# APPLYING CLIMATE ANALOGUE CONCEPT TO ASSESS ADAPTION OF FRIESIAN CATTLE BREED TO CHANGING AND VARIABLE CLIMATE IN THE KENYA HIGHLANDS

**JAMES CHEGE WANGUI**

**A thesis submitted to Graduate school in partial fulfillment for the requirements of the Master of Science Degree in Livestock Production Systems of Egerton University**

**EGERTON UNIVERSITY**

**MARCH 2018**

## DECLARATION AND RECOMMENDATION

### Declaration

This thesis is my original work and to the best of my knowledge has not been presented for an award of any degree or diploma in this or any other university.

Signature: ______________________________ Date: _____/ _____/ 2018

**James Chege Wangui**

KM11/3587/13

### Recommendation

This thesis has been prepared with our supervision and has been accepted for final submission with our approval and recommendation as the university supervisors

1. Signature: ______________________________ Date: _____/ _____/ 2018

**Prof. Bockline Omedo Bebe**

Professor of Livestock Production Systems

Department of Animal Sciences

Egerton University

2. Signature: ______________________________ Date: _____/ _____/ 2018

**Dr. James Ombiro Ondiek**

Senior Lecturer

Department of Animal Sciences

Egerton University

## COPYRIGHT

## DEDICATION

To my mother Ms Wangui Kiagiri, for her sacrifice and commitment to invest in my education, my wife Wanjiku, daughter Wangui, son Njoroge and sisters Wanjiku and Nyambura for standing by my side during the entire study time.

## ACKNOWLEDGEMENT

Am thankful to God for seeing me through this work. The author acknowledges Egerton University for financial support through University Council Masters Scholarship, African Climate Change Fellowship Program (III) for providing research funds. Am thankful to my supervisors, Prof. Bebe, Prof. Oseni and Dr. Ondiek and other faculty staff at Egerton University and Obafemi Awolowo University for their time, direction and advice which made this work complete. Obafemi Awolowo University family is appreciated for their hospitality during the fellowship, Ngongongeri and Gogar Farms for allowing use of their animals in this research and the Biotechnology Center of Kenya Agricultural and Livestock Research Organizations (KALRO), Biotechnology Research Center for hematological analysis. Further acknowledgement is to Egerton University, Kenya Meteorological Department, Water Resources Management Authority and Gogar Farm for providing valuable climate data used in this study.

## ABSTRACT

Compared to other dairy cattle breeds, Friesian is considered more sensitive to climate change induced stresses of thermal load, feed and water scarcity and disease outbreaks in the tropics, but it is a popularly utilized dairy cattle breed in Kenya highlands across the production environments. This study applied climate analogue concept with Njoro being the reference site and its 2050's climate analogue site identified on criteria of similarity index of 0.8-0.9. The study projected utilization of Friesian under changing and variable climate based on the differences between Njoro presently and its 2050's climate analogue site (Shawa) in animal heat load stress, physiological and hematological responses, production performance, and farm climate-smart management practices. Results suggest that Njoro in the 2050's will likely experience increasing temperatures, but changes in rainfall are uncertain. The increasing temperatures will likely be accompanied with mild thermal stress for Friesian cattle, especially during dry seasons or drought periods. The likely climate change and variability could increase prevalence of East Coast Fever (ECF), Anaplasmosis, Foot and Mouth Disease (FMD) and Pink eye diseases and shift preference from Friesian to Ayrshire cattle breed. Friesian cattle will likely experience some elevated physiological and hematological responses, though will remain within the normal margins but could decrease fertility and milk yield. Dairy production system will likely shift from intensive to pasture grazing on natural pastures with greater use of hay, but disease control and sourcing of climate adaptation information are unlikely to change. With the magnitude of challenges expected for utilization of Friesian cattle breed in Njoro in the 2050's, establishing farmers network platforms is suggested to foster sharing of experiences between the climate analogue sites.

## TABLE OF CONTENTS

# LIST OF TABLES

## LIST OF FIGURES

## LIST OF ABBREVIATIONS

| | |
|---|---|
| **CCAFS** | CGAIR Research Program on Climate Change and Food Security |
| **CGAIR** | Consultative Group on International Agricultural Research |
| **CSA** | Climate Smart Agriculture |
| **CSL** | Climate Smart Livestock |
| **EPA** | United States Environmental Protection Agency |
| **FAO** | Food and Agriculture Organization of the United Nations |
| **GCMs** | Global Climate Models |
| **GDP** | Gross Domestic Product |
| **GHGs** | Green House Gases |
| **GLM** | General Linear Model |
| **IPCC** | International Panel on Climate Change |
| **MCH** | Mean Corpuscular Hemoglobin |
| **MCV** | Mean Corpuscular Volume |
| **MoLD** | Ministry of Livestock Development |
| **PCV** | Packed Cell Volume |
| **RBC** | Red Blood Cells |
| **SRES** | Special Report on Emissions Scenarios of IPCC |
| **TPP** | Total Plasma Proteins |
| **WBC** | White Blood Cells |

# CHAPTER ONE

# INTRODUCTION

## 1.1 Background

Climate change is evidenced by marked increases in average global temperatures and marked changes in precipitation, melting of ice caps and glaciers and reduced snow cover, increases in ocean temperatures and ocean acidity (IPCC, 2012). Importantly, ambient temperatures and rainfall have both direct and indirect effects on livestock physiology and reproduction and their feed resource base. Changes and variability in climate are already being observed globally (IPCC, 2012). It is projected that the phenomenon will be more marked in future in the tropics if adaptive capacities remain low especially for livelihoods dependent on rain-fed agriculture and livestock assets (IPCC, 2012). Agriculture is a climate sensitive productive sector and a dominant driver of national economies in most of the developing countries including Kenya (IPCC, 2012) where it accounts for 30% of the GDP and dairy sector contributing about 4 % of the GDP (Mawa *et al.*, 2014; Omondi & Njehia, 2014).

Dairy industry in Kenya is dominated by smallholders who utilize Friesian cattle breed due to its high milk yielding potential, unselective feeding behavior in zero grazing production units and large body weight translating to a high salvage value (Bebe *et al.*, 2003). Friesian breed is however poorly adapted to climate change related stresses and is more demanding in nutritional, health and environmental management (McManus *et al*., 2009). Friesian cattle in smallholder dairy farms is managed in mixed crop-dairy systems utilizing zero grazing, semi zero grazing or free grazing systems and often require management modification of the environment to ameliorate effects of high ambient temperatures, water scarcity and low quality pastures (McManus *et al.*, 2009). Comparatively, the thermal regulatory attributes enabling Zebu adaptability in the tropics have been discussed by Daramola *et al.*, (2012) and includes physiological responses, cellular mechanisms and behavioral changes. Physiological responses to heat stress include increase in skin and rectal temperatures, sweating rate, respiration rate and pulse rate. The cellular mechanisms include changes in hematological parameters, of which, the relevant ones are packed cell volume (PCV), blood cell counts and hematimetric parameters measured by the mean corpuscular volume (MCV) and mean corpuscular hemoglobin (MCH). The behavioral changes include shade seeking and change in feeding times (McManus & Paludo, 2009; McManus *et al*., 2009; Hashem *et al.*, 2011).

The regions where smallholders utilize Friesian breed in Kenya are projected to experience increased ambient temperatures and variable rainfall (Ogalleh *et al.*, 2012). Under such circumstances, the comfort zone for the Friesian cattle is likely to shift and expose Friesian to adaptation difficulties related to stresses of thermal load, water scarcity, and dietary change and disease outbreaks. Thermal stress is directly associated with interruption of physiological processes which reduce feed intake and consequently milk yield, changes in milk composition and reproductive performance. Water is an essential nutrient for physiological functions, thermal regulation and a major constituent of the circulatory fluids, and therefore scarcity is likely to heighten the thermal stress effect. On the other hand, dietary stresses will lead to insufficient supply of nutrients for maintenance, production and reproduction that will further aggravate effects of thermal stress. This implies that changing and variable climate will likely compromise adaptability of the Friesian breed, translating into loss of livestock assets and income, which would predispose smallholder farmers to poverty incidences (FAO, 2013).

Other effects of climate change include changes in distribution patterns and occurrences of diseases and parasites. Unlike Zebus, which are known to have tolerance to common tropical diseases and parasites, Friesian cattle to the contrary are less hardy and highly susceptible (Beatty *et al.*, 2006). It is, therefore, likely that the breed may succumb to the emerging diseases and parasites ultimately increasing veterinary cost and further lowering herd profitability.

One region where Friesian utilization is dominant in smallholder farms is Njoro which has climate moderated by high altitude and bimodal rainfall supporting high biomass production, which is favorable to use of dairy breeds. However, the projected changes and variability in climate suggest that Friesian cattle in smallholder farms in Njoro will likely experience high-level stresses of climate change impacts (Ogalleh *et al.*, 2007). Nevertheless, application of climate analogue concept (Ramírez-Villegas *et al.*, 2011) allows identifying some areas elsewhere already experiencing the climatic conditions that Njoro is projected to have in the next 30 to 50 years. Identification of such analogue sites is relevant for informing on adaptation practices that farmers in Njoro will need when exposed to similar stresses of climate change and variability. Ramírez-Villegas *et al.* (2011) analysis has estimated that, about 70% of the expected future climates are currently existing somewhere in the world. The search for climate analogue sites can be in areas already sharing similar present climatic conditions with a reference site (Njoro) or that have already experienced climatic conditions of the reference site in the past. Climate analogue tool, developed by CGAIR Research

Program on Climate Change and Food Security (CCAFS) is designed to identify adaptation options by connecting and mapping sites with statistically similar climates across space and time (Ramírez-Villegas *et al.*, 2011). The spatial analogues aids in identifying promising climate analogous sites for a reference site now and in 2050's. Where such sites are identified, comparative differences between the breed in Njoro and its present and future spatial analogue sites in physiological responses, production performance and farmers application of climate smart practices can inform potential for adaptation failures in Friesian utilization. Further, identification of the spatial future analogue site can foster knowledge sharing among farmers between the climate analogous sites with which to support development of adaptation strategies.

### 1.2 Statement of the Problem

Friesian cattle breed is the most kept dairy breed in the Kenya highlands, though they are more likely to suffer stresses of thermal load, water and feed scarcity, and disease outbreaks on exposure to changing and variable climate. These climate change related stresses disrupt normal homeostatic mechanisms, which adversely impact on reproductive and production performance. This would present challenges to sustainable productive utilization of Friesian cattle breed when climate change and variability reach the magnitude projected in the Kenya highlands in the 2050s. Farmers, especially smallholders will require climate smart management practices to utilize Friesian cattle breed productively under such increased variable and changing climate. Application of climate analogue concept is an option for rapidly identifying differences in physiological and hematological responses and variations in reproduction and production performances of the Friesian cattle in Njoro and its 2050's climate analogue sites, which can inform promising adaptation options for utilization of the breed.

### 1.3 Objectives of the Study

The study sought to enhance adaptive capacity of Friesian cattle breed to the projected climate change scenarios in the Kenya highlands for its sustainable utilization. The specific objectives were:

i. To identify climate analogue sites and compare heat load and disease incidences of Friesian cattle between Njoro and its climate analogue sites in the 2050's.
ii. To compare physiological and hematological responses of Friesian cattle breed utilized in Njoro and in its 2050's climate analogue site.

iii. To compare reproductive and production performance of Friesian cattle breed attained in Njoro and in its 2050’s climate analogue site.
iv. To compare climate-smart management practices for Friesian cattle breed between dairy farms in Njoro and in its 2050’s climate analogue site.

### 1.4 Research Questions

i. What is the expected ambient temperatures, rainfall, Thermal Humidity Index (THI) and climate related disease incidences in Njoro in the 2050’s based on its climate analogue?
ii. What is the expected physiological and hematological responses of Friesian cattle breed in Njoro 2050’s based on its climate analogue?
iii. What is the expected reproductive and production performance levels of Friesian cattle breed in Njoro in 2050’s based on its climate analogue?
iv. What are the expected climate-smart management practices in the dairy farms of Njoro in 2050’s based on its climate analogue?

### 1.5 Justification

Identifying future climate analogue sites to Njoro in 2050’s where Friesian cattle is being utilized, will help connect farmers, researchers and policy makers to the likely future climatic conditions the breed will experience. This will help compare current and future Friesian cattle adaptability and dairy management practices, which will determine the likely adaptation options to apply. Farmers will get exposed to the projected future climatic challenges facing the breed thereby helping them plan and adapt with climate change. This will be through farm visits to the identified future analogue sites where they can learn climate smart practices, technologies and strategies from farmers already experiencing their future challenges now. Comparative studies on physiological and hematological response differences of the Friesian breed in present and future climate analogues will help inform on the suitability of the current breed in the future climatic challenges. This will therefore guide researchers on the studies needed to enhance the breed adaptability and sustainability of smallholder production systems utilizing the breed. Coupled with farm visits, farmers will further benefit from research findings that have been linked and validated with their future climatic challenges. On the other hand, policy makers will be able to formulate informed policies and regulations fostering adaptation to climate change and, therefore, ensure food security, livelihood and sustainability of smallholder production systems.

# CHAPTER TWO
# LITERATURE REVIEW

## 2.1 Historical Background of Dairy Industry in Kenya

Dairy industry successes in Kenya trace back to early 20$^{th}$ century when the white settlers imported exotic dairy cattle breeds from their native countries to increase milk production in the country. It was not until after passing of the colonial policy paper, Swynnerton plan of 1954, that the Kenyan African communities in the high potential cropping areas began engaging in small-scale commercial dairy production (Thurston, 1987). To support the dairy industry in Kenya, the white settlers established an efficient system of inputs services and output market that facilitated growth of a dynamic large-scale dairy industry in Kenya (Thorpe *et al.,* 2000; Ngigi, 2004).

After independence in 1963, the government effected several changes in the industry to ensure uptake by the Kenya Africans and facilitate growth of smallholder dairy production system. Some of the changes were provision of subsidized clinical and artificial inseminations services, abolishment of Kenya Co-operative Creameries (KCC) contract and quota milk marketing system and extensive training of local animal services providers (Ngigi, 2004). However, services provision by the government were exceeded by the growth and demand in the dairy industry and in 1992, Dairy Development Policy was implemented which led to liberalization of the dairy sector. The policy ended KCC monopoly in milk marketing and allowed private actors to engage in milk marketing, clinical and artificial inseminations services (Thorpe *et al.,* 2000; Ngigi, 2004).

The aftermath of the policy change was rapid growth of smallholder dairy industry and formal and informal milk marketing value chains (Thorpe *et al.,* 2000). It also led to expanded use of artificial insemination and massive upgrading of local cattle breeds with high yielding exotic dairy cattle of which Friesian was the most preferred. Today, smallholder dairy industry enjoys over 80% of the marketed milk and provides millions of Kenyans with employment and income along the value chain (FAO, 2011).

## 2.2 Friesian Cattle Utilization and Performance in Smallholder Production Systems

Kenya has the most developed dairy industry in East and Central Africa and utilizes high producing exotic breeds and their crosses (Thorpe *et al.,*2000; Mawa *et al.,* 2014; Bingi & Tondel, 2015). Common dairy cattle breeds in Kenya are Friesian, Ayrshire, Guernsey and Jersey and their crosses with Friesian being the most common (Thorpe *et al.,* 2000; Bebe *et al.,* 2003; MoLD, 2010; FAO, 2011; Ngeno *et al.,* 2014). The dairy industry is characterized by both commercial large-scale and smallholder production systems. Smallholders dominate the dairy industry and are commonly found in the medium to high cropping potential areas with higher concentrations close to urban areas. Over 85% of dairy cattle in the country are owned by smallholder farmers and produce over 80% of the total marketed milk (Thorpe *et al.,* 2000; Bebe *et al.,* 2003). Friesian and Ayrshire breeds accounts for over 50% of the dairy population kept by smallholder farmers, although Friesians exceeds the Ayrshire population (Thorpe *et al.,* 2000; Bebe *et al.,* 2003). These breeds are large, less adaptable and require intensive management which lacks in smallholder production systems, attributes that have led to experts discouraging their use in the system due to resource limitations (Bebe *et al.,* 2003; Chaiyabutr *et al.,* 2008).

Smallholder dairy production systems are characterized by farm sizes of about 3 to 5 acres (1.2 to 2.0 ha), although some, especially close to urban areas, may have less than 0.5 acre (0.2 ha) while those in agricultural areas can have slightly more than 20 acres (8 ha) (Thorpe *et al.,* 2000; FAO, 2011). The number of dairy cattle kept is influenced by land size owned with 2 to 5 heads producing an average of 5 to 10 liters of milk daily being common (FAO, 2011; Ngeno *et al.,* 2014). Low inputs and pitiable management, characteristic of smallholder production system leads to low production (Bebe *et al.,* 2003; Chaiyabutr *et al.,* 2008). Climate change will therefore, have multiplier effects on stresses experienced by exotic dairy cattle further reducing milk production which will negatively affect food security and livelihoods of millions along the dairy value chain. Keeping a large breed such as Friesian which is least adaptable to heat stress coupled with poor management characteristic in smallholder system, will increase effects of climate change eroding gains achieved over a century in the industry, inevitably collapsing smallholder dairy farmers to abject poverty.

## 2.3 Global Indicators of Climate Change and Variability

Climate change and variability refers to alterations in the prevailing state of climatic conditions on all the temporal and spatial scales characteristic to a region (FAO, 2013). These alterations are evident and are expected to even worsen in future (FAO, 2011; IPCC, 2012). Several schools of thoughts have emerged to explain the most probable causes of climate change over time. Some studies explain climate change as a natural occurrence attributed to changes in sun’s energy or earth orbital cycles, while others have incriminated climate change as largely being attributed to anthropogenic activities with natural events playing only an additive role (Washington and Pearce 2012; FAO, 2013).

In either schools, however, indicators of climate change and variability include increase in global temperatures, precipitation variability and increased frequency of extreme events (Washington and Pearce, 2012; FAO, 2013). Observed evidences due to changes in climate indicators have been discussed in various studies and includes; melting of glaciers around the world, melting of ice in the arctic, increase in ocean temperatures, rising sea levels, elevated carbon dioxide concentration and responses by animals and plants by shifting habitat ranges (IPCC, 2013). Climate change and variability will therefore affect different regions, ecosystems and sectors of the economy in varying magnitudes depending on the sensitivity of the systems to climate change and largely due to their ability to adapt to the emerging risks associated to climate change (Gaughan *et al.*, 2010).

In their study, Washington and Pearce (2012) indicate a general trend towards a warmer mean temperatures and variation in intensity and frequency of rainfall other than the amount particularly in the short rain seasons in East Africa with FAO (2010) indicating a similar trend in Kenya. This will therefore influence production systems, crops and livestock utilized in East Africa and Kenya in particular. Systems utilizing exotic breeds, which are less thermal tolerant, will be more severely affected which is already a major constraint in Africa (Gaughan, 2012). Such systems include smallholder dairy production system in Kenya highlands in which Friesian, a heat stress susceptible cattle breed is prominent (Bebe *et al.*, 2003; McManus, 2009; McManus, 2010; Ngeno *et al.*, 2014).

**2.4 Impact of Climate Change on Livestock Production Systems**

Livestock contribute to and is affected by climate change both directly and indirectly (Meena *et al.*, 2012). It is estimated that livestock contributes about 18% of the total anthropogenic greenhouse gas emissions (GHGs) through natural enteric fermentation by ruminants, manure handling, land use and land use changes during pastures expansion and feed crop establishment ( FAO, 2011). Direct effects of climate change on livestock are through heat load stress, humidity and wind speed (Meena *et al.*, 2012) while indirect effects are through stresses in feed and water and changes in diseases and parasites prevalence (FAO, 2013).

The effects will be more severe in the tropics where ambient temperatures are already high, extreme events are more intense both in magnitude and frequency and feed and water resources are scarce (Meena *et al.*, 2012). Systems utilizing exotic livestock breeds and those found in the climate marginalized areas will be more vulnerable (FAO, 2013). Exotic breeds are known to be highly susceptible to heat load stress, utilize low quality feeds poorly and have higher water demands (Ngeno *et al.*, 2014). They are also more susceptible to tropical diseases and parasites to which the indigenous breeds are tolerant or resistant. For this reason, they are kept under semi to intensive production systems in the highlands where climatic conditions are near their temperate requirements.

## 2.5 Thermal Comfort Zone in Cattle

Bioclimatology refers to the study of the interaction of living things with their atmospheric environment, a study extended to livestock as animal bioclimatology (FAO, 2013). The atmospheric environment includes climate parameters; heat, solar radiation, rainfall, wind and relative humidity, which influence animals' physiological and homeostatic equilibrium (Pangestu *et al.,* 2000; Gaughan *et al.,* 2010). However, heat stress is the most significant in the tropics as it influences animal survival and productivity (Pangestu *et al.,* 2000; Gaughan *et al.,* 2010; Ngeno *et al.,* 2014). At comfort zone, animal's heat production balances heat loss to the environment. However, as environmental heat increases to warm zone, animals' initiate sensible thermal regulatory mechanisms to help regulate body temperatures (Gaughan *et al.,* 2010). At hot zone, the animal thermal regulatory mechanism responds by initiating physiological and behavioral mechanism to elevate heat dissipation to the environment (Gaughan *et al.,* 2010). Physiological mechanisms in cattle include; increased heart rates, respiratory rate and sweating rate, while behavioral mechanisms include shade seeking, increased time spent standing around water troughs and changing the feeding time (Pangestu *et al.,* 2000). To reduce metabolic heat production, animals reduce feed intake and consequently increases water intake influencing reproductive and production performance. Evaporative water loss, leads to decrease in body electrolytes that further influence hematological components equilibrium (McManus *et al.,* 2009; Hashem *et al.,* 2011).

### 2.5.1 Heat stress effects on physiological responses

Heat stress results when the heat energy flowing from the surrounding environment to the animal exceeds the rate of heat dissipation by the animal (Moran, 2012). This is influenced by a combination of climate factors (heat, solar radiation, rainfall, wind and relative humidity), animal properties (rate of metabolism and moisture loss) and thermoregulatory mechanisms (sensible and latent) (Gaafar *et al.,* 2011). To link and measure level of heat stress and likely effects on livestock performance, several schemes coined Temperature Humidity Index (THI) have been developed and used (Kucevic *et al.,* 2013). THI combines temperatures and relative humidity to a single comfort index which provides the likely level of thermal stress for an animal (Moran, 2012; Kucevic *et al.,* 2013). The THI scheme (Equation 3) commonly used for cattle in the tropics groups thermal stress levels as; $72 > \text{THI}$, Thermal comfort zone; $72 \leq \text{THI} < 78$, mild; $78 \leq \text{THI} < 89$, severe; $89 \leq \text{THI} < 98$, very severe thermal stress and $98 <$ danger zone (Beatty, 2005; Gantner*et al.,* 2011; Moran, 2012; Kucevic *et al.,* 2013).

Physiological responses in cattle to heat stress aim at reducing metabolic heat production and increase rate of heat loss from the body to the environment (Hanshen, 2004; Gaafar *et al.,* 2011). Physiological mechanisms in lowering metabolic heat production involve reducing feed intake, thyroid secretions and subsequently reducing production and reproduction performance (Calamari *et al.*, 2007; Chaiyabutr *et al.,* 2007). While responses to increase heat dissipation from the body are increase in heart rate to increase blood flow to the periphery and superficial areas to increase sensible heat loss and activation of evaporative heat loss mechanisms involving an increase in sweating and respiratory rate (Hansen, 2004; McManus *et al.,* 2010). Unlike Friesians, local zebus have been reported to elevate sweating rate with no significant change in heart and respiratory rates after exposure to heat stress indicating thermal stress tolerance and adaptability (McManus *et al.,* 2009). Local zebus and Friesian cattle, therefore, respond differently to increasing ambient temperatures with climate change and variability, with Friesian being more susceptible (Ngeno *et al.*, 2014).

### 2.5.2 Hematological changes under heat stress

Evaporative heat dissipation mechanism leads to loss of electrolytes from the body subsequently causing dehydration and alteration of hematological equilibrium. Hematological indicators of dehydration and therefore inefficient thermoregulatory mechanism are increase in packed cell volume (PCV) and total plasma proteins (TPP) (Hashem *et al.,* 2011; McManus *et al.,* 2009). While variation in white blood cells (WBC) can be due to thermal stress, it can also be induced by excitement induced by epinephrine or an inflammatory response (The Merck Veterinary Manual, 2013). Stress induced changes in WBC is the most common response in heat stressed cattle and is usually mediated by corticosteroids and epinephrine hormone (McManus *et al.,* 2009). The response is characterized with general leucocytosis with lymphopenia being the most consistent change and monocytosis and eosinopenia being variable (The Merck Veterinary Manual, 2013).

Red Blood cells (RBC) mass remains constant over time in a healthy animal, with a balance in production and destruction of mature RBC to ensure equilibrium (The Merck Veterinary Manual, 2013). Dehydration in heat stressed animals usually causes loss of plasma volume with resultant hemoconcentration leading to relative erythrocytosis, which is an increase in number of RBC without an increase in total mass (The Merck Veterinary Manual, 2013). Relative erythrocytosis will also result from stress and excitement associated with heat stress causing splenic contraction, which releases RBC into the circulation (The Merck Veterinary Manual, 2013). These variations in hematological parameters are used as indicators of heat stress in animals (McManus *et al.,* 2011, 2009).

### 2.5.3 Breed differences in adaptation

Different cattle breeds exhibit different responses to thermal stress. At high temperatures, *Bos indicus* cattle (local zebu) perform better than *Bos taurus* (Friesian) due to their higher thermal stress tolerance, lower metabolic rates, thinner fur and their more efficient heat loss mechanisms (Pereira & Jr, 2008). Having evolved in the tropics, local zebus have developed both anatomical and physiological adaptation features to enhance their survival in the tropics.

Local zebus have a small body frame that is elevated from the ground, a hump, which is a localized fat deposit, thin shiny hair coat, and loose skin with numerous well-developed sweat glands and a well-developed superficial vascular system (Hansen, 2004). Physiologically, local zebus utilize water more efficiently than the Friesian by reducing volumes and rates of picturation and producing small volumes of concentrated milk higher in total solids, while using it in evaporative thermoregulation (Beatty *et al.*, 2006; Hansen, 2004). On the contrary, Friesians have a large body frame, thick hair coat, thick skin with few and poorly developed sweat glands and vascularization, which makes them less thermal tolerant (Hansen, 2004). They are also characterized with higher metabolic rates to support maintenance and production demands and are less efficient in water metabolism in thermal regulation, which ameliorates effects of heat stress (Hansen, 2004). With projected increase in ambient temperatures with climate change, Friesian cattle will be more predisposed to the effects of thermal stress which will likely deteriorate its performance (McManus *et al.*, 2009) and hence utilization in smallholder production systems.

## 2.6 Climate Smart Practices in Dairy Production Systems

Food and Agriculture Organization of the United Nations (FAO) (2013) defines climate smart agriculture (CSA) as an approach ensuring sustainable agricultural development for food security under climate change by enhancing adaptation and mitigation practices. Projections by FAO (2013) estimates that global population is going to increase by more than 30% by 2050, majority of which will be in developing countries like Kenya prompting an increase of about 60% in food demand (FAO, 2013,). Consequently, within the same timeline, climate change effects are expected to cause a decline of about 60% in agricultural productivity (FAO, 2013). Decrease in agricultural productivity will translate to an exemplified decrease in feed resources available for livestock, particularly in mixed crop-livestock production systems. This decrease will be associated with loss of arable land partly due to increase in population, urban centers and infrastructures development and largely due to unfavorable farming conditions with climate change (FAO, 2013). Animal source foods;

meat, dairy, and eggs are an important source of high quality proteins and calories and their demand is projected to be on the rise in concomitant with population (FAO, 2013). Bulk of milk production in Kenya is usually from less than 10% of cattle population predominantly Friesian which are also very susceptible to heat stress with climate change (FAO, 2011). There is therefore need to identify climate smart management practices applicable in smallholder dairy production systems in Kenya to ensure, adaptation, mitigation and sustainability of the system with climate change. Identification of climate smart management practices with positive impact elsewhere, especially in areas that have already experienced climatic conditions similar to Kenyan highlands, particularly Njoro in the past will be a mile stone of achievement (Ramírez-Villegas, 2011).

Promising climate smart agriculture practices and technologies applicable in smallholder dairy production systems have been highlighted by FAO (2013) and include; practices that reduce vulnerability to effects of climate change and variability (Adaptation) and those that help reduce or stabilize GHGs emission (Mitigation) from the dairy industry ultimately enhancing sustainability and food security. Climate smart agriculture practices enhancing adaptation capacities include activities that increase physical, economic and social and human resilience while those that enhance mitigation include activities that increase carbon sequestration and reduce or stabilize GHGs emission (FAO, 2012). In smallholder dairy production systems, climate smart agriculture practices augmenting resource use efficiency are key component in improving adaptation and mitigation capacities (FAO, 2013). Opportunities that enhance resource use efficiency include activities targeting climate smart agriculture practices in; feeds production and management; water use efficiency; ruminants' health management; breeding technologies and waste management (FAO, 2013, 2012).

Feeds account for about 60% of the input resources in dairy production (FAO, 2013). Consequently, feeds production in the livestock sector have been estimated to contribute about 6% of the sectors GHGs emissions from fossil fuels used in manufacturing chemical fertilizers and during mechanized planting of forages (FAO, 2013). In addition, about 36% of sector GHGs is emitted from land use and land use changes during establishment and expansion of forages by replacing forests and other natural vegetation and through soil disturbance (FAO, 2013). Climate smart agriculture practices in feeds production should therefore target to reduce and sequester GHGs while increasing production per unit area of forages. Activities promoting climate smart agriculture practices in feed production include; use of high yielding forage varieties, efficient grazing management, efficient pasture management, integrated soil and water management, water use efficiency and management and agro-forestry (FAO, 2013). Feeds management on the other hand, include activities enhancing palatability, digestibility and utilization of feed resources by animals (Migwi *et al.*, 2013). Crop residues account for up to 50% of ruminants' diets in mixed crop- livestock production systems while pastures of low quality dominate ruminants' diets in free grazing and semi zero production systems (FAO, 2013). Although these feed resources are inexpensive, they are characterized with low palatability and digestibility, deficiency of crude protein, minerals and vitamins due to high lignification thereby leading to poor utilization by ruminants', especially exotic breeds such as Friesian. These attributes leads to low production and substantially increases enteric GHGs production (FAO, 2013). Climate smart agriculture practices should therefore, target on increasing digestibility which will lead to increased milk production per unit of feed provided and hence reduce enteric GHGs production. Activities enhancing climate smart agriculture practices in feeds management include; feed processing, use of feed additives, use of total mixed rations and pastures conservation (FAO, 2013; Migwi *et al.*, 2013).

Water is integral input resource in livestock production and an essential nutrient for physiological functions in both plants and animals. In dairy production, water is used for drinking, services, cooling as mist sprays in hot areas and in irrigated pasture production. Globally, dairy production, particularly in intensive production systems is the highest water user of all the livestock industries and therefore will be most likely affected with shortage as is predicted for most areas in the tropics (FAO, 2013). Climate smart agriculture practices will therefore have to focus on improving efficiency in the varied water uses in the dairy industry. Documented climate smart agriculture practices include; cultivation of drought resistant pastures, use of pastures with short life cycles, use of irrigation techniques that maximize water use efficiency, keeping drought resistant animals, species switching, waste water recycling and water harvesting (FAO, 2013).

Survival, multiplication and spreading of disease causing microorganisms, vectors and parasites are almost entirely influenced by climatic parameters (temperatures, precipitation, relative humidity and wind speed) (IPCC, 2012). Projected global warming, variations in frequency and intensity of rainfall, variations in relative humidity and wind speeds will provide optimal conditions for some pathogens proliferation and spread as well as inhibit others (IFAD, 2009). This will result in shifting of diseases and parasite among regions, emergence of new diseases and parasites as well as changes in transmission modes (FAO, 2013). On the other hand response of animals to diseases or parasites is largely influenced by their adaptability which is a factor of immune system. Climate smart agriculture practices in smallholder dairy production systems therefore targets approaches such as; keeping diseases resistant or tolerant breeds, enhanced animal health and disease risk management, switching of livestock species and integration of livestock species (FAO, 2012, 2013). Other strategies enhancing climate smart agriculture practices in smallholder dairy production systems include; climate related risk management through climate smart agriculture practices such as early climate warning, climate index based livestock insurances; diversification to climate resilient systems e.g. switching production objectives, changing farm products proportion; improved waste management such as biogas production, direct injection of manure, improved livestock diets, use of feed additives, composting, covering with nylon bag (FAO, 2013).

### 2.7 Climate Analogue Concept

Climate is shifting among regions, such that, climatic conditions being experienced in a particular region has already, is or will be experienced in another region. CGAIR (2011) indicates that, about 70% of climatic conditions being experienced today have, will or are already being experienced elsewhere. Identifying an area today that is experiencing projected future climatic condition will help realize the farming conditions of future today and therefore help farmers, researchers and policy makers to make informed decision, studies and plans in adapting to the expected climatic and farming conditions.

Several models have been developed to help predict future climatic scenarios each with its own merits and demerits. A common limitation with the models is the inability to match the projected climatic scenarios with the areas in which they are already being experienced, an attribute present in climate analogue tool developed by CCAFS (Ramírez-Villegas, 2011). Climate analogue tool provides both spatial and temporal analogue sites to the reference site. Using one or a combination of more Global Climate Models (GCMs) and any of the three Special Report on Emission Scenarios (SRES scenarios) of IPCC, climate analogue tool uses climate and bioclimatic variables to search for areas in future with predicted conditions of the reference site (Ramírez-Villegas, 2011). To achieve this, the tool uses the reference site climatic scenarios to forecast the expected future scenarios using specified climate and bioclimatic variables and then compares sites in the specified search range sites presently experiencing corresponding forecasted climatic scenarios (Ramírez-Villegas *et al.,* 2011). Similarly, present day analogous sites and potential site to which the reference site is a potential future analogue can also be identified (Ramírez-Villegas *et al.,* 2011). Identified analogous sites can become comparative study sites to which smallholder dairy farmers in Njoro utilizing Friesian cattle, researchers and policy makers can draw adaptive lessons to implement in Njoro to adapt and mitigate against climate change and therefore ensure sustainability of the system. Analogue sites approach can further enable farmers, researchers and policy makers establish exchange programs to guide adaptations with climate change.

# CHAPTER THREE
# METHODOLOGY
## 3.1 Identifying climate analogue sites

Njoro in the Rift valley highlands of Kenya was the selected reference study area since it has high population of dairy farms utilizing Friesian cattle breed. Njoro lies between latitude 00$^o$19'00" S and longitudes 36°06'00" E and the location is in Low Highlands (LH3) and Upper midlands (UM4) ecological zones with an altitude of 2168 M to 2800 M above sea level (a.s.l). The rainfall ranges between 700 mm to 1000 mm in the lower and upper ecological zones and is bimodal rainfall, with long rains in March to June and short rains in October to December. Njoro is cool and wet climate with mean minimum temperatures of 10.5$^o$C and maxima of 25.5$^o$C, which is suitable for mixed crop- livestock farming (MoLD, 2010). In consultation with the local Livestock and Fisheries extension office, a site with the highest concentration of dairy farms keeping Friesian cattle breed was identified and its coordinates (Latitude -0.382, Longitudes 35.937) used to calculate the analogue sites using the climate analogue tool online platform accessible at http://www.ccafs-analogues.org/tool/ (Ramírez-Villegas *et al.*, 2011).

Backward time direction was applied with Global Climate Models (GCMs) ensemble option and Special Report on Emissions Scenarios of IPCC (SRES) A1B to calculate future analogue sites. Climate variables of interest were mean monthly temperatures and total monthly rainfall, which were ran separately or combined. When combined, a weight of 0.5 was used for each variable to ensure equal contribution in calculating the analogues. In each run, applicable rotations (none, monthly mean temperature, monthly rainfall or both) were applied to check for seasonality effects. The default resolution of 30 arc seconds was maintained and the minimum threshold of similarity index was set at 0.5. However, due to the high number of sites, only those with similarity index greater than 0.7 were considered further in this study. A nine-month growing period from March to November was assumed as the replica to Njoro. Outputs from the runs with their respective rotations were eight Tag Image File Format (TIFF) images.

The TIFF images were exported to ArcGIS, ArcMap 10.3 for reclassification and sites identification. Reclassification involved grouping pixels into classes with intervals of 0.1 with 0.5- 0.6 class set as the minimum and 0.9- 0.99 as the maximum. Kenya divisions shape file as at 1998 was then overlaid on the reclassified images to help in manual site identification and tally for each class of similarity index. Sites selection was a stepwise elimination process. The first step involved selection of site whose administrative polygon had more than 75 % uniformity for a given similarity index. The second step involved eliminating all sites that had lower than 50 % occurrence in all the eight possible runs with applicable rotations. The third stage considered proximity of the climate analogue sites to Njoro, with the three closest sites for each class of similarity index selected. The final stage involved selection of two sites with the highest percentage of occurrence. The two sites were used as the likely climate analogue sites for Njoro in the 2050's at their respective similarity index. However, only the site with the highest similarity index, percentage of occurrence and closest to Njoro was used for on the ground studies.

Shawa area in Rongai Sub County had the highest percentage of occurrence and similarity index and was considered the best representative of climate analogue site to Njoro in the 2050's. Njoro and Shawa (Fig. 1) therefore became the climate analogues in this study.

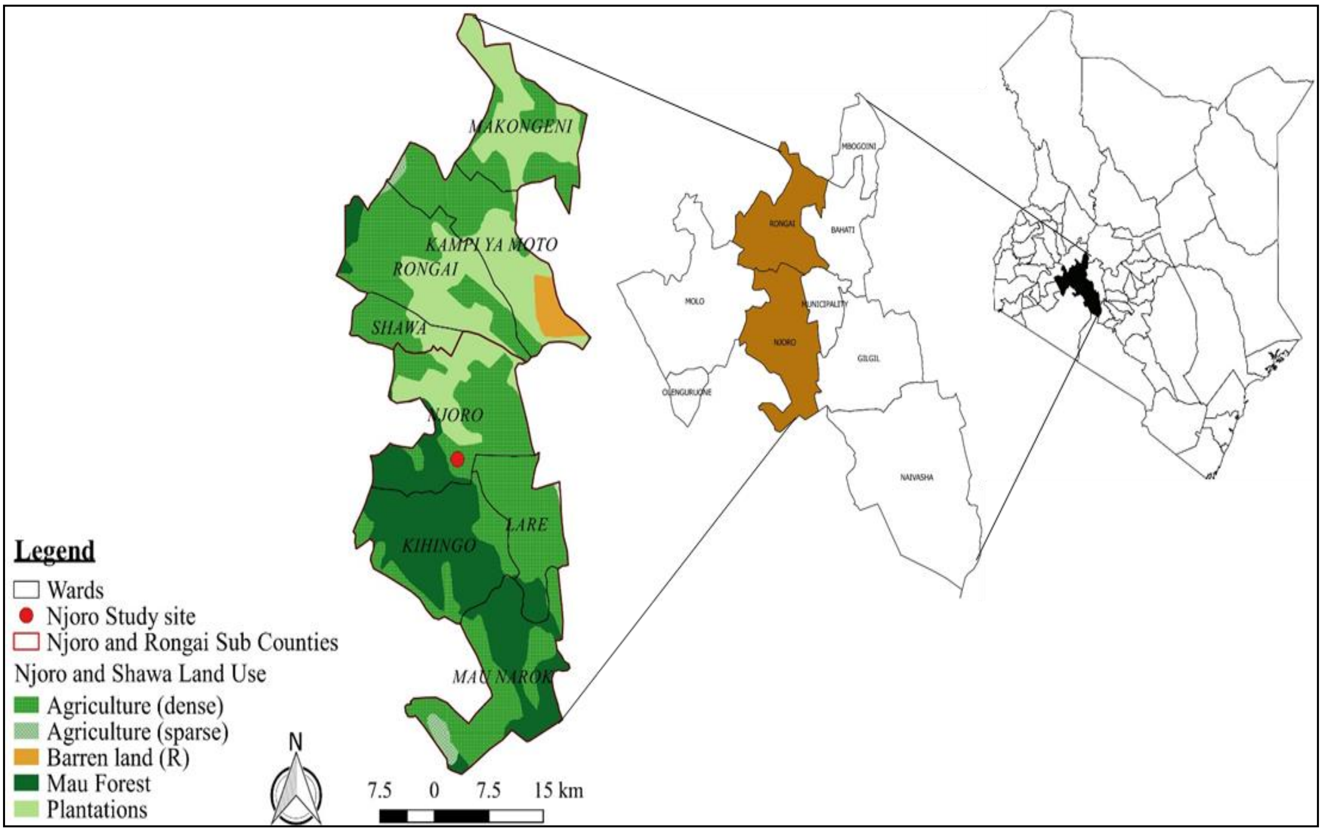


**Figure 1. The study sites in Rongai and Njoro sub counties**

Shawa is in Rongai sub county which lies between latitudes 00$^{o}$03'00" and 00$^{o}$21'00" and longitudes 35$^{o}$45'00.00" and 36.8$^{o}$08'59.99" with an altitude of 1650 to 1850 M a.s.l (Fig. 1). It is within lower midlands (LM 3) and upper midlands (UM 3) ecological zones and receives an annual rainfall of about 600 mm to 1000 mm with temperature ranges of 17.0$^{o}$C to 29.0$^{o}$C (Ogeto *et al.*,2011).

### 3.2 Measuring Friesian Cattle Physiological and Hematological responses

A commercial dairy farm keeping Friesian cattle breed was identified in each site to access animals to measure physiological and hematological indicators. Ngongongeri farm was selected in Njoro site and Gogar farm in Shawa site. Thirty mature healthy and non-gravid Friesian cows were selected within two age groups (young cows aged 4 ± 1 years and old cows aged 7 ±1years) in each farm. In both farms, cows were exposed directly to climatic stresses in semi-intensive management practices.

Physiological response variables measured were; rectal temperatures (RT), respiratory rates (RR), heart rates (HR) and sweating rate (SR). These parameters were taken twice a day (0700hr and 1400hr) for four days. Rectal temperature was measured using digital thermometer placed against rectal walls and readings taken after thermometer completion beep. Heart rate and respiration rate were determined using a clinical stethoscope for one minute each. Sweating rate was measured using a technique described by Schleger and Tuner (1995) and adapted by McManus *et al.,* (2009) and Katawatin *et al.,* (2015). Three discs of about 0.5 $cm^2$ cut from Whatman #1 filter paper soaked in 10% aqueous solution cobalt chloride and dried were placed on a shaved area of about 5 $cm^2$ on lumbar vertebra. Average time taken for the discs to change color from blue to pink was observed using a stop watch. Sweating rate was then calculated using Schleger and Tuner (1995) equation SR = 384466.901/t ($g\ m^{-2}h^{-1}$), with t being time in seconds taken by the disc to change color (McManus *et al.,* 2009).

To determine hematological parameters, about 10 ml of whole blood was collected through coccygeal venipuncture into vacutainer tubes with Ethylenediaminetetraacetic acid (EDTA) on the fourth day when physiological parameters were measured. Samples were chilled and transported to Kenya Agriculture and Livestock Research Organizations (KALRO), Biotechnology Research Center within 24 hours for analysis. Automated blood analysis using coulter Hematological Analyzer (AC.T diff Beckman Coulter™) was used to investigate hematological parameters; Packed Cell Volume (PCV), blood cells counts (white blood cells (WBC), red blood cells (RBC) and Platelets (Plt)), hemoglobin concentrations (Hbg) and hematimetric parameters (mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH) and mean corpuscular hemoglobin concentration (MCHC)). In addition, manual differential leucocytes counts were used to determine leukocyte types (lymphocytes, monocytes, eosinophils and basophils) in percentages from a thin wright stained smear under optical microscope targeting fields of 100 cells.

### 3.3 Collecting Animal and Farm Data

A cross sectional survey of 107 randomly selected smallholder farms (54 in Njoro and 53 in Shawa) was conducted to obtain data on reproductive and production performance of Friesian cattle breed and climate smart practices on the farm. The farms were within 20 Kilometer diameter of the points of reference in each study site. Semi structured and pre tested questionnaire (Appendix I) was used to collect data on; cattle breeds kept, production system practiced, Friesian cattle milk yields, production trends, reproductive diseases and disorders, inseminations per conception and their trend for the last ten years. The data on climate smart management practiced in the climate analogue sites were on; farm characteristics, livelihood sources, pasture types, pasture area used over time, agronomic practices for pasture production, types of feeds used, feeding method, water sources and use, manure management and diseases control for Friesian cattle production. The target was to identify practices and technologies of relevance for the three objectives of climate smart agriculture; productivity, adaptation and mitigation benefits.

### 3.4 Sourcing Secondary Data on Climate Variables and Friesian Cattle Diseases

Long term meteorological data for total monthly rainfall and mean monthly temperatures (Maximum, minimum and mean) were obtained from Government institutions and individual farms. Rainfall and temperatures data for 71 and 30 years respectively for Njoro were obtained from Egerton University. Rainfall data for 74 years for Shawa was obtained from Gogar farm in Rongai and temperatures data for 29 years from Kenya Meteorological Department. Rainfall data for Gituamba for 51 years and temperature data for 8 years were obtained from Water Resources Management Authority (WRMA) in Rumuruti. In addition, secondary data on animal diseases were sourced from the local government veterinary offices in Njoro and Rongai sub county offices.

### 3.5 Statistical Analysis

Data was organized in MS Excel spread sheets and exported to SAS (2008) and SPSS version 20 for statistical analysis. The SAS (2008) statistical application was used for continuous data and SPSS for categorical data.

#### 3.5.1 Identification of climate analogue sites to Njoro in 2050's

The frequency of occurrence of a given site, for a specific class of similarity index, for all the climate variable runs with applicable rotations was used to determine the percentage of occurrence of the site using the model;

1. $\% \; of \; occurence = \frac{\sum Y_i}{8} 100$

Where:

$\sum Y_i$= Total count of a given site for a specific class of similarity index out of the potential 8 outcomes obtained.

**3.5.2 Comparing climate variables, heat stress and climate associated diseases between the climate analogue sites**

Analysis of variance with General Linear Model (GLM) procedure of SAS (2008) was fitted to determine the mean differences in climatic variables (monthly total rainfall, monthly mean temperatures, monthly minimum temperatures and monthly maximum temperatures) for Njoro and its climate analogue sites in 2050's with the model:

2. $Y_{ij} = S_i + E_{ij}$

Where:

$Y_{ij}$ = Climatic variables

$S_i$ = Fixed effect of sites

$E_{ij}$ = Random error component associated with $Y_{ij}$

The same model was fitted in regression analysis to determine time series trends for each climate variable.

To determine heat stress for Friesian cattle breed in climate analogue sites, Temperature Humidity Index (THI) was used and determined using the model:

3. $THI = (1.8)T_a - (1 - RH)(T_a - 14.3) + 32$

Where:

$T_a$ = Average ambient temperatures

RH = Average relative humidity as a fraction (Musari *et al.*,2014)

The THI indices were classified as; THI less than 72 indicated Friesian cattle were within thermal comfort zone, $72 \leq$ THI $< 78$ in mild thermal stress, $78 \leq$ THI $< 89$ in sever thermal stress, $89 \leq$ THI $< 98$ in very severe thermal stress and $98 <$ in danger zone (Beatty, 2005; Gartner *et al.*, 2011; Moran, 2012; Kucevic *et al.*, 2013). Further, analysis of variance with General Linear Model (GLM) procedure of SAS (2008) was used to determine the mean differences in THI between climate analogue sites, by fitting the model;

4. $Y_{ijk} = S_i + T_j + E_{ijk}$

Where:

$Y_{ijk}$ = THI for a given climate analogue site

$S_i$ = Fixed effect of sites

$T_j$ = Time of day

$E_{ijk}$ = Random error component associated with $Y_{ijk}$

Counts for diseases mentioned in each climate analogue sites were used to determine differences between sites using chi square with cross tabulation. Further, Odds ratio in logistic regression was used to determine recalled occurrence of diseases reported in Njoro and in Shawa to determine the likely occurrence of the diseases in Njoro in the 2050's.

### 3.5.3 Comparing Friesian cattle physiological responses and hematological parameters between climate analogue sites

Analysis of variance with General Linear Model (GLM) procedure of SAS (2008) was used to determine the mean differences in physiological response variables (RR, RT, HR, and SR) and hematological variables (blood cells volumes, blood cells counts and hematimetric parameters) between climate analogue sites, by fitting the model:

5. $Y_{ijk} = S_i + T_j + E_{ijk}$

Where:

$Y_{ijk}$ = THI, Physiological and hematological response variables

$S_i$ = Fixed effect of sites

$T_j$ = Time of day

$E_{ijk}$ = Random error component associated with $Y_{ijk}$

### 3.5.4 Comparing Friesian cattle reproductive and production performance between climate analogue sites

Analysis of variance was used to determine mean differences between the climate analogue sites in production (milk yield) and reproduction performance (Calving interval and repeat rates) using a general linear model;

6. $Y_{ijk} = S_i + T_j + E_{ijk}$

Where:

$Y_{ijk}$ = Production or reproduction performance variable

$S_i$ = Fixed effect of site

$T_j$ = Season and random

$E_{ijk}$ = Random error term associated with $Y_{ijk}$

### 3.5.5 Comparing climate smart agriculture practices between the climate analogue sites

Using cross tabulation of frequencies, likelihood chi square test was deployed to compare management practices, susceptibility to climate related diseases and diseases incidences between the climate analogue sites.

## CHAPTER FOUR

## RESULTS

### 4.1 Likely Climate Analogue Sites to Njoro in 2050's

Climate analogue sites to Njoro in 2050's varied with climatic variables and rotations applied. Total monthly rainfall (Figure 2) with none rotation run showed most part of Kenya to be analogous to Njoro in the 2050's with a similarity index higher than 0.5. Application of rainfall rotation, eliminated arid and semi-arid areas and restricted sites with similarity index of 0.8- 0.99 to rift valley and western Kenya highlands.

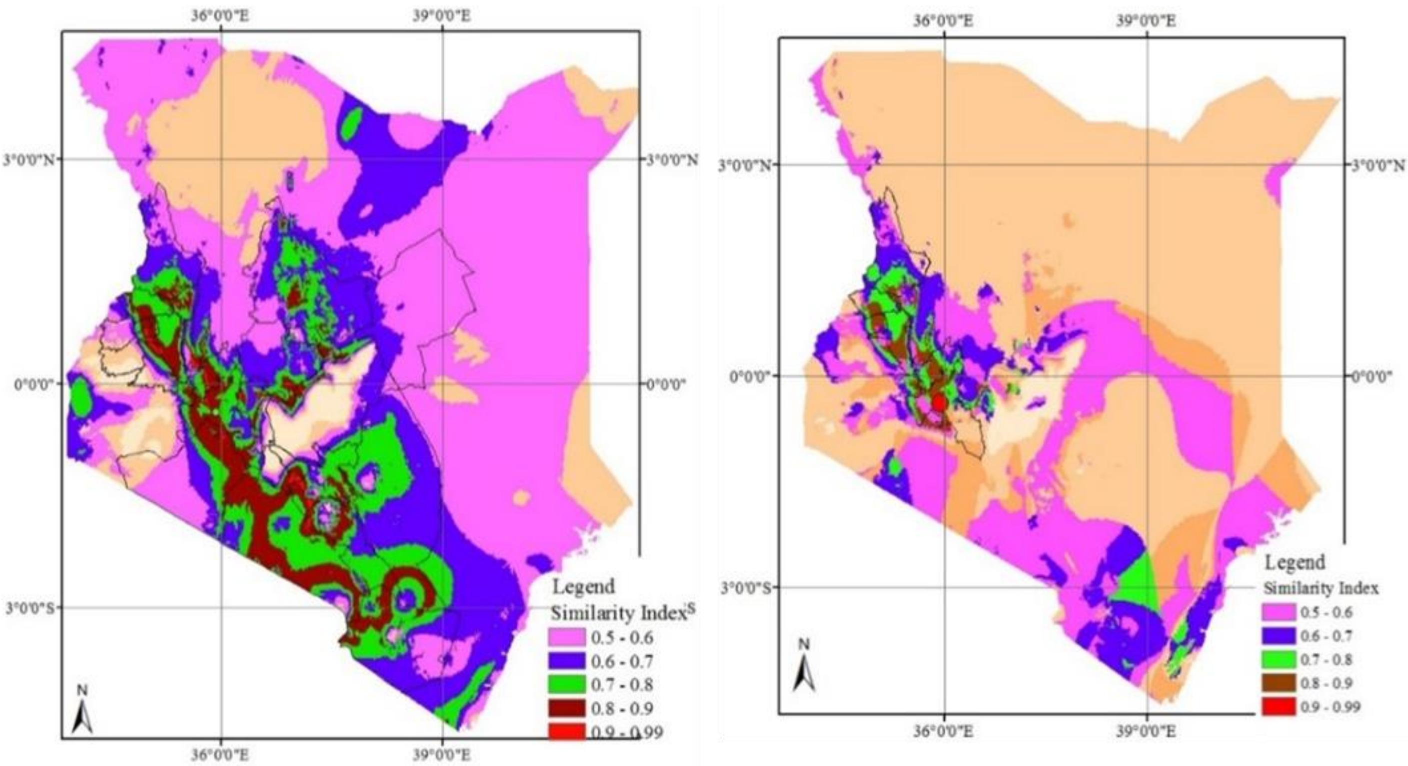


**Figure 2. Climate analogue sites to Njoro in 2050's based on Mean monthly rainfall run with none rotation (left) and with rainfall rotation (right)**

Mean monthly temperature runs (Figure 3) showed limited sites with similarity index higher than 0.8. Application of none rotation produced areas in Uasin Ngishu, Narok and Nakuru counties as having similarities index higher than 0.8. Application of temperature rotations produced areas in Nakuru and Nanyuki in Laikipia County with a similarities index higher than 0.8 and eliminated areas in Uasin Ngishu and Narok.

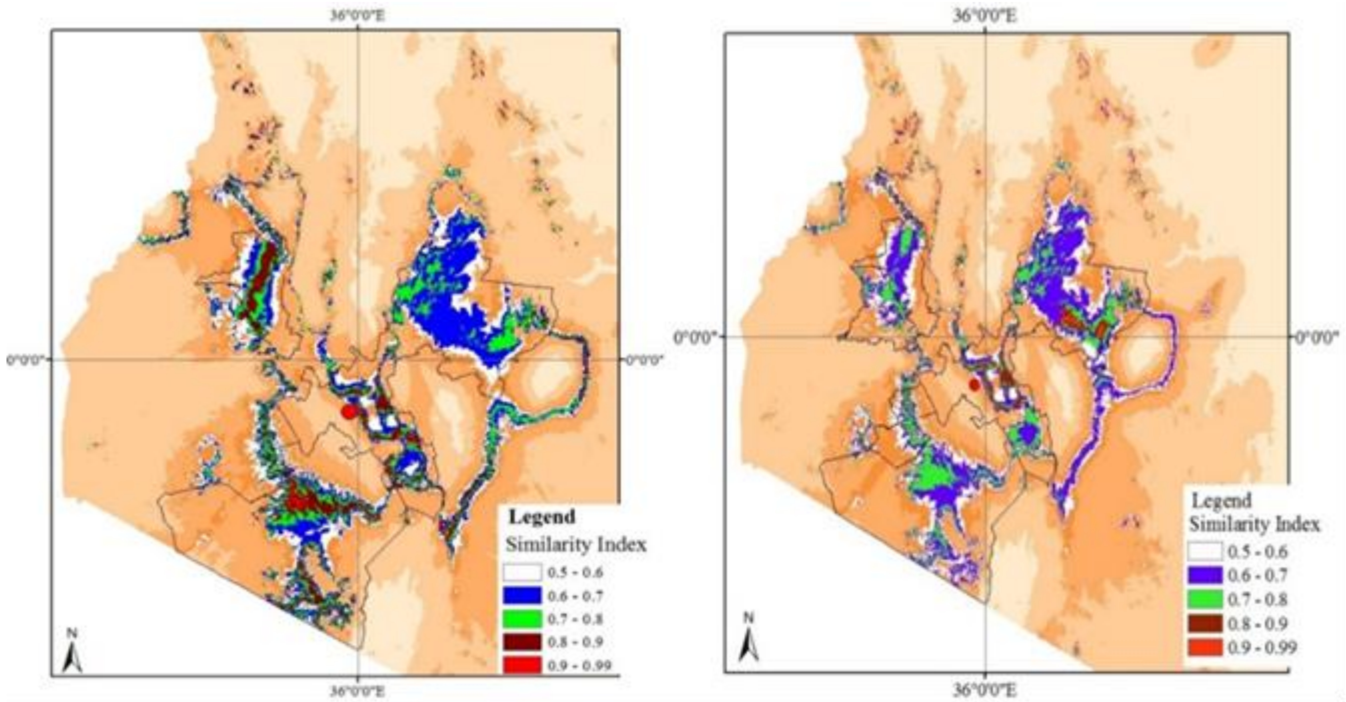


**Figure 3. Climate analogue sites to Njoro in 2050's based on Mean monthly temperature run with none rotation (left) and with temperatures rotations (right)**

Runs using total monthly rainfall and mean monthly temperatures combined (Figure 4) with none and both rotations agreed on all sites, producing almost similar images. The two rotations produced areas in Uasin Ngishu, Nakuru and Narok with similarity index of 0.8-0.9. Application of temperature rotations produced the fewest climate analogue sites with similarity index higher than 0.8 and were restricted in Nakuru, Trans Nzoia and West Pokot Counties. Rainfall rotations produced similar sites as with none and both rotation but lowered similarity indexes for sites in Narok to 0.5 -0.7 and in Trans Nzoia County to 0.5- 0.6.

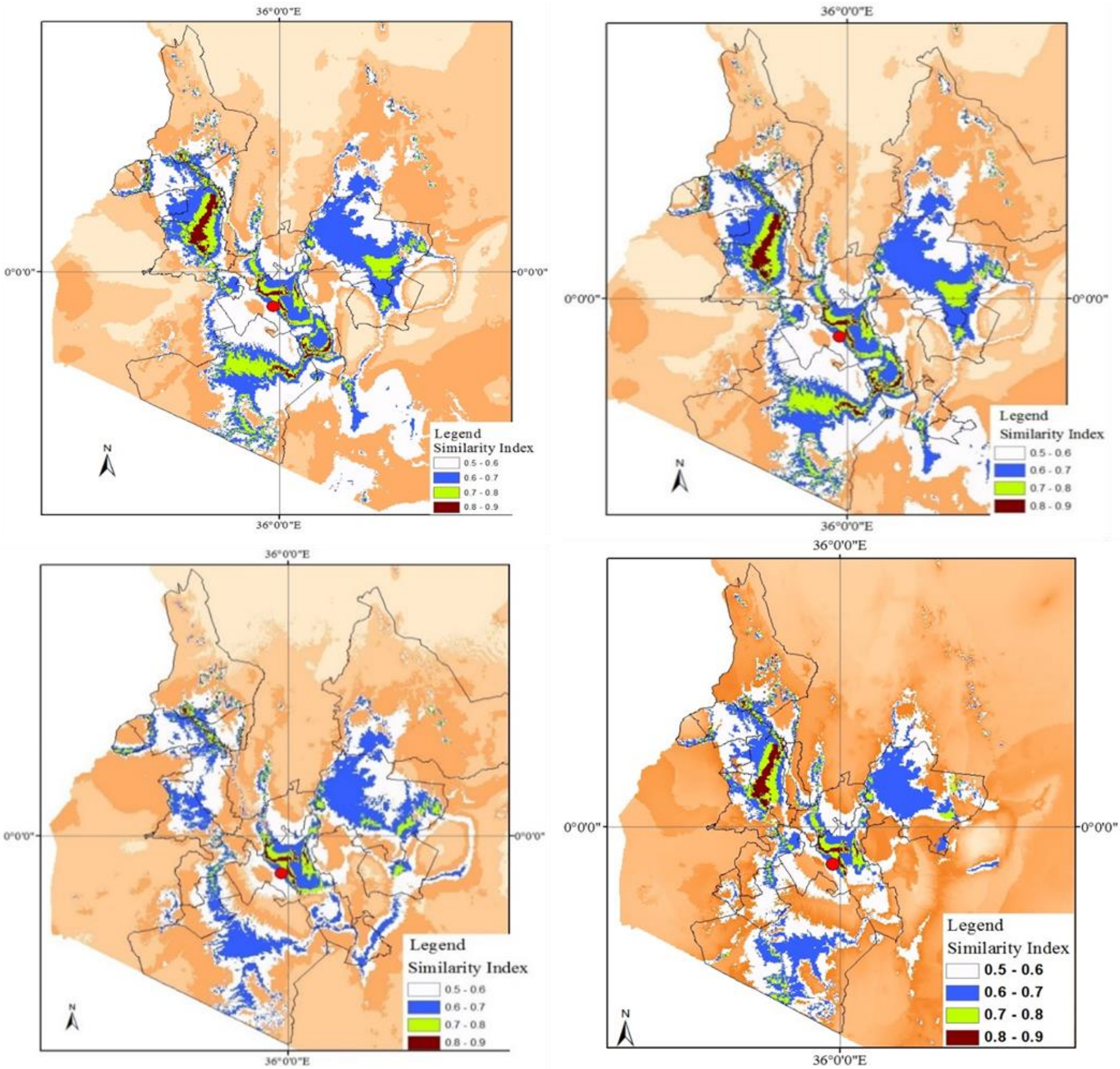


**Figure 4. Climate analogue sites to Njoro in 2050's based on total monthly rainfall and mean monthly temperatures combined with none rotation (top left), both rotation (top right), temperature rotation (bottom left) and rainfall rotation (bottom right)**

However, all runs with applicable rotations agreed on the eastern part of Nakuru County and western parts of Laikipia County as the likely climate analogue sites at varying levels of similarity index. Shawa in Nakuru County with a similarity index of 0.8- 0.9 and Gituamba in Laikipia County with a similarity index of 0.7- 0.8 were selected as the most likely future climate analogue sites to Njoro in 2050's (Table 1). They had consistent similarity index of 0.7- 0.8 and 0.8- 0.9 respectively in all the runs and had more than 75% of single pixel coverage.

**Table 1. Percentage (%) occurrences of climate analogue sites to Njoro in 2050's for eight runs and climatic variables**

| Similarity index | Site | Climatic parameters and rotation: Temperature N | T | Rainfall N | R | Rainfall and Temperatures N | T | R | B | Freq | % Occurrence |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.80-0.90 | Shawa | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 8 | 100 |
| | Ngeria | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 6 | 75 |
| | Moiben | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 4 | 50 |
| 0.70-0.80 | Gituamba | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 8 | 100 |
| | Lare | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 5 | 62.5 |
| | Rongai | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 6 | 75 |

Where N is none rotation, T is temperature rotation, R is rainfall rotation and B is both temperature and rainfall rotation.

Using long term climate data for 50 years since 1964, all climatic variables differed between Njoro and its future climate analogues sites (Table 2). Njoro had the highest monthly rainfall and lowest temperatures with the reverse observed for Gituamba. The model probabilities suggested that rainfall will likely recede while temperatures will likely increase in Njoro in the 2050's.

**Table 2. Climatic variables for Njoro and its future climate analogue sites Shawa and Gituamba**

| Analogue sites | Monthly Total Rainfal | Monthly Mean temperatures | Monthly Minimum temperatures | Monthly Maximum temperatures |
|---|---|---|---|---|
| Njoro | $86.3 \pm 2.14^{a}$ | $16 \pm 0.12^{a}$ | $10.2 \pm 0.16^{a}$ | $23.3 \pm 0.20^{a}$ |
| Shawa | $80.8 \pm 2.11^{b}$ | $18.5 \pm 0.13^{b}$ | $11.5 \pm 0.17^{b}$ | $25.5 \pm 0.20^{b}$ |
| Gituamba | $61.5 \pm 2.54^{c}$ | $23.2 \pm 0.23^{c}$ | $20.6 \pm 0.30^{c}$ | $26.1 \pm 0.36^{c}$ |

Means with different letter superscript within a Colum differ at $p<0.05$

Rainfall trends showed highest annual increase in Njoro (3.30 mm, $R^2$ = 0.044) compared to Shawa (1.00 mm, $R^2$ = 0.005) and Gituamba (2.32 mm, $R^2$ = 0.023) (Fig. 5).

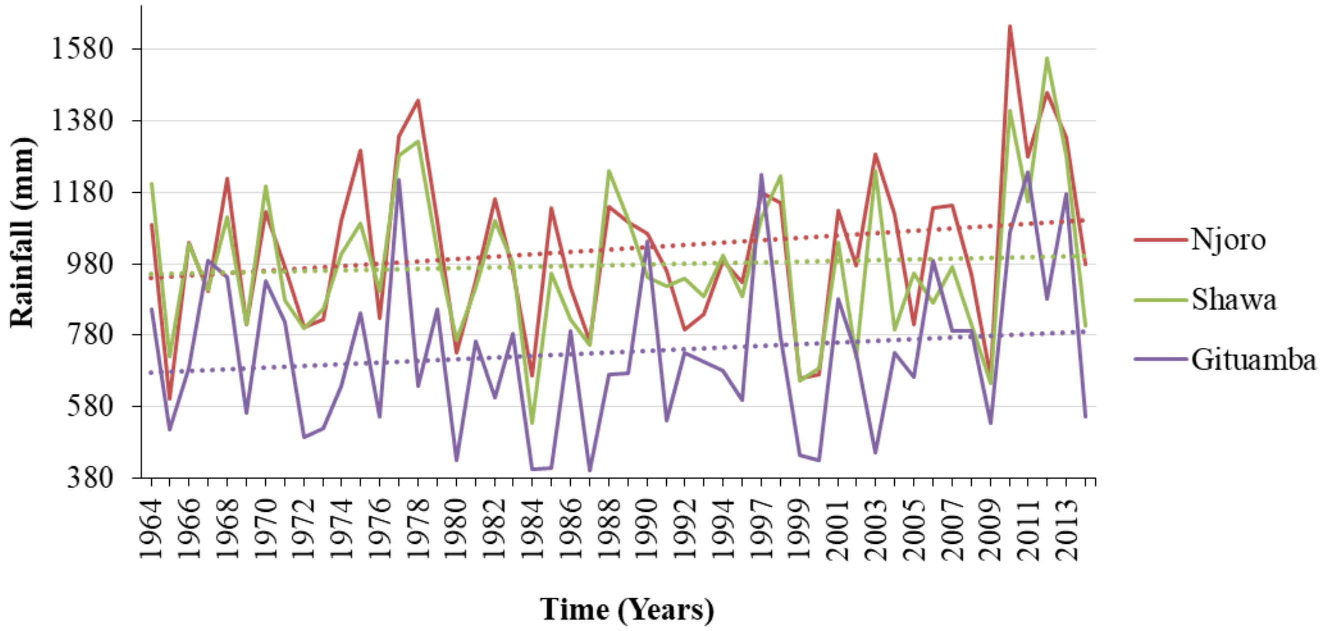


**Figure 5. Total Annual Rainfall trend for Njoro, Shawa and Gituamba**

The increase was highest in the October- November- December (OND) short rains season (Figure 6) with Gituamba having the highest increase (2.39 mm, $R^2$ = 0.086), Njoro (2.03 mm, $R^2$ = 0.099) while Shawa had the lowest (0.95 mm, $R^2$ = 0.021). Unlike the analogue sites, Njoro showed a declining trend for March- April- May (MAM) season rainfall (-0.29 mm, $R^2$ = 0.001), while Shawa and Gituamba had a weak increasing trend of (0.04 mm, $R^2$ = 0.000) and (0.28 mm, $R^2$ = 0.001) respectively (Figure 7).The low $R^2$ values indicated high inter annual and diannual variability in amount and distribution of rains in the sites.

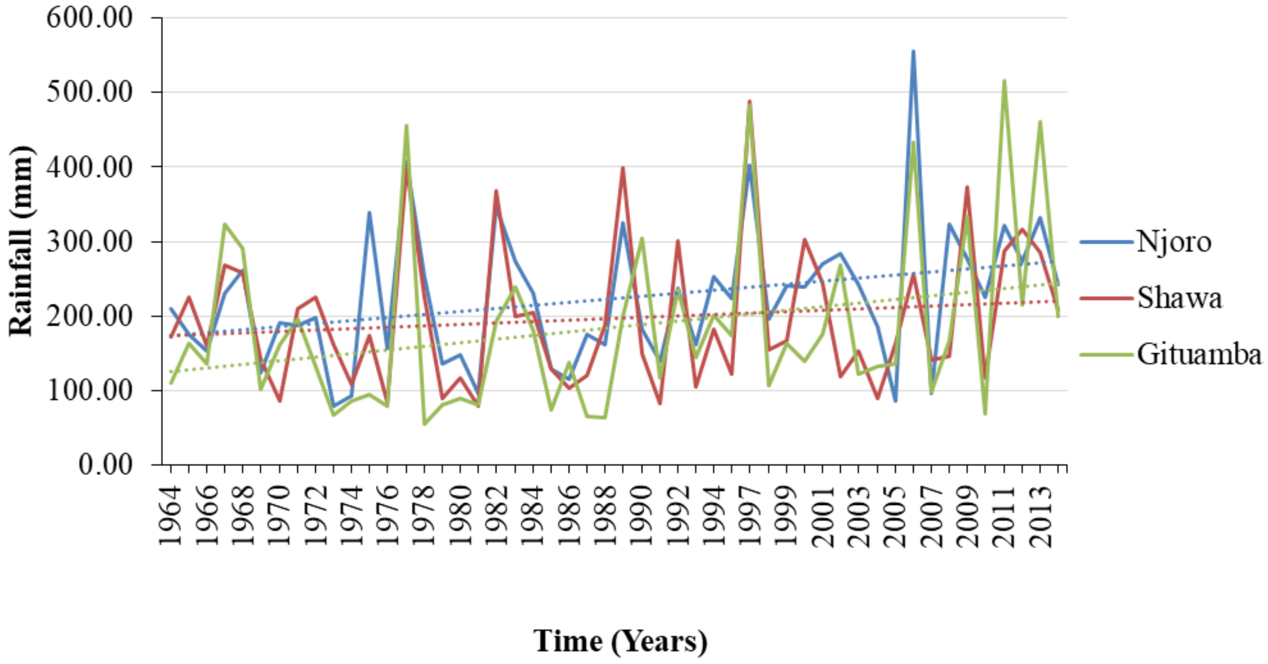


**Figure 6. October November and December season total rainfall trend for Njoro, Shawa and Gituamba**

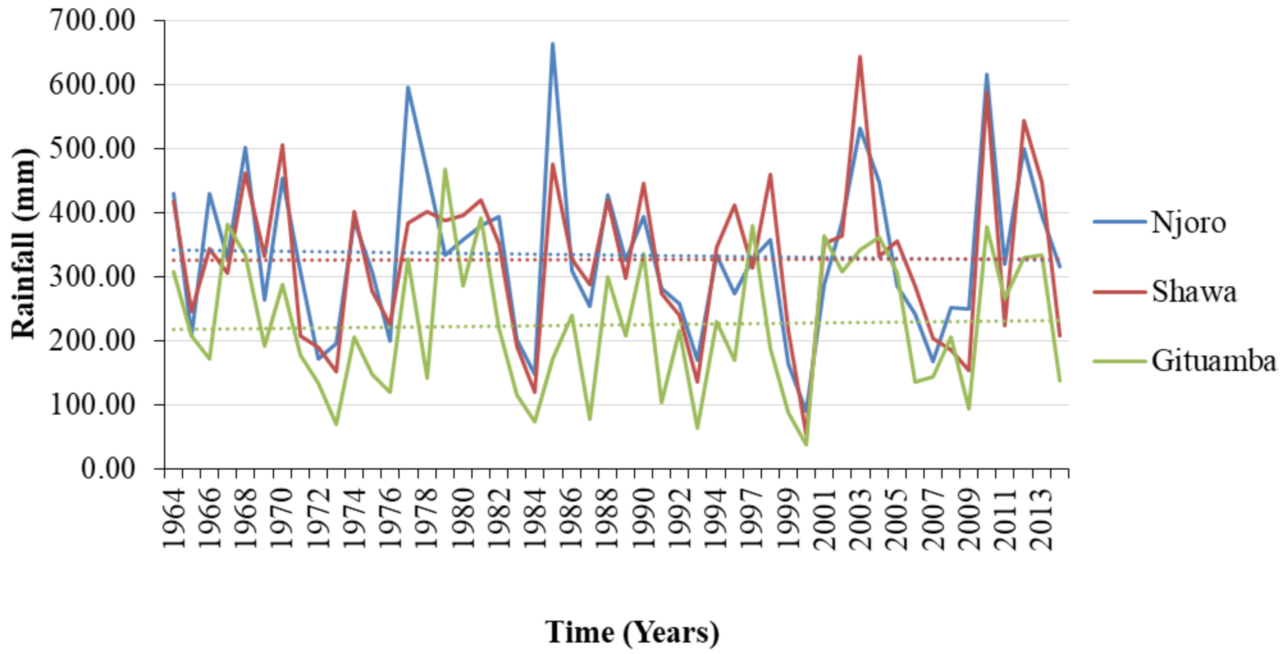


**Figure 7. March April and May season total rainfall trend for Njoro, Shawa and Gituamba**

The variability followed rain seasons with MAM season and particulary the month of April having the highest variability for all sites (Figure 8). Intrestingly for Njoro, the month of August had higher raifall variability than November in the OND season suggesting a trimodal characteristic.

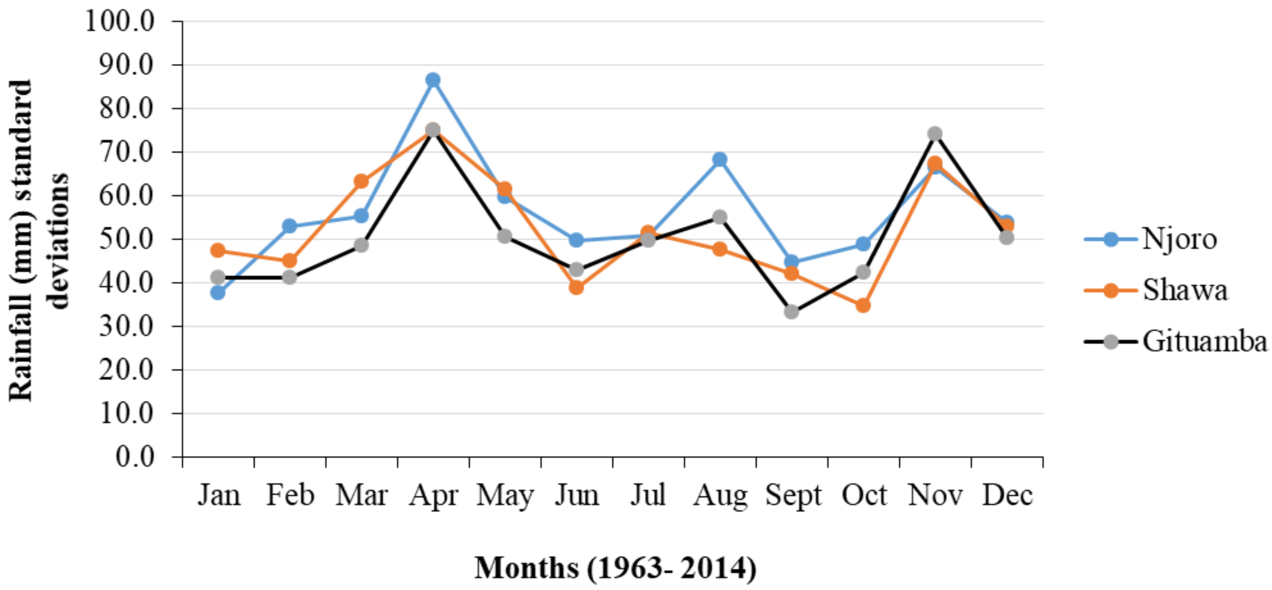


**Figure 8. Monthly rainfall standard deviations for Njoro, Shawa and Gituamba**

The World Metereological Organisations recomends use of climate data of more than 30 consecutive years with minimal interuptions in climate change studies by the World Metereological Organisations (World Meteological Organisation, 2007). The temperature data for Gituamba was for eight years and was not used as it did not meet the World Metereological Organisations recomendations.

Temperature trends in the last 30 years for Njoro and Shawa trends agreed with model predictions (Table 2) of increasing temperatures (Figure 9). Shawa (0.07ºC, $R^2$ = 0.806) showed the highest rate of increase for mean annual minimum temperature compared to Njoro (0.02 ºC, $R^2$ = 0.294). On the other hand, Njoro (0.03ºC, $R^2$ = 0.301) had the highest increase in mean annual maximum temperature compared to Shawa (0.02ºC, $R^2$ = 0.070). This resulted in a higher rate of increase in mean annual temperature inShawa (0.05ºC, $R^2$ = 0.561) than in Njoro (0.03ºC, $R^2$ = 0.514).

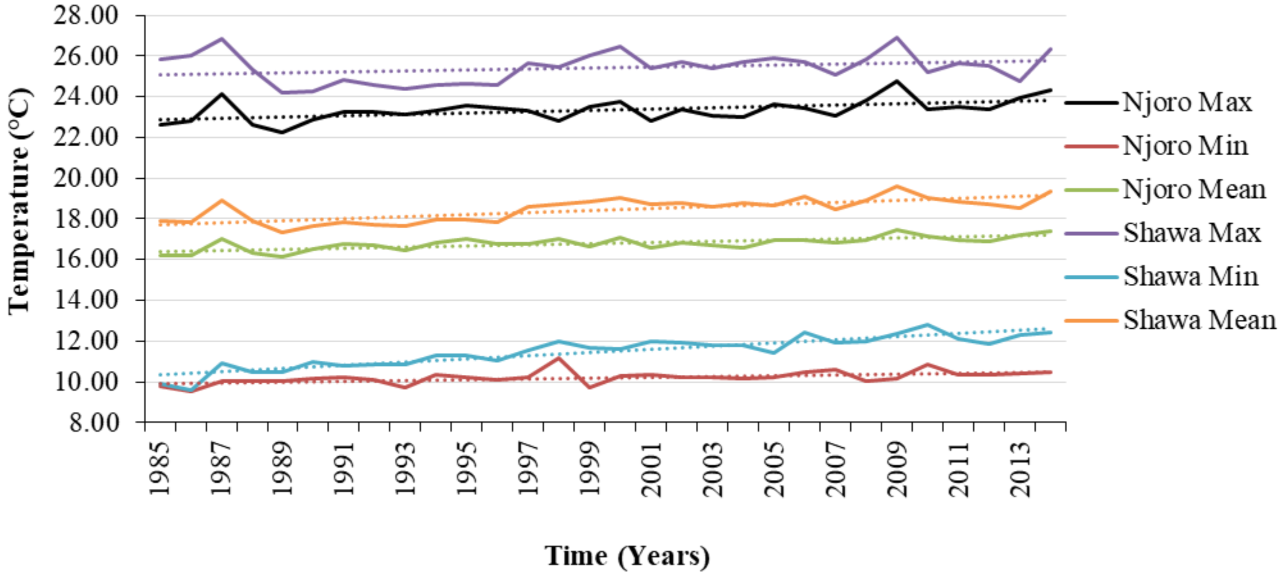


**Figure 9. Maximum, Minimum and Mean Temperatures for Njoro and Shawa**

To the majority of farmers in Njoro and Shawa (84.5 to 98.4%), the indicator of climate change was changes in rainfall than changes in temperatures (Figure 10) and the changes manifested as prolonged dry spell, droughts or flooding (Figure 11).

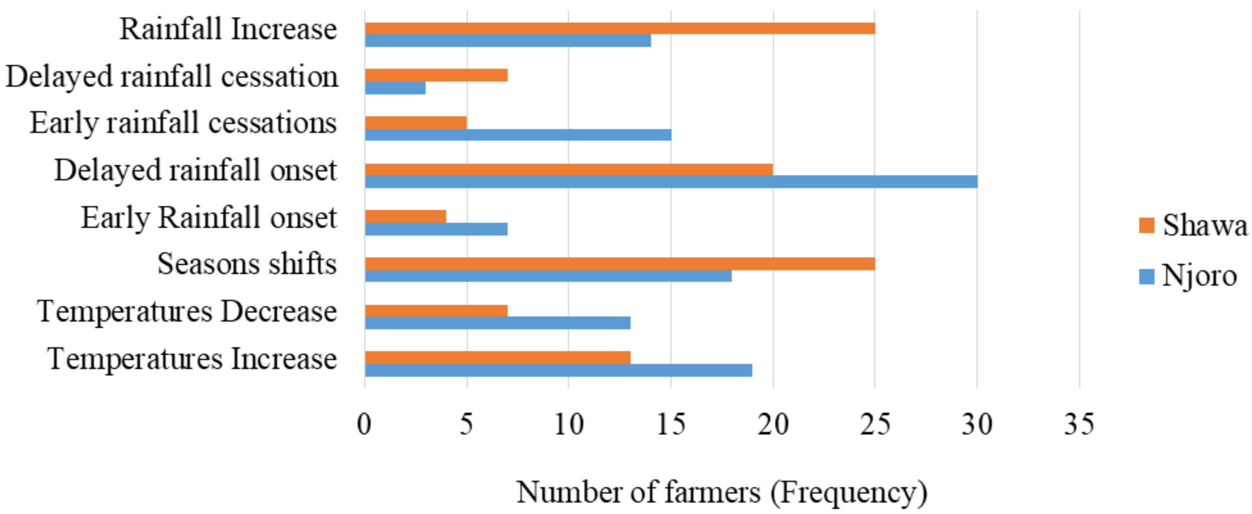


**Figure 10. Indicators of climate change and variability in Njoro and Shawa**

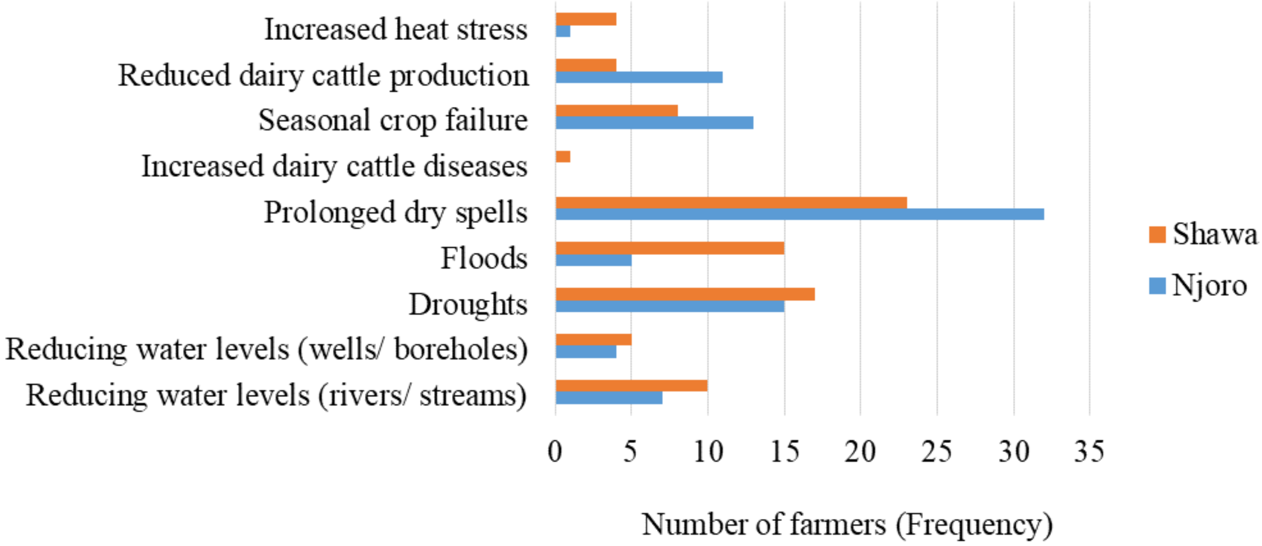


**Figure 11. Effects of climate change and variability in Njoro and Shawa**

### 4.2 Likely Thermal Stress in Njoro in the 2050's

There were marked differences in geographical and ecological conditions (Table 3) and in climatic conditions (Table 4) between the two climate analogue sites, but the daily THI only differed (*p=0.0001*) between times of the day (0700hrs and 1400hrs), being higher in the afternoons.

**Table 3. Study sites geographical, climatic conditions and Friesian cattle production systems**

| Description | Njoro | Shawa | Reference |
|---|---|---|---|
| Latitude | 00°18'00" | 00°03'00" | |
| | 00°48'00" | 00°21'00" | |
| Longitude | 35°47'59.99" | 35°45'00.00" | |
| | 36°06'00.00" | 36.8°08'59.99" | |
| Ecological zone | UH1 and UM3 | LH3 and UM3 | Ogeto *et al*. (2011) |
| Altitude (m a.s.l) | 1650 to 2850 | 1650 to 1850 | Ogeto *et al*. (2011) |
| Rainfall (mm) | 600 to 1800 | 600 to 1000 | Ogeto *et al*. (2011) |
| Temperature (°C) | 11.5 to 24.5 | 17.0 to 29.0 | Ogeto *et al*. (2011) |
| Friesian feeding system | Zero grazing | Semi Zero grazing | Ngeno *et al*. (2014) |

UH- Upper Highlands, LH- Lower Highlands, UM- Upper Midlands

**Table 4. Thermal conditions during the study period in Njoro and Shawa**

| Climate variables | Climate analogue sites | Time of the day | |
|---|---|---|---|
| | | 0700hrs | 1400hrs |
| Wet bulb temperatures | Njoro | 14.8±0.57 | 15.7±0.45 |
| (°C) | Shawa | 12.7±1.64 | 17.1±1.16 |
| Dry bulb temperatures | Njoro | 19.7±0.88 | 26.6±1.43 |
| (°C) | Shawa | 19.0±1.38 | 28.7±1.81 |
| Mean minimum temperature | Njoro | $11.8±0.52^a$ | $18.3±0.70^a$ |
| (°C) | Shawa | $13.0±1.40^b$ | $26.6±0.80^b$ |
| Mean maximum temperature | Njoro | $27.3±1.17^a$ | $27.6±0.26^a$ |
| (°C) | Shawa | $19.0±1.40^b$ | $29.8±0.59^b$ |
| Mean temperature | Njoro | $19.5±0.46^a$ | $23.0±0.43^a$ |
| (°C) | Shawa | $16.0±1.25^b$ | $28.2±0.29^b$ |
| Relative Humidity | Njoro | $56.2±9.60^a$ | $26.0±7.07^a$ |
| (%) | Shawa | $66.9±9.03^b$ | $28.8±10.86^a$ |
| Temperature Humidity Index | Njoro | 64.8±0.96 | 66.9±0.50 |
| | Shawa | 60.2±1.81 | 73.3 ± 1.26 |

Means with different letter superscripts for each variable within a column differ ($p<0.05$) between the analogue sites

### 4.3 Likely Physiological and hematological responses of Friesian cattle breed in Njoro in the 2050's

The physiological response indicators measured (Table 5) in Friesian cows in the two climate analogue sites, those in Shawa had higher heart rates ($p=0.0001$), respiration rates ($p= 0.0004$) and sweating rates ($p= 0.0009$) in the afternoon regardless of age group, but the rectal temperatures did not differ ($p=0.0863$).

**Table 5. Friesian cattle physiological response measures in the climate analogue site for time of day and cattle age groups**

| Physiological measures | Climate analogue sites | Time of the day | | Age group | |
|---|---|---|---|---|---|
| | | 0700hrs | 1400hrs | 4 ±1 years | 7 ± 1 years |
| Rectal temperature | Njoro | 37.9±0.53 | 38.9±0.32 | 38.5±0.63 | 38.3±0.68 |
| ($^{o}$C) | Shawa | 37.9±0.41 | 38.8±0.43 | 38.4±0.64 | 38.2±0.55 |
| Sweating Rate | Njoro | 227.3±70.11$^{a}$ | 408.2±84.86$^{a}$ | 284.4±124.19$^{a}$ | 305.2±142.03$^{a}$ |
| (g $m^{-2}h^{-1}$) | Shawa | 183.1±60.64$^{b}$ | 413.0±107.89$^{b}$ | 320.1±129.96$^{b}$ | 320.2±130.81$^{b}$ |
| Respiration Rate | Njoro | 32.2±5.67$^{a}$ | 43.5±5.40$^{a}$ | 38.4±8.52$^{a}$ | 37.5±7.43$^{a}$ |
| (Breaths/minute) | Shawa | 28.4±4.55$^{b}$ | 51.9±11.27$^{b}$ | 40.3±13.77$^{b}$ | 39.9±15.87$^{b}$ |
| Heart Rate | Njoro | 58.3±6.01$^{a}$ | 63.4±7.90$^{a}$ | 60.3±7.71$^{a}$ | 61.3±7.28$^{a}$ |
| (Beats/minute) | Shawa | 62.5±4.59$^{b}$ | 73.1±5.83$^{b}$ | 68.2±7.85$^{b}$ | 67.1±6.78$^{b}$ |

Means with different letter superscripts for each variable in a column differ (*$p<0.05$*)between the analogue sites

The hematological and hematimetric measures obtained in Friesian cows are shown in Table 6. The differences between the two climate analogue sites were higher for platelets (Plt) (*$p= 0.0087$*) and lower Packed Cell Volume (PCV) (*$p= 0.0001$*), hemoglobin concentration (Hgb) (*$p= 0.0001$*), mean corpuscular hemoglobin (MCH) (*$p= 0.0001$*), mean corpuscular volume (MCV) (*$p= 0.0048$*) and corpuscular hemoglobin concentration (MCHC) (*$p= 0.0001$*) in Shawa, regardless of time of day and age group.

**Table 6. Friesian cattle hematological measures between climate analogue sites for time of day and cattle age groups**

| Hematological Parameters | Climate analogue sites | Time of the day | | Age group | |
|---|---|---|---|---|---|
| | | 0700hrs | 1400hrs | 4 ±1 years | 7 ± 2 years |
| PCV (%) | Njoro | 31.6±3.47[a] | 32.0±3.44[a] | 30.9±3.14[a] | 32.5±3.54[a] |
| | Shawa | 26.6±3.61[b] | 26.7±3.39[b] | 26.2±3.64[b] | 27.5±3.05[b] |
| RBC (x106 cells/µl) | Njoro | 6.9±0.85 | 6.7±0.68 | 6.7±0.59 | 6.9±0.88 |
| | Shawa | 7.0±0.69 | 6.6±0.61 | 6.7±0.76 | 6.9±0.45 |
| Plt (x103 cells/µl) | Njoro | 213.4±94.62[a] | 198.3±108.83[a] | 191.2±116.22[a] | 216.5±89.31[a] |
| | Shawa | 273.9±134.42[b] | 289.9±149.70[b] | 322.6±134.16[b] | 213.4±128.92[b] |
| Hgb (g/dl) | Njoro | 10.9±1.36[a] | 10.7±1.24[a] | 10.6±1.16[a] | 11.0±1.37[a] |
| | Shawa | 8.9±1.23[b] | 8.6±1.06[b] | 8.6±1.26[b] | 9.0±0.90[b] |
| MCV | Njoro | 46.1±3.77[a] | 48.1±3.20[a] | 46.3±3.54[a] | 47.7±3.58[a] |
| | Shawa | 38.2±3.56[b] | 40.3±3.84[b] | 39.0±3.89[b] | 39.8±3.71[b] |
| MCH | Njoro | 15.8±1.11[a] | 16.1±1.08[a] | 15.8±1.21[a] | 16.1±0.99[a] |
| | Shawa | 12.8±1.10[b] | 13.0±1.14[b] | 12.8±1.22[b] | 13.0±0.94[b] |
| MCHC | Njoro | 34.5±1.20[a] | 33.5±0.72[a] | 34.2±1.08[a] | 33.8±1.12[a] |
| | Shawa | 33.1±2.55[b] | 32.3±1.82[b] | 33.0±1.88[b] | 32.2±2.68[b] |

Means with different letter superscripts for each variable within a column differ (*$p<0.05$*)between the analogue sites

The hematological measures including all leucocytes were however not different between the two climate site analogues, but lymphocytes and neutrophils were the most numerous while basophils were missing in the differential counts and neutrophils to lymphocytes (N/L) ratio higher in Shawa. These results are therefore not presented.

**4.4 Likely Performance of Friesian Cattle in Njoro in the 2050's**

In both the climate analogue sites, mating was by both artificial insemination (AI) and natural mating, but in Shawa natural mating was more frequently used (47.2 vs 24.1 %) and AI less frequently used (37.7 vs 37.7%) compared to Njoro (Figure 12).

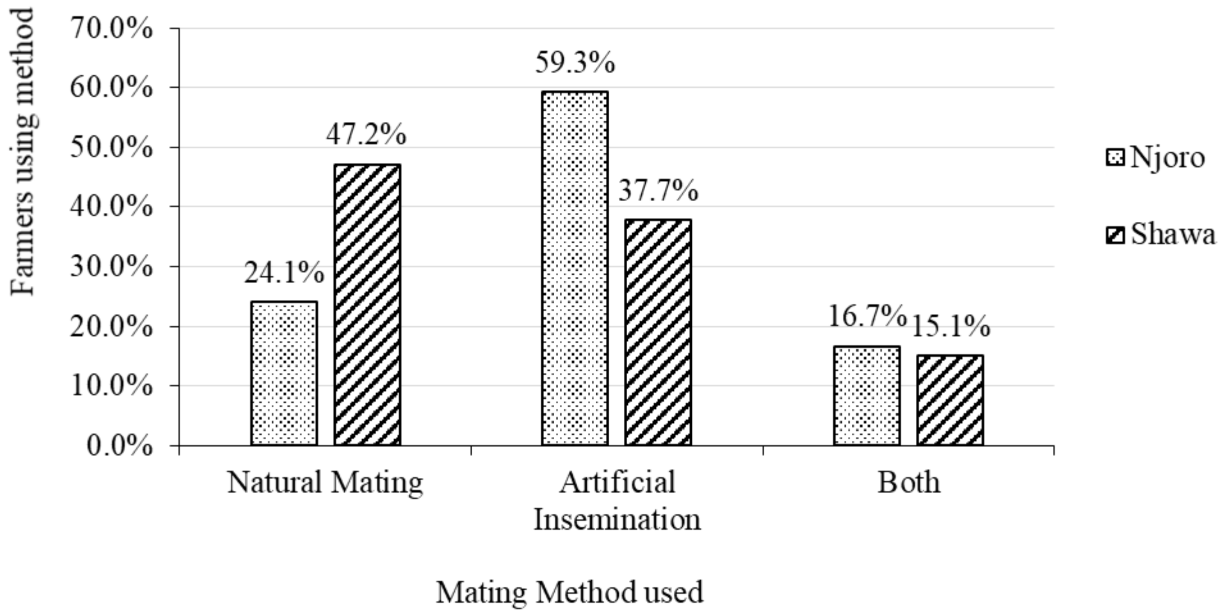


**Figure 12. Preferred Friesian cattle mating method by smallholder farmers in Njoro and Shawa**

There were no significant differences observed between the two climate analogue sites in inseminations per conception and in calving intervals. However, Friesian cattle breed attained a 0.9 to 2.1 month (Table 7) shorter calving interval on average than the Ayrshire or Friesian crosses (15.4 -15.6 vs 16.5 -17.7 month).

**Table 7. Insemination per conception and calving intervals for breeds kept in climate analogue sites.**

| Breed | Climate analogue sites | Inseminations per conception (n) | Calving interval (months) |
|---|---|---|---|
| Friesian | Njoro | 1.3±0.72 | 15.4±5.30 |
| | Shawa | 1.1±0.26 | 15.6±5.46 |
| Friesian crosses | Njoro | 1.2±0.56 | 17.2±5.94 |
| | Shawa | 1.3±0.55 | 16.5±5.80 |
| Ayrshire | Njoro | 1.4±0.79 | 17.5±8.67 |
| | Shawa | 1.6±0.96 | 17.7±5.47 |

Farmers in Shawa compared to Njoro (16.7 vs 29.2%) indicated fewer cases of retained afterbirth among the common reproductive diseases.. However, the two sites were not different in cases of mastitis (18.5 vs 15.3%) or abortions (3.7 vs 4.2%).

Table 8 shows that Friesian cattle attained 23.6% less milk in Shawa compared to when in Njoro and experienced larger drop in milk yield between wet and dry seasons in

Shawa than in Njoro (56.3 vs 35.7%). In contrast, Ayrshire produced 28% more milk in the dry seasons compared to rainy season in Shawa.

**Table 8. Milk yield for Friesian cattle and other breeds between climate analogue sites**

| Breed | Climate analogue sites | Wet season milk yield (Litre/cow/day) | Dry season milk yield (Litre/cow/day) | Overall milk yield (Litre/cow/day) |
|---|---|---:|---:|---:|
| Friesian | Njoro | 12.9±5.73 | 8.3±7.07 | 10.6±6.10 |
| | Shawa | 11.2±5.04 | 4.9±3.09 | 8.1±3.68 |
| Friesian crosses | Njoro | 7.6±4.44 | 3.9±2.64 | 5.7±3.43 |
| | Shawa | 7.3±2.37 | 3.9±2.11 | 5.6±1.91 |
| Ayrshire | Njoro | 9.6±3.77 | 5.0±2.97 | 7.3±3.00 |
| | Shawa | 12.4±4.60 | 6.4±3.93 | 9.4±4.03 |

### 4.5 Likely Climate-Smart Management Practices in Njoro in the 2050's

Table 9 shows that in both climate analogue sites, farmers predominantly practiced mixed farming on small farm holding, but farmers in Shawa allocated larger acres to grazing pastures (0.7 vs 0.4 acres) on which they (Figure 13) predominantly grazed their Friesian cattle (20.8 vs 9.3%).

**Table 9. Education, main occupation and farming characteristics observed in the sampled households in Njoro (n= 54) and Shawa (n= 53)**

| Variable | Level | Climate Analogue Sites | | Significance |
|---|---|---:|---:|---:|
| | | Njoro | Shawa | |
| Main occupation | Livestock farming (%) | 1.9 | 0.0 | *p= 0.635* |
| | Mixed farming (%) | 66.7 | 69.8 | |
| | Salaried employment (%) | 24.1 | 26.4 | |
| | Self-employment (%) | 7.4 | 3.8 | |
| Land use | Total acres (Mean (SD) | 3.4 (4.1) | 4.2 (6.7) | *p= 0.489* |
| | Subsistence Crops (Acres) | 0.6 (0.86) | 0.8 (1.35) | *p= 0.444* |
| | Commercial Crops (Acres) | 1.3 (2.89) | 1.2 (3.180 | *p=0.834* |
| | Natural Pastures(Acres) | 0.4 (0.76) | 0.7 (1.54) | *p=0.006* |
| | Improved Pastures (Acres) | 0.4 (0.99) | 0.5 (0.76) | *p=0.683* |
| | Woodlot (Acres) | 0.1 (0.27) | 0.1 (0.33) | *p=0.675* |

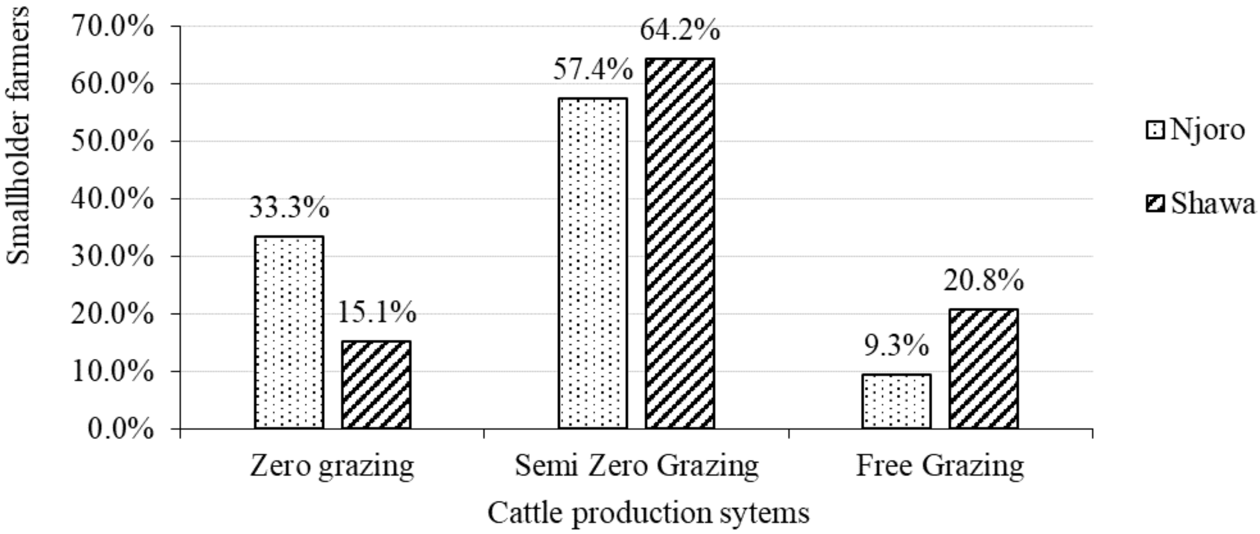


**Figure 13. Dairy cattle production in Njoro and Shawa**

In both the climate analogue sites, farmers' sourced climate related information from the electronic media, extension services and from other fellow farmers, in that order of importance but they did not directly source climate information from the meteorology department (Table 10).

**Table 10. Percentage (%) distribution of households by sources of climate information sought**

| Information source | Climate analogue sites | |
|---|---|---|
| | Njoro | Shawa |
| Traditional/ Indigenous knowledge | 9.3 | 4.8 |
| Mass media (radio and TV) | 42.6 | 42.7 |
| Meteorology Department Services | 1.5 | 1.6 |
| Other fellow farmers | 20.6 | 24.1 |
| Extension services | 24.1 | 23.6 |
| Internet | 2.0 | 3.2 |

Table 11 shows that compared to Njoro, more farmers in Shawa utilized natural pastures (22.2 vs 45.3%), sourced on-farm feeds (20.4 vs 36.8%) and produced hay (9.3 vs 32.1%), but fewer utilized improved pastures (11 vs 25%). In both sites, farmers' sourced water from multiple sources (piped and non-piped) and used manure on the farm to improve soil fertility (25%).

**Table 11. Percentage of farmers for different pastures management practices in the last ten years for Njoro (n= 54) and Shawa (n= 53)**

| Management practice | Levels | Climate analogue sites | | Significance ($X^2$) |
|---|---|---|---|---|
| | | Njoro | Shawa | |
| Pastures types utilized | Natural | 22.2 | 45.3 | *p= 0.009* |
| | Improved | 47.2 | 20.8 | |
| | Both improved and natural pastures | 30.6 | 34.0 | |
| Main Source of Feeds | On farm | 20.4 | 36.8 | *p=0.025* |
| | Off farm | 9.3 | 5.7 | |
| | Both on and off farm sources | 70.4 | 57.5 | |
| Pastures Conservation | No pasture conservation | 70.4 | 60.4 | *p=0.015* |
| | Hay making | 9.3 | 32.1 | |
| | Silage making | 7.4 | 1.9 | |
| | Both silage and hay making | 13.0 | 5.7 | |

In both the climate analogue sites, the disease (Fig. 14) mostly associated with climate change was East Coast Fever (12 vs15%) but fewer farmers in Shawa indicated pneumonia (2 vs 9%) or and Foot and Mouth Disease (4 vs 8%). In both the sites, farmers adopted similar disease control strategies, applying vaccination, quarantine or hygiene practices (Table 12)

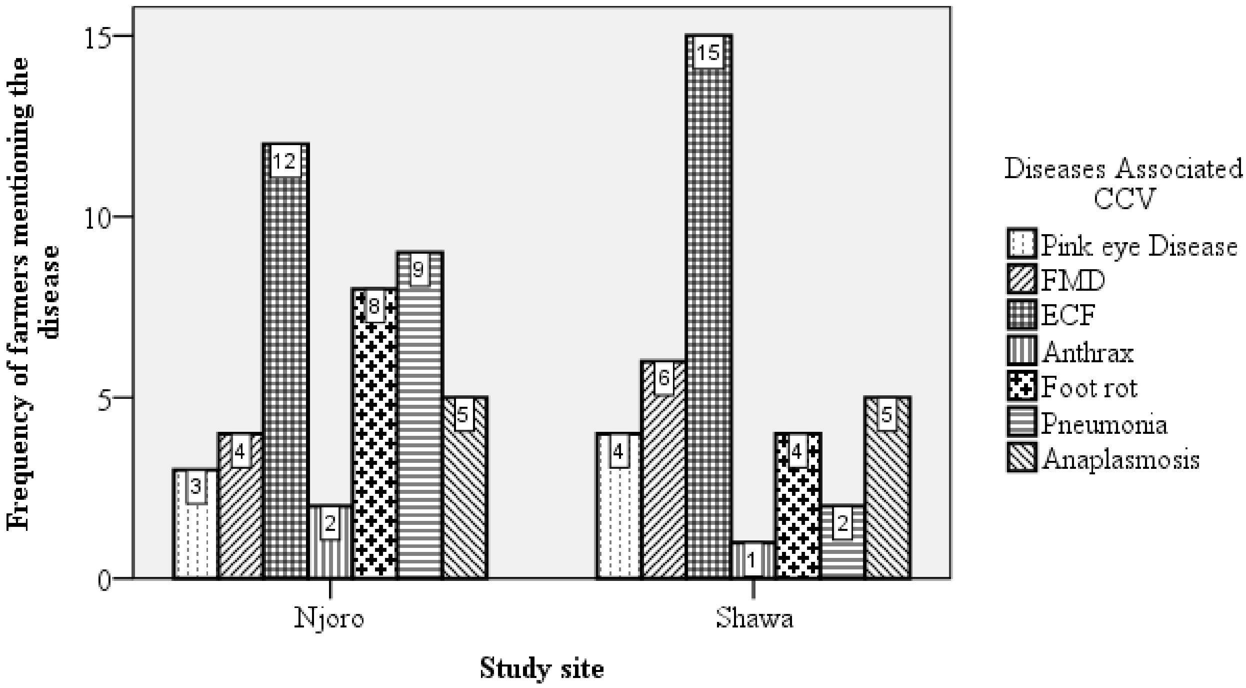


**Figure 14. Climate associated diseases mentioned by farmers in Njoro and Shawa**

**Table 12. Disease control strategies in Njoro (n= 54) and Shawa (n= 53)**

| Disease control strategies | Climate Analogue site | |
|---|---|---|
| | Njoro (%) | Shawa (%) |
| Vaccinations | 37 | 43 |
| On farm Quarantines | 42 | 39 |
| Farm hygiene | 21 | 18 |

# CHAPTER FIVE

# DISCUSSION

## 5.1 Likely Climate Change and Resulting Animal Thermal Stress in Njoro in the 2050's

This study applied climate analogue concept to assess adaptive capacity of Friesian cattle breed to the future projected climate change scenarios in the Kenya highlands in 2050's. Application of climate analogue concept identified Shawa as a likely climate analogue site to Njoro in the 2050's with high similarity index (0.8-0.9). A comparison of present situation in Njoro to its 2050's analogue site is used to discuss the projections for utilization of Friesian in Njoro under expected climatic conditions in 2050's. The indicators used are the Thermal Humidity Index (THI), physiological and hematological responses, reproductive and production performance and climate smart agriculture practices.

Based on temperatures and rainfall patterns observed in Shawa, an increasing trend in temperatures is likely but trends in rainfall is uncertain, in Njoro in the 2050's. This is in agreement with other studies within the region that show increasing trends in temperature (Washington & Pearce, 2012; Daron, 2014; Marais *et al.,* 2014; Musau *et al.,* 2015; Gichangi *et al.,* 2016). However, rainfall in Kenya show mixed signals, with some studies reporting an increasing trend (Mcsweeney *et al.,* 2010), a decreasing trend (Ngeno *et al.,* 2014) or lack of a clear trend (Washington & Pearce, 2012; Gichangi, 2016). Uncertainty in rainfall trends can be attributed to heterogeneous topography, altitude, vegetation, influence of water bodies and atmospheric forces (Herrero *et al.,* 2010; Owiti & Zhu, 2012; Washington & Pearce, 2012; Daron, 2014) resulting in greater variability in rainfall amounts and distribution (King'uyu *et al.,* 2009; Huho *et al.,* 2012; Huho & Kosonei, 2013; Musau *et al.,* 2015).

The observed differences in THI between Njoro and Shawa analogues sites indicates likelihood of Friesian cattle breed suffering mild heat stress during the dry seasons in Njoro in the2050's. Physiological and hematological responses as thermal stress indicators in Friesian cattle have been discussed in detail (Willard *et al.,* 2008; Van *et al.,* 2010; Etim *et al.,* 2014; Mazzullo *et al.,* 2014; Radkowska & Herbut, 2014; Golher *et al.,* 2015; Onasanya *et al.,* 2015) as well as their link with THI (Bouraoui *et al.,* 2002; Dikmen & Hansen, 2009; Salem & Bouraoui, 2009; Gantner *et al.,* 2011). Exposure to mild thermal stress can cause alterations in homeostatic mechanisms resulting in reduced production, reproductive and health performance in dairy cattle (Gaafar *et al.,* 2011; Moran, 2012). This suggests there would be need for farmers keeping Friesian to implement measures to ameliorate thermal stress especially in dry and drought periods when practicing pasture grazing, which was predominant in Shawa presently.

## 5.2 Likely Friesian cattle physiological and hematological responses in Njoro in the 2050's

Rectal temperature (RT) was not a differentiating indicator of thermal stress in Friesian cattle between the climate analogue sites, though it has high correlation with body core temperatures (Barnes *et al.,* 2004; Gebremedhin *et al.,* 2008; McManus *et al.,* 2009; Ganaie *et al.,* 2013). Friesian cows had RT within the normal ranges, suggesting thermal stress conditions in Njoro in 2050's will not be notable with changes in RT. Above normal RT range signifies overwhelmed thermal regulation mechanisms, when THI exceeds 75 in dairy cattle (Kucevic *et al.,* 2013). At thermal comfort zone, the normal RT for cattle ranges from 36.7$^{o}$C to 39.3$^{o}$C (Mercks Veterinary Manual, 2015), but dairy cattle can range between 38.4$^{o}$C and 39.1$^{o}$C with an average of 38.6$^{o}$C (Gantner *et al.*, 2011; Moran, 2012; Kucevic *et al.*, 2013).

Other physiological measures can be indicators of thermal stress such as sweating rates and heart rates (HR), which were higher in Shawa relative to Njoro. Heightened sweating rates (SR) is the initial response for heat dissipation in cattle and varies among breeds. With mild thermal stress of Friesian cattle suggested to be likely during dry seasons in the 2050's in Njoro, utilization of upgraded Friesian to pedigree level should be discouraged because of a likelihood of increased vulnerability to thermal stress. Sweating rate accounts for between 70 % to 80 % of evaporative heat loss with the remainder being through the respiratory routes (Hansen, 2004).Friesian cattle experience limitations in sweating rate coupled with high metabolic rates to maintain the large body sizes and high production levels (McManus *et al.,* 2009). Importance of heat dissipation through respiratory avenue is observed through increased respiratory rates (RR) that graduate into panting with increase in thermal stress from mild to severe (Moran, 2012). Projections made in this study show a likelihood of RR slightly above the normal ranges during afternoon hours (1400hrs), which corresponds to elevated ambient temperatures and THI (Ganaie *et al.,* 2013). There exist breed differences in sweating efficiency, which suggests alternative breeds for adaptability to thermal stress are possible. The *Bos indicus* demonstrate more efficiency in sweating than the *B. taurus* owing to high number of well-developed sweat glands in the skin (Jian *et al.,* 2013; WMO, 2012). Notwithstanding breed differences, skin color also affect SR, with black color having higher rates (Gebremedhin *et al.,* 2008). The SR observed in this study were higher than those reported by other workers ( McManus *et al.,* 2009; Gomes *et al.,* 2011) but were within the observed margins (Gebremedhin *et al*., 2008; Jian *et al.*, 2015) for Friesian breed and it crosses in near similar climatic conditions.

Changes in physiological responses with heat stress causes alterations in hematological profile making it a complement indicator of thermal stress. The study observed differences in hematological and hematimetric parameters except red blood cells (RBC) between Friesian cows in Njoro and those in Shawa. The Red Blood Cells count were highest for Friesian cows in Shawa at 0700hrs and lowest at 1400hrs compared to those in Njoro. Conversely, hemoglobin concentration and hematimetric parameters (MCV, MCH and MCHC) were highest for Friesian cows in Njoro than for those in Shawa. Increase in thermal stress triggers erythrolysis to reduce oxygen supply to the cells to suppress metabolic heat production (Das *et al.*, 2016) and hence the observed changes in RBC, hemoglobin concentration and hematimetric parameters.

The leukogram of the study animals in both sites were within the normal ranges for cattle (Jackson & Cockcroft, 2002; Roland *et al.*, 2014) except for the white blood cells which were overly exaggerated, likely due to erroneous configuration of correction values for WBC in the coulter hematogical analyzer. On the other hand, packed cell volume (PCV) were lower in Friesian cows in Shawa relative to Njoro, which can be attributed to hemoconcentration resulting from electrolytes loss under elevated evaporative heat loss through heightened sweating and respiration rates (McManus *et al.*, 2009; Merck's veterinary manual, 2015).

### 5.3 Likely Production Performance of Friesian Cattle Breed in Njoro in the 2050's

Breed preferences in Shawa relative to Njoro suggest that Ayrshire utilization will likely dominate over Friesian for milk production. Friesian cattle is a large breed requiring high quality and quantity feeds to supply nutrients for its high milk production potential and maintenance of the large body, which present management challenges for resource poor farmers (Bebe *et al.,* 2003; Musalia *et al.,* 2007; Bebe *et al.,* 2008; Matiri *et al.,* 2013; Omondi and Njehia, 2014). In Shawa, the number of inseminations per conception were higher and calving intervals longer, suggesting a likely poorer fertility of Friesian in Njoro in the 2050s' which can result from poor animal husbandry practices for high yielding genotypes (Kucevic *et al.*, 2013).

### 5.4 Likely Climate Smart Agricultural Practices in Smallholder Dairy Farms in Njoro in the 2050's

The farmers, perceived that, temperatures and rainfall were increasing in both sites. In response, farmers (in Shawa) will likely adopt extensive grazing and utilize unimproved pastures. This contrast promotion of dairy intensification for increased productivity and for adaptation and mitigation to climate change impacts (Cassandro *et al.,* 2013; FAO, 2013;

Wambugu *et al*., 2014;). Intensification demands optimum feeding, health and environmental management which are weak or lacking in smallholder dairy farms (Bebe *et al.,* 2003; Chaiyabutr *et al.,* 2008). This would justify practicing pasture conservation through hay making to address feed scarcity during dry seasons and drought periods.

Results suggest that farmers will unlikely substantially change their disease control strategies in Njoro in the 2050's. In both climate analogue sites, farmers are presently applying vaccination, hygiene and quarantine. This is despite likelihood of increased disease outbreaks with the changing climate influencing pathogens and disease transmission modes (FAO, 2013). On farm quarantines and farm hygiene are biosecurity measures essential in diseases prevention while vaccinations are critical in controlling prevalent and suspected diseases in the farm and will be necessary in Njoro in the 2050's. Adopting biosecurity measures, vaccinations, and livestock movement control in diseases and parasites control and prevention have been suggested as viable management options, although inadequately practiced in smallholder farms (Mclaws & Rushton, 2016).

From the results, just like disease control strategies, farmers are less likely to change climate smart agricultural practices. Sourcing climate change related information is necessary and farmers show likely continued heavy reliance on mass media, extension services and on fellow farmers, but limited direct sourcing from the Meteorological Service Department. Therefore dissemination of climate information though mass media, extension services and through fellow farmers will have to be strengthened and made informative to intended potential users towards 2050's for effective adaptation.

### 5.5 Likely Climate Change Induced Diseases in Njoro in the 2050's

In both climate analogue sites, most farmers acknowledged climate change and variability (CCV) associated diseases were increasing. This can be attributed to increasing favorable conditions for multiplication, spread and change in transmission modes for disease causative agents and vectors with increasing temperatures and variability in rainfall (IFAD, 2009). Further, the use of Friesian cattle breed which is poorly adapted to climate change induced stresses found under tropical conditions (McManus *et al.,* 2011) coupled with indiscriminate breeding towards the pedigree status as reported in Kenyan smallholder farms (Kosgey *et al.,* 2011; Muasya *et al.,* 2013) could explain the reported increase in CCV associated diseases in more farms in Njoro than in Shawa.

Based on the most mentioned diseases in Shawa, disease prevalence more likely in Njoro in the 2050's are East Coast Fever (ECF), Anaplasmosis, Foot and Mouth Disease (FMD) and Pink eye (infectious keratoconjutivatis). The expected rise in tick borne diseases corresponds to favorable ambient environment for ticks proliferation (Mureithi & Mukiria, 2015). Prolonged dry periods causes dustiness which aggravate spread of Pink eye disease with marked changing and variable climate (MoLD, 2010). Cases of pink eye could also increase due to free grazing system which exposes the animals to dustiness during the dry season, which Shawa reported.

# CHAPTER SIX

# CONCLUSIONS AND RECCOMMENDATIONS

## 6.1 Conclusion

Based on the results obtained, the study can conclude that;

i. Climate analogue sites for Njoro in the 2050's exists in Kenya.
   a. The temperatures for Njoro in the 2050's will increase while rainfall is uncertain.
   b. The projected changes in climate by the 2050's will result in mild thermal stress for Friesian cattle especially during the dry/ drought seasons.
   c. The changes in climatic conditions will result in increased prevalence of ECF, Anaplasmosis, Foot and Mouth Disease and Pink eye disease.

ii. The Friesian cattle will respond to the mild thermal stress by having elevated physiological and hematological responses but within the normal margins.

iii. The impact of mild thermal stress on Friesian cattle will be a decrease in milk yield and fertility.

iv. Smallholder farmers in Njoro and its future climate analogue site in the 2050's applied climate smart practices most of which were similar.

## 6.2 Recommendations

The study recommends the following interventions to enhance adaptive capacity for sustainable utilization of Friesian cattle breed with the projected climate change scenarios in the Kenya highlands.

i. Modification of management to ameliorate effects of climate change.
ii. Routine diseases surveillance, prevention and control.
iii. Promotion of pastures/ fodder conservation.
iv. Establishment of farmers network platforms to foster sharing of experiences between the climate analogue sites.

## REFERENCES

Beatty, D. T. (2005). *Prolonged and continous heat stress in cattle: Physiology, welfare, and electrolyte and nutritional interventions*. *Ph.D thesis, Murdoch University*. Retrieved from http://core.ac.uk/download/pdf/11230894.pdf

Beatty, D. T., Barnes,  a, Taylor, E., Pethick, D., McCarthy, M., & Maloney, S. K. (2006). Physiological responses of Bos taurus and Bos indicus cattle to prolonged, continuous heat and humidity. *Journal of Animal Science*, *84*(4), 972–85. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/16543576

Bebe, B. O. (2008). Dairy heifer rearing under increasing intensification of smallholder dairy systems in the Kenya highlands. *Livestock Research for Rural Development*, *20*(2), 1–9.

Bebe, B. O., Udo, H. M. J., Rowlands, G. J., & Thorpe, W. (2003). Smallholder dairy systems in the Kenya highlands: Breed preferences and breeding practices. *Livestock Production Science*, *82*(2–3), 117–127. http://doi.org/10.1016/S0301-6226(03)00029-0

Bingi, S., & Tondel, F. (2015). *Recent developments in the dairy sector in Eastern Africa Towards a regional policy framework for value chain development*.

Bouraoui, R., Lahmar, M., Majdoub, A., Djemali, M. N., & Ronald, B. (2002). The relationship of temperature-humidity index with milk production of dairy cows in a Mediterranean climate.

Cassandro, M., Mele, M., & Stefanon, B. (2013). Genetic aspects of enteric methane emission in ruminants livestock. *Italian Journal of Animal Science*, *12*(3). http://doi.org/10.4081/ijas.2013.e73

Chaiyabutr, N., Chanpongsang, S., & Suadsong, S. (2008). Effects of evaporative cooling on the regulation of body water and milk production in crossbred Holstein cattle in a tropical environment. *International Journal of Biometeorology*, *52*, 575–585. http://doi.org/10.1007/s00484-008-0151-x

Daramola, J. O., Abioja, M. O., & Onagbesan, O. M. (2012). Heat Stress Impact on Livestock Production. In V. Sejian, S. M. K. Naqvi, T. Ezeji, J. Lakritz, & R. Lal (Eds.), *Environmental Stress and Amelioration in Livestock Production*. Berlin: Springer-Verlag Berlin Heidelberg. http://doi.org/DOI 10.1007/978-3-642-29205-7

Daron, D. J. (2014). *Regional Climate Messages: East Africa. Scientific report from the CARIAA Adaptation at Scale in Semi-Arid Regions (ASSAR) Project, December 2014*. Cape Town, South Africa. Retrieved from http://www.uct.ac.za/

Das, R., Sailo, L., Verma, N., Bharti, P., Saikia, J., & Kumar, R. (2016). Impact of heat stress on health and performance of dairy animals : A review. *Veterinary World*, *9*(3), 260–268. http://doi.org/10.14202/vetworld.2016.260-268

Dikmen, S., & Hansen, P. J. (2009). Is the temperature-humidity index the best indicator of heat stress in lactating dairy cows in a subtropical environment ? *Journal of Dairy Science*, *92*, 109–116. http://doi.org/10.3168/jds.2008-1370

FAO. (2011). Dairy development in Kenya. *Fao*. Retrieved from http://www.fao.org/docrep/013/al744e/al744e00.pdf

FAO. (2013). *Climate smart agriculture source book*. Rome, Italy: Food and Agriculture Organization of the United Nations.

Gaafar, H. M. ., Abu El-Hamd, M. ., El-Gendy, M. ., Bassiouni, M. ., Halawa, A. ., & Shamiah, S. . (2011). Effect of heat stress on perfprmance of dairy Friesian cows 2-Reproductive performance. *Researcher*, *3*(5), 94–100. Retrieved from http://www.sciencepub.net/researcher

Ganaie, A. H., Shanker, G., Bumla, N. A., Ghasura, R. S., Mir, N. A., Sa, W., & Gb, D. (2013). Biochemical and Physiological Changes during Thermal Stress in Bovines. *Journal of Veterinary Sciences and Technology*, *4*(1), 1–6. http://doi.org/10.4172/2157-7579.1000126

Gantner, V., Mijić, P., & Kuterovac, K. (2011). Temperature-humidity index values and their significance on the daily production of dairy cattle. *Daily Production of Dairy Cattle*, *61*(1), 56–63.

Gaughan, J. B., Mader, T. L., Holt, S. M., Sullivan, M. L., & Hahn, G. L. (2010). Assessing the heat tolerance of 17 beef cattle genotypes. *International Journal of Biometeorology*, *54*(6), 617–627. http://doi.org/10.1007/s00484-009-0233-4

Gebremedhin, K. G., Hillman, P. E., Lee, C. N., Collier, R. J., Willard, S. T., Arthington, J. D., & Brandl, T. M. B. (2008). Sweating rates of dairy cows and beed heifers in hot conditions. *American Society of Agricultural and Biological Engineers*, *51*(6), 2167–2178.

Gichangi, E. M., Wamuongo, J. ., Gatheru, M., Njiru, E. N., Mungube, E. O., & Wambua, M. J. (2016). Assessment of climate variability and change in semi-arid eastern Kenya. *Climatic Change*, *130*(April), 287–297. http://doi.org/10.1007/s10584-015-1341-2

Golher, D. M., Thirumurugan, P., Patel, B. H. M., Upadhyay, V. K., Sahu, S., Gaur, G. K., & Bhoite, S. H. (2015). Effect of drinking water temperature on physiological variables of crossbred dairy cattle at high altitude temperate region of Himalayas. *Veterinary World*, *8*(10), 1210–1214. http://doi.org/10.14202/vetworld.2015.1210-1214

Gomes, R., Sandro, A., & Maia, C. (2011). Evaporative cooling and cutaneous surface temperature of Holstein cows in Resfriamento evaporativo e temperatura cutânea de vacas Holandesas em ambiente tropical. *Revista Brasileira de Zootecnia*, *40*(5), 1143–1147.

Hansen, P. J. (2004). Physiological and cellular adaptations of zebu cattle to thermal stress. *Animal Reproduction Science*, *82–83*, 349–360. http://doi.org/10.1016/j.anireprosci.2004.04.011

Hashem, M. A., Alam, M. M., Rahman, M. M., Hossain, M. M., Haque, M. R., Sobhan, Z., & Islam, M. S. (2011). Effect of heat stress on behavior, physiological and blood parameters of goat. *Progress Agriculture*, *22*(1&2), 37–45.

Herrero, M., Ringler, C., Steeg, J. Van De, Koo, J., & Notenbaert, A. (2010). Climate variability and climate change and their impacts on Kenya's agricultural sector. *ILRI, Nairobi. Kenya*, 1–56.

Huho, J. M., & Kosonei, R. C. (2013). the Opportunities and Challenges for Mitigating Climate Change Through Drought Adaptive Strategies : the Case of Laikipia County , Kenya. *Academic Research International*, *4*(3), 453–465.

Huho, J. M., Ngaira, J. K. W., Ogindo, H. O., & Masayi, N. (2012). The changing rainfall pattern and the associated impacts on subsistence agriculture in Laikipia East District, Kenya. *Journal of Geography and Regional Planning*, *5*(7), 198–206. http://doi.org/10.5897/JGRP12.018

Jackson, P. G. G., & Cockcroft, P. D. (2002). Appendix 2 Laboratory Reference Values : Haematology (p. 302). Blackwell Science Ltd.

Jian, W., Duangjinda, M., & Vajrabukka, C. (2013). Differences of skin morphology in Bos indicus , Bos taurus , and their crossbreds. *International Journal of Biometeorology*, (Pan 1963). http://doi.org/10.1007/s00484-013-0700-9

Jian, W., Ke, Y., & Cheng, L. (2015). Physiological Responses and Lactation to Cutaneous Evaporative Heat Loss in Bos indicus , Bos taurus , and Their Crossbreds. *Asian Australasian Journal of Animal Sciences*, *28*(11), 1558–1564.

King'uyu, S., Kilavi, M., Omeny, P., Muigai, E., & Njogu, A. (2009). Climate Change Indices for Kenya. *Journal of Meteorology and Related Sciences*, 49–55. Retrieved from http://www.kms.or.ke/phocadownload/vol 5 paper 6.pdf

Kosgey, I. S., Mbuku, S. M., Okeyo, A. M., Amimo, J., Philipsson, J., & Ojango, J. M. (2011). Institutional and organizational frameworks for dairy and beef cattle recording in Kenya : a review and opportunities for improvement. *Animal Genetic Resources*, *48*, 1–

11. http://doi.org/10.1017/S2078633610001220

Kucevic, D., Plavši, M., Trivunovi, S., Radinovi, M., & Bogdanovi, V. (2013). Influence of microclimatic conditions on the daily production of dairy cows. *Biotechnology in Animal Husbandry*, *29*(1), 45–51. http://doi.org/10.2298/BAH1301045K

Marais, S., Africa, S., Uk, R. M., Mustelin, J., Uk, P. W., & Germany, J. W. (2014). Final draft IPCC WGII AR5 Chapter 16, (October 2013), 1–79.

Matiri, F. M., Kiruiro, E. M., Ara, J. N. K., & Amboga, S. C. (2013). The contribution of crop residues and constraints to utilisation in dairy production : Case study of central Kenya. *African Crop Science Conference Proceedings*, *11*, 931–935.

Mawa, I.L, Kavoi, M.M, Baltenweck, I, Poole, J. (2014). Profit efficiency of dairy farmers in Kenya: An application to smallholder farmers in Rift Valley and Central Province. *Journal of Development and Agricultural Economics*, *6*(11), 455–465. http://doi.org/10.5897/JDAE2014.0561

Mclaws, M., & Rushton, J. (2016). Foot-and-Mouth Disease Impact on Smallholders - What Do We Know , What Don ' t We Know and How Can We Find Out More ?, 1–15. http://doi.org/10.1111/tbed.12507

McManus. C, Prescott. E, Paludo. G.R, Bianchini. E, Louvandini. E.H, M. A. . (2009). Heat tolerance in naturalized Brazilian cattle. *Livestock Science*, *120*(April 2016), 256–264. http://doi.org/10.1016/j.livsci.2008.07.014

Mcmanus, C., & Paludo, G. R. (2009). Heat tolerance in Brazilian sheep : Physiological and blood parameters. *Tropical Animal Health and Production*, *41*, 95–101. http://doi.org/10.1007/s11250-008-9162-1

Mcsweeney, C., New, M., & Lizcano, G. (2010). *UNDP Climate Change Country Profiles: Kenya*.

Meena, H., Singh, S. K., Kolekar, D. V, & Singh Y.P. (2012). Climate Change Impacts on Livestock and Adaptation Strategies to Sustain Livestock Production Climate Change Impacts on Livestock and Adaptation Strategies to Sustain Livestock Production. *Journal of Veterinary Advances*, *2*(7), 407–412.

Ministry of Livestock Development (MoLD). (2010). *Development of a Workable Disease Control Strategy in Cattle*.

Moran, J. (2012). Environmental management. In *Managing High Grade Dairy cows in the tropics* (pp. 131–141). Csiro Publishing.

Muasya, T., Peters, K. J., & Kahi, A. K. (2013). Breeding structure and genetic variability of the Holstein Friesian dairy cattle population in Breeding structure and genetic variability of the Holstein Friesian dairy cattle population in Kenya. *Animal Genetic Resources*, (June). http://doi.org/10.1017/S2078633613000039

Murage, A. W., & Ilatsia, E. D. (2011). Factors that determine use of breeding services by smallholder dairy farmers in Central Kenya. *Tropical Animal Health and Production*, *43*(1), 199–207. http://doi.org/10.1007/s11250-010-9674-3

Mureithi, D., & Mukiria, E. W. (2015). An Assessment of Tick-Borne Diseases Constraints to Livestock Production in a Smallholder Livestock Production System : a Case of Njiru District , Kenya. *International Journal of Research in Agriculture and Forestry*, *2*(10), 43–49.

Musalia, L. M., Wangia, S. M. M., Shivairo, R. S., Okutu, P., & Vugutsa, V. (2007). Dairy production practices among smallholder dairy farmers in Butere/Mumias and Kakamega districts in Western Kenya. *Tropical Animal Health and Production*, *39*(3), 199–205. http://doi.org/10.1007/s11250-007-9011-7

Musari, A., Adewale, A., & Olonade, K. (2014). Determination of heat stress in North- West Region of Nigeria. *Research Journal in Engineering and Applied Sciences*, *3*(4), 232–238.

Musau, J., Sang, J., Gathenya, J., & Luedeling, E. (2015). Hydrological responses to climate change in Mt. Elgon watersheds. *Journal of Hydrology: Regional Studies*, *3*, 233–246. http://doi.org/10.1016/j.ejrh.2014.12.001

Ngeno, K., Omasaki, S. K., & Bebe, B. O. (2014). Assessment of the Vulnerability and Adaptation Strategies to Climate Variability and Change of the Bos taurus Dairy Genotypes under Diverse Production Environments in Kenya Assessment of the Vulnerability and Adaptation Strategies to Climate Variability a. *Journal of Animal Production Advances*, *3*(7), 186–196. http://doi.org/10.5455/jva.20130717125129.Online

Ngigi, M. (2004). Successes in African Agriculture : The Case of Smallholder Dairying in Eastern Africa. Conference Paper No.16. Paper presented at the NEPAD/IGAD regional conference. Nairobi, Kenya

Ogalleh, S. A., Vogl, C. R., Eitzinger, J., & Hauser, M. (2012). Local Perceptions and Responses to Climate Change and Variability: The Case of Laikipia District, Kenya. *Sustainability*, *4*, 3302–3325. http://doi.org/10.3390/su4123302

Omondi, W., & Njehia, B. (2014). Herd Characteristics on Smallholder Dairy Farms in Western Kenya. *Journal of Animal Science Advances*, *4*(8), 996. http://doi.org/10.5455/jasa.20140827111904

Pangestu, M., Subagyo, Y., & Rustomo, B. (2000). Heat Tolerance and Productivity of Local and Imported Holstein-Friesian Cows in Indonesia. *Asian Australasian Journal of Animal Sciences* 13, (July), 505–508.

Pereira, A. M. F., & Jr, F. B. (2008). Effect of thermal stress on physiological parameters , feed intake and plasma thyroid hormones concentration in Alentejana , Mertolenga , Frisian and Limousine cattle breeds, 199–208. http://doi.org/10.1007/s00484-007-0111-x

Ramírez-Villegas, J., Lau, C., Köhler, A.-K., Signer, J., Jarvis, A., Arnell, N., … Hooker, J. (2011). *Climate Analogues: Finding tomorrow's agriculture today* (No. Working Paper no. 12). Cali, Colombia. Retrieved from www.ccafs.cgiar.org

Roland, L., Drillich, M., & Iwersen, M. (2014). Hematology as a diagnostic tool in bovine medicine. *Journal of Veterinary Diagnostic Investigation*, *26*(5), 592–598. http://doi.org/10.1177/1040638714546490

Salem, M. Ben, & Bouraoui, R. (2009). Heat Stress in Tunisia : Effects on dairy cows and potential means of alleviating it. *South African Journal of Animal Science*, *39*(Supplement 1), 256–259.

Suklerd, S., Katawatin, S., Duangjinda, M., & Roytrakul, S. (2015). 763 Pattern of Hsp72and Hsp73 expression, and physiological responses in the cattle with different thermo-tolerant capacity. *Khon Kaen Agriculture Journal*, *43*(4), 763–772.

Thorpe, W., Muriuki, H. G., Omore, A., Owango, M. O., & Staal, S. (2000). Dairy development in Kenya: the past, the present and the future. *Animal Production Society of Kenya KARI Naivasha*.

*The Merck Veterinary Manual*. (2013). New Jersey, USA: Merck Sharp & Dohme Corp.

Van, C. G., Retea, C., & Motorga, V. (2010). Changes in the Hematological Profile of Holstein Primiparous in Periparturient Period and in Early to Mid Lactation. *Animal Sciences and Biotechnologies*, *43*(2), 244–246.

Wambugu, C., Franzel, S., & Rioux, J. (2014). Options for Climate-Smart Agriculture at Kaptumo Site in Kenya. *Working Paper*, *No.185*(World Agroforestry Centre,Nairobi). http://doi.org/http://dx.doi.org/10.5716/WP14394.PDF Titles

Washington, R., & Pearce, H. (2012). Climate Change in East African Agriculture: Recent Trends, Current Projections, Crop-climate Suitability, and Prospects for Improved Climate Model Information, (February). Retrieved from http://ccafs.cgiar.org/resources/tools-maps-models-and-data/testing-climate-models-agricultural-impacts

World Meteorological Organization. (2012). *Guide to Agricultural Meteorological Practices*. Geneva, Sitzerland: World Meteorological Organisations, Geneva, Switzerland.

# APPENDICES

## Appendix 1: Questionnaire for data collection

**EGERTON UNIVERSITY**
**FACULTY OF AGRICULTURE**
**DEPARTMENT OF ANIMAL SCIENCES**

**QUESTIONAIRE FOR THE RESEARCH ON APPLYING CLIMATE ANALOGUE CONCEPT IN IDENTIFYING ADAPTATION OPTIONS FOR FRIESIAN CATTLE UTILIZATION IN SMALLHOLDER SYSTEMS EXPERIENCING CHANGING CLIMATE**

**Introduction**

This survey is conducted by a post graduate student of Egerton University in the Department of Animal Sciences in the partial fulfillment for a Master's of Science Degree in Livestock Production Systems. The information provided will be used for academic work only and will be treated with ultimate confidentiality.

**GENERAL INFORMATION**

**Date of survey: __________ Time started: _________Study site: [_ _] RS, [_ _] PA, [_ _] FA**

Name of the enumerator: ____________________ Questionnaire Code: ______ HHID: _______

Sub County: ____________________ Ward: ___________________ Village: _________________

GPS Coordinates:

Longitude [_ _] (1= North, 2= South): ____ºDEG1____ ''MIN1 ____ SEC1

Latitude (East): ____ºDEG2____ ''MIN2 ____ SEC2

## 1. HOUSEHOLD CHARACTERISTICS

| | | |
|---|---|---|
| **1.1.** Name of the Respondent | | |
| **1.2.** Name of the HHH | | |
| **1.3.** Sex of the HHH | [ ] | 1= Male, 2= Female |
| **1.4.** Relationship of the Respondent to HHH | [ ] | 1= HHH, 2=Spouse, 3= Child, 4= Grandchild, 5= In-law, 6=Employee, 7=Neighbor |
| **1.5.** Education level of the HHH | [ ] | 1= None, 2= Primary, 3= Secondary, 4= Tertiary |
| **1.6.** HH main occupation | [ ] | 1= crop farming, 2= Livestock farming, 3= Mixed crop-livestock framing, 3= Salaried employment, 4= self employment, 5= Farm laborer in other farms, 6= Others (Specify) |

## 2. FARM CHARACTERISTICS

2.1 How many parcels of land are owned by the Household? [ ]

Provide the following information about each land parcel that the household uses.

| | **Land 1 (*Where the homestead is located*)** | **Other parcels of land** | |
|---|---|---|---|
| **2.2.** Size in Acres | [_____] | [_____] | [_____] |
| How is the land owned allocated to different land uses (Specify in acres) | | | |
| i. Homestead (includes houses, livestock sheds etc) | [_____] | | |
| ii. Subsistence crop production | [_____] | [_____] | [_____] |
| iii. Commercial crop production | [_____] | [_____] | [_____] |
| iv. Improved pastures | [_____] | [_____] | [_____] |
| v. Natural pastures | [_____] | [_____] | [_____] |
| vi. Woodlot | [_____] | [_____] | [_____] |
| vii. Fish ponds | [_____] | [_____] | [_____] |
| iii. Un usable land | [_____] | [_____] | [_____] |

## 3. ANIMAL CHARACTERISTICS

**3.1.** What is the main system of keeping cattle in your farm? [____]
1= Zero grazing, 2= Semi zero grazing, 3=Free grazing

**3.2.** In order of importance, list the three most important **livestock species**currently kept in your farm and the reasons for each species.

| **Rank** | **Livestock species** | **Reasons** | | |
|---|---|---|---|---|
| | | **1** | **2** | **3** |
| **1.** | | | | |
| **2.** | | | | |
| **3.** | | | | |

**3.3.** In order of importance, list the three most important **cattle breedscurrently**kept in your farm, number of years kept and the reasons for each breed

| **Rank** | **Cattle breed** | **Number of years kept** | **Reasons** | | |
|---|---|---|---|---|---|
| | | | **1** | **2** | **3** |
| **1.** | [____] | [____] | | | |
| **2.** | [____] | [____] | | | |
| **3.** | [____] | [____] | | | |

**BREEDS CODE**

1= Friesian 2= Local Zebu, 3= Aryshire, 4= Guernsey, 5= Jersey, 6=Others (Specify) ______________

**3.4.** Are these the same cattle breeds you kept FIVE years ago? [____]
1= Yes, 2= No

**3.5.** If the answer to question 3.4 is No. Give the reasons for changing the cattle breed

| | | | |
|---|---|---|---|
| **Cattle Breed Changed from** | [____] | [____] | [____] |
| **Reasons** | [____][____][____] | [____][____][____] | [____][____][____] |

## 4. PRODUCTION PERFORMANCE AND TRENDS

**4.1.** Indicate the average peak and low cattle **MILK PRODUCTION** in liters during the wet and dry seasons over the past five years.

| Cattle | Breed (CODE) | Parity | Wet Season | | Dry Season | |
|---|---|---|---|---|---|---|
| | | | Peak | Low | Peak | Low |
| 1. | [____] | [____] | [____] | [____] | [____] | [____] |
| 2. | [____] | [____] | [____] | [____] | [____] | [____] |
| 3. | [____] | [____] | [____] | [____] | [____] | [____] |

**4.2.** Indicate the observed **TRENDS** in peak and low milk production per season over the past five years per breed

| Breed (CODE) | Wet Season | | Dry Season | |
|---|---|---|---|---|
| | Trend | | Trend | |
| | Peak | Low | Peak | Low |
| [____] | [____] | [____] | [____] | [____] |
| [____] | [____] | [____] | [____] | [____] |
| [____] | [____] | [____] | [____] | [____] |

**Trends:** 1= Increase, 2= Decrease, 3= No Observable change

**4.3.** According to your opinion, what could have led to the observed **TRENDS** in milk yield per season and breeds

| Breed (CODE) | Wet Season | | | Dry Season | | |
|---|---|---|---|---|---|---|
| | Reasons | | | Reasons | | |
| | 1 | 2 | 3 | 1 | 2 | 3 |
| [____] | | | | | | |
| [____] | | | | | | |
| [____] | | | | | | |

**4.4.** Indicate estimated **MILK USE** in the farm during wet and dry seasons

| Cattle breed | No of cows milked | Season | Average milk yield (litres)/ Day | Lactation duration (Months) | Amount | | | Where sold | Price per litter |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Consumed at home | Sold | Spoilage | | |
| [____] | [____] | Dry | [____] | [____] | [____] | [____] | [____] | [____] | [____] |
| [____] | [____] | | [____] | [____] | [____] | [____] | [____] | [____] | [____] |
| [____] | [____] | | [____] | [____] | [____] | [____] | [____] | [____] | [____] |
| [____] | [____] | Wet | [____] | [____] | [____] | [____] | [____] | [____] | [____] |
| [____] | [____] | | [____] | [____] | [____] | [____] | [____] | [____] | [____] |
| [____] | [____] | | [____] | [____] | [____] | [____] | [____] | [____] | [____] |

## 5. REPRODUCTIVE PERFORMANCE OF DAIRY CATTLE IN THE FARM

**5.1.** What are the observed repeat rates per season in cattle breeds currently kept in your farm?

0= No repeats, 1= Once, 2= Twice, 3= Thrice, 4= More than three times

| Cattle Breed | Repeat rates | |
|---|---|---|
| | Wet seasons | Dry seasons |
| [____] | [____] | [____] |
| [____] | [____] | [____] |
| [____] | [____] | [____] |

**5.2.** What are the calving rates for dairy cattle in your farm per year?

| | | | |
|---|---|---|---|
| **Cattle Breeds** | [____] | [____] | [____] |
| **Calving Rates** | [____] | [____] | [____] |

**5.3.** Have you observed reproductive disorders or diseases in your farm? [____]

1= Yes, 2= No

**5.4.** If Yes, rate the susceptibility of cattle breeds in your farm to observed reproductive diseases and disorders

1= Most Susceptible, 2= averagely susceptible, 3= least susceptible, 4= Never susceptible

| | | | |
|---|---|---|---|
| **Cattle Breeds** | [____] | [____] | [____] |
| **Susceptibility** | [____] | [____] | [____] |

**5.5.** In order of importance, indicate the reproductive diseases and disorders per breed and per season observed in your farm in the past five years.

| Cattle Breed | Wet season | | Dry season | |
|---|---|---|---|---|
| | Diseases | Disorders | Diseases | Disorders |
| [____] | [____][____][____] | [____][____][____] | [____][____][____] | [____][____][____] |
| [____] | [____][____][____] | [____][____][____] | [____][____][____] | [____][____][____] |
| [____] | [____][____][____] | [____][____][____] | [____][____][____] | [____][____][____] |

**5.6.** How do you respond to the observed reproductive diseases and disorders? [____][____][____]

1= Consult private animal health professional, 2= Consult government animal health professional, 3= Consult a friend/ neighbor/ relatives, 4= Own treatment, 5= Consult in agrovets/ veterinary pharmacy

## 6. CLIMATE RELATED DISEASES, INCIDENCES AND TRENDS

**6.1.** Other than the stated reproductive diseases and disorders, have you observed new diseases that were not present about five years ago that can be associated with climate change? [____]

1= Yes, 2=No

**6.2.** If **Yes,** indicate the disease, cattle breeds susceptibility, number of incidences in the last 5 years and trends in disease prevalence.

| Cattle Breed | Disease 1 | | | Disease 2 | | | Disease 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Susceptibility | Incidences | Trend | Susceptibility | Incidences | Trend | Susceptibility | Incidences | Trend |
| [____] | [____] | [____] | [____] | [____] | [____] | [____] | [____] | [____] | [____] |
| [____] | [____] | [____] | [____] | [____] | [____] | [____] | [____] | [____] | [____] |
| [____] | [____] | [____] | [____] | [____] | [____] | [____] | [____] | [____] | [____] |

## 7. CLIMATE SMART LIVESTOCK MANAGEMENT PRACTICES

**7.1.** Are you aware of climate change and variability? [____]

1=Yes, 2=No

**7.2.** If yes, what are the indicators of climate change and variability?
1[____], 2[____], 3[____], 4[____], 5[____]

**7.3.** What are the observed changes due to climate change and variability?
1[____], 2[____], 3[____], 4[____], 5[____]

**7.4.** In response to climate change and variability, indicate livestock management practices that you've been practicing in your farm during the wet and dry seasons (list at least five)

| **Management Objectives** | **CSL practices** | **Season** | |
|---|---|---|---|
| | | **Wet** | **Dry** |
| **Feeds production practices** | | | |
| Pasture types utilized in your farm | 1= Natural Pastures, 2= Improved pastures | [__] | [__] |
| Main sources of feeds in the farm | 1=On farm, 2= Off farm, 3= Both | [__] | [__] |
| **i. Pastures management practices** | | | |
| Pasture area used over time | 1= Increase, 2= Decrease, 3= No change | | |
| Considerations in Pastures establishment | Improved and certified pastures seeds | [__] | [__] |
| | Short cycle pastures | [__] | [__] |
| | Drought resistant | [__] | [__] |
| | Disease resistant | [__] | [__] |
| Land management in pasture establishment | Use of herbicides | [__] | [__] |
| | Zero tillage system | [__] | [__] |
| | Shift cultivation | [__] | [__] |
| | Rotation cultivation | [__] | [__] |
| | Mixed grass and legumes establishment | [__] | [__] |
| Pastures management | Chemical fertilizers application | [__] | [__] |
| | Organic manures application | [__] | [__] |
| | Restricted irrigation | [__] | [__] |
| | Predetermined cutting regimes | [__] | [__] |
| Pastures conservation | Conservation by hay making | [__] | [__] |
| | Conservation by ensiling | [__] | [__] |
| Hay making technologies | stacks, | [__] | [__] |
| | bales, | [__] | [__] |
| | loose hay | [__] | [__] |
| Silage making technology | Tubes, | [__] | [__] |
| | Tanks | [__] | [__] |
| | Bunker | [__] | [__] |
| | Excavated silos | [__] | [__] |
| | above ground silos | [__] | [__] |
| **ii. Grazing management** | | | |
| Adjusting grazing pressure | 1= Increase cattle number, 2= decrease cattle number, 3= No change in animal number | [__] | [__] |
| Grazing control and management | Rotation grazing | [__] | [__] |
| | Setting aside | [__] | [__] |
| | Postpone grazing | [__] | [__] |
| | Continuous grazing | [__] | [__] |
| **iii. Feeding practices** | | | |
| Feeding criteria | 1= Weight based, 2= production based, 3= Ad lib, 4= Age based | [__] | [__] |

| | | | |
|---|---|---|---|
| Feeding method | 1= Stall feeding, 2=entire grazing, 3= regulated stall and grazing | [__] | [__] |
| If entirely grazing, is there supplementation | 1= yes, 2= no | [__] | [__] |
| Supplementation provided | 1= minerals and vitamins, 2= concentrates, 3= Forages | [__] | [__] |
| If stall feeding, common feedstuffs used | Fodder Grass (Specify spp) _______________ | [__] | [__] |
| | Fodder Legumes (Specify spp) _____________ | [__] | [__] |
| | Crop residues (Specify spp) _______________ | [__] | [__] |
| | Agro- industry byproducts (Specify) ____ | [__] | [__] |
| | Fodder trees (Specify spp) _________________ | [__] | [__] |
| Feed processing practices | Chopping | [__] | [__] |
| | Milling | [__] | [__] |
| | Grinding | [__] | [__] |
| | Pelleting | [__] | [__] |
| | Mixing into TMR | [__] | [__] |
| Feeds quality improvement practices | Soaking crop residues in water + salt | [__] | [__] |
| | Soaking crop residues in water + urea | [__] | [__] |
| | Use of molasses/ and urea | [__] | [__] |
| | Use of additives | [__] | [__] |
| Additives used | Ionophores | [__] | [__] |
| | Probiotics (Yeast, bacteria) | [__] | [__] |
| | Essential oils | [__] | [__] |
| | Enzymes | [__] | [__] |
| | Hormones | [__] | [__] |
| **iv. Water use and management practices** | | | |
| Sources of water | Piped, | [__] | [__] |
| | River | [__] | [__] |
| | Well | [__] | [__] |
| | Water pan | [__] | [__] |
| | Roof harvested, | [__] | [__] |
| | Purchase, | [__] | [__] |
| | Others | [__] | [__] |
| Water use | Drinking | [__] | [__] |
| | Service | [__] | [__] |
| | Cooling | [__] | [__] |
| | Pasture irrigation | [__] | [__] |
| Cattle Watering Frequency | 1=Ad lib, 2= Thrice, 3= Twice, 5= Once, 6= Less than once a day | [__] | [__] |
| Water use management | Metered use (Paid) | [__] | [__] |
| | Night irrigation | [__] | [__] |
| | Drip irrigation | [__] | [__] |
| | Timed animal watering | [__] | [__] |
| | Integrated water recycle | [__] | [__] |
| **v. Breeding practices** | | | |
| Breeding tools | A.I | [__] | [__] |
| | MOET | [__] | [__] |
| | Natural mating | [__] | [__] |

| | | | |
|---|---|---|---|
| Selection criteria | Heat tolerance | [__] | [__] |
| | Disease Tolerance | [__] | [__] |
| | Milk yield | [__] | [__] |
| | Milk quality | [__] | [__] |
| | Longevity | [__] | [__] |
| | Fertility | [__] | [__] |
| | Coat color | [__] | [__] |
| | Docility | [__] | [__] |
| | Others (Specify) | [__] | [__] |
| **vi. Animal health management practices** | | | |
| Sources of animal health services | Government practitioners | [__] | [__] |
| | Private practitioner, | [__] | [__] |
| | Agrovets attendants | [__] | [__] |
| | Do it self, | [__] | [__] |
| | CBO/NGO practitioners | [__] | [__] |
| | Others | [__] | [__] |
| Diseases control strategies | Vaccinations | [__] | [__] |
| | On farm quarantines | [__] | [__] |
| | Rotation grazing | [__] | [__] |
| | Priority grazing | [__] | [__] |
| | Animal's Cleanliness | [__] | [__] |
| | Worker's cleanliness | [__] | [__] |
| | Others (Specify) | [__] | [__] |
| **vii. Waste management practices** | | | |
| Manure management and utilization | Biogas | [__] | [__] |
| | Compost | [__] | [__] |
| | Fish pond fertilization | [__] | [__] |
| | Heap covering | [__] | [__] |
| | Direct farm use | [__] | [__] |
| | Others (Specify) | [__] | [__] |
| **viii. Other practices** | | | |
| Reducing exposure to climate related risks in you cattle rearing | Early weather warning, | [__] | [__] |
| | Weather indexed livestock insurance | [__] | [__] |
| | Others | [__] | [__] |
| Diversification to climate resilient systems | 1= switching production objectives, 2=changing farm products proportion (specify) | [__] | [__] |
| **ix. Cow shed** | | | |
| Floor | 1= Earthen, 2= Wire, 3= Concrete, 4= timber | [__] | [__] |
| Wall | 1= Earthen, 2= Wire, 3= Concrete, 4= timber, 5= None | [__] | [__] |
| Roof | 1= Iron sheets, 2= Grass thatch, 3= Polythene lining, 4= None | [__] | [__] |
| **x. Sources of information** | | | |
| Common sources of information | Traditional/ Indigenous knowledge | [__] | [__] |
| | Radio | [__] | [__] |
| | Television | [__] | [__] |
| | Directly from meteorological department | [__] | [__] |
| | Other farmers | [__] | [__] |

| | | | |
|---|---|---|---|
| | Government extension Agents | [__] | [__] |
| | Private extension agents | [__] | [__] |
| | NGOs/ FBOs/ CBOs | [__] | [__] |
| | Internet | [__] | [__] |
| Membership to agricultural groups | 1=Yes, 2=No | [__] | [__] |
| Agricultural group | Producer groups | [__] | [__] |
| | Cooperative/ Society- Marketing | [__] | [__] |
| | Processing | [__] | [__] |
| | Environmental management group | [__] | [__] |

## Appendix 2: publications and conference presentations

a. Published manuscripts

**Wangui, J.C.,** Bebe, B.O., Ondiek, J.O., & Oseni, S.O. (2018). Application of climate analogue concept in assessing likely physiological and hematological responses of Friesian cattle to changing and variable climate in the Kenya Highlands. Paper accepted for publishing (23-02-2018) by South African Journal of Animal Sciences.

b. Conference presentation

**Wangui, J.C.,** Bebe, B.O., Ondiek, J.O., & Oseni, S.O. (2017). Applying climate analogue concept to assess adaption of Friesian cattle breed to changing and variable climate in the Kenya highlands. African Climate Change Fellowship Program Culmination conference for the ACCFP-III, January 30- 31, 2017. Dar es Salaam,Tanzania.

**Wangui, J.C.,** Bebe, B.O., Ondiek, J.O., & Oseni, S.O. (2016). A look into future of Friesian cattle utilization in smallholder systems in Kenya highlands: Application of climate analogue concept. Animal Production Society of Kenya (APSK) Scientific Symposium, April 27-29, 2016. Kisumu Hotel, Kisumu, Kenya.

c. Poster presentation

**Wangui, J.C.,** Bebe, B.O., Ondiek, J.O., & Oseni, S.O. (2016). Physiological Responses of Friesian Cattle Breed Under Varying Thermal Stress Conditions in Kenya. 1st World Congress on Innovations for Livestock Development, June 26– 30, 2016. Sentrim Elementaita Lodge, Nakuru, Kenya.