location of Kajiado County.

2.2.4. Methane Sources and Levels

Methane sources are known but specific levels of methane from the various sources remains debatable (Cicerone and Oremland, 1988). Methane gas, emitted mainly from human activity is the second most important greenhouse gas in the atmosphere (WMO, 2013). In the work of IPCC (2007), methane levels in the atmosphere are by far higher compared to the natural values of the pre-industrial period. In other words, whereas the ice core records of the last 650,000 years range between 320-790 ppb, the pre-industrial to the year 2005 values range from 715 ppb-1774 ppb. It is the alarming rate of increase of levels of methane gas in the atmosphere that makes scientists to be curious about the sources from which it originates.

This study acknowledges that enteric methane levels from cattle in Kenyewa are not known. In their work, Lines-Kelly (2014); EDF, (2017) and WMO, (2013) observed that methane is emitted from natural sources and human activities. Natural sources of methane are freshwater, permafrost, gas hydrates, termites, wildfires, wetlands, oceans, lakes and wild animals (Scharpenseel *et al.,* 1990; WMO, 2013; Moss *et al.*, 2000; Lines-Kelly, 2014). IPCC (1992) supplement gave the anthropogenic sources of methane, the emission estimate and the range except for the range of domestic sewage treatment and asphalt pavement. In their Greenhouse Gas Bulletin, WMO (2012) estimated that 40% of methane is emitted into the atmosphere by natural sources while the greater percentage of approximately 60% comes from anthropogenic sources.

According to Broucek (2014), enteric methane emissions globally were 74 Teragrams (Tg) in the year 1982, with 74 per cent being released by cattle alone. This amount increased to 84 Tg in 1990 but decreased to 80 Tg in 1994 (Lassey, 2007). Globally, cattle emit enteric methane gas amounting to about 39-60 Tg y^{-1} (Scharpenseel *et al.* 1990). Gibbs and Johnson (1994) concur, stating that in the year 1994, the planet had 1.3 billion cattle that produced 58.4 Tg of enteric methane. Methane gas produced by cattle is highest in North America followed by Europe which amounts to 11 Tg^{y-1} and 8 Tg^{y-1} respectively (Scharpenseel *et al.* 1990). In the United States of America cattle accounted about 5.4 Tg per year of enteric fermentation (Mangino *et al.* 2006). India which has the largest population of livestock in the whole world recorded a total of 6 Tg of enteric methane per year emitted from its cattle (Singhal *et al.* 2005). Clearly, enteric methane emissions were higher in India than in the USA though for two different years. In Kenya, the level of enteric fermentation from livestock sub-sector was estimated 15.2 Mt CO_2 e and 18 Mt CO_2 e in the year 2000 and 2010 respectively. Kenya has quantified enteric methane emissions from the entire livestock sub-sector unlike USA and India who estimated enteric methane emissions from cattle independently. However, the Kenyan estimates are still low compared to those from the other two countries. This study attempted to compute enteric methane levels from cattle production in Kenyewa Location of Kajiado County.

2.2.5. Estimating Methane Emission from Cattle Sector

It is possible to measure or estimate methane emission from cattle despite the complexity of the process (Goopy *et al.* 2015; IPCC, 2006). There are various methods that can be used to quantify emissions but extreme care needs to be taken in order to get accurate results.

Drawing from IPCC guidelines, methane emissions from cattle can be estimated by multiplying the number of cattle by an emissions factor IPCC (1996; 2006); Gibbs *et al.* (2000) using the following formula,

Equation 2.1

$$CH_4\ Emissions = Number\ of\ cattle\ x\ CH_4\ Emissions\ Factor$$

Source: Gibbs *et al*. (2000)

The emissions factors emanate from Tier 1, Tier 2 and Tier 3 methods (Goopy *et al.* 2015; Ogle *et al.* 2014; Gibbs *et al.* 2000). Tier 1 method depends on animal numbers' data, default equations and emissions factors that are generated from studies that have already been done (Ogle *et al.* 2014; Gibbs *et al.* 2000). These studies reveal that emission factors vary with region and cattle type (Thorpe 2008). Similar sediments that emission factors differ with region are echoed by Herrero *et al.* (2008), who further noted that the type of production system as an important factor. The disadvantage with this method is that it doesn't depend on feed characteristics and emission factors are general and as such are not specific to a particular country. As David (2015) observes, lack of country-specific emission factors leads to a great deal of uncertainty. Despite the challenges associated with IPCC Tier 1 methodology, it is a useful method of quantifying emissions. As clarified by, Ida *et al.* (2012) the methodology to use depends on the aim of the exercise and the availability of the equipment, time, money and skill. Gibbs *et al.* (2000) noted that the choice of methodology to use depended on data availability and magnitude of emissions. The second method, the Tier 2 is a complicated one and depends on detailed country-specific data on animal data and feed characteristics (Ogle *et al.* 2014; Gibbs *et al.* 2000). This specific data is on nutrient requirements, feed intake and methane conversion rate for a particular feed type. Tier 3 depends on equations and emission factors used that are specific to the particular country (Ogle *et al.* 2014).

The shortcomings of Tier 1 method are overcome by use of Tier 2 and Tier 3. The methodologies can be grouped into: Indirect estimation, direct measurement and use of an equipment called greenfeed® emission monitoring apparatus (Goopy *et al.* 2015, Zimmerman and Zimmerman, 2012). According to from Johnson and Johnson (1995); Goopy *et al.* (2015), estimation from diet and in vitro incubation are indirect measurements of estimating methane emissions from cattle. The direct measurements are: respiration chambers, head boxes, ventilated hoods; face masks, mass balance techniques, micrometeorological and tracer methods. Quantifying emissions from sources whose levels have not been determined is an important step and guide towards reducing enteric methane emission from that particular source. For this study, the greenfeed® emission monitoring apparatus, respiration chambers and face masks among other equipment were not available. Moreover, IPCC recommends the use of Tier 2 and Tier 3 in estimating emissions from large emission sources (Ogle *et al.* 2014; Gibbs *et al*. 2000).

Therefore, this study relied on Tier 1 methodology to estimate methane gas emissions from enteric fermentation in cattle production in Kenyewa Location of Kajiado County. In the United States of America and in Canada, in the year 2006 and 2007 respectively, methane emissions from enteric fermentation were estimated using the International Panel on Climate Change (IPCC) Tier 2 approach (Ominski *et al.* 2007). In India, IPCC Tier 1 methodology was used to estimate methane emissions from livestock (Patra, 2014). In South Africa, in 2010, enteric fermentation methane emissions were estimated using IPCC Tier 2 approach (Witi and Stevens, 2014). According David (2015), the Kenya enteric fermentation methane emissions were estimated using IPCC Tier 1 methodology in the year 2010. IPCC Tier 1 approach was used in India (a BRICS country) and Kenya (a Developing country), even for the largest greenhouse gas emissions. This is unlike the developed countries that used Tier 2 methodology.

In this study, sufficient data required to use IPCC Tier 1 methodology was garnered with the available time, money and skill. The study sought to estimate the level of methane from enteric fermentation from cattle in Kenyewa Location using IPCC default emissions factors for Kenya estimated at 40 and 31 Kgs for dairy and non-dairy cattle respectively (GoK, 2012). The product of number of cattle and methane emissions factors give methane emissions in kilograms. To show the contribution of cattle in Kenyewa to global greenhouse effect and thus climate change the quantity of methane so obtained has to be expressed as CO_2-equivalent.

According to Brander (2012) and Lines-Kelly (2014), to determine contribution of the particular quantity methane to the global greenhouse effect, the amount of methane is multiplied by methane's global warming potential (GWP).

2.2.6. Technological Options for Reducing Methane Emission from Enteric Fermentation

The existing technological options for reducing enteric methane emissions in Kenyewa Location, their viability, level and, potential for participation of Maasai in Kenyewa in climate change mitigation activities are intertwined. Mitigation of methane emissions is a matter of global concern (CEC, 1996). Indeed mitigation calls for coordinated efforts by the nations of the world. Mitigation of climate change is done at regional, national and local levels. Mitigation is urgent and as observed by Olago (2012) the process involves awareness creation, coordination by various institutions to avoid duplication of activities, resource mobilization and involvement of various stakeholders, realistic planning and implementation. Africa's contribution to climate change is insignificant (Odingo, 2001) yet it is a recipient of diverse impacts of climate change. Consequently, the continent is seriously involved in adaptation to climate change. HBS (2010) confirmed that adaptation measures are a priority to Kenya. Pastoralist communities have learnt to adapt to the impacts of climate change. Mitigation of climate change has rightfully been postponed so as to industrialize, urbanize and agro-industrialize.

Kenya will at one time be ready to carryout mitigation activities. Kenya's cattle industry, especially among the pastoralists offers an opportunity to mitigate enteric methane emissions. Methane gas leaves the atmosphere after about twelve years which is far shorter that than that of carbon dioxide (Lines-Kelly, 2014). Therefore, technological options to reduce methane emissions are quicker in slowing global warming compared to those that reduce carbon dioxide emissions and bring other additional benefits (Odingo, 2001; Goopy *et al.* 2015; CEC, 1996). Measures have been or can be put in place to reduce enteric methane releases. It is important to first determine what options to reduce enteric methane emissions are already in place and determine their viability. Viability is an assurance of sustainability and is made possible by involvement of the local community in order to incorporate technological options into already existing traditional practices of cattle production. Participation of the local community in climate change mitigation strategies and potential for adoption of other technologies was very crucial.

According to CEA (2014) mitigation strategies are grouped into three: feeding practices, supplements and additives, herd management and breeding. Similar measures have been outlined by Johnson and Johnson (1995).

They include: enhanced nutrition, breeding, growth promotants and ionophores. Silvestri and Knox (2012) stated that better feed, improved management practices, better breeds, incentives, policies and regulation were good mitigation options for the developing world. Buddle *et al.* (2011) focuses on measures aimed at abatement of enteric methane emissions from pasture-grazed ruminants. Vaccination, supplementation, breed selection and feed additives are the measures outlined in that journal. Lines-Kelly (2014) gives the following options for reducing enteric methane emissions in a livestock production system: Enhanced animal management, sound pasture management, feed supplements, breeding and rumen manipulation.

CEA (2014) outlined feeding practices, supplements and additives and animal management and breeding are the enteric methane abatement measures. According to Ominski and Wittenburg (2004), technical options for reducing enteric methane gas emissions include: feeding management measures such as forages of high digestibility, legumes and good quality water and giving balanced rations. Mitigating enteric fermentation can be achieved by reduction of cattle numbers and increase in cattle productivity (CEC, 1996). But in his work, Bailey *et al.* (2014) noted that the viable strategy to mitigate enteric fermentation is by eating less meat and dairy product. IPCC (1992) outlined technical options for reducing enteric methane gas emissions that were categorized as: feed processing, strategic supplementation, additives that improve production, improved breeds, improved reproduction, disease control and aggressive marketing of the surplus cattle products.

FAO (2013) observed that even though enteric methane mitigation measures are effective, the level of implementation all over the world is quite low. The enteric methane mitigation measures are similar regardless of the place they are being implemented. This study settled for the IPCC recommended strategies which offered a wider range from which to choose. The choice of technological options for reducing enteric methane emissions depends on viability issues. Drawing from CEA (2014), the important viability issues to consider are: Improved productivity, affordability, certainty and safety. Increased productivity, cost effectiveness, consistence with culture as well as systems of production and decrease in cattle numbers with enhanced productivity is the basis of viability criteria (IPCC, 1992). Generally, all technological options for reducing enteric methane emissions lead to increased productivity but the affordability, certainty and safety have to be well determined (CEA, 2014).

IPCC (1992) recommends that planners, policy makers and implementers of enteric methane mitigation strategies make their choice carefully. Herrero *et al.* (2011), working on mitigation of climate change in livestock systems in Kenya found out that any measure that decreases enteric methane can be considered viable only if a certain level of output can be obtained with fewer animals under proper feeding. There are technological options for reducing enteric methane emissions that are still being researched on so their viability is yet to be determined (Lines-Kelly, 2014). Animal breeding for a trait of low methane emission is one of these measures. Some measures for reducing enteric methane emissions are risky and as such are not viable so they cannot be used any more, for instance steroids (IPCC, 1992). Buddle *et al.* (2011) noted that it is the method or production system that has a bearing on viability of strategies for reducing enteric methane emissions. Another observation made is that there are no viable strategies for reducing enteric methane emissions in cattle on extensive system of production. This was disputed by Peters *et al.* (2012) who noted that livestock herders in the tropics can reduce enteric methane emissions steadily through reseeding denuded areas with better quality pasture. This study concurs with the latter and seeks to determine the viability of existing enteric methane mitigation strategies in Kenyewa Location of Kajiado County. In the developed countries, options for achieving reduced enteric fermentation methane emissions are being implemented already.

The Impact of Ruminant Livestock on Greenhouse Gas Emissions was studied in the United Kingdom (UK) and well established in a scientific review. According to Hopkins and Lobley (2009) the UK study was carried out on forage-based livestock sector. The study was carried out on beef, sheep and dairy production to analyze their impact on emissions of the three main GHGs: carbon dioxide, methane and nitrous oxide. In addition, the studies dealt with measures that can or have been put in place to reduce methane releases. The main findings were that the total UK agricultural greenhouse gas emissions have decreased by 17% since 1990. Furthermore, methane emissions have decreased by 52% since 1990. This decrease in methane emissions was as a result of decrease in livestock numbers and improved feeding practices. In Germany the Animal Husbandry Act was enforced to reduce enteric methane emissions through improved feeding practices (CEC, 1996). In the developing countries increasing demand for cattle products is usually satisfied through increasing cattle numbers rather that improved productivity (Silvestri and Knox, 2012). In Kenya, mitigation on climate change in livestock system was studied in 6 districts (Garissa, Othaya, Njoro, Mbeere, Gem and Siaya).

According to Herrero *et. al*. (2011), the research was done on the impact of alternative feeding strategies on milk, manure and methane production. This research determined the amount of methane emitted per unit of output. It further determined mitigation of methane using different feed management strategies. The findings were that mitigation is possible because the same amount of milk is produced with fewer animals through proper feeding practices. Moreover, Incentives and availability of ready market are other important factors in achieving enteric methane mitigation. This study sought to determine the level of participation of the Maasai in Kenyewa in climate change mitigation strategies and further, the potential for adoption of other recommended climate change mitigation strategies.

Kenya ratified to the United Nations Framework Convention on Climate Change (UNFCCC) in the year 1994. In addition, a National Climate Change Response Strategy (NCCRS) was published in 2010. Implementation of measures geared towards adaptation to climate change is on-going in some areas of Kenya (GoK, 2013). Adaptation cannot replace mitigation IPCC (2007), as each has a unique role in the fight against Climate Change. Drawing from UNDP (2013), Kenya has put in place measures including the development of National Climate Change Action Plan (2013-2017) and the Mitigation Action Plan. This study sought to determine the real situation in Kenyewa Location of Kajiado County in Kenya.

2.2.7. Research Gaps

Many studies have been done in the developed countries, for instance, a Scientific Review of the Impact of UK Ruminant Livestock on Greenhouse Gas Emissions by Hopkins and Lobley (2009), but this study was done in a developing country. Had a wide scope of coverage, for example, Mitigation of Climate Change in Livestock Systems in Kenya by Herrero *et. al*. (2011), but this study is done on a sample area. Have tackled both intensive and extensive form of cattle production such as the work of Wittenburg (2008) on Enteric Methane Emissions and Mitigation Opportunities for Canadian Cattle Production Systems but this study is done only on extensive form of cattle production. Have been done on entire sectors such as livestock, for example, the work of David (2015) on Current Knowledge for estimation of emissions and Priorities for Mitigation and Adaptation-focus on Livestock in Kenya but this study was specifically on cattle.

Other studies have focussed on carbon dioxide emissions, for instance, Emissions from Fuel Combustion by OECD/IEA (2007) but this study's focus were on enteric methane emissions. Have included other anthropogenic sources of methane, for example, the work of David (2015) but this study had a special emphasis on enteric fermentation in cattle. Have been done on climate change impacts, vulnerability, adaptation or resilience, for example, Analysis of Climate Change and Variability Risks in the Smallholder Sector by Ojwang et al. (2010) but this study focuses on potential climate change mitigation strategies. Have given general or grouped technological options for reducing enteric methane gas emissions, for example, CEA (2014) but this study gave specific technological options for reducing enteric methane gas emissions in Kenyewa Location.

2.3. Theoretical Framework

The study considered several theories such as climate change: processes, characteristics and threats (Rekacewicz, 2005). This theory was useful but quite complex and with a lot of variables yet insufficient for this study. Also, the links among climate change, greenhouse gas emission impacts and socio-economic activities was considered (IPCC, 2001). This theory emphasizes adaptation measures unlike mitigation so could not be used.

This study adopted a theory that has advanced from the original Pressure-State-Response (PSR) framework proposed by Rapport and Friend (1979), the DPSIR framework. 'DPSIR' has been effective in environmental reporting by the Organization for Economic Cooperation and Development (OECD), United Nations Environmental Programme (UNEP) among other organizations. DPSIR refers to Drivers, Pressures, State, Impacts and Responses. Drivers lead to Pressures which result to a State that cause Impacts to which Responses are done to curb the problem. The 'DPSIR' framework in this study was a useful tool in communicating in a simple way to policy makers and stakeholders about the relationship between the Maasai community, their cattle and the environment.

2.4. Conceptual Framework

The conceptual framework's clockwise description is that of Drivers-Pressures-State-Impacts-Responses and their linkages. There has been an increased demand for cattle products due to increased population growth rates and growing incomes leading to increase in cattle population and consequent rise in enteric methane emissions. World meat consumption has increased six times from 47 million tons in 1950 to 284 million tons in 2005 (WPF 2011). Increase in consumption of cattle products is not only at global but also at regional, national and local scale. In Kenyewa Location of Kajiado County, affluence can be demonstrated by the general increase in consumption of beef in Kenyewa community who dispose of their cattle in Masimba, Sultan Hamud and Emali.

In this framework, number of cattle is the independent variable while enteric methane emissions per year are the dependent variable. Increasing enteric methane emissions in the atmosphere is a contributing factor to anthropogenic greenhouse effect that leads to global warming and climate change as evidenced by temperature change, variation in precipitation, sea level rise and extreme events. Impacts of climate change especially cyclical droughts make cattle keepers extremely vulnerable. Implementation of technological options for reducing enteric methane gas emissions can be described in a counter clockwise manner as Responses feedback to Drivers, Pressures, State and Impacts (IPCC, 2007; EEA, 2001). Technological mean score is the independent variable while enteric methane emissions per year are the dependent variable. Technological options for reducing enteric methane gas emissions are effective only if they lead to decrease in cattle numbers for a given level of output. Decreased cattle numbers lead to decreased enteric methane emissions.

Reduction in methane emissions slows global warming and climate change readily than reduction of other greenhouse gases. This lessens perils of climate change on ecosystems, water resources, food security, settlements and society and, human health. Adaptation to climate change complements mitigation in the fight against climate change. Reduction of cattle numbers is an effective strategy to reduce enteric methane emissions that requires no skill or cost (Thorpe 2008; CEC 1996). Another way is reduction of consumption of cattle products especially beef and milk, a strategy that has health benefits as well (UNEP 2012). The study did not focus on reduction in cattle numbers or cutting down on milk and beef consumption.

The study's focus was on technological options for reducing enteric methane gas emissions in Kenyewa Location of Kajiado County.

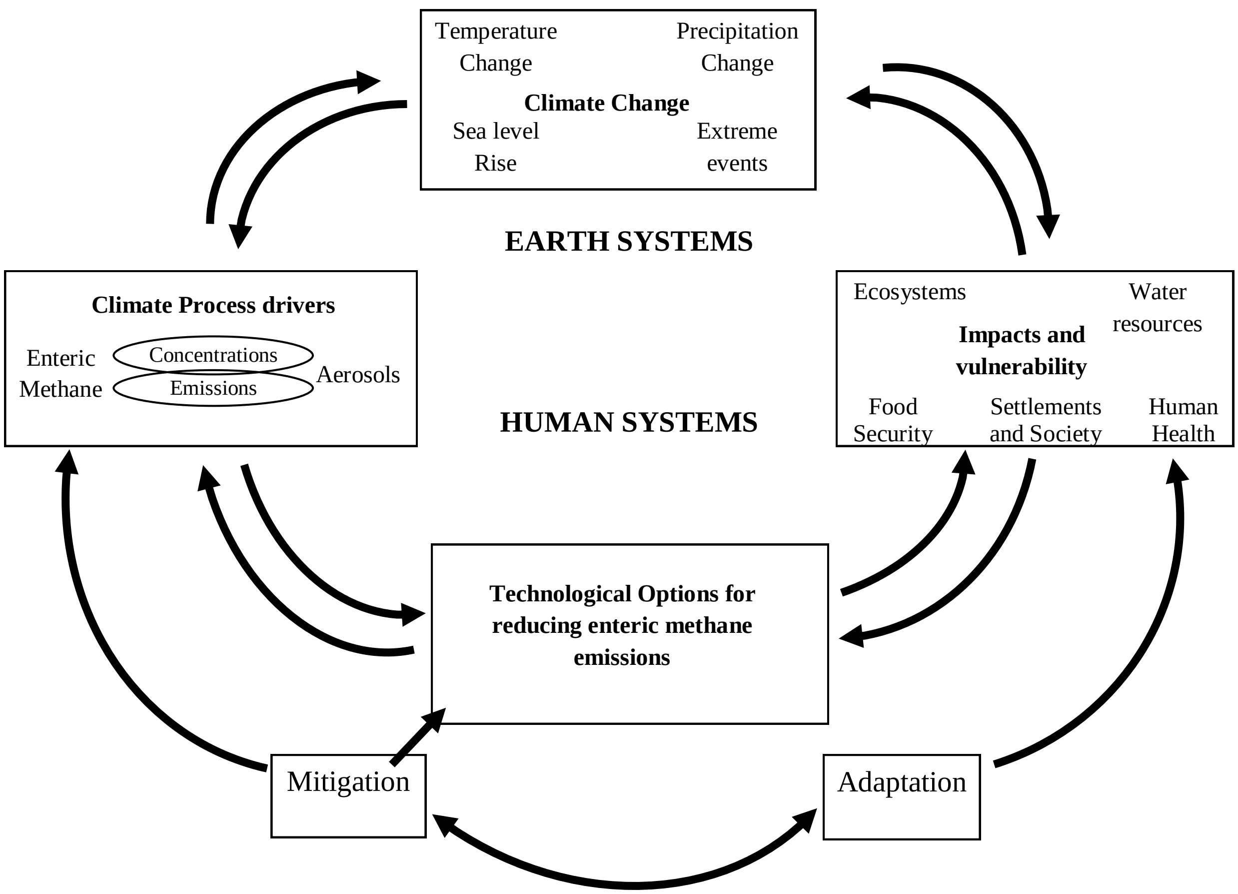


Figure 2.1: Conceptual framework

Source: *Modified from IPCC (2007)*

CHAPTER THREE

3.0. THE STUDY AREA

3.1 Location and Size

Kenyewa Location of Kajiado County in Kenya is located between longitudes 37^{0}28’0”E+37^{0}42’0”E and latitudes $2^{0}9^{'}$0”S+2^{0}18’0”S (figure 3.3). It is bordered to the South by Merueshi Location, to the West by Poka Location and to the East and North by Makueni County (figure 3.2). Its geographic location places it within the Equatorial belt and yet its climate is that of tropical semi-arid and this is largely explained by the moderating effect of altitude, distance from the sea and relief.

Kenyewa Location is in Kenyewa-Poka ward, Kajiado East Sub-County of Kajiado County (figure 3.1). Kenyewa Location covers an area 309.9 Km^2 (GoK 2009), making it potentially under high land pressure due to increasing population of both human and livestock. The location is divided into two sub-locations, Masimba and Kiboko (figure 3.2 and 3.3). Kenyewa Location of Kajiado County falls under the arid and semi-arid areas (ASALs) and is part of the southern rangelands of Kenya. As stated by NEMA (2004), ASALs occupy about 88 per cent of the Kenyan land mass and support millions of livestock (above 50 %) and wildlife (80-90 %). It is in the ASALs that Pastoralism form of livelihood has proved to be viable, providing above 50% of red meat consumed in Kenya (NEMA, 2004). Enteric methane gas emissions are high in the ASALs due to large cattle numbers and this trend is likely to continue.

Cattle keepers provide their herds with shelter against adverse weather conditions and from wild animals. In addition, they are responsible for nutrition and safe drinking water of the livestock. On their part, cattle provide meat, milk, income, organic manure, bio-fuel, livelihood, employment, leather, traction and a means of diversification (Gerber *et al.* 2013; Thornton and Herrero 2011). This harmony notwithstanding, cattle industry is a source of anthropogenic greenhouse gases and consequent global warming (Peters et al. 2012; GoK, 2013; Thornton et al. 2011). FAO (2006) noted that livestock production was responsible for 18 per cent of global greenhouse gas emissions and this placed it ahead of the transport sector. Ecological, political and economic ideologies aside, enteric methane emissions from cattle cannot be under rated.

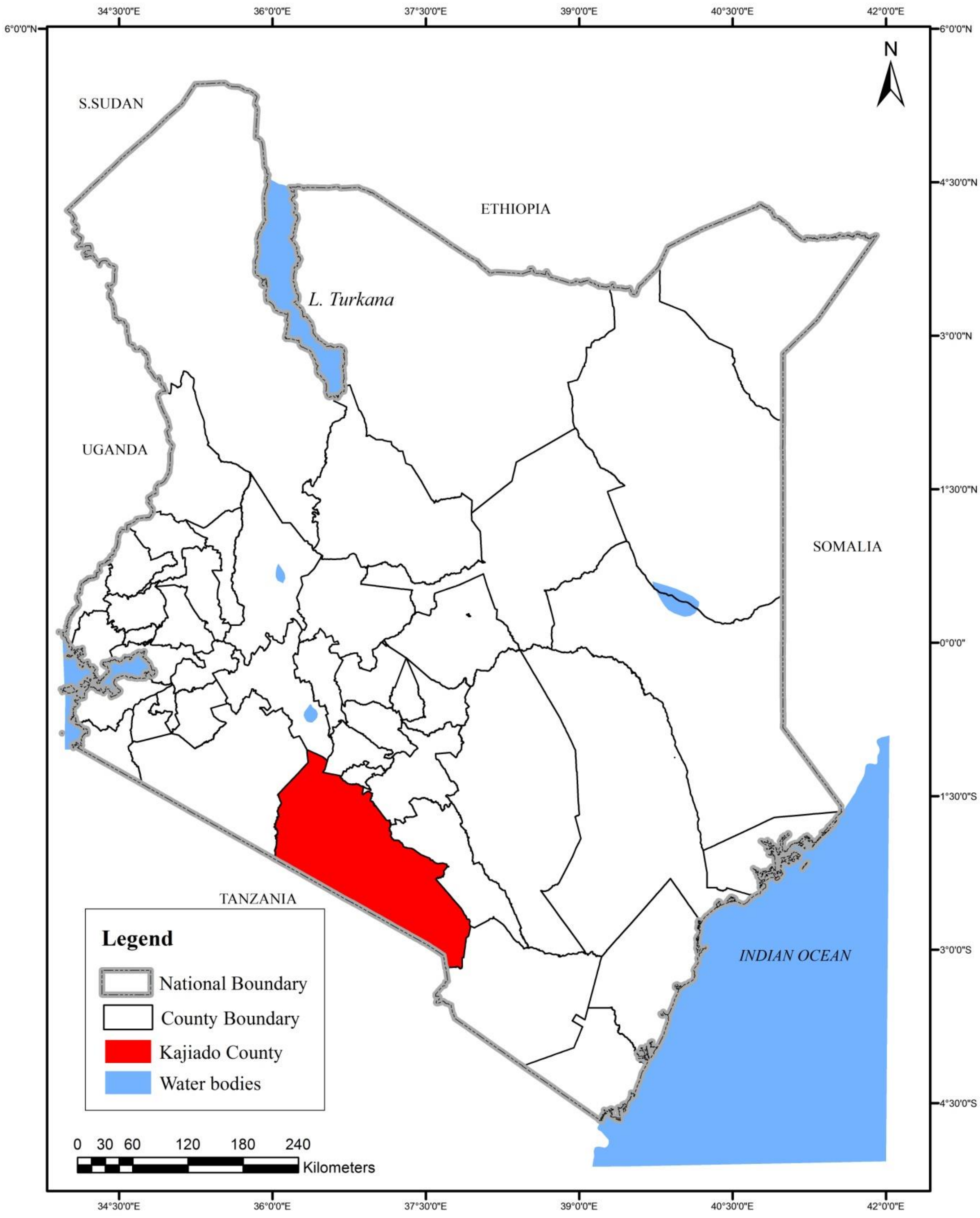


Figure 3.1: The location of Kajiado County in Kenya

Source: *Kenya National Bureau of Statistics (2017)*

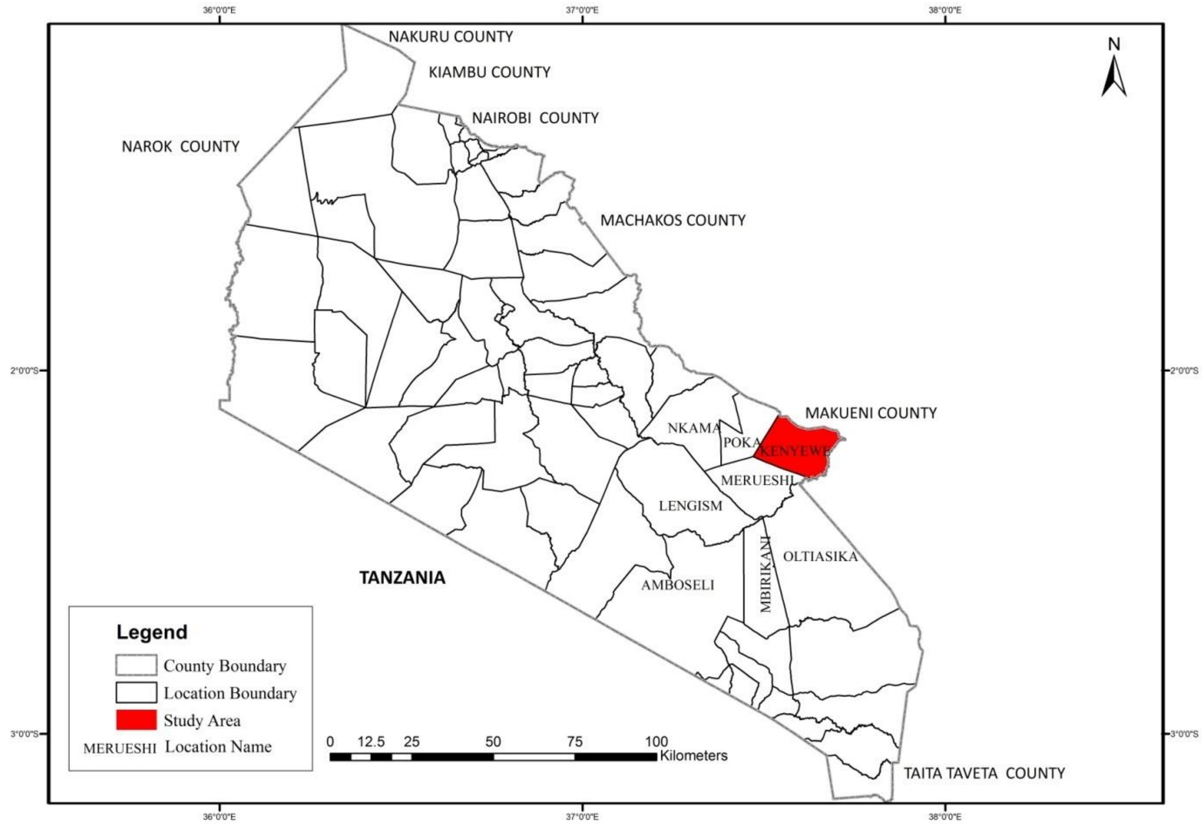


Figure 3.2: The Location of Kenyewa in Kajiado County

Source: *Kenya National Bureau of Statistics (2017)*

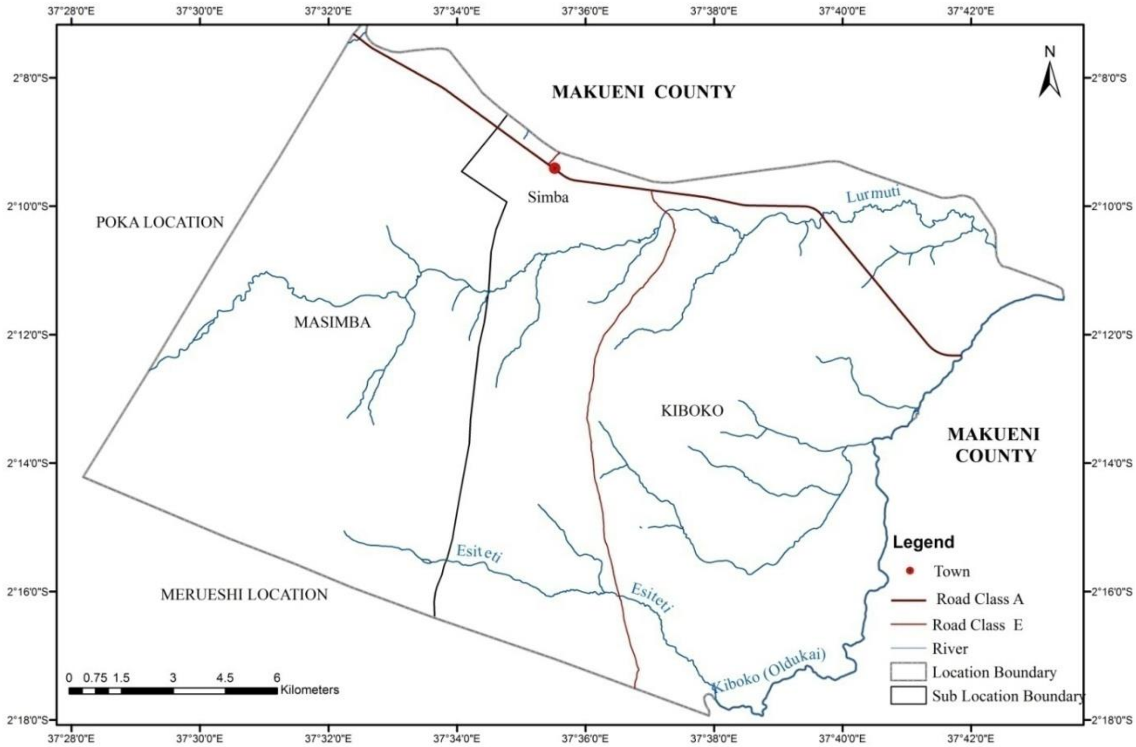


Figure 3.3: Administrative Sub-Locations in Kenyewa

Source: *Kenya National Bureau of Statistics (2017)*

3.2. Geology and soil

Rocks in Kenyewa Location of Kajiado County are underlain by basement type of rock which has gneiss (GoK 1966; Wafuke et al. 2011). This parent rock affects ground water quality and quantity, soils and land cover. This is very important because when seasonal sources of water dry up, the herders depend on borehole water. Soil originates from the rocks after the weathering process (Orodho, 2006). Due to high temperature, insufficient rainfall and few micro-organisms, soils in Kenyewa are poor in nutrients required for plant growth. The soils in Kenyewa Location are stony clay and sand soils of dark, red or reddish- brown colour (plate 3.1). The soils are shallow and poor in organic matter owing to low unreliable rainfall received in the area (NEMA, 1994). During the dry season, the clay soils easily crack but when it rains they become waterlogged due to poor drainage (Orodho, 2006). Leaching characterizes the sandy soils. These kinds of soils are unsuitable for growth of some and favour only limited variety of forage. Good quality herbage leads to low enteric methane emissions while poor quality ones leads to high enteric methane emissions.

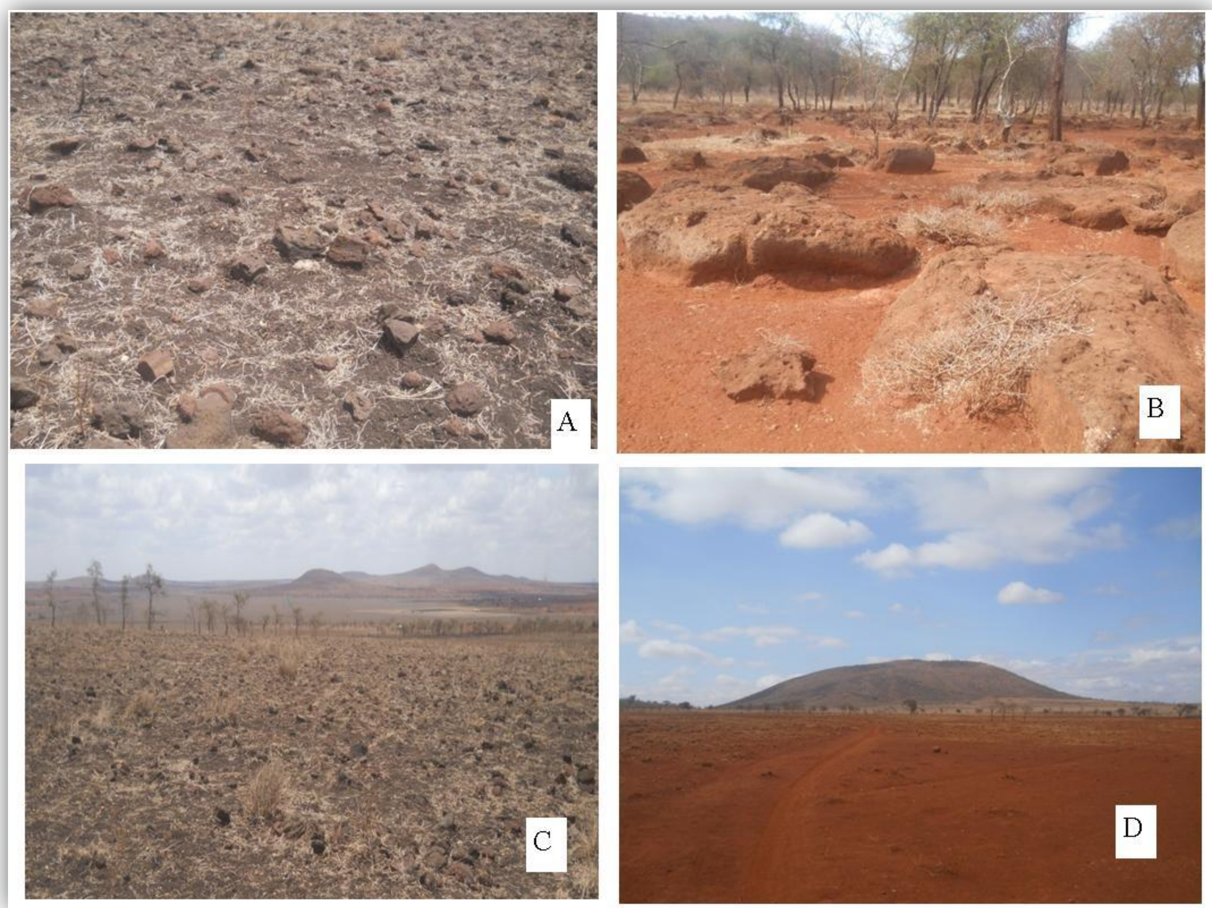


Plate 3.1: Soils in Kenyewa Location **Source**: *Field Study*

Plate 3.1 illustrates geology and soil in Kenyewa Location of Kajiado County.

A. Stony sandy soils

B. Stony clay soils

C. Gravelled sandy soils

D. Reddish- brown clay soil

Soils in Kenyewa, as evidenced by plate 3.1, are stony and support limited pasture. Cattle are ruminants and therefore utilize that kind of forage that could have otherwise gone to waste and convert it into useful products that human beings can utilize. In the process of digesting that kind of pasture, methane is released as a by-product. Poor quality forage produces more methane than forage of good quality.

3.3. Climate and Hydrology

Climate and hydrology defines seasonality, movement and cattle numbers. Kenyewa Location falls at approximately 2^0 south of the equator (TARDA 1984) hence has bimodal type of rainfall. Kenyewa Location falls within the arid and semi-arid areas (ASALs) whose weather is not only hot but also dry and evapotranspiration rate higher than the available rainfall doubled (GoK, 1992; Wafuke *et al.* 2011). According to Bekure *et al*. (1991) and Rutten (2005), Kenyewa is in the semi- arid climatic zone (Table 3.1). The short rains fall between October and December while the long rains are experienced beginning from March to May (GoK 2013). The rainfall amount is in the range of 450 mm to 800 mm per annum (Bekure *et al*. 1991). The rainfall pattern is low, erratic and uncertain with temperatures being quite high (Wafuke et.al. 2011; GoK 2013; Orodho 2006). November to April is the hottest period while July and August are coolest (TARDA 1984).

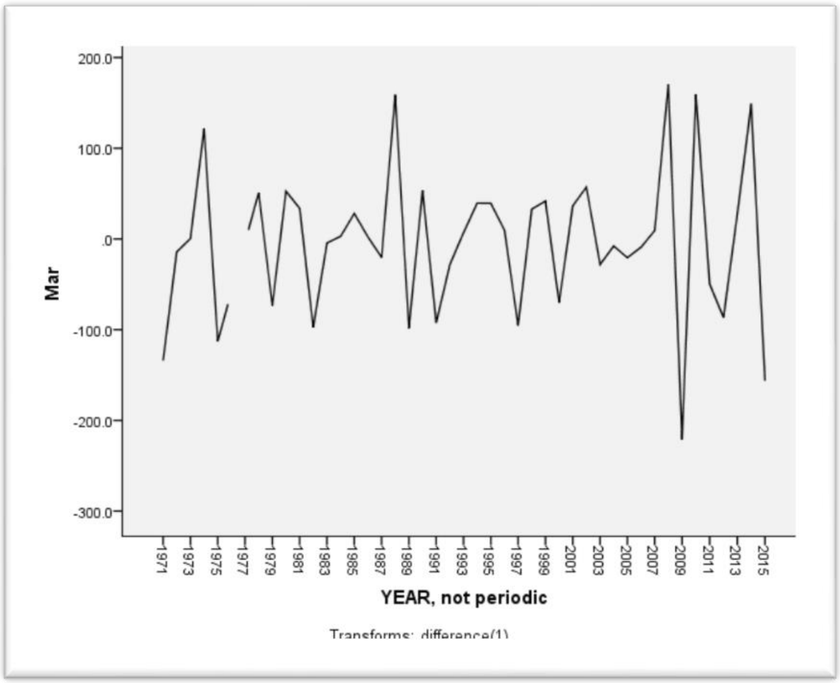
Table 3.1: Climatic zones in Kenya rangelands

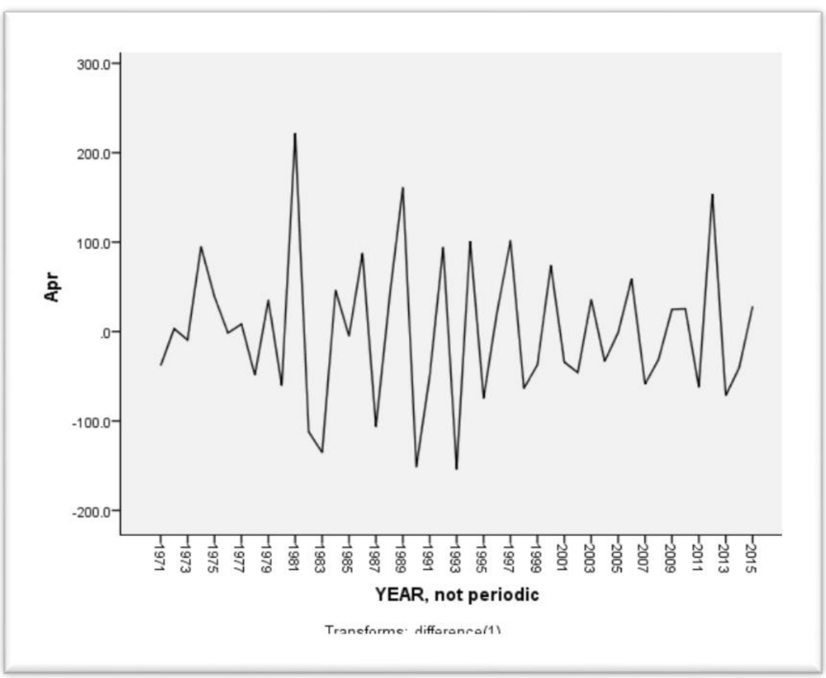
Agro-ecological zones	Climate	Moisture index (%)	Annual Rainfall (mm)	% of Kenya lands area
IV	Semi-humid to semi-arid	40-50	600-1100	5
V	Semi-arid	25-40	450-800	15
VI	Arid	15-25	300-550	22
VII	Very arid	<15	150-350	46

Source: Bekure *et al*. 1991

Wind speed in Kenyewa Location is quite low, below eleven kilometres per hour (TARDA 1984). However, alternative sources of energy in the area which are also more reliable include firewood, charcoal, electricity and, solar (GoK 2013). Temperature and rainfall data is available; Makindu Meteorological Station being the reference point. Rainfall data analysis for the period between 1971 and 2015 shows the peak of the long and of short rains (figures 3.4 and 3.5, 3.6 and 3.7). March and April (figures 3.4 and 3.5) and November and December (figures 3.6 and 3.7) depict the wettest period.

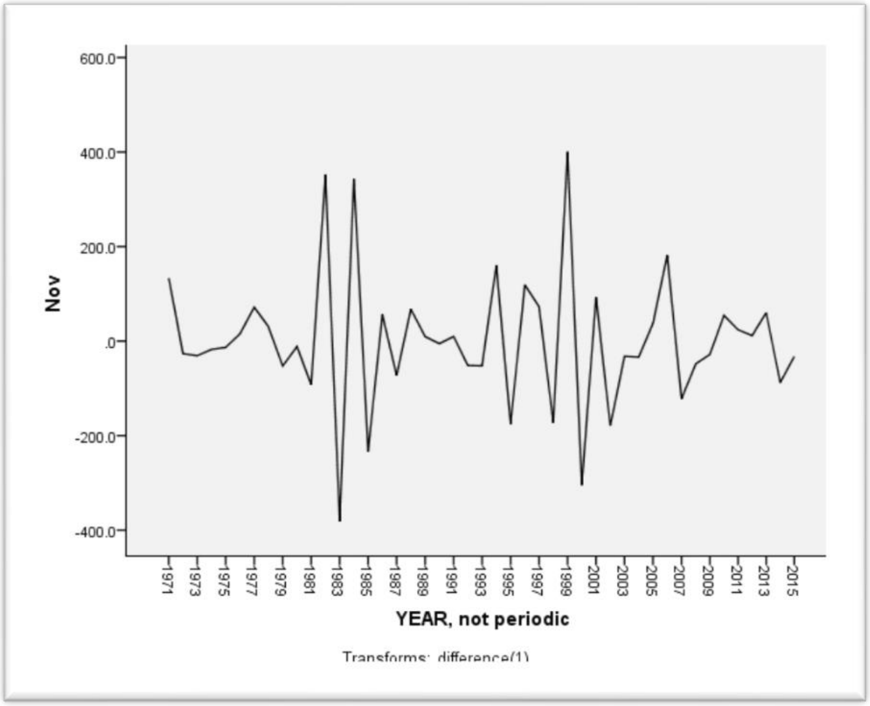
The period is characterized by succulent pasture and increasing cattle numbers as herders purchase more cattle. As cattle numbers increase, enteric methane emissions from cattle production in Kenyewa also increase.

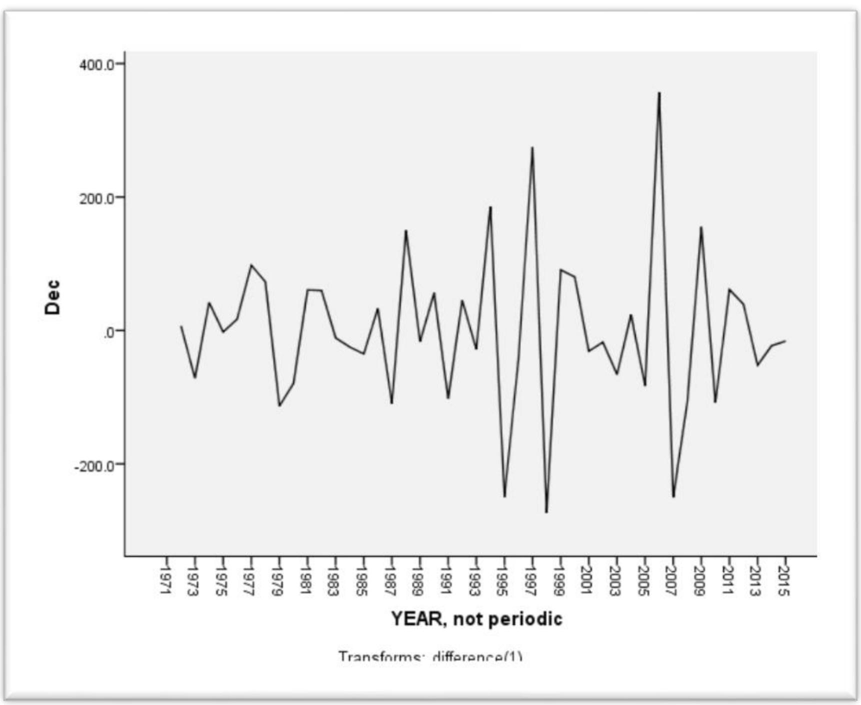




Figures 3.4 and 3.5: Peak of the long rains

Source: *Field study*





Figures 3.6 and 3.7: Peak of the short rains

Source: *Field study*

Water is very crucial to the economy of Kenyewa Location of Kajiado County. It is used for domestic purposes and watering livestock, among other uses. Water sources in the area are both natural as well as man-made (Rutten 2005). Natural water sources are rivers, streams and springs (map 3.3).The largest river in Kenyewa location is Kiboko River that flows from the East and has numerous tributaries in Kiboko sub-location and fewer in Masimba sub-location (Wafuke et al. 2011). Kiboko River supplies water to the area all the year round because even during the dry spell, water is fetched from sand-dams made within the river bed. Apart from the natural water sources; there are those that are man-made shallow wells, water pans, dams and boreholes.

In Kenyewa Location, water points are limited and far from the homesteads (plate 3.2) which amplifies the perils of climate change in the area. The intensity of water shortage becomes magnified in dry seasons because by then seasonal springs dry up. In drought periods, cattle depend on borehole water. In some areas, cattle depend on water from sand-dams in the river beds. As a result of continuous use, this water becomes low in quality and unpalatable to cattle. This lowers feed intake in cattle (Schütz 2012) and lowers growth rate and slaughter weights. Cattle then delay in reaching disposal time and continue emitting enteric methane unnecessarily. As a result there is a general increase in the contribution of cattle in the area to the anthropogenic greenhouse effect.

All livestock watering points in Kenyewa have water troughs. These can be cleaned from time to time to maintain water quality. It also ensures that cattle take water to their satisfaction and this improves feed intake. However, due to the nature of the scramble for water between cattle and small stock, some animals get into the trough. When this happens, accompanying dirt causes livestock to detest the water. Consequently, feed intake is lowered leading to lowered productivity. Low productivity in cattle results to increase in enteric methane emissions per unit of output.

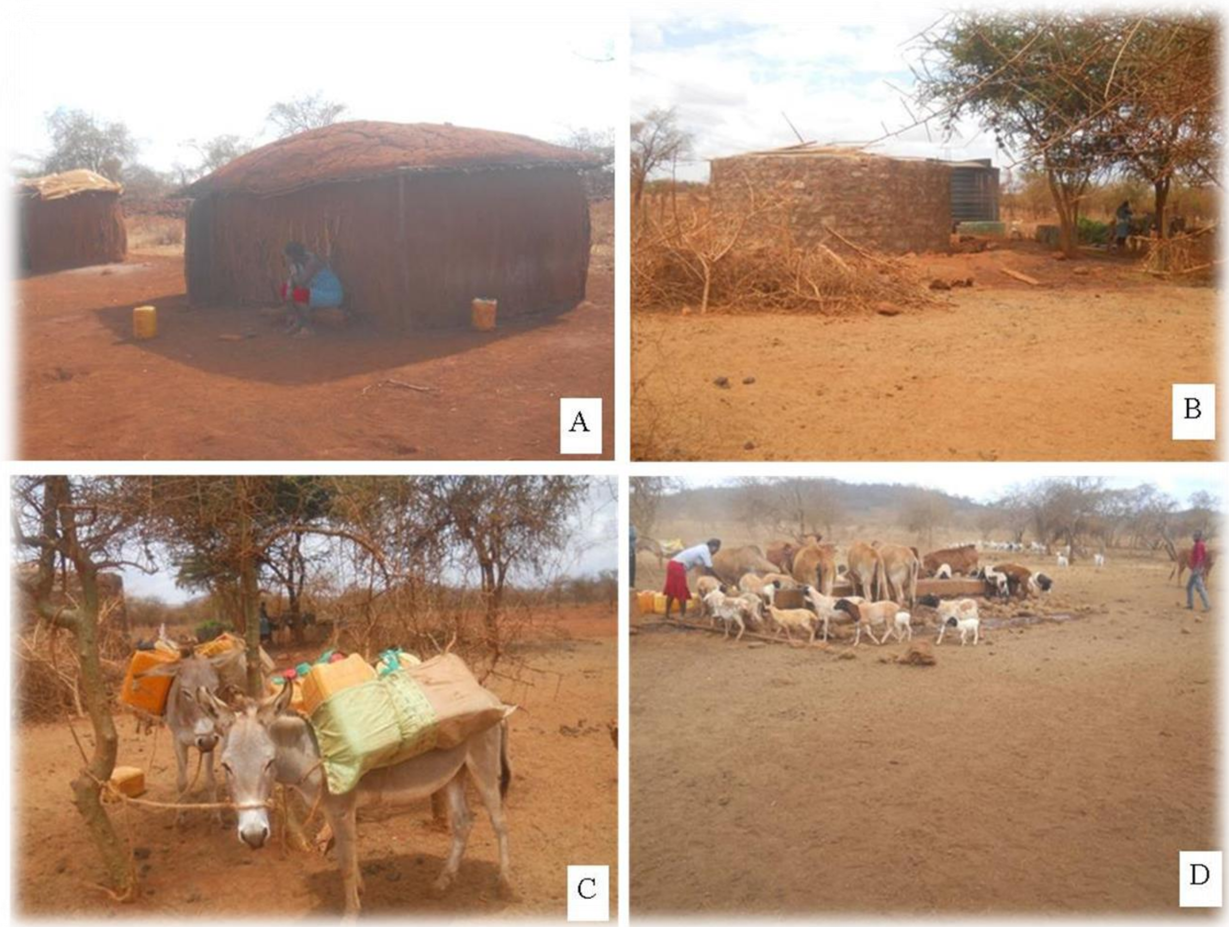


Plate 3.2: Water shortage in Kenyewa Location

Source: *Field Study*

Plate 3.2 shows that water points are limited and far from the homesteads in Kenyewa location.

A: A lady seriously contemplating on where to fetch water

B. A huge tank constructed by AMREF to relieve the community from perils of water shortage

C. Donkeys carrying several jerry cans of water

D. Scramble for water by cattle and small stock

3.4. Vegetation

The environment affects vegetation that grows in any given area (Orodho, 2006). In Kenyewa, the problem is further aggravated by overgrazing, charcoal burning, felling of trees for fuel and bush clearing to pave way for cultivation (GoK, 2013). The dominant vegetation types observed are open grasslands, bush and woodland (Homewood 2004). Drawing from GoK (2005; 2013) the indigenous and exotic trees in Kenyewa location include: *Acacia tortilis, Acacia drepanolobium, Balanites aegyptica, Acacia mellifera, Boscia coriacea, Melia volkensii, Adonsonia digitata* among other types. The grass that dominates the area is *Chloris roxburghiana.*

The other grass species are: *Cymbopogon* spp., *Eragrostis superba*, *panicum atrosanguineum* and *Themeda triandra*. Invasive species have been observed in the area and include *Lantana camara* and *Solonum incanum* among others. Vegetation decline in Kenyewa location, as noted by GoK (2013) is due to overgrazing as cattle kept tend to exceed the optimum carrying capacity of the land and charcoal burning for sell or owner's own use (plate 3.4), bush clearing to pave way for crop farming and felling trees for firewood. According to Orodho (2006), climate change particularly drought conditions determine pasture quantity and quality. This is by lowering the quantity and nutritive value of the pasture. Some forage can even become too coarse for cattle to utilize (plate 3.3). Drawing from IPCC (1992), when forage is low in quality, it increases enteric methane releases per unit of feed. This results to increases in contribution of cattle to enteric methane emissions and to the anthropogenic greenhouse effect.

Plate 3.3: Coarse forage in Kiboko sub-location **Source:** *Field Study*

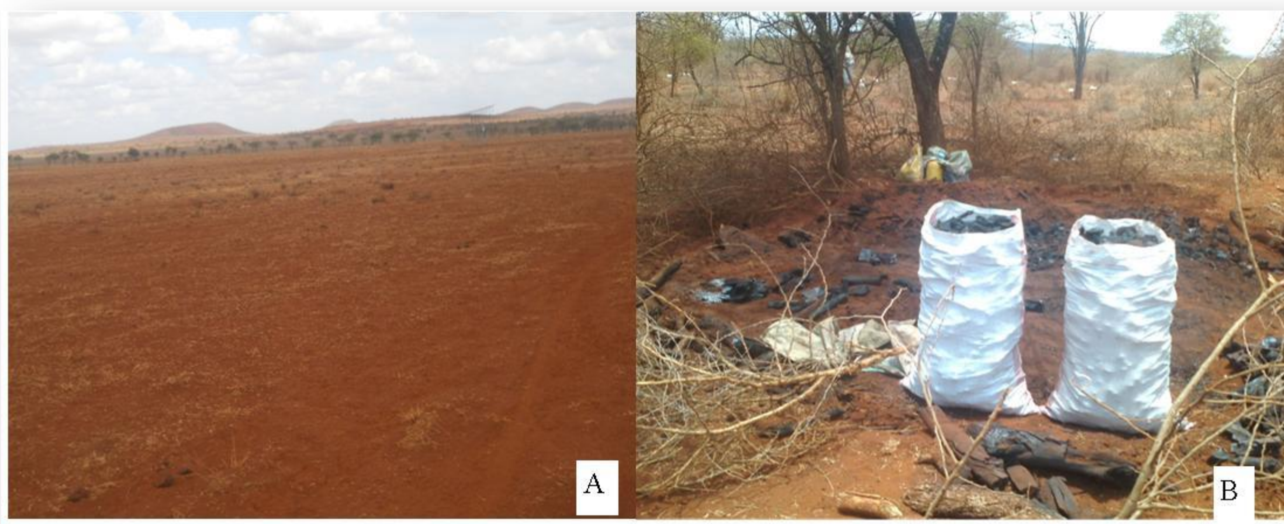


Plate 3.4: Vegetation decline in Masimba Sub-Location

Source: *Field Study*

3.5 Land Use

According to the latest census report, Kenyewa location of Kajiado county had a population of approximately 4,208 but this number is still increasing (GoK 2009; GoK 2016). More than half of the population in Kenyewa location live below the poverty line (Johnson and Wambile 2011). The inhabitants of Kenyewa location practice livestock rearing as their main source of livelihood. Though the livestock herders keep goats, sheep, poultry and donkeys, cattle dominate their herds (plate 3.5). The main livestock products are beef and milk with hides and skins being key by-products. Cattle release more enteric methane compared to the other domestic ruminant livestock (UNEP 2012). In Kenyewa Location, cattle herding is mainly done on extensive production system leading to numerous advantages.

Firstly, cow dung does not accumulate and this reduces methane emission levels per unit area. Secondly, water resources get minimal pollution from cattle waste and this increases water intake by cattle which improve their feeding and production. Finally, cattle tend to utilize the rangeland more efficiently deriving nutrients from coarse forage that would have otherwise gone to waste (ADBG 2010). Apart from livestock production, Kenyewa community practice rain-fed subsistence farming (GoK 2016). This practice is done to a limited scale since vast areas of land are not arable and rainfall remains unreliable (GoK 2013). Crops grown in the area are maize, beans, green grams, peas and cassava. Horticultural production of both fruits and vegetables is done under irrigation (TARDA 1984). The main vegetables grown in the area are tomatoes (plate 3.6).

According to GoK (2013), trade and commerce is another source of livelihood in Kenyewa location. Tourism-related practices are done by both men and women. Women do traditional beadwork (Ayiemba and Owuor 2015).Other activities are nurturing tree seedlings in nurseries and selling the seedlings to earn income (plate 3.7).The Maasai in Kenyewa location dispose of their products mainly at Masimba, Emali and Sultan Hamud shopping centres. Women do hawking of milk in market centres while men sell culls and steers to generate income.

Plate 3.5: Cattle production in Kiboko Sub-location; *the main breeds kept are Sahiwal and Boran crosses*

Source: *Field Study*

The breeds of cattle kept in Kenyewa Location of Kajiado County are crosses of sahiwal and boran. Sahiwal crosses are dual-purpose breeds; they produce both meat and milk. Boran crosses are beef animals. Sahiwal and boran crosses, however, have one thing in common, that their emission default values, provided by IPCC is 31 Kg of enteric methane per head per year, because they are non-dairy (dual-purpose and beef) respectively (GoK, 2012).

Plate 3.6: Horticulture in Masimba Sub-Location **Source:** *Field Study*

Plate 3.7: Tree nursery in Masimba Sub-location **Source:** *Field Study*

CHAPTER FOUR

4.0. METHODOLOGY

4.1. Study Design

The study of enteric methane gas emissions from cattle production in Kenyewa location of Kajiado County in Kenya in relation to climate change mitigation was based on a multi-stage sample survey beginning with a purposive selection of the study area. The study area selection was based on a location occupied by a society living in a harsh environment but who use a mixture of in-built cattle production skills and modern interventions to create livelihoods. Kenyewa cattle keepers have access to a cattle vector and disease surveillance station, a breeding farm and a research institution in addition to extension services all of which inform herders on modern methods of cattle production that could contribute to climate change mitigation as measured by exposure. The selected study area was then stratified based on administrative sub-location units to provide spatial representation of cattle breeding characteristics and therefore spatial emission of enteric emission. The two strata were then sampled in terms of homesteads (manyattas) by simple random method in order to reduce bias in statistical representation. From each homestead only the head of the homestead was interviewed taking into consideration the decision- making control, resource control and hierarchy in the community.

The resulting sample data were used to generate information on levels of methane emission, existing methane emission mitigation options, viability of the mitigation options, level of participation of the Maasai in climate change mitigation activities and potential for implementation of climate change mitigation activities. To generate the required information, the study used a combination of empirical formula and statistical procedures. The empirical formula used was that provided by the IPCC (2006) to compute the annual enteric methane emission per cow given the critical value of 31 and 40 for non-dairy and dairy cattle respectively. Annual methane values after being scaled down gave enteric methane per year, enteric methane produced during the ruminating period each day, enteric methane per hour, enteric methane per cattle per year and, enteric methane per cattle per hour (appendix IX).

In this study, both primary and secondary data were used in which primary data collected were on the name of the homestead (manyatta), the manyatta X, Y coordinates points, administrative sub- locations as bio-data needed in determining the spatial location of the study sites. Bio-data also included the respondent's age in years, education level, environmental or livestock training or sensitization. Other primary data were on number of mature cattle, cattle breed type, distance cattle travel to the grazing area, distance cattle travel to the watering point, time of the day when cattle rest, the pattern cattle lie when they rest, what characterizes the cattle rest period, what cattle emit when they belch, what the emission does, whether calves belch and why, whether cattle numbers over the last five years have been increasing or decreasing and why this was so. All this information was necessary for computing enteric methane emissions in Kenyewa location of Kajiado County.

To get information on existing technological options required for enteric methane emission mitigation, primary data were collected on cattle productivity on feeding, watering, disease control, supplementation and marketing of the surplus cattle products. Viability of existing technological options was measured by collecting information on: productivity increase, cost-effectiveness, consistency with Maasai culture and systems of production and decrease in cattle numbers for the same level of output. For purposes of measuring the level of participation of Kenyewa community in enteric methane emission mitigation, data gathered included implementation of mechanical and chemical feed processing, strategic supplementation, production enhancing agents, improved genetic characteristics, improved reproduction, disease control and,the manner in which marketing of culls and steers is done in the major outlets of Kenyewa.

To determine the potential for implementation of enteric methane mitigation strategies data was gathered on willingness to adopt other recommended technological options that improve cattle productivity, are consistent with Maasai culture and systems of production are affordable and lead to reduction in cattle numbers while maintaining the same level of output. All primary data were collected from the field in Kenyewa location of Kajiado County in Kenya for the period of about a year (April 2016 to May 2017) using200 questionnaires, 200 field observation sheets, 200 GPS points, 50 photographs 2 key informants meetings and 1 focus group discussions.

Secondary data were required for sampling frame, sample size determination and to support primary data for analysis. Secondary data were collected on list of all the manyattas from the Ministry of Youth, Sports, Gender, Culture and Social Services and gave the sample frame. Monthly temperature means and rainfall total for the last twenty and forty six years respectively for Makindu Weather Station were sourced from Kenya meteorological Department database and were used in analysis of climate change trends. Cattle numbers for Kajiado County were obtained from the ministry of Agriculture, Livestock and Fisheries livestock office in Kajiado. The geographic map of Kenya, Kajiado County and Kenyewa location was used for spatial analysis was sourced from the Survey of Kenya through Kenya National Bureau of Statics.

4.2. Data Collection

4.2.1. Reconnaissance Survey

Preliminary survey prior to the main fieldwork was conducted in April 2016 in order to ensure quality data collection. This was accomplished by first identifying key informants and opinion leaders for Kenyewa community. To qualify as key informant, one had to be well acquainted on matters of cattle production in relation to climate change mitigation. Opinion leaders were selected on criteria of patriarchy and decision making in the society. Key informants and opinion leaders were important in influencing reception at the Kenyewa community. This was followed by familiarization with the geographic layout of Kenyewa location and its inhabitant's livelihood activities. This was done in order to identify the target population and prepare for foreseen problems.

Visits were made to the county offices in Kajiado and Government of Kenya's Kiboko Zoological Investigations and Efficacy Trial Centre. KALRO ARLRI-Kiboko and TARDA's Emali Livestock Multiplication Project who are the key stakeholders in cattle industry in Maasai land were also visited. It was established what type of permit was required for this study and from whom. Photographic records were made for the areas visited capturing the soils, pasture and forage, cattle production infrastructure and watering points and these were used in informing the sampling procedure.

It was during this period that rapport with the target population was established. The research instruments were tested for viability in Ol Tukai village of Kiboko Sub-location. Each homestead head was subjected to an interview in order to ensure that they understood the contents of the questionnaire. Timing was done to establish how long each interview took and make necessary adjustments. The questions that were not clear were restructured to ensure clarity. The GPS receiver was used to mark the location of key geographical features relating to cattle rearing that needed to be revisited during the main field survey. Practice with different functions of the GPS receiver helped to establish the best ones for this study. It was also necessary to be familiar with GPS receiver set ups under different environmental set ups in Kenyewa Location so as to improve on location measurement accuracies given known measurement points.

The camera was tested for clarity and adjusted to take photographs at long range to avoid interference with routine cattle feeding and rest hours. Enquiries were made on what is allowed culturally to photograph and what is not. It was established when it was acceptable culturally to take notes. After the interview, key responses were recorded in the notebook. Key observations and GPS X and Y coordinate pairs were also recorded. Other issues considered in the preliminary survey were existing supporting data that included a list of all the manyattas in Kiboko and Masimba sub-locations from the Ministry of Youth, Sports, Gender, Culture and Social Services, monthly temperature means and rainfall total for the last twenty and forty five years respectively for Makindu Meteorological Station sourced from Kenya Meteorological Department database and were used to show climate change trends. The information would validate the data to be collected in the main survey, aid in creation of sample frame and in computing the sample size.

After the reconnaissance survey, a research permit was obtained from the County Government of Kajiado, Ministry of Lands, Physical Planning, Environment, Wildlife and Natural Resources (appendix I). The sampled manyattas represented by the numbers were then used to trace the homesteads by their heads. Prior arrangements were made before tracing the manyattas to avoid interference with their livelihood activities.

4.2.2. Sampling Frame and Sample Size

All the homesteads (manyattas) in Kenyewa location of Kajiado County constituted the study population but only those homesteads that had designated heads (395) constituted sampling frame or target population (appendix VI). From the sampling frame, a stratified sample was drawn by first sub-dividing the target population into two strata on the basis of administrative sub-location for better spatial representation. The two strata were Kiboko and Masimba respectively. From which simple random samples were drawn of proportional sizes of 115 and 76 respectively arrived at using the formula:

Equation 4.1

$$n = \frac{z^2 p.q.N}{e^2(N-1) + z^2 p.q}$$

Where:

N = Total number of homesteads in Kenyewa location

n = Sample Size

p = Sub-location proportion (sample proportion)

q = 1-p

e = Acceptable error level at 0.05

z = Standard variant value = 1.96

Source: Chava and David (1996)

The desired sample size, n, was then arrived at as follows:

$$n = \frac{z^2 p.q.N}{e^2(N-1) + z^2 p.q}$$

$$= \frac{1.96^2(0.6 \times 0.4) \times 395}{0.05^2(394) + 1.96^2(0.6 \times 0.4)}$$

$$= \frac{3.84 \times 0.24 \times 395}{(0.0025 \times 394) + (3.84 \times 0.24)}$$

Kiboko 0.6 x 191 = 115

Masimba <u>0.4 x 191 = 76</u>

191

Total number of homesteads in Kenyewa location= 395

Desired Sample size of homesteads in Kenyewa location = 191

Although the desired sample size was 191, the study used a sample of size 200 which was distributed as,

Kiboko	0.6 x 200 = 120
Masimba	0.4 x 200 = 80
	200

4.2.3 Data Collection Instruments

A number of instruments were used in the data collection exercise and these included:

- The questionnaire
- Field notebook
- Camera
- Global positioning system receiver

The questionnaire was designed to capture information on cattle production in relation to climate change in Kenyewa Location of Kajiado County. The questionnaire (appendix III) had four sections namely bio-data, cattle and enteric methane emissions, existing technological options for reducing enteric methane emissions, their viability and level of participation of the Maasai community in cattle climate change mitigation activities. The fourth section was on potential for methane climate change mitigation activities. The questionnaire was structured in such a way that it had both open-ended and closed-ended questions.

The open-ended questions gathered information on the respondents' perspective on bio-data, cattle and enteric methane fermentation, existing technological options for reducing enteric methane emissions, their viability and level of participation of the Maasai community in cattle climate change mitigation activities and potential for climate change mitigation strategies.

The questionnaire's closed-ended questions were used to restrict responses within defined limits and fit them in for statistical analysis. After an interview, issues that had emerged out of the various responses were written in the field notebook. The camera was used for photography necessary in authenticating the study records of cattle production in Kenyewa Location of Kajiado County in relation to climate change. The cameras used in this study were digital so as to ease transfer to spatial analysis. They were a Sony 10 mega pxls, Cannon 1 xus 145 and Samsung 26 x 16.2 mega pixels, two of which were set to give both date and time. The date and time were important in cattle feeding activities in the Maasai community and this in turn affected the peak enteric methane emissions. The cameras were set in such a way that they could capture photographs at long range so as to avoid interference with cattle grazing and rest periods. Field notes were made after taking photographs.

The field notebook complimented by pencil (to ease any necessary amendments) was used to record observations. Observation was done directly and did not rely on respondents of the study to avoid bias. This study used observation to ascertain whether what respondents said was true or false. Through observation, breeds of cattle and enteric methane mitigation measures that were mentioned by the respondents were cross-checked. In addition, enteric methane mitigation measures that were not mentioned by respondents but were under implementation were determined. Available pasture and challenges facing cattle keepers in the area were determined through direct observation. The GPS receiver is the user- receiver component of the Global Positioning System used primarily to determine location, time and altitude all of which are useful in navigating the global Earth. The Global Positioning System (GPS) receiver was used to capture the X and Y coordinate pairs for geo-referencing manyatta information The GPS receiver was a Garmin GPS MAP 78s whose map unit was set in metres projection UTM Zone 37 S while the datum was WGS84. After getting the GPS coordinates points, recording was done in the field notebook.

Plate 4.1 illustrates the use of the various instruments in data collection namely:

A. Use of the questionnaire

B. Use of camera

C. Use of GPS by researcher

D. Use of notebook by research assistant

Plate 4.1: The use of questionnaire, camera, GPS receiver and field notebook

Source: *Field Study*

4.2.4 Sampling Procedure

To acquire sample data from the target population necessary in addressing the problem, objectives and hypotheses using the research instruments already described, the study used multistage procedure as follows. All the manyattas in Kenyewa Location of Kajiado County were listed thus constituting the sampling frame or target population of 395. The selected study area was then stratified based on administrative sub-location units giving two hundred and thirty (230) and one hundred and sixty five (165) manyattas in Kiboko and Masimba sub-locations respectively and this gave two sampling clusters (Appendix VI). The desired sample size was 191 from which a sample size of 115 and 76 for Kiboko and Masimba sub-location respectively were drawn using simple random sampling. The sub-location units represented the sampling strata from which, using the same proportions, a selection of simple random was done until a number of 120 homesteads from Kiboko and 80 from Masimba, respectively, were attained.

The homesteads from Kiboko were assigned Kiboko numbers while the ones from Masimba were assigned Masimba numbers. To draw the sample size in question, the first step involved assigning random numbers (which were extracted from the table of random numbers) to each manyatta head. The random numbers were then placed in a drum which was then rolled to give a thorough mixture. From the drum numbers were drawn with replacement to give each manyatta an equal chance of being represented in the sample data. If a number that had already been drawn was redrawn, it was ignored because it was duplication. This was repeated until a sample consisting of two hundred (200) manyattas; one hundred and twenty (120) manyattas in Kiboko Sub-location and eighty (80) manyattas in Masimba Sub-Location were achieved.

The sampled manyattas represented by the numbers were then used to trace the homesteads by their heads. Prior arrangements were made before tracing the manyattas to avoid interference with their livelihood activities. The homesteads were each assigned geo-referencing values (X, Y coordinates) which were necessary in spatial representation and mapping of methane emissions in Kenyewa location. Additional information on homesteads were captured using observation sheets which were used to capture information on manyatta location, cattle numbers, breed and, existing technological options for enteric methane emissions. One manyatta after another were traced by the homestead heads until all the 200 sampled manyattas were covered.

Upon arrival at every homestead, linking up with any available member of the homestead helped to identify the head of the homestead (plate 4.2). Rapport was created after which the questionnaire was executed.

Plate 4.2: The third sampled manyatta; *creating a rapport* **Source:** *Field Study*

Plate 4.3: Head of Manyatta interview scene; *note the presence of a key informant*

Source: *Field Study*

The interviewing of the manyatta head was done exhaustively for about one hour (Plate 4.3) at all sampled homesteads. The filling of the questionnaire was done by the researcher or research assistant. Interviewing went hand in hand with observing, photographing and taking of GPS X and Y coordinates point. Then field notes were written with details of the outcome of the interviews, observations, photographing and taking of GPS X and Y coordinates point. Direct observation garnered information on cattle production in Kenyewa as it relates to climate change. Cattle production has been associated with land degradation and this was the essence of observation illustrated by plate 4.4. There were several grass species observed in Kenyewa Location, but *Chloris roxburghiana* was the dominant one (Plate 4.5). Indigenous trees especially *Balanites aegyptica* (plate 4.4) were dominant in the area, acting as home for different species of birds.

Plate 4.4: Making observations; *these were denuded lands*

Source: *Field Study*

Plate 4.5: Observing the most dominant grass in the area; *Chloris roxburghiana*

Source: *Field Study*

The tracing of the manyattas involved travelling long distances and the logistics are as displayed in plate 4.6. The paths were rugged and very dusty in the dry period, when most of the work was done. For comparison purposes some work was done during the rainy period during which roads were very muddy and at times totally impassable.

Plate 4.6: motor-bike means of transport: *the area was characterized by rugged earth roads and homesteads that were really far apart*

Source: *Field Study*

All the sampled 200 homesteads in Kenyewa Location were traced by the manyatta heads and are illustrated by figure 4.1. The various villages of Kiboko and Masimba sub-locations were well covered in this study. The villages include, Nkusso, Esiteti, Noomao, Noonkoben, Enyuata, Olkoilanga, Enkonerei, Parmaeoi and Doinyolenkai. However, very little work was done in Ol Tukai because that area had been covered during reconnaissance survey.

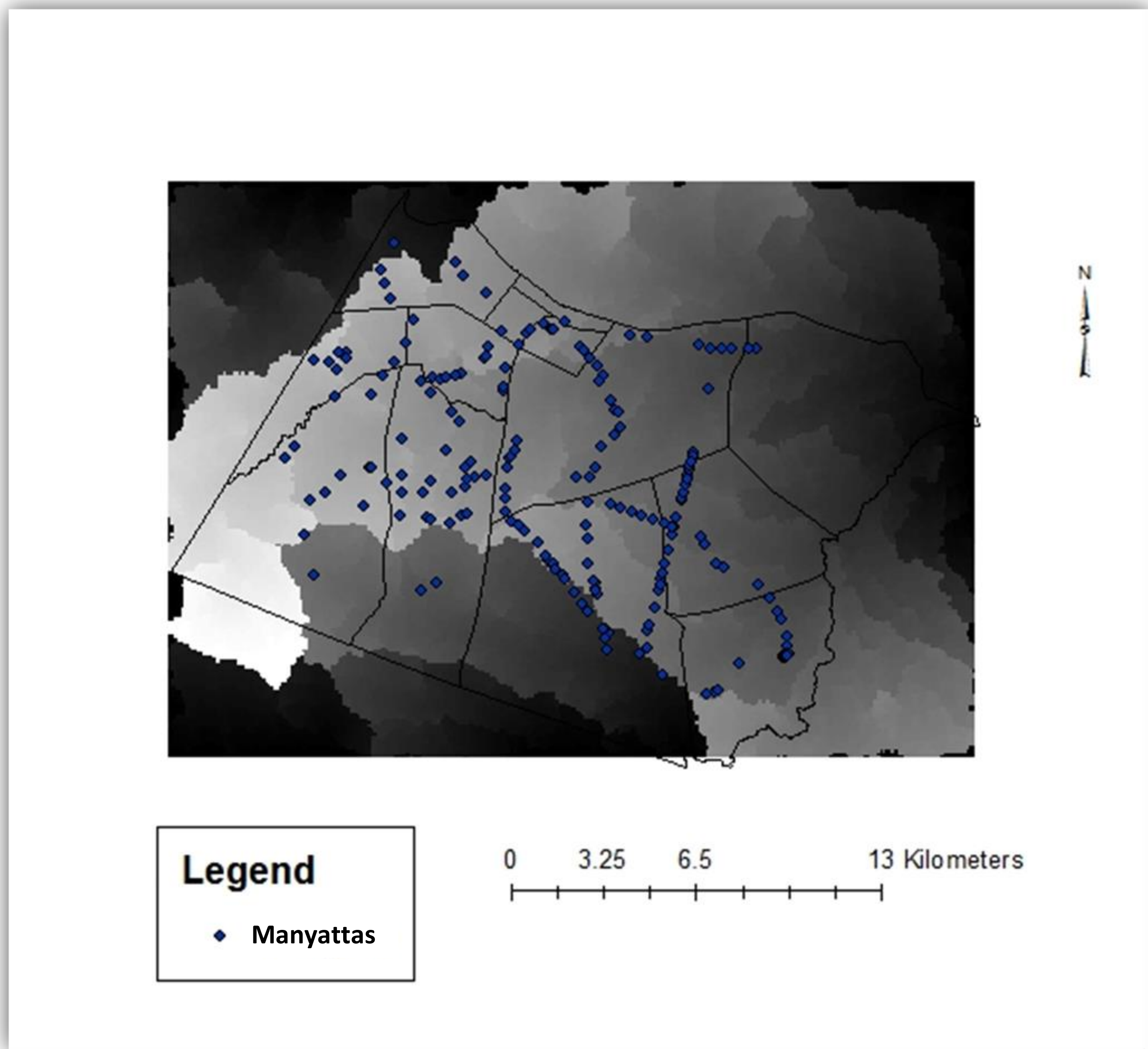


Figure 4.1: Sampled Manyattas in Kenyewa Location

Source: Field Study

Some of the results of the sample survey were authenticated in a focus group discussion held in the Kajiado County Agriculture office (plate 4.7).

Plate 4.7: Focus group discussion **Source:** *Field Study*

This was in order to obtain from extension officers in Kajiado County the measurable variables that respondents in Kenyewa location couldn't provide. Those present included a range management officer, an agricultural officer and a livestock officer.

Two separate key informants groups consisting of eight and five members each held informal discussion on enteric methane gas emissions from cattle production in Kenyewa location in relation to climate change mitigation. One group met in Nkusso village in Masimba while the other met in Kiboko. The discussion was on cattle numbers, measures that improve productivity in cattle, the viability of these options, and level of participation in climate change mitigation activities and potential for implementation of other climate change mitigation strategies in Kenyewa Location of Kajiado County.

Plate 4.8: Researcher and key informants in Masimba Sub-Location; *male heads of* manyattas *dominated the meeting due* to *patriarchy in Masai land*

Source: *Field Study*

Plate 4.9: Researcher and Key informants at KALRO-ARILRI Kiboko; *discussion focussed on grass quality in relation to cattle productivity*

Source: *Field Study*

4.3. Data Processing and Analysis

4.3.1. Data Processing

The field notebook served as a guide during the data processing exercise for outcome of interviews, observations, photography and GPS references thereby giving insight of what to include and what to bypass. All the questionnaires were checked to ascertain that all the expected responses had been captured and ensure integrity. A codebook was created where all items were coded for rating purposes. Then the two hundred responses were entered in excel and cleaned accordingly. Creation of sub-files was done to accommodate all the multiple responses.

A problem arose of different levels of measurement for whereas methane emission level was scale measurement existing technological options was nominal measurement. This problem was addressed by a data mining exercise carried out to convert the nominal measures of existing technological options into scale measures. Then the data was entered in Statistical Package for Social Scientists (SPPS) program version 20 software for analysis. All photographs were first downloaded on the computer desktop. Then one by one they were opened. The ones that were clear, creative and strategic were included in the document. The others were bypassed but still kept for record. The GPS X and Y coordinate points were captured first in excel. Then they were entered into Statistical Package for Social Scientists (SPPS) program version 20 software for analysis.

4.3.2. Data Analysis Techniques

4.3.2.1. Estimating Enteric Methane Emissions Levels

In this study methane emission was assumed to be cattle enteric fermentation centred. The steps that were followed to compute enteric methane emissions levels were: Mature cattle numbers (cattle above four weeks of age) and cattle types were obtained from the manyatta heads at all sampled manyattas and crosschecked through observation. Secondly, enteric methane levels in Kenyewa Location of Kajiado County were modified by type of cattle emission factors (Appendix V) as indicated in Kenya's Climate Change Action Plan: Mitigation (2012). Cattle in the area were either non-dairy (sahiwal and boran crosses) or the dairy cows (Friesian /Holstein). Therefore, emission factors found to be 31 and 40 for non-dairy and dairy cattle respectively. Thirdly, the number of cattle was then multiplied by the emissions factor to obtain methane levels in Kenyewa Location of Kajiado County. The methane levels were computed using the IPCC Empirical formula specified as:

$$CH_4\ Emissions = Number\ of\ cattle\ x\ CH_4\ Emissions\ Factor$$

Source: Gibbs *et al*. (2000)

After this the enteric methane values were computed for cattle in each manyatta to give methane per year, methane for the ruminating period each day, methane per hour, methane per cattle per year and methane per cattle per hour (appendix VI). Estimates for levels of enteric methane emissions were done for Kenyewa Location and Kajiado County. To get enteric methane emissions for Kenyewa Location 7108 (non-dairy cattle) was multiplied by 31 (methane emissions factor) and added to the product of 2 (dairy cattle) and 40 (methane emissions factor). To get the contribution of Kenyewa cattle to the global greenhouse effect the total enteric methane (220,428) was multiplied by the global warming potential of methane (220,428x25). At the time of the study, Kajiado County had 174,290 dairy and 581,020 non-dairy cattle. Enteric methane emissions for the dairy cattle were obtained by multiplying 174,290 by 40 and the product added to methane emissions for enteric methane emissions for non-dairy cattle (58,1020x31). To get the contribution of Kajiado County cattle to the global greenhouse effect the total enteric methane gas emissions was multiplied by the global warming potential of methane, thus 24,983,220x25 (Kg CO_2-Eq.).

The computed methane emission levels were subjected to a sequential analysis (time series where time is the ordered number of cattle) given number of cattle. The resulting methane values were then used to compute the strength of association between the cattle numbers and the methane emission levels using Pearson's correlation coefficient specified as,

Equation 4.2

$$r = \frac{\sum_{i=1}^{n}(x_i - \overline{r})(y_i - \overline{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \overline{x})}\sqrt{\sum_{i=1}^{n}(y_i - \overline{y})^2}}$$

Where:

n = Sample size

x_i , y_i = Single sample indexed with i

$\overline{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$ *(the sample mean; and analogously for* $\overline{y}$

Then the result of correlation analysis was then used further in estimating how cattle numbers affected the level of methane emission using the Pearson's simple linear regression analysis specified as: $\hat{Y}_i = b_0 + b_1 x + e$. After estimating how cattle numbers affected variations in methane emission, it was important to establish whether the estimated methane emission values were chance events and this study used single sample t-test where t was specified as:

Equation 4.3

$$t = \frac{\overline{x} - \mu_0}{\frac{s}{\sqrt{n}}}$$

Where: t = limits of the confidence interval

$\overline{x}$ = Sample mean

μ_0 = Value from the *t* - table corresponding to half of the desired alpha level at *n – 1*degrees of freedom.

s = Sample Standard deviation

n = Size of the sample

To establish the norms in the methane emission levels, the control plot was used to determine the mean emission. Having established the status of the estimated methane emission levels, there was a need to establish the variation boundaries in order to have some measure of the normal emission levels. The study relied on Control chart to compute the long term mean, upper limit and lower limit based on Moving average measure.

4.3.2.2. Establishing the Existing Technological Options for Reducing Enteric Methane Emissions

This study sought to determine enteric methane mitigation technological measures that exist in Kenyewa Location of Kajiado County. It had been established at the reconnaissance survey that Kenyewa community did not know that technological options led to enteric methane emissions mitigations. The way to get the information therefore involved finding out what the community knows then gradually moving to the unknown

Cattle number trends over the past five years and reasons for it were established. Technologies under implementation that improve cattle productivity were determined but this would have had no bearing on enteric methane emissions mitigations unless it led to decreased cattle numbers while sustaining a particular level of output. Since cattle numbers affect methane emissions and existence of technological options to reduce methane emissions are mainly due to cattle rearing, attempt was made to relate methane emissions levels with existing technological options. This activity faced the problem of different levels of measurement. Whereas methane emissions levels were scale measurement, existing technological options was nominal measurement. A data mining exercise was carried out to convert the nominal measures of existing technological options into scale measures using the following procedure: A multiple response variable was created, V20 by first assigning every potential response variable name with shared values (or answers).

A multiple response frequency analysis was run using the created response variable. The resulting multiple frequency scores were ranked from the highest to the lowest resulting in n categories. The group ranked first was assigned a quantitative value of n and the 2^{nd} n-1, 3^{rd} n-2 that went on up to the last rank. The resulting values constituted likert scale therefore quantitative values which could be entered in higher statistical analysis like correlation or regression. For all the technological score categories for each respondent a mean score was computed by summarizing all the options and dividing by the number of options for each group (depending on answers one gave) for some gave 10 others 12 and so on. Since there was an association between the computed methane emission levels and technological mean score there was need to measure the strength of association and in this case Pearson’s linear correlation was used. After getting the measure the strength of association, it was important to measure the statistical significance of the technological scores. In this case ANOVA was used. For ANOVA, the test statistic was specified as:

Equation 4.4

$$F = \frac{\Sigma n_j(\bar{X}_j - \bar{X})^2 / (k-1)}{\Sigma\Sigma(X - \bar{X}_j)^2 / (N-k)}$$

Where: H_0: $\mu_1 = \mu_2 = \mu_k$ = critical value

$df_1 = k-1$

$df_2=N-k$-In the test statistic

n_j = the sample size in the j^{th} group (e.g., j =1, 2, 3, and 4 when there are 4 comparison groups),

$\bar{X}_j$ = sample mean in the j^{th} group

$\bar{X}$ = overall mean.

k = number of independent groups

N = total number of observations in the analysis

The critical value is found in a table of probability values for the F distribution and significant tests were at an alpha level of 0.05.

4.3.2.3. Determining the Viability Existing Technological Options in Methane Mitigation

This study attempted to determine the viability of enteric methane mitigation technological measures that exist in Kenyewa Location of Kajiado County. This information was obtained from manyatta heads. The first step was identification of viability issues that are important in Kenyewa Location using a checklist that consisted of the IPCC recommended viability criteria. These were: increased productivity, affordability, consistency with Maasai culture and systems of production and decrease in cattle numbers for the same level of output. This was followed by a cross tabulation of technological options for reducing enteric methane emissions with the technological options viabilities. Finally, determination as to whether the difference observed between technological options for reducing enteric methane emissions and the technological options viabilities were significant or chance events was done using Kruskal Wallis test. Data was sorted in an ascending manner for all samples to give a set. Ranks were then assigned to the already sorted data and different ranks for each sample added up. The H statistic was specified as:

Equation 4.5

$$H = \left[\frac{12}{n(n+1)}\sum_{j=1}^{c}\frac{T_j^2}{n_j}\right] - 3(n+1)$$

Where: n = sum of sample sizes for all samples

c = number of samples

T_j = sum of ranks in the j^{th} sample

n_j = size of the j^{th} sample

The critical chi-square value was obtained at an alpha level of 0.05. The H value was compared to the critical chi-square value.

Equation 4.6

$$x^2 = \sum \frac{(O-E)^2}{E}$$

Where: χ^2 = Chi-square

O = Observed frequency

E = Expected frequency

4.3.2.4. Determining the Level of Participation of the Maasai in Kenyewa Location to Climate Change Mitigation Strategies

To determine participation of the Maasai in Kenyewa Location to climate change mitigation strategies, a standard tablet provided by IPCC 1992 was used. IPCC recommended climate change mitigation strategies were general so this study domesticated them for Kenyewa Location by modifying them into technological options that were viable for Kenyewa Location to get a minimum requirement for Kenyewa Location.

The minimum requirement of viable climate change mitigation strategies in Kenyewa was seventeen. These included, chopping of feeds, molasses, mineral lick, dairy meal saltlick, crossbreeding, genetic improvement, selective breeding, strategic feeding, improved pasture management, clean water, borehole water, vaccination, deworming, timely culling, timely sale of steers and eliminating surplus production of milk. The level of Maasai participation in these activities and was obtained from the field survey in Kenyewa Location but authenticated by the focus group discussion. Malpractices caused by poverty were revealed by key informants meetings and focus group discussion, for instance, poor mixing of acaricide and treating animals without consulting animal health assistants. Some practices were identified through direct observation.

After establishing the strategies under implementation it was crucial to find out whether the level of participation in climate change mitigation strategies values were chance events and this study used single sample t-test where t was specified as:

$$t = \frac{\bar{x} - \mu_0}{\frac{s}{\sqrt{n}}}$$

Where: t = limits of the confidence interval

$\bar{x}$ = Sample mean

μ_0 = Value from the *t* - table corresponding to half of the desired alpha level at *n – 1*degrees of freedom.

s = Sample Standard deviation

n = Size of the sample

4.3.2.5. Measuring the Potential of the Community Participation in Climate Change Mitigation Strategies

This information was obtained from the manyatta heads and responses were on potential for adoption of other viable climate change mitigation strategies. The measures are IPCC recommended and internationally accepted on the basis of viability and hence sustainability for cattle production in Kenyewa Location of Kajiado County. The measures ought to. Increase productivity, be affordable, consistent with Maasai culture and systems of production and lead to decreased cattle numbers while sustaining the same level of output.

CHAPTER FIVE

5.0. RESULTS AND DISCUSSION

5.1 Methane Emission Levels in Kenyewa Location

Climate change is a major challenge confronting humanity in the 21st century (Remling 2011). Climate change is caused by both natural and manmade factors (IPCC, 2007). While natural greenhouse effect makes the earth warm enough to maintain life, anthropogenic greenhouse effect threatens life and livelihoods (Harris et al. 2015). Human-induced greenhouse gases include carbon dioxide, methane and nitrous oxide among other gases (IPCC 2007). Methane is one of most significant greenhouse gases in the atmosphere and has of late been a focal element in the international climate change forums mainly due to its production through anthropogenic activity. Indeed, a greater percentage of methane emissions are from human rather than the natural sources (Moss et al. 2000). Livestock production leads to emission of greenhouse gases (Peters et al. 2012). Cattle production in particular, though being a source of food, income and employment among other benefits cause global warming through greenhouse gas emissions (Thornton et al. 2011). Methane emission levels in the sampled area within Kenyewa Location of Kajiado County that constituted a total of 200 manyattas were computed using the IPCC Empirical formula specified as:

$$CH_4\ Emissions = Number\ of\ cattle\ x\ CH_4\ Emissions\ Factor$$

Source: Gibbs *et al*. (2000)

This study sought to compute enteric fermentation contribution by cattle in Kenyewa Location of Kajiado County to anthropogenic greenhouse effect. Computation of enteric fermentation contribution by cattle in Kenyewa Location was done by using the Tier 1 methodology of the Intergovernmental Panel on Climate Change (IPCC). Enteric methane levels in Kenyewa Location of Kajiado County were modified by type of cattle emission factors (Appendix X) as indicated in Kenya's Climate Change Action Plan: Mitigation (2012). This study established that the total number of cattle in the homesteads (manyattas) in the sample area of Kenyewa Location of Kajiado County were 3681, an average of 18 per homestead.

The breeds of cattle kept in Kenyewa Location were non-dairy cattle of sahiwal and boran crosses and the dairy cattle, the Friesian. In the sample area, there were only 2 dairy cows (Friesian) and the rest totalling to 3679 were non-dairy cattle. Analysis of the data showed that at the time of the study, the total methane emissions per year for cattle in the sample area were 114129 Kg, an average of 570 Kg per homestead. Total enteric methane emissions in Kenyewa Location, at the time of the study was 220,428 Kg which accounted for a contribution to the global greenhouse effect of 5,510,700 Kg CO_2-Eq. Kajiado County produced 24,983,220 Kg which is a total contribution of 624,580,500 Kg CO_2-Eq. to global the greenhouse effect. Total methane emissions per hour are 13, an average of 0.065. Cattle in the sample area ruminated for a total of 1915.5 hours, an average of 9.58 hours.

During this period an estimated 184.45 Kg of enteric methane, an average of 0.92 Kg was released from the rest areas as cattle chew cud. Enteric methane levels per cattle per hour were 0.42 Kg. The computed enteric methane was 40 Kg of enteric CH_4 per head per year and 31 Kg of enteric CH_4 per head per year for dairy and non-dairy cattle respectively. The level of enteric methane emissions in Kenyewa Location accounted for 0.88 per cent of the total enteric methane emissions from Kajiado County and an insignificant amount in the global anthropogenic greenhouse effect. These enteric methane levels are lower than those reported by South Africa of 76.4 Kg of enteric CH_4 per head per year and 78.9 Kg of enteric CH_4 per head per year for dairy and non-dairy cattle respectively (Toit et al. 2013).

The enteric methane levels are similar to default values (appendix VIII) provided by IPCC of 40 Kg of enteric CH_4 per head per year and 31 Kg of enteric CH_4 per head per year for dairy and non-dairy cattle respectively (GOK, 2012). The enteric methane emission factors are much lower compared to those of developed countries such as North America, Western Europe, Eastern Europe, Oceania and Latin America (Appendix V). The enteric methane emission factors for North America is 118 Kg of enteric CH_4 per head per year and 47 Kg of enteric methane per head per year for dairy and non-dairy cattle respectively (IPCC, 1996). Computed enteric methane levels, after being scaled down gave methane per year, methane produced during the ruminating period each day, methane per hour, methane per cattle per year and methane per cattle per hour (appendix IX). The computed methane emission levels were subjected to a sequential analysis (time series where time is the ordered number of cattle).

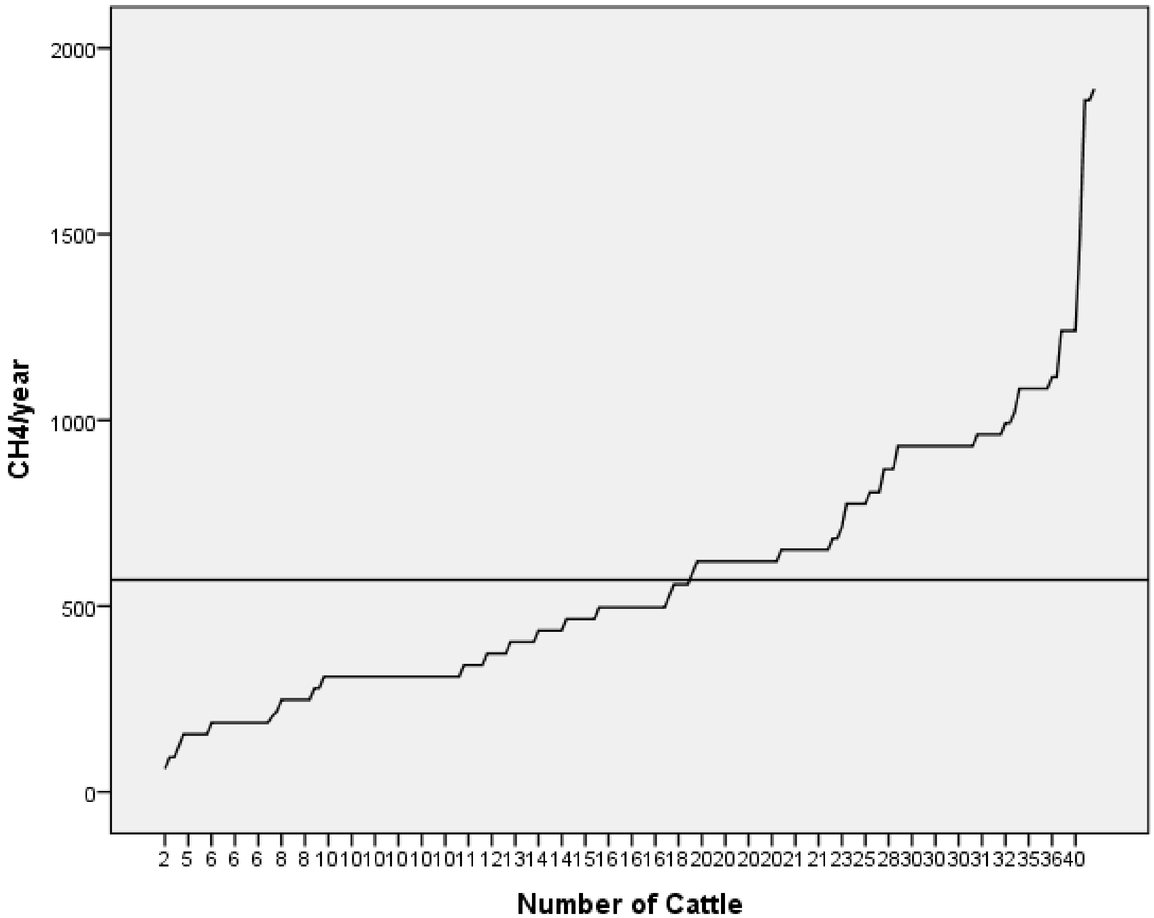


Figure 5.1: Annual Methane Emissions by Number of Cattle in Kenyewa Location

Source: *Field study*

The sequential plot (Figure 5.1) indicated a tendency to have increase in methane emission with increase in number of cattle. However, at some point, cattle numbers seemed to increase very minimally and so did enteric methane emissions. This was due dependence on nature for majority of Kenyewa herders and low resilience. Since the sequential plot indicated a tendency to have increase in methane emission with increase in number of cattle, there was need to measure the strength of association and in this case Pearson's linear correlation was used. The correlation was significant at the 0.01 level (2-tailed). The correlation results necessitated further statistical exploration to specify how number of cattle affected the levels of methane emission and the study used Pearson's Simple linear Regression techniques to estimate values of methane given number of cattle.

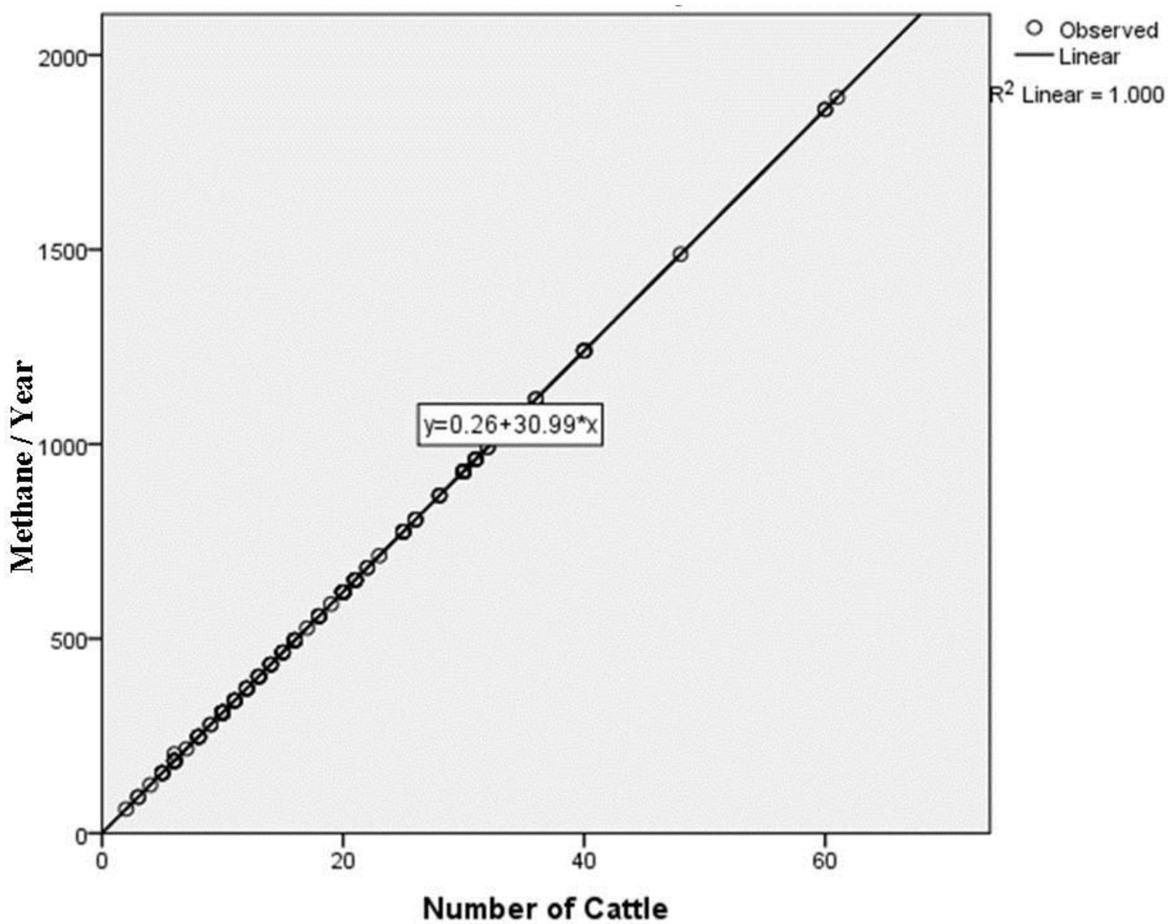


Figure 5.2: Relationship between Methane Emissions and Number of Cattle in Kenyewa

Source: *Field study*

Regression analysis results indicated perfect fit of cattle numbers and enteric methane emissions (Figure 5.2). The null hypothesis stated that enteric methane emissions from cattle production in Kenyewa Location of Kajiado County are minimal and thus insignificant in global anthropogenic greenhouse effect. The study used single sample t-test to measure whether the observed emission levels were random or significant variations. The student's t test was used in determining the significance of the difference between the means of methane emission per year and number of cattle both of which were on an interval scale. The calculated t-value was 22.6 while critical value was 51 and 85 at α 0.05 (2-tailed) and 199 degrees of freedom. Observed emission levels were minimal and therefore not significant variations. There was no adequate evidence to reject the null hypothesis.

These findings were similar to WISP who noted that in Africa, cattle industry's contribution to global climate change was minimal (WISP 2010). This was in line with Odingo (2001) who noted that Africa's contribution to greenhouse gas emissions is and will continue to be insignificant. Having established the status of the estimated methane emission levels, there was a need to establish the variation boundaries in order to have some measure of the normal emission levels. The study relied on Control chart to compute the long term mean, upper limit and lower limit based on Moving average measure (Figure 5.3).

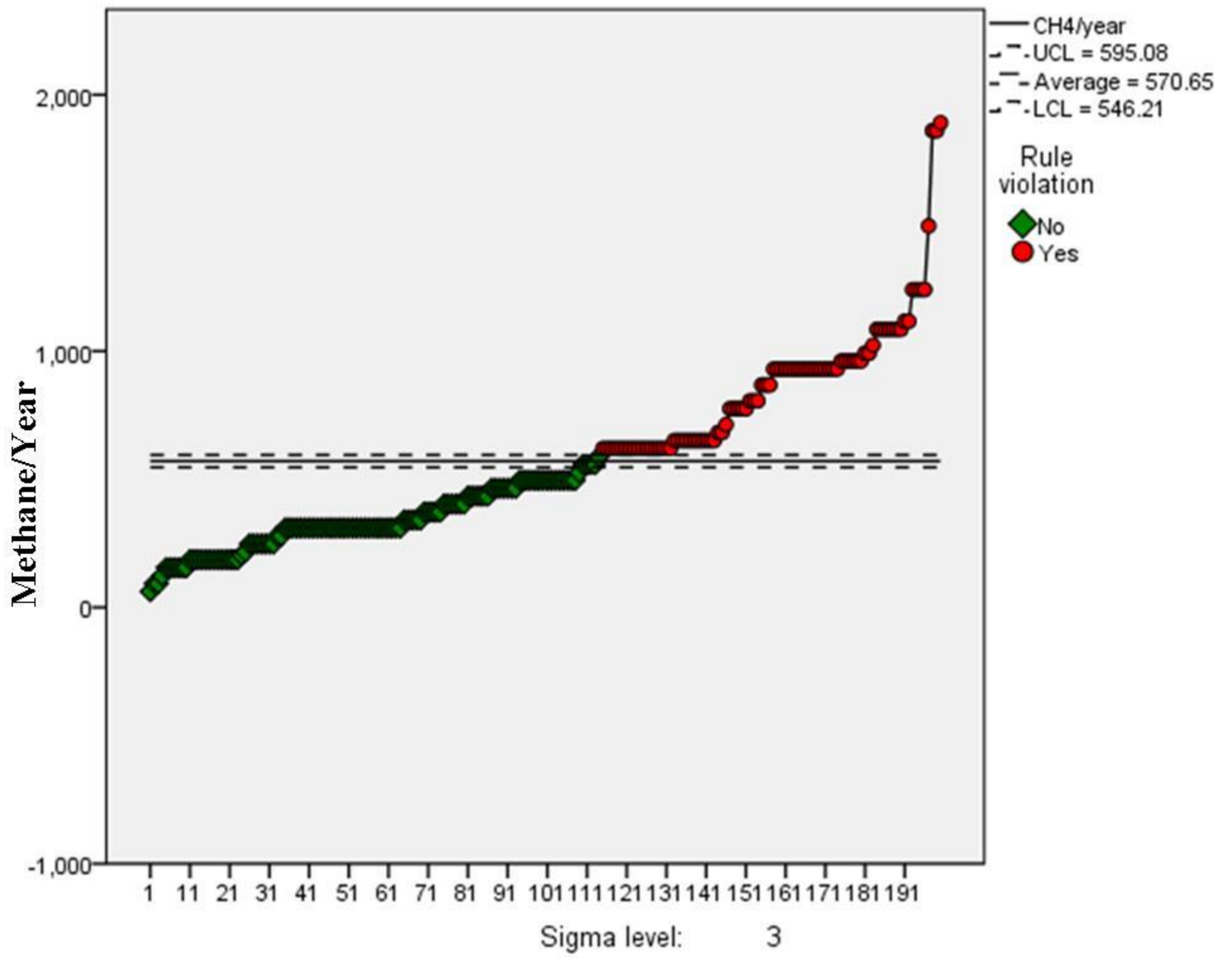


Figure 5.3: *Control Chart* **Source**: *Field study*

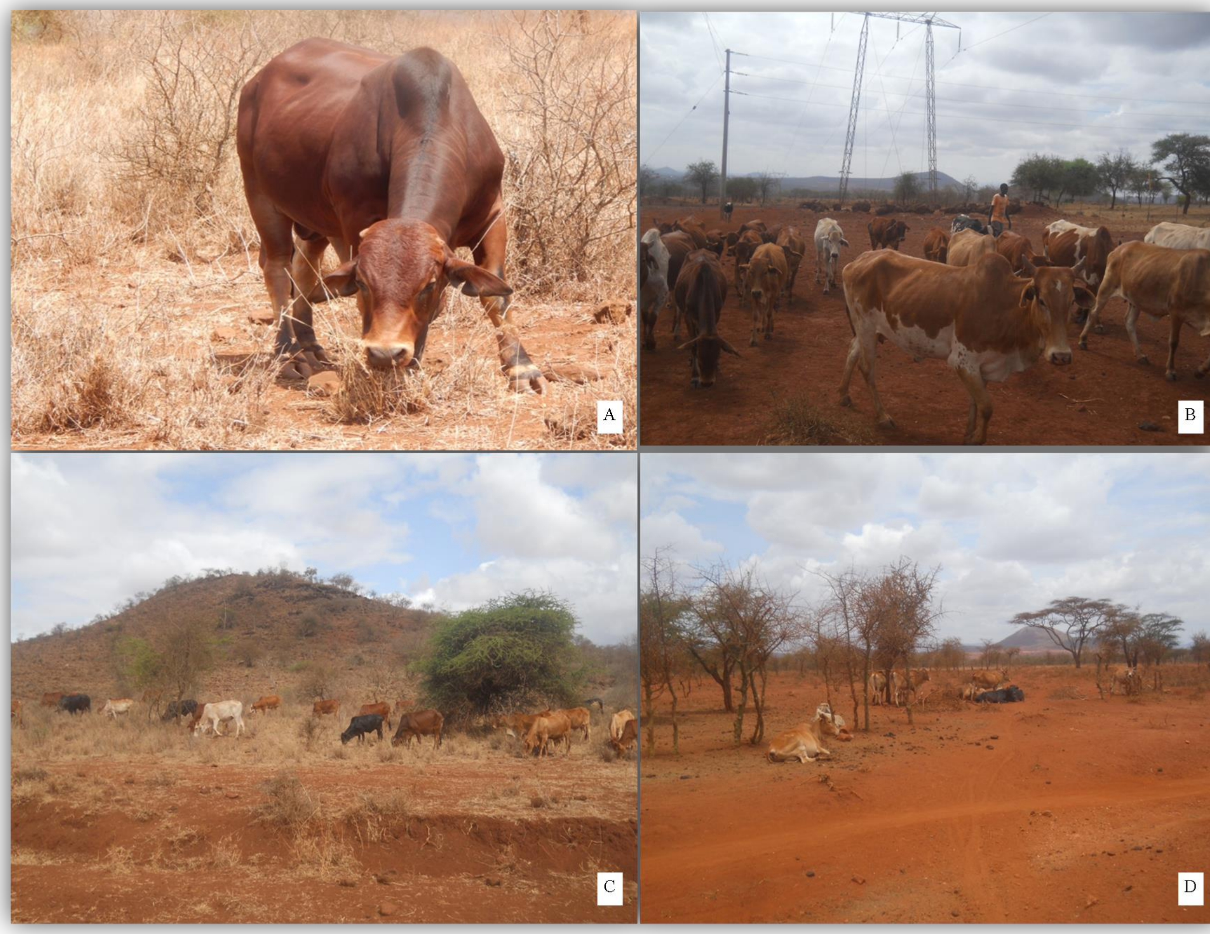


Plate 5.1: Cattle; *enteric methane emitters* **Source:** *Field Study*

Plate 5.1 illustrates cattle production in Kenyewa Location of Kajiado County.

A: A breeding bull during grazing hours

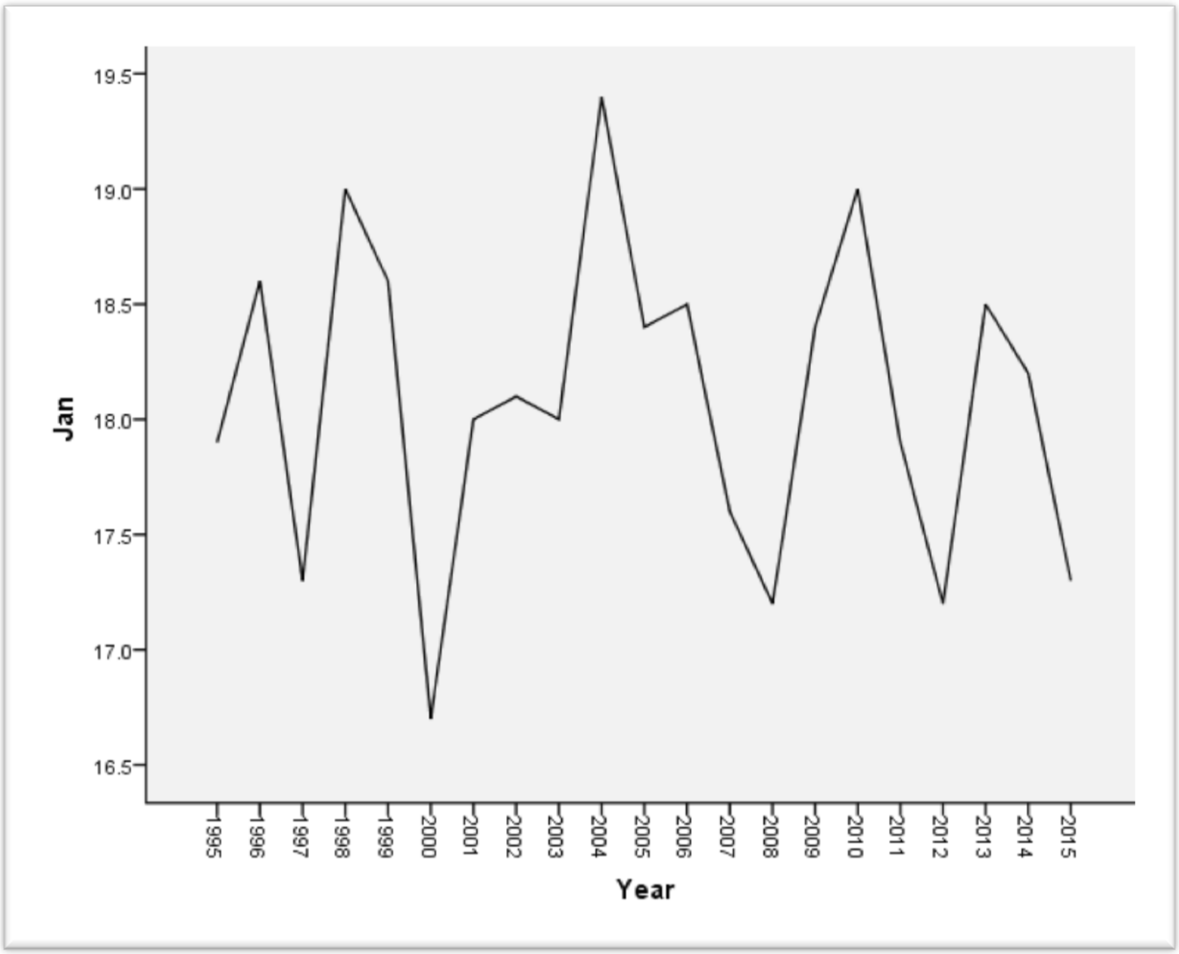
B. Cattle on transit

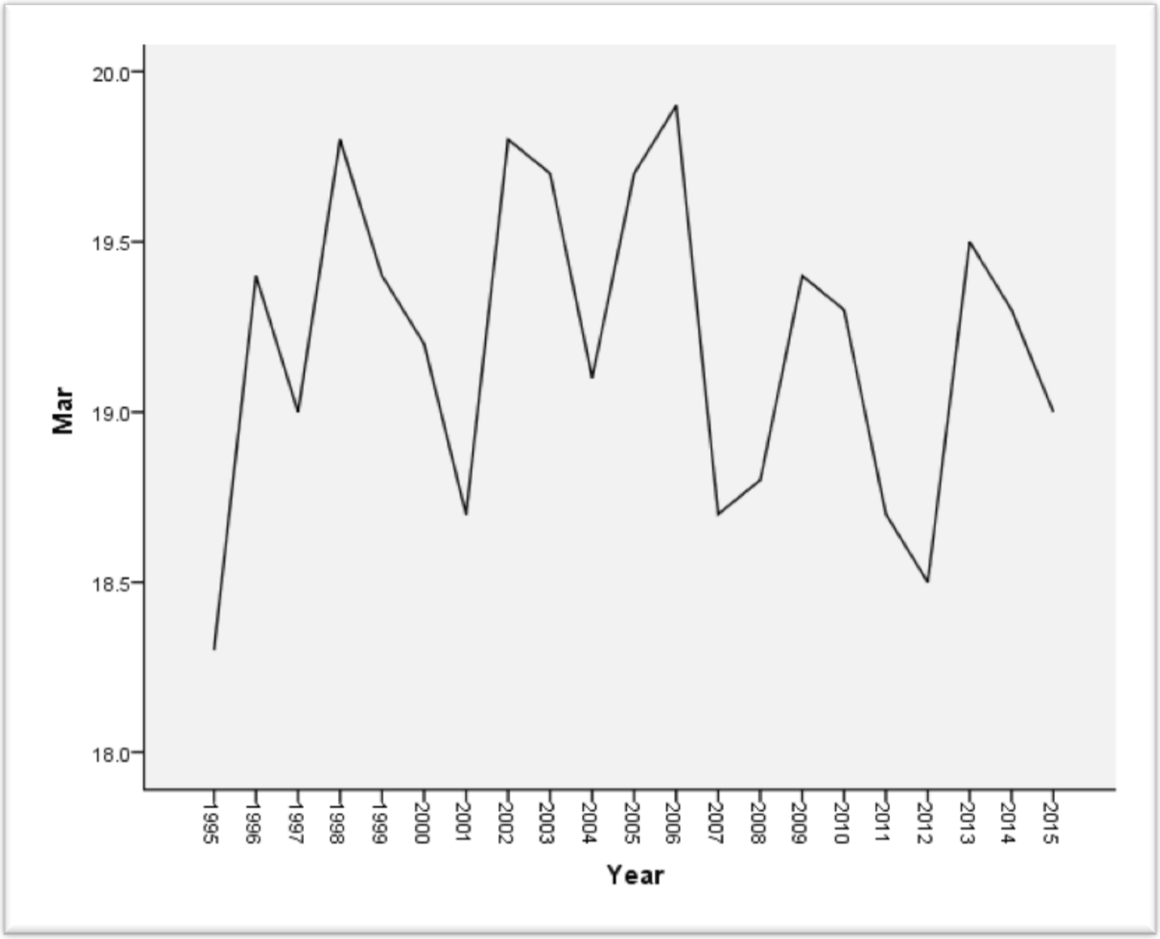
C. Cattle during grazing hours

D. Cattle during rest periods

As was determined from the study, cattle (plate 5.1), among all domestic ruminants, were the main enteric methane emitters. The breeding bull shown in plate 5.1 (A) was emitting enteric methane and dispersing it from one place to another as it fed and so were the cattle in plate 5.1 (C).The amount released as they fed was small. When on transit, they emit methane but also in small amounts (plate 5.1 B). Cattle rest periods (plate 5.1 D) were the cud-chewing time when animals were all together and were the peak of enteric methane emissions.

Methane is a gas responsible for global warming and so a need arose to analyse temperature data in order to establish the trends of temperatures for Makindu from1995 to 2015. The Makindu mean temperatures for the months of January to December were subjected to a row sequential plot (roll plot) where time was the ordered years from 1995 to 2015. The months of January and March which depicted the high temperatures over the years were chosen as an example (Figures 5.4). These were periods of low quality and quantity forage. Low quality forage leads to increased cattle enteric methane emissions per unit of product.

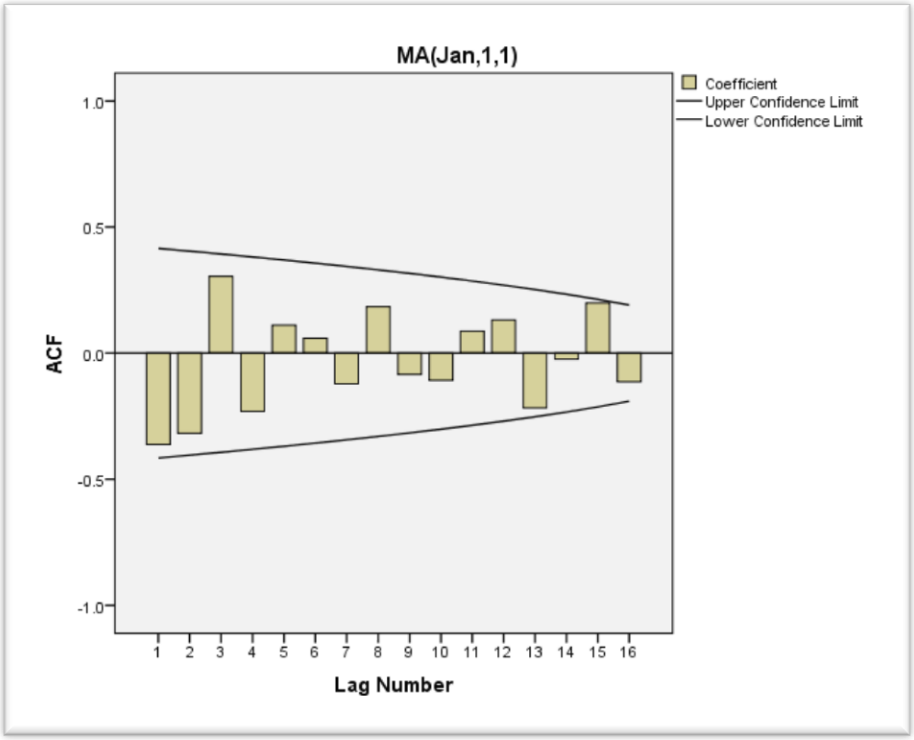


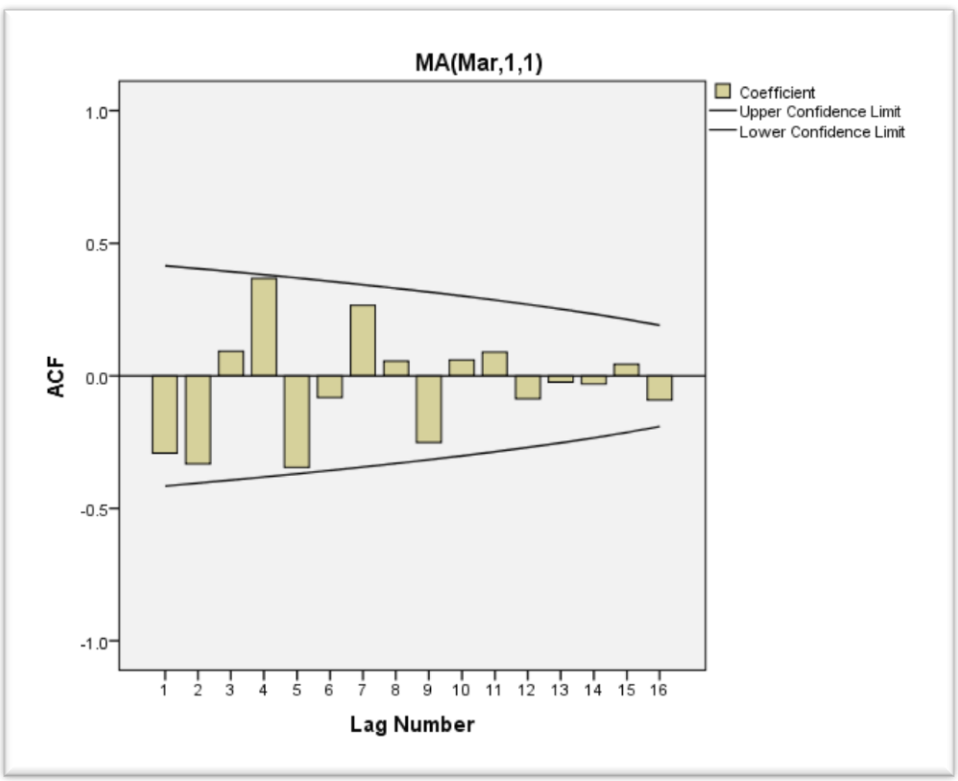


Figures 5.4: Makindu Temperatures for the month of January and March: *1995-2015*

Source: *Field study*

A model was then created with; months being the dependent and year the independent variable. After the models were created, the nature of the changes in means temperatures, whether cyclic or periodic were established by use of means (Figures 5.5).

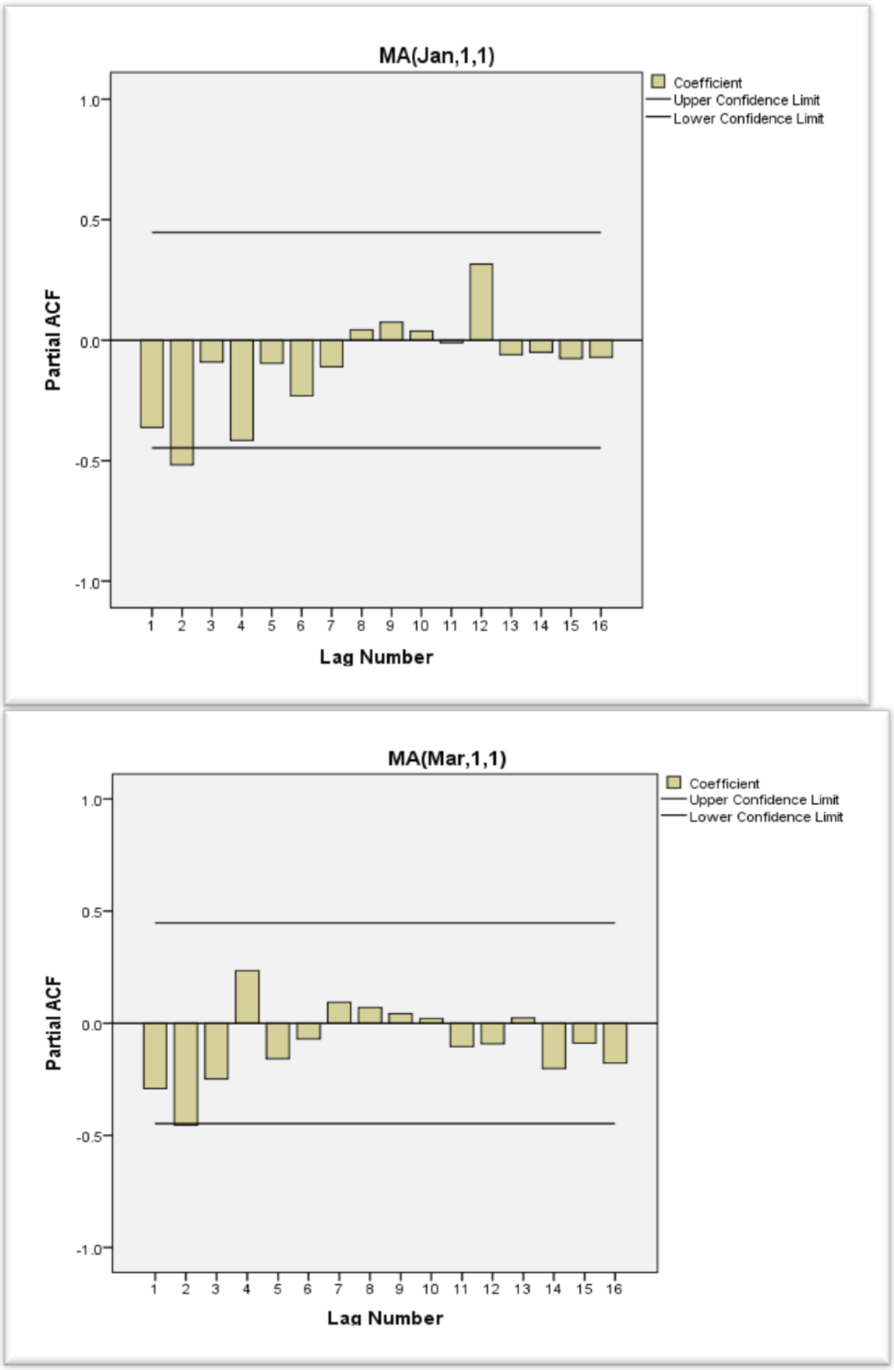




Figures 5.5: Time series of temperatures for the month of January and March: *1995-2015*

Source: *Field study*

After the models were created, the nature of the changes in means temperatures, whether cyclic or periodic were established by use of medians (Figures 5.6).



Figures 5.6: Time series of temperatures for the month of January and March: *1995-2015*

Source: *Field study*

Results of the analysis indicated that changes in mean temperature depict a cyclic pattern over the twenty –year period, 1995-2015.

5.2 The Existing Technological Options in Kenyewa Location for Reducing Enteric Methane Emissions

Every nation of the world has its cattle industry currently confronted with a three-ford set of difficulties. These are, to meet increasing demand for beef and milk for its growing population, adapt to climate change and reduce enteric methane emissions (Lines-Kelly, 2014). Africa's contribution to global warming is very minimal yet the continent is quite vulnerable to climate change impacts (HBS, 2010). Though the continent is actively involved in adaptation to climate change, it also requires mitigation strategies. The cattle industry has been identified as a major contributor to environmental woes including climate change but the same sub-sector provides a platform for climate change mitigation (FAO, 2006.). Methane has a global warming potential 25 times that of carbon dioxide over a century time-frame and leaves the atmosphere within a shorter period of 12-17 years compared to other greenhouse gases (IPCC, 2007; Lines-Kelly, 2014). For these reasons, mitigation of enteric methane is a rewarding process.

In this study, an association was established between methane emission and cattle numbers. Therefore, reduction of cattle numbers was a strategy that can readily reduce enteric methane emissions. From the field survey, focus group discussion and key informants meetings, it was established that reduction of cattle numbers in Maasai land is unpopular. Cutting down on beef or milk consumption could have been effective measures of reducing enteric methane emissions. From observations in all outlets for marketing of cattle in Kenyewa Location, it was evident that cattle products are a delicacy in Maasai land. In most markets in this area, beef is packed as a take away meal. Therefore, reduction in consumption of cattle products cannot be effective in enteric methane emissions in Maasai land. Therefore, an attempt was made in this study to determine the existing technological options for reducing enteric methane emissions. Analysis of the data showed that 8.3% of the respondents do strategic feeding as a technological option to reduce enteric methane emissions in Kenyewa Location of Kajiado County. 2.8%, 11.0% and 0.1% of the respondents had put in place improved pasture management, clean water and borehole water respectively. A total of 11.1% of the respondents carry out disease prevention and control by way of treatment, spraying against ticks, vaccination and deworming.

Eleven point one percent of the respondents manipulate the cattle rumen function by giving saltlick to their cattle. Timely culling and timely sell of steers are technological options for reducing enteric methane emissions done by 11.1 % of the respondents. A meagre 0.1% of the respondents manipulate the cattle rumen function by use of dairy meal, mineral lick and molasses. The indigenous practices in Kenyewa Location are similar to range management practices in the traditional African society (Niamir, 1990). Modern interventions are similar to those done in developed countries namely, enhanced nutrition, breeding, growth promotants and ionophores (Johnson and Johnson 1995). Also, these measures are similar to those outlined by Silvestri and Knox (2012) that were recommended for the developing world. Technological options for reducing enteric methane emissions in Kenyewa location are also similar to those for pasture-grazed ruminants (Buddle *et al.* 2011). Therefore, manipulation of feeds and feeding, breeding, veterinary care, rumen functions and marketing strategies result in reduction of enteric methane emissions and are effective.

The identified technological options for mitigating enteric methane emissions were fourteen in number namely: strategic feeding, improved pasture management, clean water, borehole water, treatment, spraying, vaccination, deworming, saltlick, dairy meal, mineral lick, molasses, timely culling and timely sale of steers. Percentages and totals were based on respondents. Strategic feeding was one way of improving productivity in Kenyewa Location of Kajiado County. Well fed cattle reach slaughter weight faster and this reduces enteric methane emissions per unit of feed intake. To the herders in Kenyewa Location, strategic feeding of the cattle was an art. Percentages and totals were based on respondents. It all began with timely release of the cattle to the grazing fields. Cattle were grazed starting from 7.00 a.m in the morning so that they will have sufficient time to graze. The herder led the cattle so that they do not graze hurriedly and trample carelessly on the pasture. Then slowly by slowly moved forward and let cattle graze slowly thus getting maximum benefit out of the available pasture. Herd splitting was done depending on age, sex and productivity phase of the cattle. The herd was divided into various age groups such that calves, weaners and mature cattle above four months of age grazed separately. Steers grazed separately from the cows while lactating herd were separated from the dry herd.

Improved pasture management included fencing and paddocking that allowed for rotational grazing. Maximum utilization of pasture improved livestock productivity. Clean water was preferred by cattle rather than dirty water. Clean water was palatable and when cattle take more of it, their feeding improved and this improved their productivity. Non-dairy cattle consumed a total of 40 litres per head per day while dairy cattle took seventy five litres per head per day (TARDA, 1984). When surface water dried up; borehole water was the best alternative.

Disease control included prevention and routine treatment. Preventive measures included deworming, spraying and vaccination while routine treatment was the curative measure. Good health was a prerequisite to increased productivity and healthy animals reached slaughter weight faster hence decreased enteric methane emissions per unit of feed. Spraying was done to protect cattle against tick-borne diseases such as east coast fever. Vaccinations were government programs done to control foot and mouth disease and black quarter among other diseases. Deworming was for eliminating internal parasites which were rampant in grazed cattle including roundworms, tapeworms, flukes and coccidia. The herders in Kenyewa Location were very keen on timely deworming and vaccination. Routine treatment and spraying prevented cattle losses and improved productivity and hence reduction in enteric methane emissions. Saltlick, dairy meal, mineral lick and molasses were supplements that led to increased productivity because animals got minerals that were not readily available in pasture. Supplements altered rumen function leading to a decrease in enteric methane emissions. Timely culling and timely sale of steers helped in reducing cattle numbers at the appropriate time thereby reducing enteric methane emissions.

Results from the survey showed that eighty two percent of the respondents said that for the past five years, the cattle numbers were at times increasing and other times decreasing, a scenario they attributed to climate variability. This group of cattle keepers were purely dependent on nature for survival of their cattle herds. However, eighteen per cent of the respondents said that over the past five years the numbers of their cattle were decreasing due to improved production. Responses from the latter group indicated extra benefits of enteric methane emissions mitigation apart from those observed by the majority of respondents. This group did not attribute decrease in cattle numbers to climate variability but rather to improved production showing that enteric methane emissions mitigation strategies lead to resilience in cattle production.

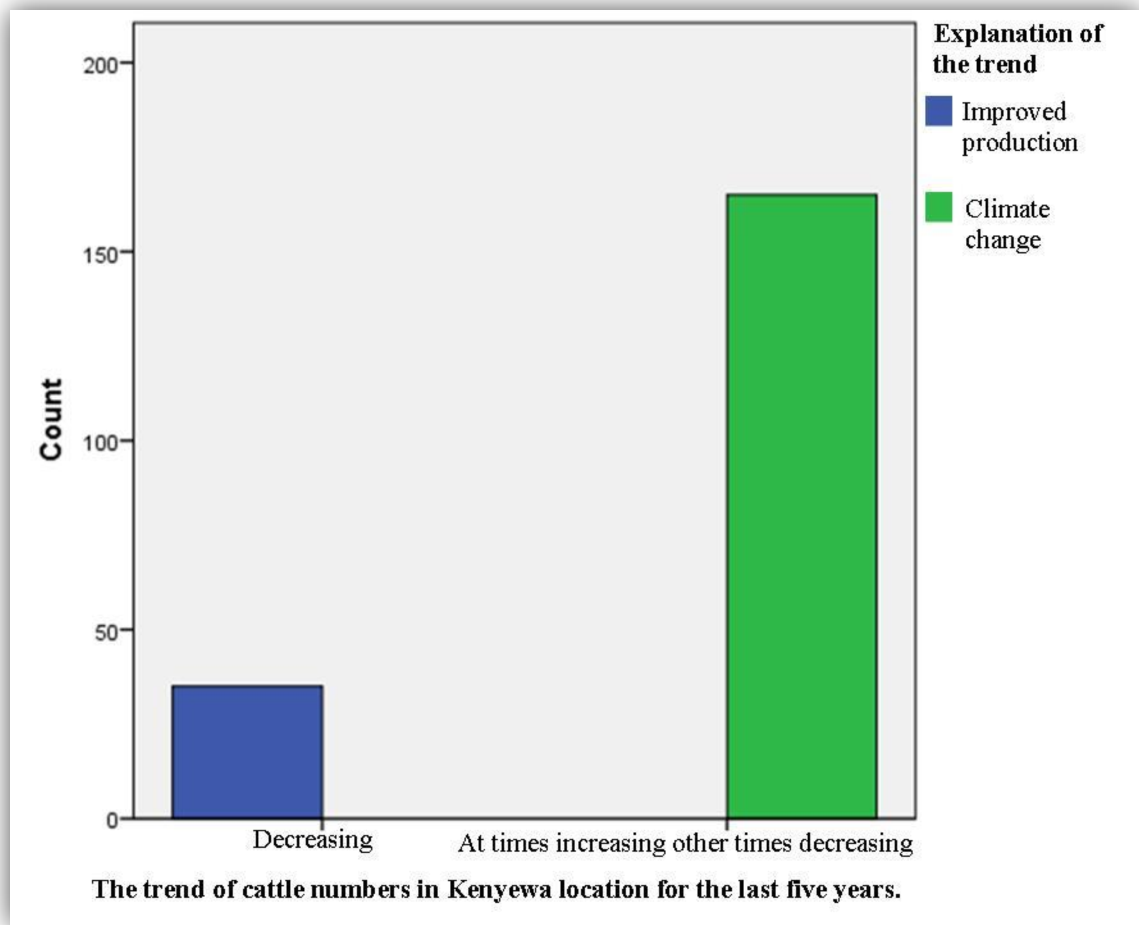


Figure 5.7: Trend of cattle numbers in Kenyewa over a 5-year period

Source: *Field study*

Some respondents said that improved production has led to decrease in cattle numbers for the same level of output (figure 5.7). This group of respondents said that the technological options for reducing enteric methane emissions. Led to decreased cattle numbers given the same output level. The explanation that cattle numbers were at times increasing and other times decreasing was given by respondents who depend on nature for grazing of their herds. To them climate change (interpreted in this study to mean climate variability) was the reason for that particular trend in cattle numbers.

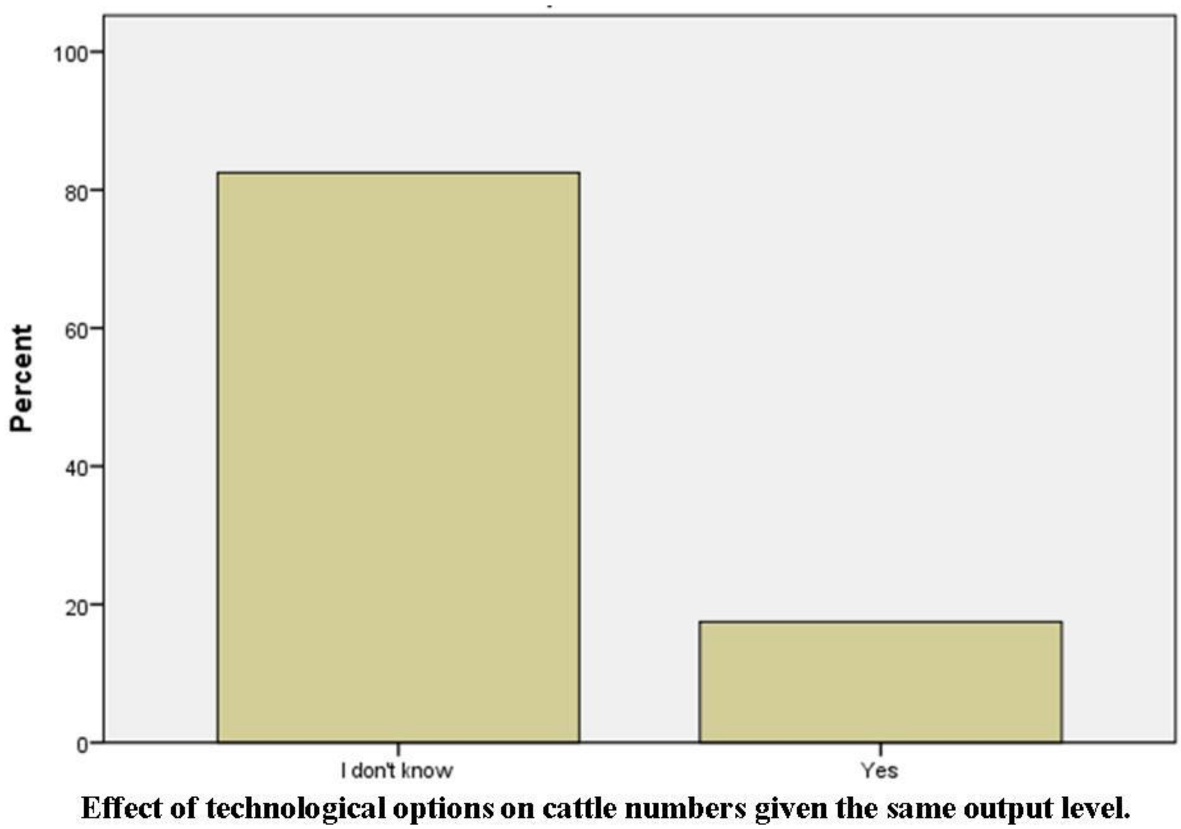


Figure 5.8: Trend of cattle numbers in Kenyewa over a 5-year period

Source: *Field study*

Cattle numbers affected enteric methane emissions and existence of technological options to reduce enteric methane emissions were mainly due to cattle rearing (plate 5.8) so an attempt was made to relate methane emissions levels with existing technological options. After estimating how cattle numbers affected variations in methane emission, it was important to establish whether the estimated methane emission values were chance events and this study used single sample t-test where t was specified as: $t = \dfrac{\bar{x} - \mu_0}{\frac{s}{\sqrt{n}}}$

This activity faced the problem of different levels of measurement. Whereas methane emissions levels were scale measurement, existing technological options were nominal measurement. A data mining exercise was carried out to convert the nominal measures of existing technological options into scale measures. The technological options were then cross-tabbed with likert scores so as to show association between the variables. The technological options for reducing enteric methane emissions were given ranks 1,2,3,4 and 5. Technological options for reducing enteric methane emissions with the highest score were the most common while the ones with lowest score were the least common. The mean score was between 4 and 5. The options can be ranked from the highest to the lowest common ones as follows: treatment, spraying, vaccination, deworming, saltlick, timely culling and timely sale of steers have the highest ranking. These are followed by clean water, strategic feeding and improved pasture management. The final rank which is also the lowest is shared by borehole water, dairy meal, mineral lick and molasses.

The technological options for reducing enteric methane emissions were grouped into, sound veterinary care, supplements, aggressive marketing of cattle products, feed and nutrition and good quality water. Some of the technological options for reducing enteric methane emissions were acquired but others are part of their traditional cattle production practices. The traditional cattle production practices are saltlick, timely culling and sale of steers, clean water and strategic feeding. The acquired cattle production practices were treatment, spraying, vaccination, deworming, improved pasture management, borehole water, dairy meal, mineral lick and molasses. Since there was an association between the computed methane emissions per year and technological mean score there was need to measure the strength of association and in this case Pearson's linear correlation. The correlation is significant at the 0.05 level (2-tailed). The null hypothesis stated that there are no existing technological options for reducing enteric methane emissions from cattle production in Kenyewa Location of Kajiado County. The technological mean score was tested whether it was chance or significant event using ANOVA. The test statistic is the F statistic which gave a value of 5.16. The critical value was 2.272 at 199 degrees of freedom and α 0.05 level (2-tailed).The null hypothesis is, therefore, rejected and the alternative hypothesis adopted.

		Responses		Percent of Cases
		N	Percent	
Technological options	Strategic feeding	149	8.3%	74.5%
	Improved pasture management	51	2.8%	25.5%
	Clean water	199	11.0%	99.5%
	Borehole water	1	0.1%	0.5%
	Treatment	200	11.1%	100.0%
	Spraying	200	11.1%	100.0%
	Vaccination	200	11.1%	100.0%
	Deworming	200	11.1%	100.0%
	Saltlick	200	11.1%	100.0%
	Dairy meal	1	0.1%	0.5%
	Mineral lick	1	0.1%	0.5%
	Molasses	1	0.1%	0.5%
	Timely culling	200	11.1%	100.0%
	Timely sale of steers	200	11.1%	100.0%
Total		1803	100.0%	901.5%

Table 5.1: Existing technological options for reducing enteric methane emissions in Kenyewa

Source: *Field study*

Plate 5.2: Some technological options for reducing enteric methane gas emissions in Kenyewa Location

Source: *Field Study*

The field survey and direct observations showed some technological options for reducing enteric methane emissions that were evident in Kenyewa Location (plate 5.2)

A. A: Dairy farming
B. Hay bailing
C. Cattle drinking from watering troughs
D. Hay banda to store baled hay for use in period of pasture shortage
E. Preserving feed as standing hay in a fenced paddock
F. Aggressive marketing of steers and culls in Emali holding ground

5.3 The Viability of Technological Options in Reducing Enteric Methane Emissions

Viability of technological options for reducing enteric methane emissions is very crucial in choosing appropriate ones for any particular area. IPCC, 1992; CEA, 2014; Herrero *et al.* 2011; and Peters *et al.* 2012 recommends that all stakeholders involved in planning and implementation of technological options for reducing enteric methane emissions carefully determine their viability. Increased productivity, cost effectiveness, consistence with culture as well as systems of production and decrease in cattle numbers while maintaining the same level of output is the viability criteria.

The results from the survey (figure 5.9) show that 20.0% of the respondents indicated that the existing technological options for reducing enteric methane emissions increased productivity were affordable and consistent with Maasai culture and systems of production 14.8 % of the respondents did not know if cattle numbers have decreased with the same production level. Cattle numbers had decreased with the same production level were indicated by 5.1 % of the respondents. Generally, there were four key sustainability issues on existing technological options for reducing methane emissions in Kenyewa location of Kajiado County. These were, increased productivity, affordable, consistence with Maasai culture and consistent with Maasai systems of production. This implied that the technological options for reducing enteric methane in Kenyewa Location met most of the stipulated viability criteria. This was in line with CEA (2014) and IPCC (1992).

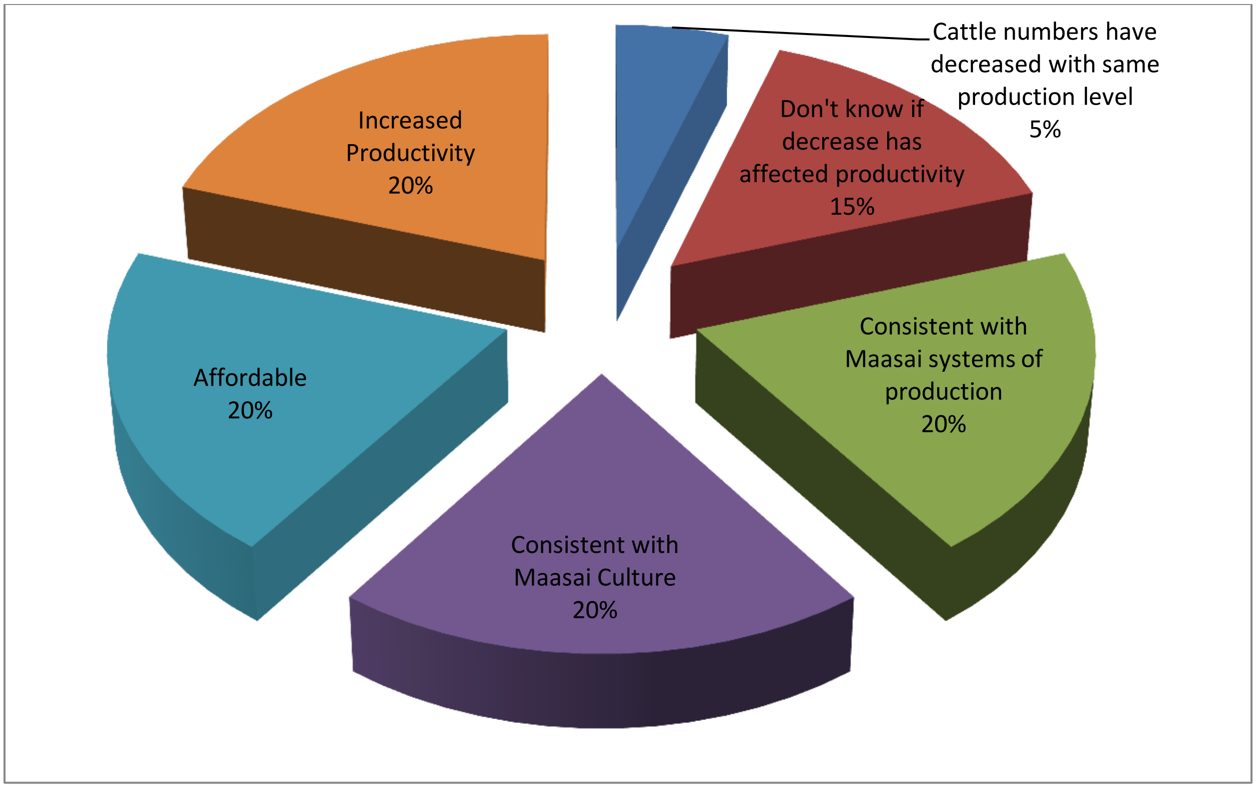


Figure 5.9: Responses on technological options viabilities

Source: *Field study*

To examine the association, the technological options for reducing methane emissions were cross tabulated with the technological options viabilities. The null hypothesis stated that the existing enteric methane emission mitigation strategies in Kenyewa Location of Kajiado County are not viable. Kruskal Wallis test was used to test whether viability issues were significant or chance events. The null hypothesis was rejected owing to the fact that the critical chi-square value is 13 which was less than H statistic value of 14 at α 0.05 level (2-tailed) and 13 degrees of freedom. The null hypothesis is rejected and the alternative hypothesis adopted.

5.4 Level of Participation in Climate Change Mitigations

Mitigation of methane emissions calls for coordinated efforts by the nations of the world (CEC, 1996). As observed by Olago (2012), mitigation of methane emissions involves awareness creation, coordination by various institutions to avoid duplication of activities, resource mobilization and involvement of various stakeholders, realistic planning and implementation.

It was important to first determine what options to reduce enteric methane emissions were already in place, their viability and whether they had a bearing on climate change mitigation.

Only then can a decision be made with involvement of the local community on how to incorporate other measures into viable existing ones thus achieve climate change mitigation. The results from the survey indicated that 99.5 per cent of the respondents in Kenyewa practice 8 climate change mitigation measures out of seventeen while 0.5% of the respondents implemented 11 climate change mitigation strategies.

199 respondents were found to participate in 8 climate change mitigation strategies fully. These practices were on-going and were practiced by herders of non-dairy cattle. They include: strategic feeding or improved pasture management, clean water or borehole water, vaccination, deworming, saltlick, selective breeding, timely culling and timely sale of steers. Treatment and spraying was excluded from the list of climate change mitigation strategies after the interviews with key informants and focus group discussions. This is because the Maasai in Kenyewa do not do treatment and spraying correctly. The key informants meetings, focus group discussion and direct observation revealed one extra technological option for mitigating enteric methane emissions that was not mentioned by the respondents. This was selective breeding practiced by all the herders in Kenyewa Location. One cattle keeper in Kenyewa was found to participate in eleven climate change mitigation strategies. The respondent, a dairy farmer practiced: improved pasture management, clean water, vaccination, deworming, saltlick, timely culling, timely sale of steers, mineral lick, molasses, dairy meal and selective breeding.

The level of participation of the majority of Kenyewa respondents in climate change mitigation strategies, as determined in this study was below the minimum requirement. This is in line with FAO (2013) who observed that even though climate change mitigation options are effective; their level of implementation is quite low worldwide. The null hypothesis stated that the level of participation of Maasai community of Kenyewa Location of Kajiado County in climate change mitigation strategies is insignificant (below the minimum requirement of seventeen). It was found appropriate to test whether the climate change mitigation strategies were chance or significant events by use of one-sample T-test. The value of t was 534.333 at α 0.05 (2-tailed) and 199 degrees of freedom. The large value of t indicated that the difference was a significant and not a chance event. There was no sufficient evidence to reject the null hypothesis. The climate change mitigation strategies in Kenyewa Location were below the minimum requirement of seventeen.

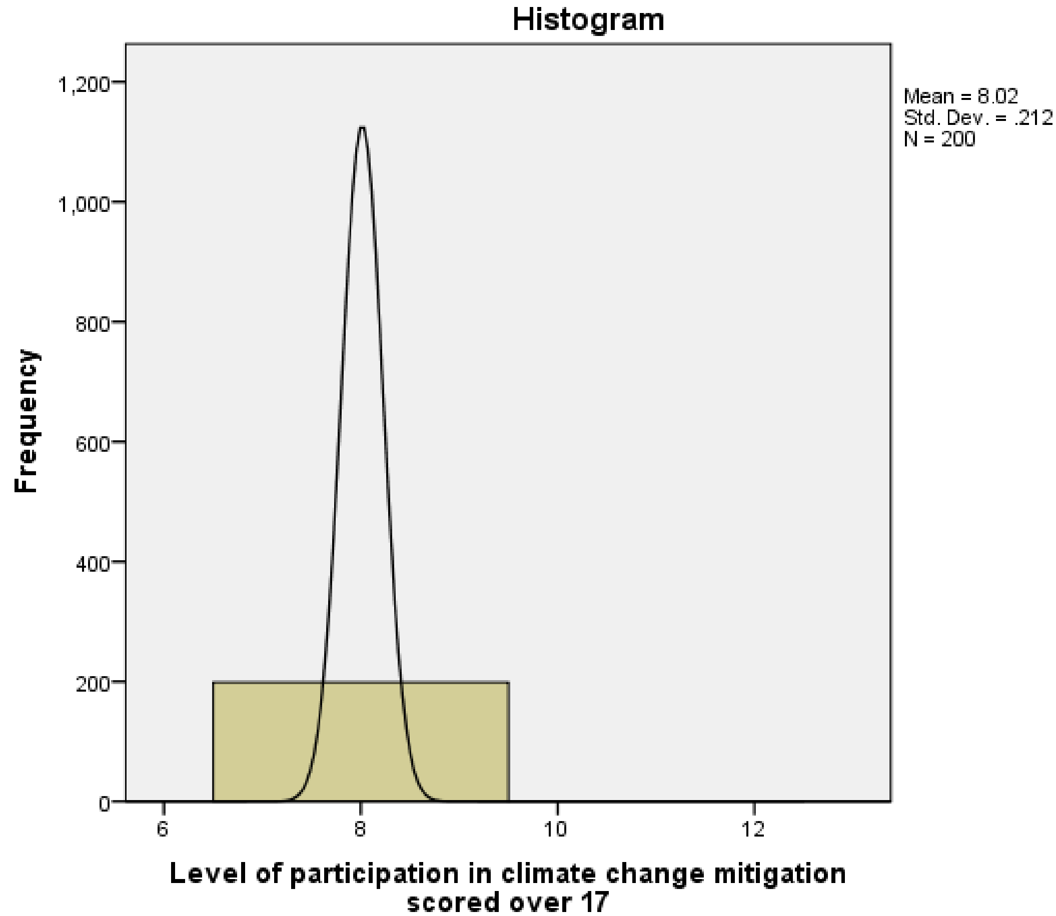


Figure 5.10: Participation in climate change mitigation strategies

Source: *Field study*

5.5. The Potential for Participation in Climate Change Mitigations

In the developing countries increasing demand for cattle products is usually satisfied through increasing cattle numbers rather that improved productivity (Silvestri and Knox, 2012). The cattle industry offers an opportunity to mitigate enteric methane emissions. In the developed countries, options for achieving reduced enteric fermentation methane emissions are being implemented already. In the developing countries, there is potential for implementation of enteric methane mitigation options. The results of this study indicated that 92% of the respondents in Kenyewa Location would like to adopt climate change mitigation strategies. There were a small proportion of respondents, eight per cent who were totally adamant.

They were not willing to adopt the options, however appealing these were in terms of improving productivity, low-cost, consistent with Maasai culture and systems of production. The technological options that reduce enteric methane emissions are said to offer mitigation potential. There is a potential for adoption of climate change mitigation options in Kenyewa Location.

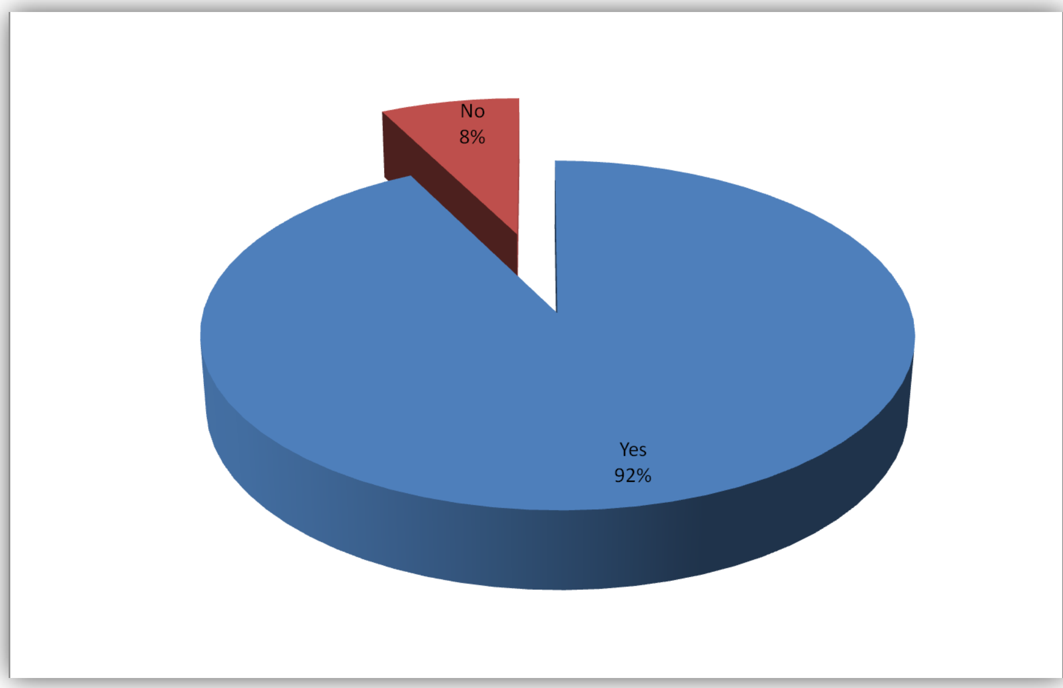


Figure 5.11: Willingness to adopt other recommended mitigation strategies

Source: *Field study*

CHAPTER SIX

6.0. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1. Summary

Analysis of the data showed a tendency to have an increase in methane emission with increase in number of cattle. Regression analysis results indicated perfect fit of cattle numbers and enteric methane emissions. At the time of the study, the total methane emissions per year for cattle in the sample area were 114129 Kg. Total enteric methane emissions in Kenyewa Location, at the time of the study was 220,428 Kg which accounted for a contribution to the global greenhouse effect of 5,510,700 Kg CO_2-Eq. Kajiado County produced 24,983,220 Kg which is a total contribution of 624,580,500 Kg CO_2-Eq. to global the greenhouse effect. The computed enteric methane was 40 Kg of enteric methane per head per year and 31 Kg of enteric methane per head per year for dairy and non-dairy cattle respectively. The level of enteric methane emissions in Kenyewa Location accounted for 0.88 per cent of the total enteric methane emissions from Kajiado County and an insignificant amount in the global anthropogenic greenhouse effect. The null hypothesis stated that enteric methane emissions from cattle production in Kenyewa Location of Kajiado County are minimal and thus insignificant in global anthropogenic greenhouse effect. There was no adequate evidence to reject the null hypothesis.

Analysis of the data showed that 8.3% of the respondents do strategic feeding as a technological option to reduce enteric methane emissions in Kenyewa Location of Kajiado County. 2.8%, 11.0% and 0.1% of the respondents had put in place improved pasture management, clean water and borehole water respectively. A total of 11.1% of the respondents carried out disease prevention and control by way of treatment, spraying, vaccination and deworming. Eleven point one percent of the respondents manipulated the cattle rumen function by use of saltlick. Timely culling and timely sell of steers were technological options for reducing enteric methane emissions done by 11.1 % of the respondents. A meagre 0.1% of the respondents manipulated the cattle rumen function by use of dairy meal, mineral lick and molasses. Also, these measures were similar to those outlined by Silvestri and Knox (2012) that were recommended for the developing world. Technological options for reducing enteric methane emissions in Kenyewa location were also similar to those for pasture-grazed ruminants (Buddle *et al.* 2011).

The null hypothesis stated that there are no existing technological options for reducing enteric methane emissions from cattle production in Kenyewa Location of Kajiado County. The null hypothesis was rejected and the alternative hypothesis adopted. The results from the survey show that 20.0% of the respondents indicated that the existing technological options for reducing enteric methane emissions increased productivity were affordable and consistent with Maasai culture and systems of production. Fourteen point eight per cent of the respondents did not know if cattle numbers have decreased with the same production level. Cattle numbers have decreased with the same production level were indicated by 5.1 % of the respondents. This implied that the technological options for reducing enteric methane in Kenyewa Location met most of the stipulated viability criteria. This was in line with CEA (2014) and IPCC (1992). The null hypothesis stated that the existing enteric methane emission mitigation strategies in Kenyewa Location of Kajiado County are not viable. The null hypothesis was rejected and the alternative hypothesis adopted.

The results from the survey indicated that 99.5 per cent of the respondents in Kenyewa practiced 8 climate change mitigation measures out of seventeen while 0.5% of the respondents implemented 11 climate change mitigation strategies. The null hypothesis stated that the level of participation of Maasai community of Kenyewa Location of Kajiado County in climate change mitigation strategies is insignificant (below the minimum requirement of seventeen). The climate change mitigation strategies in Kenyewa Location were below the minimum requirement of seventeen. There was no sufficient evidence to reject the null hypothesis. The results of this study indicated that 92% of the respondents in Kenyewa Location would like to adopt climate change mitigation strategies. There were a small proportion of respondents, eight per cent who were totally adamant. There is a potential for adoption of climate change mitigation options in Kenyewa Location.

6.2. Conclusions

1. The level of enteric methane emissions in Kenyewa Location accounted for 0.88 per cent of the total enteric methane emissions from Kajiado County and an insignificant amount in the global anthropogenic greenhouse effect. Nonetheless, that minimal level cumulatively was a contributing factor to global warming and subsequent climate change.
2. There were already existing indigenous and modern interventions of reducing enteric methane emissions in Kenyewa Location. They should not be discarded rather serve as a foundation upon which extra measures of enteric methane emissions mitigation could be built upon.
3. The existing technological options for reduction of enteric methane in Kenyewa Location were viable and thus sustainable.
4. The level of participation of the Maasai in Kenyewa Location of Kajiado County to climate change mitigation strategies is insignificant (below the minimum requirement of seventeen).
5. There is potential for participation of Maasai in Kenyewa Location of Kajiado County to climate change mitigation strategies.

6.3. Recommendations

6.3.1. Policy Recommendations

1. Officers of National Environment Management Authority (NEMA) at the counties are obliged to raise public awareness about the increasing enteric methane levels and its role in global warming.
2. Extension officers in the ministry of Agriculture, Livestock and Fisheries and cattle industry stakeholders in Kajiado should strengthen already existing technological options for reducing enteric methane emissions in Kenyewa location of Kajiado County.
3. The Kenya government should subsidize the prices of cattle production inputs.
4. Officers of National Environment Management Authority (NEMA) should do awareness creation and capacity building on other recommended technological options for reducing enteric methane emissions.
5. The Kenya government should put in place preparatory measures for climate change mitigation strategies through sufficient institutional frameworks and proactive governance.

6.3.2. Research and Academia

Research and academia are very important stakeholders of livestock production in relation to climate change.

This study recommended future research on:

1. A more accurate estimation of enteric methane emissions in cattle by use of Tier 2 or Tier 3 methods.
2. Other viable enteric methane mitigation measures.
3. This study can be replicated on a large sample in order to make a comparison between cattle in relation to climate change on extensive and intensive forms of cattle production.

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APPENDICES

Appendix I: Permit

COUNTY GOVERNMENT OF KAJIADO

P.O BOX 11-01100, KAJIADO
Tel +254 708299339 .0708299391 .0726986445

MINISTRY OF LANDS, PHYSICAL PLANNING, ENVIRONMENT, WILDLIFE & NATURAL RESOURCES

ENVIRONMENT DEPARTMENT

When replying please quote

7th June, 2015

OUR REF: CGK/PHY ENV DEP/VOL.1/010

TO WHOM IT MAY CONCERN

REF: AGNES NTHENYA KIMONGA

The above named is undertaking a masters degree at the University of Nairobi in the Department of Geography and Environmental Studies.

As part of this, she is to undertake a project **"Methane Emmissions from Enteric Fermentation in cattle: A study of climate change mitigation strategies"** in Kenyawa location within Kajiado County.

The purpose of this letter is to authorize her to collect any data that may be useful in her area of study. Please accord her the necessary assistance.

COUNTY GOVERNMENT OF KAJIADO
Chief Officer Environment Urban Areas & Partnerships
07 JUN 2016
Signature............

J.W.Kanini
County Environment Officer

Appendix II: World Cattle Inventory: Ranking of Countries

World		998,313,000	
Rank	Country	2017	% of World
1.	India	303,350,000	30.39%
2.	Brazil	226,037,000	22.64%
3.	China	100,085,000	10.03%
4.	United States	93,500,000	9.37%
5.	European Union	89,250,000	8.94%
6.	Argentina	53,515,000	5.36%
7.	Australia	27,750,000	2.78%
8.	Russia	18,430,000	1.85%
9.	Mexico	16,500,000	1.65%
10.	Turkey	14,047,000	1.41%
11.	Canada	12,100,000	1.21%
12.	Uruguay	11,845,000	1.19%
13.	New Zealand	9,903,000	0.99%
14.	Egypt	6,995,000	0.70%
15.	Belarus	4,320,000	0.43%
16.	Japan	3,800,000	0.38%
17.	Ukraine	3,780,000	0.38%
18.	South Korea	3,106,000	0.31%

Source: *FAS/USDA (head)*

Appendix III: Kenyewa Community Questionnaire

I am Agnes Nthenya Kimongo Reg./No-C50/69237/2011 from the University of Nairobi undertaking a research on Methane Gas Emissions by Enteric Fermentation from Cattle Production in Kenyewa Location of Kajiado County: a Study of Potential Climate Change mitigation measures. I am therefore kindly asking for assistance in the acquisition of the information required to meet the objectives of the study by responding to details on the questionnaire. The information you provide will be treated with utmost confidentiality and to be used strictly for academic purpose. Thanks in advance for your assistance.

Questionnaire number ______ Interviewer____________________________________

Location: X______________Y______________

Date of interview______/_____/2016

Bio-Data

1. What is name of your Manyatta? ____
2. What is your Sub-location? ____
3. What is your age (years)? ________
4. What is your education level?
    a. No formal education [ ]
    b. Primary [ ]
    c. Secondary [ ]
    d. College [ ]
    e. University [ ]
5. Any Environmental/livestock training or sensitization?
    a. Yes [ ]
    b. No [ ]
6. If yes, which one ____

Cattle and Enteric Methane Emission

7. How many mature cattle (above 4 weeks of age) do you have? ______________________
8. Which breed are they? ____
____
9. How far are the cattle grazing area from here? _____________________________________
10. In addition to the normal night hours, what time of the day do your cattle rest? ____
11. When cattle rest, in what pattern do they lie?
    a. Come together in a group [ ]
    b. Scatter [ ]
12. How far is the watering point for cattle from here? _________________________________
13. What characterizes the cattle resting period? _______________________________________
14. When cattle belch, what do they emit? ____
15. What do you think this emission does? ____
____
16. Do calves belch?
    a. Yes [ ]
    b. No [ ]
17. Explain your answer____
____
____

Existing Technological Options for Reducing Enteric Methane Emissions, their viability and level of participation of the Maasai Community in Climate Change Mitigation Activities

18. Over the past five years, have your cattle numbers been increasing or decreasing?
    a. Increasing [ ]
    b. Decreasing [ ]
    c. At times increasing other times decreasing [ ]

19. Explain the trend in question 18 above. ____

____

____

State the particular technologies you are implementing that improve cattle productivity?

____

____

20. Have the technological options you have put in place led to decreased cattle numbers while maintaining the same level of output?

a. Yes [ ]

b. No [ ]

c. I don't know [ ]

21. Describe the viability of these technological options of improving productivity in cattle?

	Improved Nutrition	Supplements	Disease Control	Aggressive Marketing of cattle products
Increased productivity?				
Cost				
Consistent with maasai culture Consistent with Maasai systems of production				
Reduction in cattle numbers while maintaining the same level of output				

23. Do you participate in climate change mitigation strategies?

Activity	Yes	No	Explain
Mechanical and chemical feed processing			
Strategic supplementation			
Production enhancing agents			
Improved production through improved genetic characteristics			
Disease control through routine treatment, deworming, control of ecto-parasites and vaccination			
Marketing of culls and steers			

Potential for Climate Change Mitigation Strategies

24. If there are other technological options that improve cattle productivity apart from the ones you are implementing, would you like to adopt them?

a. Yes [ ]

b. No [ ]

25. If the options are consistent with your culture/ systems of production, would you like to adopt them?

a. Yes [ ]

b. No [ ]

26. I f the options are affordable, would you like to adopt them?

a. Yes [ ]

b. No [ ]

27. If the options lead to reduction in cattle numbers while maintaining the same level of output, would you like to adopt them?

a. Yes [ ]

b. No [ ]

Thank you for your cooperation

Appendix IV: Questionnaire for Extension Officers

1. How many mature cattle (above 4 weeks of age) are there in Kenyewa Location and in Kajiado County? ______________________

2. Does Kenyewa community participate in climate change mitigation strategies?

Activity	Yes	No	Explain
Mechanical and chemical feed processing			
Strategic supplementation			
Production enhancing agents			
Improved production through improved genetic characteristics			
Disease control through routine treatment, deworming, control of ecto-parasites and vaccination			
Marketing of the surplus cattle products			

Appendix V: Enteric fermentation methane emission factors for cattle

Regional Characteristics	Cattle Type	Emissions Factor (Kg CH_4 /Head/Yr)	Comments
North America: Highly productive commercialised dairy sector feeding high forage and grain. Separate beef cow herd primarily grazing with feed supplements seasonally. Fast-growing beef steers heifers finished in feedlots on grain. Dairy cows are a small part o the population.	Dairy Non-dairy	118 47	Average milk production of 6,700kg/head/yr Includes beef cows, bulls, calves, growing steers/Heifers and feedlot cattle.
Western Europe: Highly productive commercialized dairy sector feeding high quality forage and grain. Dairy cows also used or beef calf production. Very small beef cow herd Minor amount of feeding with grains.	Dairy Non-dairy	100 48	Average Milk production of 4,200kg/head/yr Includes bulls, calves and growing steers/heifers
Eastern Europe: Commercialized dairy sector feeding mostly forages. Separate beef cow herd, primarily grazing minor amount of feedlot feeding with grains	Dairy Non-dairy	81 56	Average milk production of 2,550kg/head/yr Includes beef cows, bulls and young
Oceania: Commercialized dairy sector based on grazing. Separate beef cow herd, primarily grazing rangelands of widely varying quality. Growing amount of feedlot feeding with grains. Dairy cows are a small part of the population.	Dairy Non-dairy	68 53	Average milk production of 1,700kg/head/yr Includes beef cows, bulls and young
Latin America: Commercialized dairy sector based on grazing separate beef	Dairy	57	Average milk production of 800kg/head/yr

cow herd grazing pastures and rangelands. Minor amount of feedlot feeding with grains, growing non-dairy cattle comprise a large portion of population.	Non-dairy	49	Includes beef cows, bulls and young
Asia: Small Commercialised diary sector. Most cattle are multi-purpose, providing draft power and some milk within farming regions. Small grazing population. Cattle of all types are smaller than those found in most other regions.	Dairy Non-dairy	56 44	Average milk production of 1650kg/head/yr Includes multi-purpose cows, bulls and young
Africa and middle East: Commercialised dairy sector based on grazing with low production per cow. Most cattle are multipurpose, providing draft power and some milk within farming regions. Some cattle graze over very large areas, Cattle of all types are smaller than those found in most other regions	Dairy Non-Dairy	36 32	Average milk production of 475kg/head/yr Includes multi-purpose cows, bulls and young.
Indian Subcontinent: Commercialized dairy sector based on crop by-product feeding with low production percow. Most bullocks provide draft power and cows provide some milk in farming regions. Small grazing population. Cattle in this region are the smallest compared to cattle found in all other regions.	Dairy Non-Dairy	46 25	Average milk production of 900kg/head/yr Includes cows, bulls and young. Young comprise a large portion of the population.

.

Source: *Extract from IPCC, 1996*

Appendix VI: Manyattas in Kiboko Sub-Location

1. Mwamunka Koitumet
2. Lanket Sariku
3. Romanto Koitumet
4. Joshua Masenke
5. Maria Kerev
6. Tokoin Ipano
7. Stephen Ntokote
8. Kaasha Soyianka
9. Joel Kanchori
10. James Rikoyian
11. Paul Kiparki
12. Solomon Sariku
13. Teresia Risa
14. Lekayia Kuyan
15. James Leseyio
16. Masenke Kanchori
17. Josiah Kanchori
18. Manoe Munyaala
19. Loonke Pandiyio
20. Ole Langas
21. Piore Nabela
22. Raphael Lelion
23. Nkirimpa Karpa
24. Tipis Karpa
25. Kanani Aikoko
26. Kukayia Pararia
27. Joel Pararia
28. Tooto Kitakaya
29. Naimanta Lemukeku
30. Lemashon Likama
31. Lekalai Kipilosh
32. Surura Karpa
33. Lekoyo Ntungana
34. Kakuo Kinyangayo
35. Suai Muteepu
36. Ntooti Leserewan
37. Amos Leseyio
38. Benard Nabela
39. Kerisho Ratunka
40. Kukan Kutata
41. Seeru Lekirie
42. Tintiret Lekirie
43. Sanaek Muletra
44. Manases Kipelian
45. Kanchori Ndipa
46. Daniel Kanchori
47. Tepeyion Parmutia
48. Faith Parmutia
49. Ntitanian Mpasa
50. Nepatao Mpasa
51. Daniel Soyianka
52. Mukuria Mungai
53. Amos Musre
54. Letargues Kabisa
55. Joseph Kuyan
56. Felix Kuyan
57. Marempe Soyianka
58. Lewuanta Soyianka
59. Perian Kimiti
60. Peter Soyianka
61. Kisipo Diret
62. Moses Soyianke

63. Kihara Nengoyioyo
64. Kaetum Melenta
65. Enock Kaetuac
66. Moi Sariku
67. Emily Loomoni
68. Noolasho Diret
69. Ipancha Kukayia
70. Raila Sariku
71. Meris Shepe
72. Kishapui Kabisa
73. Kanai Kiloku
74. Pilai Kanchori
75. Lenkuuru Kanchori
76. Paps Leseyio
77. Kipanju Kuyatei
78. Kariuki Kuyatei
79. Nchayio Kutata
80. Meisan Kutata
81. Nkumama Nengoyieyio
82. Loigero Kariuki
83. Noah Kiplosh
84. Tonkei Lekirrie
85. Rukai Meisan
86. Gedion Letee
87. Putami Ronpen
88. Saimie Lepasis
89. Lakati Parmet
90. Munyere Ntoika
91. Jmalta Leseyio
92. Japeth Kakuo
93. Saloi Kakuo
94. Payiai Kakuo
95. Kamwana Kinyangaya
96. Maseto Meisan
97. Nakokoyia Sompiroi
98. Dancan Somproi
99. William Sonpnou
100. Peter Kihara
101. Mayoni Kihara
102. David Kihara
103. Junior Kisunku
104. Justus Marora
105. Leseyio Kiareto
106. Sironka Sanpeke
107. Benard Leseyio
108. Parkisia Kutata
109. Kuntai Marona
110. Dayaa Leseyio
111. Nkashipa Muru
112. Sekeyian Murry
113. Sitonik Moloma
114. William Maroru
115. Christine Kaaku
116. Jacob Tumaka
117. Nkapaapa Serina
118. Kingamu Tajeu
119. Amos Tajeu
120. Kabisa Tumate
121. Kiplosh Nenkiipa
122. Runke Marrona

123. Losojoi Parkitore
124. Oidopi Tumala
125. Kamala Donkol
126. Parkoyiel Nkaanyu
127. Sankale Leikari
128. Lembayian Tajeu
129. Kutila Tajen
130. Saitabu Parkitore
131. Munga Kaetuai
132. Osoi Kaetuai
133. Osupat Leserowan
134. Tulito Leserewan
135. Ole Toninio
136. Ole Leserewan
137. Dancan Kaetuai
138. Malulu Leserewau
139. Kipuri Moloma
140. Neenlaipa Saiko
141. Josiah Suyianka
142. Mumeita Letoire
143. Letorer Kanlol
144. David Kipingat
145. Matiko Siolompe
146. Topoika Yionti
147. Olonyokie Muteriau
148. Mukuria Minkai
149. Nengiipa Kimiti Saiko
150. Moilo Saiko
151. Jacob Letoire
152. Dami Moloma
153. Naurasho Moloma
154. Kilelo Moloma
155. Nakuru Kilelo
156. Ntayia Kilelo
157. Nkayia Kaletu
158. Lemein Kaletu
159. Junior Marona
160. James Nakudana
161. Ole Pooto
162. Moses Kilelo
163. Bob Koyie
164. Koiyie Leikari
165. Edward Tausen
166. Daniel Saetua
167. Mooke Lapelia
168. Philip Rukaine
169. Chake Nkalo
170. Koipitat Pararia
171. Tekero Tumakai
172. Kindi Moloma
173. Kibaki Kindi
174. Daniel Tuki
175. Ole Tuki
176. Oloopi Tumaka
177. Beba Karetuai
178. Sirat Kipinkat
179. Kituyion Luleira
180. Surura Lukeine
181. Moshiiri Letoire
182. Moloma Kipingat

183. Ezekiel Monee
184. Tokoin Ipurmo
185. Ntapayio Sariku
186. Kisipo Dure
187. Kaata Saiko
188. Paau Saiko
189. Letagues Pindiyo
190. Kindi Moloma
191. Ole Kishanto
192. Lankaas Pindiyio
193. Mboika Opendo
194. Opanndo Lengeny
195. Benjamin Parmet
196. Mureu Kutata
197. Turere Kalesho
198. Felix Moshira
199. Lekalai Siolompe
200. Kitesho Kipingat
201. Monjo Kalesho
202. Musa Shurie
203. Mishie Kinyangaya
204. Matura Maseto
205. Toorian Babu
206. Kailol Nkalo
207. Danya Kiyan
208. Sironka Pararia
209. Wilson Kipinkat
210. Monami Murey
211. John Kaetuai
212. Simon Kaetuai
213. Elijah Moloma
214. Menye Kosencha
215. Justus Moloma
216. Meagie Siolompe
217. Loonkushu Siolompe
218. Ole Meyagie
219. Kiako Sionpe
220. Kennedy Letoire
221. Kesuma Letoire
222. Mabaino Mutania
223. Makoi Nkalo
224. Baba Kaleli
225. Nengiipa Kimiti Saiko
226. Lekayia Mishie
227. Kutere Moloma
228. Kimare Kiloku
229. Pisoi Kiloku
230. Joshua Kinana

Manyattas in Masimba Sub-Location

231. Jonathan Leseyio
232. John Tereu
233. Stanley Tereu
234. Joel Ngeengi
235. Nkardika Nkeenki
236. Daniel Kirueny
237. Maura Kinayia
238. Samuel Kinayia
239. Moses Kinayia
240. Ntione Munke
241. Moses Ntoine
242. Nabela Ndione
243. Lekera Nkeengi
244. Moshonko Morinke
245. Montoi Morinke
246. Moloma Morinke
247. John Tinkoi
248. Paul Mankura
249. Elijah Kampaine
250. Nkamao Kapande
251. Kapande Kisubi
252. Milewa Kapande
253. Parkine Mpayieyio
254. Sairiamu Ntayia
255. Paul Ntayia
256. Kinyoto Ntayia
257. Sintila Roika
258. Kanati Selenkeya
259. Tenik Ntayia
260. Parsemel Terik
261. Noah Mukare
262. Joel Tuyia
263. Kipareu Tuyia
264. Kisharisha Tuyia
265. Lenkina Sapatie
266. Sapatie Karasi
267. Laritoo Karasi
268. Labash Turasha
269. Benjamin Pookua
270. Kapeen Keloi
271. Partarua Joshua
272. Ole Tuyia
273. Sintila Nabela
274. Stanley Oyieyio
275. Jacob Keturai
276. Kampaine Mangura
277. Susan Katitia
278. Likam Nabela
279. Ejah Nyinke
280. Meshack Mosite
281. Ntete Mosite
282. Moses Ripisian
283. Selenkea Koinet
284. Peter Sintila
285. Jonathan Sintila
286. Kanunka Kinatia

287. Timothy Tukai
288. Natioyo Tulusian
289. Mohori Tukai
290. Nalamay Tukai
291. Nepatao Tukai
292. Ole Parkisie
293. Roman Tukai
294. Elijah Tukai
295. Sapuda Meneti
296. Sintila Lankisa
297. Karei Simba
298. Mao Karei
299. Solomon Kaleli
300. Edward Sameri
301. Bismark Kaleli
302. Pore Lekimurua
303. Risa Timayio
304. Kaina Tukai
305. Lemanto Meneti
306. Lekatoo Meneti
307. Nyaru Ntayia
308. Kutata Tukai
309. Wilson Nkardika
310. Nkanguyia Karasi
311. Ezekiel Koinet
312. Kitia Parlelo
313. Francis Lenkanana
314. Towet Lenkanana
315. Lenkanana Katee
316. Denmak Lenkanana
317. Kapurua Meseno
318. Kipasi Pookwa
319. Limpau Supeyo
320. Seeto Supeyo
321. Turasha Nankosh
322. Kelelan Koinet
323. Elija Mutra
324. Kibela Kisubi
325. Kone Kaaka
326. Senteu Kaaka
327. Muntesia Koinet
328. Namun Enkop
329. Lentoe Makuta
330. Parseen Lentoe
331. Kasaro Makuta
332. Matera Lankeu
333. Ntasikoi Sinkua
334. Parngarua Oloosinteti
335. Parteruai Kimirei
336. Kimirei Kanyiko
337. Mpeleleki Morinke
338. Elijah Koitu
339. Lentura Siaka
340. Sepeleon Siaka
341. Samuel Siaka
342. Kiroine Sarorit
343. Laisunkui Kaleli
344. Samanya Siaka
345. Ipite Parseen
346. Mainka Naremisho

347. Naiponya Kaleli
348. Kaleli Munke
349. John Kaleli
350. Mutente Naremisho
351. Koitu Siaka
352. Tirimei Seleoni
353. Nkaapa Seleon
354. Kirsepei Ripisian
355. Ripisian Nabela
356. Keturai Nabela
357. Sitat Koimerek
358. Juana Koimerek
359. Mukajoo Parketo
360. Surumpen Sintila
361. David Pere
362. Geoffrey Ntarito
363. Tikoi Kaleli.
364. Kennedy Parmuya
365. Tunkei Poyio
366. Kipiton Koitu
367. Mosinko Kaleli
368. Ngira Naremisho
369. Keeja Parseen
370. Joshua Parseen
371. Marona Poyio
372. Malime Raria
373. Joshua Tomoina
374. Parmusho Teeya
375. Sakana Tomoina
376. Parkire Levamba
377. Jacob Parmusho
378. Joshua Kimayia
379. Tokoto Nkaanyu
380. Ntetu Tokoto
381. Parae Kibela
382. Munke Sinkua
383. Kimalanto Sinkua
384. Kileya Sinkua
385. Labastri Ripinua
386. Nankoshi Ripinua
387. Kitaanko Kisubi
388. Mokoi Sinkua
389. Turukei Oseur
390. Titi Pookwa
391. Kurjiji Pookwa
392. Leonard Kana
393. Morombi Kaaka
394. Lekadad Kampaine
395. Richard Keturai

Source: *Ministry of Youth, Sports, Gender, Culture and Social Services*

Appendix VII: Level and sources of agriculture emissions:

Total reference case emissions (Mt CO_2 e)

Source	**2000**	**2010**
Enteric fermentation	15.2	18.0
Burning residues	1.0	1.1
Manure management	0.44	0.52
Nitrogen fertilizer use	0.32	0.23
Flooded rice	0.06	0.07
Total	17.02	19.92

Source: *David (2015)*

Appendix VIII: Emission factors for different types of livestock

Type of Livestock	**Emission Factor Enteric Fermentation CH_4/head/year**	**Emission Factor Manure management CH_4/head/year**
Dairy cattle	40	1
Non-dairy cattle	31	1
Sheep	5	0.15
Goats	5	0.17
Pigs	1	1
Rabbits	0	0

Source: *Modified from Gok (2012)*

Appendix IX: Computed enteric methane levels

Number of Cattle/Manyatta	**CH_4/year**	**CH_4/hr**	**Ruminating hours**	**CH_4_emission**	**CH_4/per cattle/year**	**CH_4/per cattle/hr**
33	1023	0.116781	14.5	1.693321918	31	0.003767123
22	682	0.077854	14.5	1.128881279	31	0.002511416
18	558	0.063699	14	0.891780822	31	0.002054795
6	204	0.023288	14	0.326027397	34	0.000684932
18	558	0.063699	14	0.891780822	31	0.002054795
30	930	0.106164	14	1.48630137	31	0.003424658
40	1240	0.141553	14.5	2.052511416	31	0.00456621
35	1085	0.123858	14	1.734018265	31	0.003995434
5	155	0.017694	14	0.247716895	31	0.000570776
25	775	0.08847	14	1.238584475	31	0.002853881
30	930	0.106164	15	1.592465753	31	0.003424658
21	651	0.074315	14	1.040410959	31	0.00239726
20	620	0.070776	14.5	1.026255708	31	0.002283105
6	186	0.021233	14.5	0.307876712	31	0.000684932
40	1240	0.141553	14	1.98173516	31	0.00456621
16	496	0.056621	15	0.849315068	31	0.001826484
6	186	0.021233	14.5	0.307876712	31	0.000684932
5	155	0.017694	15	0.265410959	31	0.000570776
10	310	0.035388	14	0.49543379	31	0.001141553
25	775	0.08847	14.5	1.282819635	31	0.002853881
12	372	0.042466	14	0.594520548	31	0.001369863
16	496	0.056621	14	0.792694064	31	0.001826484
20	620	0.070776	14.5	1.026255708	31	0.002283105
10	310	0.035388	14	0.49543379	31	0.001141553
15	465	0.053082	14	0.743150685	31	0.001712329

5	155	0.017694	14	0.247716895	31	0.000570776
40	1240	0.141553	14	1.98173516	31	0.00456621
35	1085	0.123858	14	1.734018265	31	0.003995434
35	1085	0.123858	15	1.857876712	31	0.003995434
30	930	0.106164	14	1.48630137	31	0.003424658
15	465	0.053082	15	0.796232877	31	0.001712329
12	372	0.042466	14	0.594520548	31	0.001369863
35	1085	0.123858	15	1.857876712	31	0.003995434
35	1085	0.123858	15	1.857876712	31	0.003995434
15	465	0.053082	15	0.796232877	31	0.001712329
13	403	0.046005	14	0.644063927	31	0.001484018
30	930	0.106164	15	1.592465753	31	0.003424658
6	186	0.021233	14	0.297260274	31	0.000684932
10	310	0.035388	14.5	0.513127854	31	0.001141553
8	248	0.028311	14	0.396347032	31	0.000913242
10	310	0.035388	14	0.49543379	31	0.001141553
36	1116	0.127397	14	1.783561644	31	0.004109589
36	1116	0.127397	14	1.783561644	31	0.004109589
20	620	0.070776	14	0.99086758	31	0.002283105
8	248	0.028311	14	0.396347032	31	0.000913242
32	992	0.113242	14	1.585388128	31	0.003652968
6	186	0.021233	14	0.297260274	31	0.000684932
30	930	0.106164	14	1.48630137	31	0.003424658
10	310	0.035388	14.5	0.513127854	31	0.001141553
16	496	0.056621	14.5	0.821004566	31	0.001826484
10	310	0.035388	14	0.49543379	31	0.001141553
25	775	0.08847	14	1.238584475	31	0.002853881
10	310	0.035388	14	0.49543379	31	0.001141553
30	930	0.106164	14	1.48630137	31	0.003424658

30	930	0.106164	14	1.48630137	31	0.003424658
10	310	0.035388	14	0.49543379	31	0.001141553
20	620	0.070776	14	0.99086758	31	0.002283105
31	961	0.109703	14	1.535844749	31	0.003538813
21	651	0.074315	15	1.114726027	31	0.00239726
20	620	0.070776	14	0.99086758	31	0.002283105
21	651	0.074315	14	1.040410959	31	0.00239726
10	310	0.035388	14	0.49543379	31	0.001141553
20	620	0.070776	14	0.99086758	31	0.002283105
10	310	0.035388	14	0.49543379	31	0.001141553
20	620	0.070776	14.5	0.513127854	31	0.002283105
25	775	0.08847	14	1.238584475	31	0.002853881
30	930	0.106164	14	1.48630137	31	0.003424658
10	310	0.035388	14	0.49543379	31	0.001141553
10	310	0.035388	14	0.49543379	31	0.001141553
10	310	0.035388	14.5	0.513127854	31	0.001141553
20	620	0.070776	14.5	1.026255708	31	0.002283105
11	341	0.038927	14	0.544977169	31	0.001255708
3	93	0.010616	14	0.148630137	31	0.000342466
13	403	0.046005	14	0.644063927	31	0.001484018
9	279	0.031849	14	0.445890411	31	0.001027397
21	651	0.074315	14.5	1.077568493	31	0.00239726
10	310	0.035388	14.5	0.513127854	31	0.001141553
12	372	0.042466	14	0.594520548	31	0.001369863
21	651	0.074315	14	1.040410959	31	0.00239726
8	248	0.028311	14	0.396347032	31	0.000913242
5	155	0.017694	14.5	0.256563927	31	0.000570776
20	620	0.070776	15	1.061643836	31	0.002283105
10	310	0.035388	14	0.49543379	31	0.001141553

15	465	0.053082	14	0.743150685	31	0.001712329
4	124	0.014155	14	0.198173516	31	0.000456621
15	465	0.053082	14	0.743150685	31	0.001712329
10	310	0.035388	14	0.49543379	31	0.001141553
8	248	0.028311	14.5	0.410502283	31	0.000913242
10	310	0.035388	14	0.49543379	31	0.001141553
21	651	0.074315	14	1.040410959	31	0.00239726
2	62	0.007078	14	0.099086758	31	0.000228311
8	248	0.028311	14	0.396347032	31	0.000913242
16	496	0.056621	14.5	0.821004566	31	0.001826484
6	186	0.021233	14	0.297260274	31	0.000684932
13	403	0.046005	14	0.644063927	31	0.001484018
35	1085	0.123858	14	1.734018265	31	0.003995434
8	248	0.028311	14	0.396347032	31	0.000913242
16	496	0.056621	14	0.792694064	31	0.001826484
20	620	0.070776	14	0.99086758	31	0.002283105
6	186	0.021233	14	0.297260274	31	0.000684932
5	155	0.017694	14.5	0.256563927	31	0.000570776
14	434	0.049543	14.5	0.718378995	31	0.001598174
6	186	0.021233	14	0.297260274	31	0.000684932
28	868	0.099087	14	1.387214612	31	0.003196347
8	248	0.028311	14	0.396347032	31	0.000913242
30	930	0.106164	14	1.48630137	31	0.003424658
3	93	0.010616	14.5	0.153938356	31	0.000342466
22	682	0.077854	14	1.089954338	31	0.002511416
30	930	0.106164	14	1.48630137	31	0.003424658
16	496	0.056621	14	0.792694064	31	0.001826484
31	961	0.109703	14.5	1.590696347	31	0.003538813
6	186	0.021233	14	0.297260274	31	0.000684932

6	186	0.021233	14	0.297260274	31	0.000684932
23	713	0.081393	14	1.139497717	31	0.002625571
5	155	0.017694	14.5	0.256563927	31	0.000570776
6	186	0.021233	14	0.297260274	31	0.000684932
6	186	0.021233	14	0.297260274	31	0.000684932
19	589	0.067237	14	0.941324201	31	0.00216895
14	434	0.049543	14	0.693607306	31	0.001598174
17	527	0.06016	14	0.842237443	31	0.001940639
20	620	0.070776	14	0.99086758	31	0.002283105
35	1085	0.123858	14	1.734018265	31	0.003995434
30	930	0.106164	14	1.48630137	31	0.003424658
20	620	0.070776	14	0.99086758	31	0.002283105
20	620	0.070776	14	0.99086758	31	0.002283105
10	310	0.035388	14	0.49543379	31	0.001141553
9	279	0.031849	15	0.477739726	31	0.001027397
30	930	0.106164	15	1.592465753	31	0.003424658
11	341	0.038927	14	0.544977169	31	0.001255708
48	1488	0.169863	14.5	2.463013699	31	0.005479452
15	465	0.053082	14	0.743150685	31	0.001712329
12	372	0.042466	14	0.594520548	31	0.001369863
21	651	0.074315	14	1.040410959	31	0.00239726
10	310	0.035388	14	0.49543379	31	0.001141553
11	341	0.038927	14	0.544977169	31	0.001255708
16	496	0.056621	14.5	0.821004566	31	0.001826484
14	434	0.049543	14	0.693607306	31	0.001598174
13	403	0.046005	14	0.644063927	31	0.001484018
10	310	0.035388	14	0.49543379	31	0.001141553
10	310	0.035388	14	0.49543379	31	0.001141553
21	651	0.074315	14	1.040410959	31	0.00239726

30	930	0.106164	14	1.48630137	31	0.003424658
16	496	0.056621	14	0.792694064	31	0.001826484
40	1240	0.141553	14	1.98173516	31	0.00456621
10	310	0.035388	14	0.49543379	31	0.001141553
16	496	0.056621	14	0.792694064	31	0.001826484
31	961	0.109703	14	1.535844749	31	0.003538813
60	1860	0.212329	14	2.97260274	31	0.006849315
20	620	0.070776	14	0.99086758	31	0.002283105
18	558	0.063699	14	0.891780822	31	0.002054795
11	341	0.038927	14	0.544977169	31	0.001255708
14	434	0.049543	14.5	0.718378995	31	0.001598174
21	651	0.074315	14	1.040410959	31	0.00239726
20	620	0.070776	14	0.99086758	31	0.002283105
26	806	0.092009	14	1.288127854	31	0.002968037
10	310	0.035388	14	0.49543379	31	0.001141553
18	558	0.063699	14	0.891780822	31	0.002054795
6	186	0.021233	14	0.297260274	31	0.000684932
11	341	0.038927	14	0.544977169	31	0.001255708
21	651	0.074315	14	1.040410959	31	0.00239726
6	186	0.021233	15	0.318493151	31	0.000684932
16	496	0.056621	14	0.792694064	31	0.001826484
26	806	0.092009	14	1.288127854	31	0.002968037
14	434	0.049543	14	0.693607306	31	0.001598174
12	372	0.042466	14	0.594520548	31	0.001369863
10	310	0.035388	14	0.49543379	31	0.001141553
13	403	0.046005	14	0.644063927	31	0.001484018
13	403	0.046005	14	0.644063927	31	0.001484018
25	775	0.08847	14	1.238584475	31	0.002853881
10	310	0.035388	14	0.49543379	31	0.001141553

28	868	0.099087	14	1.387214612	31	0.003196347
31	961	0.109703	14	1.535844749	31	0.003538813
28	868	0.099087	14	1.387214612	31	0.003196347
31	961	0.109703	14	1.535844749	31	0.003538813
20	620	0.070776	14	0.99086758	31	0.002283105
60	1860	0.212329	14.5	3.078767123	31	0.006849315
30	930	0.106164	14	1.48630137	31	0.003424658
30	930	0.106164	15	1.592465753	31	0.003424658
20	620	0.070776	15	1.061643836	31	0.002283105
21	651	0.074315	14	1.040410959	31	0.00239726
10	310	0.035388	14	0.49543379	31	0.001141553
30	930	0.106164	14.5	1.539383562	31	0.003424658
15	465	0.053082	15	0.796232877	31	0.001712329
30	930	0.106164	14	1.48630137	31	0.003424658
31	961	0.109703	15	1.645547945	31	0.003538813
16	496	0.056621	15	0.849315068	31	0.001826484
61	1891	0.215868	15	3.238013699	31	0.00696347
16	496	0.056621	15	0.849315068	31	0.001826484
10	310	0.035388	14	0.49543379	31	0.001141553
16	496	0.056621	15	0.849315068	31	0.001826484
10	310	0.035388	15	0.530821918	31	0.001141553
16	496	0.056621	14	0.792694064	31	0.001826484
10	310	0.035388	15	0.530821918	31	0.001141553
16	496	0.056621	14	0.792694064	31	0.001826484
10	310	0.035388	14	0.49543379	31	0.001141553
14	434	0.049543	15	0.743150685	31	0.001598174
20	620	0.070776	14	0.99086758	31	0.002283105
32	992	0.113242	15	1.698630137	31	0.003652968
26	806	0.092009	15	1.380136986	31	0.002968037

7	217	0.024772	14	0.346803653	31	0.000799087
3681	**114129**	**13.02842**	**1915.5**	**184.4539954**		**0.420205479**
18.405	**570.645**	**0.065142**	**9.5775**	**0.922269977**		**0.002101027**
Mean CH_4 /Cattle/ Year	**31.00489**					

Source: *Field study*