EFFECTS OF PERCEIVED CLIMATE VARIABILITY ON PROVISIONING ECOSYSTEM SERVICES AMONG AGRO-PASTORAL SYSTEMS OF LAIKIPIA WEST SUB-COUNTY, KENYA

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DECLARATION AND RECOMMENDATION

Declaration

I hereby do declare that this research thesis is my original work and to the best of my knowledge, has not, wholly or in part, been submitted for an award of a Master's degree in any other institution.

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Recommendation

This thesis has been submitted with our approval as University supervisors.

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DEDICATION

I dedicate this thesis to my children Trisha and Natasha as well as my parents, Mr. Elijah Mong'oina and Mrs. Isabella Kerubo who educated me and taught me that even the largest task can be accomplished if it is done one step at a time.

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ABSTRACT

The impact of climate variability on societies around the world is increasingly evident. A vast majority of communities in Eastern Africa depend on agro-pastoralism for their livelihoods, however climate variability threatens a vast majority of these communities. Kenya is one of the most vulnerable countries and economic sectors and livelihoods frequently experience the manifestations of the problem. Climate variability therefore, affects provision of ecosystem services, especially those depended on by agro-pastoral farmers in Laikipia West sub-County, Kenya. This study determined the effects of perceived climate variability on provisioning ecosystem services (food supply/crop yield, livestock production and water availability) and response strategies employed by agro-pastoral farmers to mitigate risks in semi-arid Laikipia West sub-County. Both quantitative and qualitative data were collected through a combination of methods including: systematic quadrat sampling, key informant interviews and structured questionnaires. The study used multistage stratified sampling to select respondents and study sites; purposive sampling to select the study divisions and proportionate random sampling to select household respondents from each of the selected divisions. Four hundred agro-pastoral farmer households were selected through stratified random sampling. Statistical Package for Social Scientists (SPSS) was used for data analysis. To make reliable inferences from the data, all statistical tests were verified at $\alpha = 0.05$ level of significance. Results from the study indicated that many agro-pastoral farmers perceived that, they were experiencing climate variability and this was reflected in decreased rainfall amounts (91.1%), extended dry spells (86.0%), increased pests and diseases (77.9%) as well as increased frequency of drought (61.9%). Crop yield had declined and water availability had increased due to construction of boreholes in Laikipia West sub-County. The response strategies mainly adopted were crop diversification (85.0%), use of fertilizers/manure (83.5%), alternative livelihood practices (66.5%), water harvesting (57.6%), short season crop practices (57.1%), keeping of browsers (47.0%) amongst others. However, irrigation (37.8%) and planting of drought tolerant crop varieties (42.9%) were still not well adopted and therefore need for their promotion. It was also found out that shrub species were more diverse than those of trees with a Simpson's diversity index of 1 and 0.87 respectively. Therefore, this study recommends stakeholders to initiate campaigns on the reality of climate change and its serious consequences on crop and livestock production. In addition, implementing adaptation measures at the national, county and farm levels, as well as putting in place policies that prevent destruction of the natural environment will assist to address the challenges posed by climate variability.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF PLATES

LIST OF TABLES

LIST OF ABBREVIATIONS AND ACRONYMS

ACTS	African Centre for Technology Studies
ASALs	Arid and Semi-Arid Lands
ATPS	African Technology Policy Studies Network.
CBS	Central Bureau of Statistics
CEPSA	Consortium for Ecosystem Services and Poverty Alleviation
COP	Conferences of Parties.
CIDP	County Integrated Development Plan
DF	Department Fund
EPA	Environmental Protection Agency
FAO	Food and Agriculture Organization of the United Nations
IIRR	International Institute of Rural Reconstruction
IPCC	Intergovernmental Panel on Climate Change
IPRA	International Public Relations Association
IRIN	Integrated Regional Information Network
IWGIA	International Work Group for Indigenous Affairs
KARI	Kenya Agricultural Research Institute
KNBS	Kenya National Bureau of Statistics
MDGs	Millennium Development Goals
MoLD	Ministry of Livestock Development
NCCRS	National Climate Change Response Strategy
NGOs	Non-Governmental Organizations
PFE	Pastoral Forum Ethiopia
SPSS	Statistical Package for Social Scientists
SSA	Sub Saharan Africa
TOR	Terms of Reference
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFAO	United Nations Food and Agriculture Organization
UNFCCC	United Nations Framework Convention on Climate Change
URT	United Republic of Tanzania
WRI	World Resources Institute

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Climate variability and change is one of the biggest issues facing the world today (IPCC, 2014). The impacts of climate change are prominent worldwide (Oppenheimer *et al.*, 2014), especially in drylands, where its adverse effects are exacerbated by high rainfall variability (Kgosikoma & Batisane, 2014) coupled with high temperatures. Agriculture is the main economic activity that supports the livelihoods of millions of people in Africa. However, key challenges have emerged in the agricultural sector, climate variability being the most important. Drought in Africa affect about 220 million people every year and it is projected that by 2020, yields from rain-fed crops could fall by 50 percent in some countries; while net revenues loss from crops could fall by 90 percent **(**Huho & Kosonei, 2013**)**. The rampant food crisis that has been recently experienced in most sub -Saharan Africa countries are reminders of the continuing vulnerability of the region to the impacts of climate variability. This has been largely attributed to weak institutional capacity, limited engagement in environmental and adaptation issues, and a lack of validation of local knowledge (Adepoju & Obayelu, 2013). Climate variability has the potential to affect development activities in Africa and can hinder the achievement of the Sustainable Development Goal (SDG) no. 13, which focuses on enhancing the resilience of climate change. According to IPCC 5th assessment report, serious impacts are being felt by the poorest people majority of whom are marginalized and living developing countries (IPCC, 2014). This has led to most of the population becoming vulnerable to effects of climate variability, which has negative effects on agricultural productivity, thus the need for farmers to devise adaptation measures (Omoyo *et al.*, 2015). Africa's population is projected to double by 2050, and globally food production will need to double in order to meet the needs of increasing urban populations. Urbanization is occurring rapidly in Sub-Saharan Africa (SSA), but large rural populations are projected for at least another generation (Lamboll *et al.,* 2011). In SSA, greater areas of land are typically under range lands and are marginal for agriculture. Such areas are increasingly unable to support rainfed agriculture, due to challenges posed by climate variability and increasing population. Climate variability is perceived as being the greatest threat to agricultural production and food security in sub-Saharan countries, it is emerging as a major threat on agriculture, food security and livelihood of millions of people in many places of the world (IPCC, 2014). Agro-pastoralists in most of the sub-Saharan countries have been affected by climate variability. This is caused by a combination of factors, which include widespread poverty, dependence on natural resources, over-dependence on rain-fed agriculture, conflicts and negligence from the government (Atinkut & Mebrat, 2016).

The arid and semiarid lands (ASALs) require special attention, if Kenya is to achieve sustainable economic development. The ASALs cover more than 80% of the country’s land mass and support about 70% of the national livestock population, valued at an estimated Kshs 70 billion (World Bank, 2010). ASALs are largely used for agro-pastoralism, extensive livestock production and wildlife. The economic impact of these climate change threats to the country is enormous. In the ASALs, there is widespread livestock and crop production risks due to climate variability. In many dry regions, most agricultural households are pastoralists or agro-pastoralists who struggle to cope with current climate variability. The vulnerability of agro-pastoral and pastoral communities to climate change is higher due to the synergic effect of inadequate health services, inadequate infrastructure, poverty, lack of alternative means of income, inadequate public awareness of disease risks and illiteracy (Chinasho *et al.*, 2017). These areas have naturally high reliance on climate-sensitive activities coupled by marginalization, regular food crises and water scarcity, rapid population growth and limited economic and institutional capacity to cope with climate variability (Diallo *et al.*, 2014).

Climate variability has come with a variety of changes in rainfall levels and distribution wind speeds, extreme weather events like droughts and floods (Van Dorland *et al.*, 2011), and emerging pests and diseases (African Technology Policy Studies Network [ATPS], 2013). Mitigating and adapting to climate variability requires collective action of different stakeholders to address the situation. Research shows that a variety of climate variability adaptation forms (operational, technical, and financial) have been taken by diverse stakeholders (farmers, climate variability agencies and organizations, and governments) at local, regional and international levels (Paradhan *et al.*, 2015). These stakeholders have recognized the important role of agriculture in contribution to, and mitigation of climate variability. The concerns are on impacts and adaptations of climate variability on agricultural production and water availability because globally agriculture and water availability are strongly influenced by weather and climate. Climate variability is expected to impact on agriculture, potentially threatening established aspects of farming systems (Clark *et al.*, 2010). Climate variability will result in fundamental alterations to ecosystem structures and functions (Melese *et al.*, 2013).

Response is an urgent priority for farm households, to reduce the negative effects of climate variability because the livelihoods of many low-income households are likely, to suffer from declining food production (Ng'ang'a *et al.,* 2016). Diverse methods of mitigation have been adopted by pastoralists and agro-pastoralists including grazing management practices. Feed availability and seasonal fluctuations influence the appropriate method of response, which has an implication on the kind of property rights that can be attached to the resources (Beyene, 2016). Agro-pastoral farmers have diverse agricultural practices which include use of organic forestry (ATPS, 2013), use of local seeds which they believe are better adapted than exotic seeds, crop diversification, minimum tillage, mulching, collecting water in ponds and earth dams for irrigation, and changing their planting times based on rainfall forecasts (Paradhan *et al.,* 2015). However, agro-pastoral farmers are reactive dealing with short term challenges rather than being proactive to handle long term problems. This reactive behavior can be due to lack of information access and low understanding of mitigation and adaptation options. The ability of rural farmers to manage common systemic risks in the presence of more complex risks associated with climate variability definitely needs attention. In highly variable climates where any season can bring harsh conditions, farmers are generally reluctant to invest in more profitable technologies and practices (Hansen *et al*., 2015). This lack of investment, combined with climate variability leading to unpredictable yields, is a major factor in keeping farmers trapped in poverty.

High population growth rate in Laikipia has caused negative effects on the socio-economic development and aggravated the poverty situation in the county. Increased pressure on available resources has often degenerated into conflicts between the agro-pastoral and pastoral community, large-scale ranching enterprises, smallholder farmers and wildlife. Low productivity due to small land holdings coupled with increased occurrence of droughts and extreme weather events has increased the severity of crop failure and land degradation. This has had a larger negative impact on the livelihoods of many local communities in the county (Laikipia CIDP, 2013).

Pastoral and agro-pastoral systems occupy about 40% of Africa's land mass with significant variations among countries. In Kenya, agro-pastoral and pastoral lands occupy over 84% of the country's land area, hosting approximately 10 million people and 70% of the national livestock population (FAO, 2009). Kenya's ASAL support over 25% of the total human population and are mainly suited to extensive livestock production. However, climate change now threatens to eradicate the country's rich biodiversity (GoK, 2010).

Laikipia is one of the 47 counties in Kenya. It is a multi-ethnic tribal County which agro-pastoral and pastoral communities share with ranchers, farmers, horticulturalists and wildlife conservation areas (Laikipia CIDP, 2013). It includes extensive semi-arid lands as well as arable and urban areas. Pressures on water and land resources have increased greatly in recent years, with increased farming activities, rapid population growth, and periodic drought as well as climate variability (Laikipia CIDP, 2018).

Agro-pastoralism in Laikipia is a production system based on crop production and livestock (cattle, sheep, goats, donkeys and camels) rearing that is characterized by mobility in an ecologically fragile environment, high degree of flexibility and variability. It is managed through social organization based on traditionally authorized structures which is either territorial or clan in its jurisdiction (Laikipia CIDP, 2013). The key issues in its management are natural resources, and other political, social and economic issues associated with it. Livestock represent the major stores of wealth that utilize mobilized environment characterized by highly variable water resources and transient forage through mobility. In recent years mobility has been challenged as a result of land sedentarization and sub division (Laikipia CIDP, 2018). Even so, there is information sharing by different actors through early warning system, while meteorological department strives to provide sub county specific observatory information to farmers (MoALF, 2017).

Agro-pastoralism helps in circumventing natural resource degradation trends and poverty. However, over the past three decades agro-pastoral farmers have been faced with enormous problems as a result of extremes of climate variability and land use change. This has posed serious challenges to the provisioning ecosystem services (food supply/crop yield, agro-biodiversity maintenance and water availability) as which affect sustainability and subsequent viability. The threat that climate variability poses to these sectors, has necessitated the assessment of the potential impacts of climate at various scales in these sectors in order to reduce vulnerability and secure livelihoods of those who depend on them (Chipanshi *et al.*, 2003). Therefore, need to strengthen the response strategies or mechanisms of the agro-pastoral farmers.

1.2 Statement of the Problem

Over the years, farmers in Laikipia County's agro-pastoral systems have faced changes in the climatic environment. Their agricultural activities are most vulnerable to climate variability phenomenon due to the fragile nature of the environment that has been exacerbated by encroachment by increasing human population and unsustainable land-use activities. Climate variability is one of the greatest challenges to having healthy ecosystems and their service provision in ASALs of Kenya. It is also clear that climate variability and increasing probability of extreme climatic events will pose new challenges to the resilience of agro-pastoral community livelihoods and agro-ecosystems in Laikipia West sub-County. Despite the expected balance provided by the ecosystem, combinations of factors - including climate variability and change have put constraint on provisioning ecosystem services. This has put a strain on the livelihood of the agro-pastoral farmers. In an effort to address the challenge posed by climate variability, development agencies including the Kenyan government are supporting climate change adaptation programmes. Very often though, these initiatives have focused on communities in ASALs – with a lesser focus on the ecosystem as whole. In addition, little is known about how the agro-pastoral farmers respond to the effects of climate variability and the effects of climate variability on food supply/crop yield, water availability and agro-biodiversity maintenance in Laikipia West sub-County. This study sought to fill these knowledge gaps among agro-pastoral farmers.

1.3 Objectives

1.3.1 Broad objectives

To contribute to sustainable livelihoods by understanding of the effects of perceived climate variability on provisioning ecosystem services and response mechanisms or strategies used by agro-pastoral farmers in Laikipia West sub- County.

1.3.2 Specific objectives

i) To determine household perceptions on climate variability in Laikipia West sub-County.
ii) To evaluate spatial agro-biodiversity of woody trees and shrubs at farm level in Laikipia West sub-County.
iii) To determine the effects of climate variability on food supply, livestock kept and water availability in Laikipia West sub-County.

iv) To examine the response strategies and or mechanisms currently used by agro-pastoral farmers to cope with effects of climatic variability in Laikipia West sub-County.

1.4 Research Questions

i) What were the household perceptions on climate variability trends in Laikipia West sub-County?
ii) What was the spatial agro-biodiversity of woody trees and shrubs at farm level in Laikipia West sub-County?
iii) What were the effects of climatic variability on food supply, livestock kept and water availability in Laikipia West sub-County?
iv) What were the response strategies and or mechanisms currently used by agro-pastoral farmers to cope with effects of climatic variability in Laikipia West sub-County?

1.5 Justification of the Study

The effects of climatic variability on food supply/crop yield, livestock kept and water availability as well as spatial agro-biodiversity of woody trees and shrubs in Laikipia West sub-County have not been identified and documented, for other agro-pastoral farmers to learn and adopt. The study will be significant to the agro-pastoral communities as it will improve their awareness on the effects of climate variability on provisioning ecosystem services (food supply/crop yield and water availability), their agro-pastoral resources and area. This study will assist in contributing to achievement of objectives of the Climate Change Act, 2016 by setting out actions for mainstreaming climate change responses into sector functions.

The result on response strategies and or mechanisms informs the Kenya drought management authority on options that can be applied in other arid and semi-arid regions of Kenya. This contributes to achieving Vision 2030 through building the resilience of many livelihoods and ecosystems in Kenya. This study contributes to the objectives of National Climate Change Response Strategy (NCCRS), specifically in assessing the impacts of climate change on both natural systems and key economic sectors (Republic of Kenya, 2010).

In line with the SDGs and also Vision 2030 economic pillar, climate variability is one among the three most transformational challenges facing developed countries. It is also one of the challenges which the world at large needs to place a strong emphasis for action so as to eradicate extreme poverty and hunger. The study also contributes towards realization of the Laikipia County Integrated Development plan as climate variability is one of the major concerns because its effects have been devastating to the County. The study is also be significant to policy makers as it identifies successful community level approaches of responding to climate variability among agro-pastoral farmers.

1.6 Scope and Limitation of the Study

Analysis of climate variability requires use of climate data notably, rainfall and temperature. In this study however, analysis of climate variability was limited to household perception. In Laikipia West Sub-County, there are pastoralists, crop farmers and agro-pastoralists but the study was limited to agro-pastoral farmers only who were either small-scale or large-scale holders. Similarly, quantification of the effect of climate variability on provisioning of ecosystem services would require use of secondary data such as water level, crop yield data, livestock production data, soil quality data among others. In this study, the effects of climate variability on provisioning of ecosystem services shall be limited to household perception and field-based observations. The study focused on households that are growing crops and keeping livestock (agro-pastoral farmers) in Laikipia West sub-County because majority of the inhabitants are agro-pastoral farmers. The study was also limited to provisioning ecosystem services i.e. water availability and food supply affected by climatic variability because human livelihoods depend on them for survival. In this study the agro-biodiversity covered: woody trees and shrubs, crops grown and livestock kept by the agro-pastoral farmers. Language barrier also was a problem. This challenge was overcome by using local extension staff in order to enhance the trust of respondents hence their willingness to respond. This also solved the problem of language barrier as the extension staff understood the local language.

1.7 Definition of terms

Agro-biodiversity: These are the trees, shrubs and crops grown as well as livestock kept.

Agro-pastoral System: This is a production system that involves both the growing of crops and rearing of livestock.

Agro-pastoralist: These are settled pastoralists who cultivate sufficient areas to feed their families from their own crop production.

Agro-pastoral farmer: Is a farmer practicing both crop farming and livestock rearing.

Climate variability: refers to time scales ranging from months to decades, falling between the extremes of daily weather and the long-term trends associated with climate change.

Ecosystem Services: Are the functions of ecosystems including agro-ecosystems that are useful for human well-being. They are therefore the benefits people obtain from ecosystems.

Perceived climate variability: What the households regard or interpret as climate variability.

Provisioning ecosystem services: Are the benefits people obtain from ecosystems such as food supply/crop yield, livestock and water availability/supply.

Response mechanisms/strategies: refers to the actions or activities undertaken by the agro-pastoral farmer in ord/er to curb, prevent or minimize the effects of climate variability.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview of perceived climate variability in Africa and Kenya

Climate variability may result from, natural internal processes within the climate system or from, variations in natural or anthropogenic forces (IPCC, 2012). Climate change on the other hand, refers to a change in the state of the climate that can be identified by changes that, persists for an extended period usually decades or longer (IPCC, 2013). Climate variability and change may have a permanent negative effect on the natural resource base upon which agriculture thrives, especially considering that it is happening at a time of growing demand for basic human requirements such as: food, water, fiber and fuel and the growing need for economic development (Long, 2014).

Climate variability and change presents a fundamental challenge to the well-being of all countries, with the potential of being most harsh to developing countries. This is because of their over reliance on rain fed agricultural production, geographic exposure and their low adaptive capacity (Bruckner, 2012). Water scarcity is a well -established context for development in arid and semi-arid countries. Though, Africa as a continent has contributed least to the factors that lead to accelerated climate change, its impacts is believed to have been /enhanced. This is attributed to, low adaptive capacity, marginal climate, over-reliance on agricultural sector and existence of many other stresses. Climate variability has the potential to affect development activities in Africa and can hinder the achievement of the Sustainable Development Goal (SDG) no. 13, which focuses on enhancing the resilience of climate change. According to IPCC 5th assessment report, serious impacts are being felt by the poorest people majority of them being those who are marginalized and living in developing countries (IPCC, 2014).

Global climate changes may influence long-term rainfall patterns impacting the availability of water, along with the danger of increasing occurrences of droughts and floods (Pal & Mishra, 2017). The rainfall and temperatures (Singh *et al.*, 2013) are the most important fundamental physical parameters among the climate as these parameters determine the environmental condition of the particular region which affects the agricultural productivity (Kumar & Gautam, 2014). Agriculture and other related sectors are crucially dependent on the timely availability of adequate amount of water and a conducive climate. The rainfall received in an area is an important factor in determining the amount of water available to meet various demands such as agricultural, and domestic water supply. The pattern and amount of the rainfall (Gajbhiye *et al.,* 2016) are among the most vital factors that affect agricultural production and agriculture is dominant to India's economy and livelihood of its people (Kumar & Gautam, 2014). Climate change is already ravaging Kenya as shown for instance by the increase in the incidence and geographical spread of diseases like malaria as well as more frequent and more intense droughts, and erratic rainfall patterns (NCCRS, 2010). These impacts and others portend an increasingly worsening and worrying situation in the future, if global and national efforts are not enhanced to reverse atmospheric GHG emissions which accelerate global warming.

Kenya, located on the equator, has a semi-arid to arid climate in the northern part, mostly temperate climate in the inland and a tropical climate along the coastal region (Ambenje, 2011). Changes in temperature and rainfall extremes are already being experienced in many parts of the world and Kenya is not an exception. IPCC (2013) indicate that climate change is real with the livelihoods likely to be exposed to more climate extremes in the future (Ngaina and Mutai, 2013). Rainfall variability has also increased, with a decline in long rains season and appositive trend for short rain season (Darkoh *et al.,* 2014). Most of the annual rainfall is about 687mm which, falls during the long rains from March- May and short rains from October- December. According to the IPCC, temperatures in Kenya have risen by 1^0C over the past 50 years. With regard to precipitation, no statistically significant trend has been observed since 1960 (Tutiempo, 2011).

Climate variability and change is raising new challenges to agro-pastoral systems in ASALs, with its negative impacts on crop and livestock production due to shrinking pastures, decline in forage, and varying weather patterns which stretch the resilience of local agro-pastoral farmers. This is evident through the drought episodes experienced in Laikipia County in 1984, 1991-1992, 1993-1994 and 1999-2000, as well as the El Niño rains of 1997 to 1998 that resulted in huge loss of human lives, livestock and wild animals, loss of biodiversity, destruction of large crop fields and infrastructure facilities (IPRA, 2004). In response to these challenges and opportunities posed by climate change, Kenya has developed the National Climate Change Response (NCCRS, 2010) Strategy and Vision 2030. This study sought to determine the household perceptions on climate variability in Laikipia West sub-County.

2.2 Agricultural risks in agro-pastoralist region

Agriculture is extremely vulnerable to extreme climate variability and change as has been witnessed during the years of the major floods and drought. The impacts of climate extremes on livestock and agriculture often affect the rural poor communities who depend on agriculture and livestock for survival (Omondi *et al.*, 2014). In Kenya, agriculture is the backbone of the economy as 75% of the Kenyan population are dependent on agriculture for food and income. Statistics have also shown that, about one third of the total land area of Kenya is agriculturally productive, including the Kenyan highlands, coastal plains and the lake region. About 75% of livestock are found in the ASALs of Kenya, and this sector contributes approximately 13% of Kenya's GDP, 40% to agricultural GDP and it also employs 50% of the labor force (PDNA, 2012).

Climate variability is mostly characterized extreme weather event mostly droughts and floods. These phenomena destroy plants, depletes the soil hence reducing the yields. The past decades have experienced the increase in occurrence of extreme events which have reduced soil moisture, fertility and water resources for plants resulting in severe water stress. Reduced soil moisture decreases available water for irrigation and hinder plant growth in non-irrigated plants. Drought leads to the death of livestock leaving most small-scale farmers trapped in poverty and inability to access and afford basic social amenities. Drought leads to crop failure which leads to reduced availability of crop residues. This in turn leads to decreased soil fertility by reducing the organic component of the soil. This necessitates the application of fertilizers to avoid reduction of crop yields, hence increasing the costs of farming incurred by the households. Floods lead to soil erosion and waterlogging which interfere with release of nutrients resulting to low soil fertility and therefore reducing crop yields. (Shongwe *et al.* 2014).

In the recent past, there have been incidences of erratic rainfall in many geographic regions in the world. Rainfall frequency and intensity fluctuates, with poor distribution throughout the growing season, such that there is no rain during the maturity stage of most crops. This result in total crop failure even if the crop has been performing well during the early stages of development. Climate change impacts have been most severe to humans in the area of reduced agricultural production. Although, food crisis may be triggered by many other factors, reduced productivity arising from lower yield is mostly triggered by effects of climate variability and related events (Anyoha *et al.*, 2013). Volatility of climatic events has made it difficult for farmers to predict incidence of rain based on past observation. The expected long-term changes in climatic patterns will have significant negative effects on agricultural and economic growth in Africa (Nhemachena *et al.*, 2010). Climate variability is perceived as being the greatest threat to agricultural production and food security in sub-Saharan countries, especially on livelihood of millions of people in many places of the world (IPCC, 2014). Several studies indicate that agriculture production could be significantly impacted due to increase in temperature (Lobell *et al.*, 2012), changes in rainfall patterns (Prasanna *et al.*, 2014) and variations in frequency and intensity of extreme climatic events such as floods and droughts (Brida & Owiyo, 2013).

Floods and drought are key challenges to sustainable livestock development in Kenya. Floods lead to inundation of grazing land and animal mortality. They are often associated with diseases such as Rift Valley Fever (RVF), while drought leads to heat stress, lack of water and pasture, death of livestock, and devastation of the livelihoods, among many other miseries (Mureithi & Opiyo, 2010; Omondi *et al.*,2014). In the context of Laikipia, farmers who encroach Ewaso Narok riparian basin exacerbate similar environmental threats (GoK, 2018). Climate variability threatens the agricultural production and food security of developing countries in complex ways that demand environmentally friendly innovations. Africa's agriculture is vulnerable to climate change (Arslan *et al.*, 2015; Juana *et al.*, 2013), owing to the impact of climate variables such as temperature, humidity and precipitation (IPCC, 2011), its sensitivity to projected changes and low adaptive capacity (Hellin *et al.*, 2012). According to the IPCC fifth assessment report (2014), most of the effects of climate variability on agriculture come through water, pests and diseases, crop yields and weather hazards. Climate variability is likely to result in a decrease in annual water availability in many parts of the world due to an expected reduction in rainfall which may lead to conflicting demands between agriculture and other users. In Laikipia, for instance, water supply has continued to fall by over half and worse during the dry spells or seasons because major rivers – Nyanyuki, Timau, Tehesoni, Naromoru, and Ewaso Nyiro – are drying up (MoALF. 2017). The increased risk of water shortages will have a major effect on agricultural production.

Climate variability is perceived as being the greatest threat to agricultural production and food security in sub-Saharan countries, it is emerging as a major threat on agriculture, food security and livelihood of millions of people in many places of the world (IPCC, 2014). Effects from increasing frequency of extreme weather events are becoming common and intense. A succession of El Nino, floods, droughts and storms in recent years has shown World's vulnerability to extreme conditions, and their frequency could increase in the short to medium term. In particular, the risk of drought and the possibility of floods in some areas are expected to rise. Several studies indicate that agriculture production could be significantly impacted due to increase in temperature (Lobell *et al.*, 2012), changes in rainfall patterns (Mall *et al.*, 2006; Prasanna *et al.*, 2014) and variations in frequency and intensity of extreme climatic events such as floods and droughts (Brida & Owiyo, 2013; Singh *et al.*, 2013).

Adverse effects can also be expected from the likely rise in the spatial distribution and intensity of existing pests, diseases, and weeds, due to higher temperatures and humidity. Farmers face the challenge of dealing with increased pest problems, or new pest challenges, within the constraints of what science can provide and within the pesticide authorization regulatory frameworks. This study therefore sought to find out the effects of climatic variability on specific provisioning ecosystem services (food supply/crop yield, livestock kept and water availability).

2.3 Climate variability and spatial variation of agro-biodiversity.

Agro-biodiversity comprises a variety and variability of animals and plants that are used directly or indirectly for food and agriculture, including crops, livestock amongst others. It comprises the diversity of genetic resources (varieties, breeds) and species used for food, fodder, fibre, fuel and pharmaceuticals. It also includes the diversity of non-harvested species that support production (soil micro-organisms, predators, pollinators), and those in the wider environment that support agro-ecosystems (agricultural, pastoral, forest and aquatic) as well as the diversity of the agro-ecosystems (Rivera *et al.*, 2019). Biodiversity in agricultural landscapes, as used in this study, refers to when agro-biodiversity is superimposed on agricultural landscapes that are affected by socio-economic and ecological processes including decision of individual farmers, national policy makers and local administrators (Jackson *et al.*, 2007).

Diversity of crops both in time and space is a traditional strategy to promote diversity in income sources, minimize risks, production stability, reduced insect pest and disease incidence, efficient use of labor, increased production with limited resources and maximization of returns under low levels of technology. Crop diversity can result in higher total yields per hectare than mono-cropping, even when yields of individual components are reduced. Mixtures result in more efficient use of light, water and nutrients by plants of different height, canopy structure and nutrient requirements (Altieri *et al, 2015*). Diversity in farming systems has received increasing attention in recent years as a way of promoting sustainable agriculture throughout the world.

Climate variability is one of the major drivers of biodiversity loss as a result of frequent bush fires due to high temperatures and prolonged drought. With the warming of 3^0C, relative to 1990 levels, it is likely that global terrestrial vegetation would become a net source of carbon (Schneider *et al.,* 2007). With high confidence they concluded that a global mean temperature increases of around 4^0C (above 1990-2000 level) by 2100 would lead to major extinction around the globe. The reality of climate variability and change has finally penetrated the popular psyche, another environmental crisis- the dramatic loss of agro-biodiversity silently threatens the world's food supply.75% of the world's food crop diversity was lost in the 20^{th} century as farmers abandoned local varieties in favor of genetically uniform high yielding crops. Even though, thousands of crops have been cultivated since the dawn of agriculture, 12 crops currently supply 80% of the world's plant based dietary energy. Just 4 crops namely: rice, wheat, maize and potato supply nearly 60% of plant derived calories and proteins. In addition to relying on a small number of crops, the world's food supply also relies on an alarmingly narrow genetic base. Genetically uniform, high yielding varieties have supplanted traditional varieties for 70% of the world's maize, 50% of the wheat in Africa, Asia and Latin America and 75% of Asian rice (UNFAO, 2009).

According to Tilahun (2006) in arid and semi-arid regions where both the amount and frequency of rainfall occurrence is low, it is essential to take into account the unique rainfall characteristics so as to be able to optimally utilize the low rainfall areas for agricultural purposes. According to Kipkorir (2002), rainfall is the most important environmental factor limiting agricultural activities in the arid and semi-arid regions of the tropics. Although irrigation is believed to be an important strategy in alleviating the current food crisis, rain-fed agriculture is still the dominant practice in most developing countries. Prolonged periods of high temperatures and increasingly poor rainfall in Kyuso district were primarily responsible for the surge in crop and livestock diseases, total crop failure, livestock deaths, increased food insecurity as well as rising poverty levels (Gullet *et al.*, 2006). In Kenya, many studies have been carried out on crop productivity but few of them have done investigation whether diversity in agricultural landscape is changing in relation to changing farming practices. Limited research has been carried out to track status and location distribution of biodiversity. This study therefore, intended to characterize spatial agro-biodiversity of woody trees and shrubs at farm level in Laikipia West sub- County.

2.4. Effects of perceived climatic variability on provisioning ecosystem services

The effects of climate variability and change on a wide range of ecosystems have been observed in most of the world's regions, in reaction to global mean temperature increase since pre-industrial times (Warren *et al.,* 2011). Climate variability has a substantial impact on social, economic and environmental systems and their interactions, and thereby food, and water, biodiversity (Paz *et al.,* 2010). Some of the effects of climate variability and change are likely to include extreme weather events such as heat waves, heavy precipitation, air pollution, flooding and droughts. Unchecked climate variability could affect most terrestrial eco-regions. Increasing global temperature means that ecosystems will change; some species will be being forced out of their habitats (possibly to extinction) because of changing climate conditions, while others will be flourishing. Secondary effects of climate variability such as weather changes, rising sea level and lessened, may influence not only human activities but also the ecosystem. For the IPCC Fourth Assessment Report, experts assessed the literature on the impacts of climate variability and change on ecosystems. Rosenzweig *et al.* (2007) concluded that, over the last three decades, human- induced warming had a discernable influence on physical and biological systems. Schneider *et al.* (2007) concluded with very high confidence, that the regional temperature trends had already affected species and ecosystems around the world. With high confidence, they concluded that climate variability and change would result in the extinction of many species and a reduction in the diversity of ecosystems. The interaction of climate change and desertification reduces the provision of dryland ecosystem services and lowers ecosystem health, including loss of biodiversity, affecting food security and human wellbeing (high confidence) (IPCC, 2019). Therefore, this study sought to find out how the provisioning ecosystem services (water availability, livestock kept and food supply/crop yield) are affected by climatic variability.

Water is one of the most important natural resources and is a key component to prosperity and wealth (Arbues *et al.,* 2002). However, globally water is becoming increasingly scarce, especially in developing countries (Amer, 2004). The growing population, rising incomes and urbanization are increasing the demand for fresh water. According to IPCC (2007) a global average temperature increase exceeding 1.5 -2.5 ^{0}C (relative to the period 1980-1999), would likely have a predominant negative impact on ecosystem goods and services e.g. water and food supply. It is difficult to know what will happen to Kenya's ecosystems and ecosystem services which are recorded due to climatic variability and change. Rainfall patterns have been inconsistent as is the case in most parts of East Africa and this makes clear scenario development and even under current conditions more difficult. Kenya has always been affected by natural, weather related disasters including droughts and floods that cause death, diseases and jeopardize livelihoods. However, it is expected that such extremes could potentially increase and exacerbate current vulnerability (UNEP 2007). This study therefore sought to find out the effects of climatic variability on specific provisioning ecosystem services (food supply/crop yield, livestock kept and water availability) as well as find out the response strategies used by agro-pastoral farmers to cope with the same.

2.5 Characterization of agro-pastoral systems

Historically, the livestock and agricultural sectors have evolved independently, with very little temporal and spatial integration at farm level. The development of systems that integrate both agricultural and livestock sectors, that is, of agro-pastoral systems. Agro-pastoral systems concept cannot be limited to orthodox rotations between forage production systems for ruminants and annual crop systems. This is because the rotation of pastures and crops is not always the optimal solution, and broader and more comprehensive integration is needed to include not only situations such as the aforementioned, but also others that make capturing the potential synergism between crops, pastures and other possible components (Feng-Min *et al.,* 2008).

In large areas of Laikipia West Sub- County, the main land use in transitional properties is agro-pastoral, involving both subsistence crop cultivation and cash crop production (mainly rain fed crops including; maize, beans, Irish potatoes, sorghum amongst others as well as domestic animals including; cattle, sheep, goats, donkeys, rabbits and poultry are also kept for milk and meat requirements (Laikipia CIDP, 2013). The households in this system derive more than half of their gross revenue from crop farming and at least ten to fifty percent of their gross revenue from livestock. They hold land rights and use their own or hired labor to cultivate land and grow crops. Their herds are fewer compared to other pastoral communities. The grazing area is usually near the homestead where it can be reached in a day. The household invest in housing and infrastructure and if their herds become large, they send them away with the more nomadic pastoralists (FAO, 2001).

Traditionally grazing systems fulfill various functions through diversified and accurate use of livestock capital (gifts, sales, loans, distribution, inheritance and even thefts): organization of resource management, collective risk management, social recognition, social reproduction and collective food security management. In recent decades, more and more livestock are integrated in agricultural systems as a complementary source of income and also as a means to improve crop production by making organic matter available for soil fertility. This being so due to climatic variability and strong demographic pressure, interactions between grazing systems becoming more frequent as land forage and organic matter management and product exchange can attest (Miehe *et al., 2004*). As a result, resource management evolved through livestock lending management, common social organization for pastures, water and soil fertility management, employment for herd or crop management, marketing organization, developing a new social relationship between and inside crop-livestock systems. This is even strengthened by decentralization of Kenyan counties that will lead to integration of the different land users in local organizations with the aim of improving management of land and natural resources (Manlay *et al., 2004*).

Besides economic and production functions, the ecological functions of livestock farming gain importance in the policy agenda as environmental concerns emerge. In mixed farming systems, its contribution to soil fertility through organic matter transfer by livestock has been intensively studied and show higher yields in croplands than in production systems without livestock (Manlay *et al.*, 2004). Livestock also contribute to biodiversity maintenance, water cycle enhancement and carbon sequestration in grazing systems where grazing pressure is moderate (Miehe *et al.*, 2010; Toutain *et al.*, 2010).

The variety of trees and shrubs play a vital role in the daily life of rural communities in many areas as source of woody and non-woody products. They are contributors to water and soil conservation as well as, repositories of cultural, aesthetic and ethical values. Trees provide part of the solution to limiting climate change, and to helping society to adapt to the climatic changes through provision of shade, food, alleviation of flooding, and creating a valuable wildlife habitat (DEFRA, 2010). Trees and their products can therefore, be part of the solution to combating climate change if they are well managed, both on a global and a local scale. Global forest ecosystems store more carbon than is contained in all of the world's remaining oil stocks or in the atmosphere.

Trees and shrubs in farming systems contribute to sustainable agricultural production and food security through mitigation of the effects of extreme weather events (FAO, 2007). In addition to benefits such as the provision of wood and non-wood forest products, restoration of soil fertility, and the conservation of biological diversity, trees and shrubs improve the microclimate by buffering winds, regulating the water table and providing shade to crops and animals (FAO, 2007). Decrease of these species in Laikipia west sub-County could aggravate the food security situation.

The woody vegetation in ASALs is of immense importance performing a myriad of ecosystem services and providing a wide array of goods. They are useful particularly in terms of herbages for livestock, energy provision and also as herbal sources (Maitima, 2009). For example, assessing their distribution and composition is important for management as this can provide information necessary for plans on harvesting, conservation, identification of presence of endangered or rare species and sites with high or low species richness (Newton, 2008). In addition the number of trees and shrubs that can tolerate drought stress has declined due to factors such as frequent fire outbreaks, climate change, clearing of land for human settlement and mining activities can be identified (Omambia *et al.*, 2009). This study therefore sought to characterize spatial agro-biodiversity of woody trees and shrubs as well as crops and livestock at farm level in Laikipia West sub-County. It also sought to find out the effects of climate variability on food supply/crop yield, livestock kept and water availability in Laikipia west sub-County.

2.6 The Effects of Climate Variability on Agro-pastoral community's livelihoods in ASALs

Climate variability and change affects production systems and ecosystems at different scales. It is also expected to affect livestock and agricultural production, input supplies, water balances and other components of agricultural systems (Aydinalp & Cresser, 2008). Communities inhabiting ASALs are the most vulnerable to the impacts of climate variability and change. With the projected impacts of climate variability and change including, on ecosystems, water availability, agriculture and agro-pastoralism on the whole, the practical adaptation measures must include policies that build the resilience of communities to climate variability and change. Without adaptation efforts to the variability in climate, the people in ASALs may be forced to consider other livelihood options, including migration, in order to cope with the extreme changes (WRI, 2005).

According to WRI, (2005) the impacts of climate variability on household livelihoods especially food security will vary across agro-ecological zones. While ASALs are predominantly inhabited by agro-pastoralists and pastoralists, the livelihood make up for each group will vary from place to place. Each zone offers distinct threats and opportunities for livelihood sustenance and development, reflecting different agro-ecological conditions. Two livelihoods activities with the greatest risk across agro-ecological zones are free ranging livestock keeping and rain-fed agriculture. The semi-arid zone receives between 450-900mm of rainfall annually and typically inhabited by agro-pastoralists who make their livelihoods out of drought tolerant crops production and livestock rearing. Crop production is mainly for subsistence purposes, except for a few cash crops including fruit trees, wheat amongst others. While agro-pastoralists rely on markets for cereals and other products not produced domestically, they have greater flexibility in the sale of their livestock compared to occupants of the arid zone. Given the poor soil and limited rainfall, crop production (apart from cash crops) is undertaken for subsistence, with few resources devoted to livestock production except in areas with good access to markets. Rainfall is expected to be more variable as a result of climate variability and change. This will therefore challenge the agricultural aspect of livelihoods. To secure their livelihoods, agro-pastoralists adopt livelihood response strategies that are integrally linked to the full range of ecosystem services (WRI, 2005).

Agro-pastoralists and pastoral communities depend on livestock for a number of uses, including the direct consumption of meat, milk and blood. Livestock also provides an income through selling and it creates employment for a large number of agro-pastoral and pastoral communities. With the current changes in climate taking place, livestock productivity, survival and distribution will be affected through the reduced quantity and quality of rangeland and the prevalence of vector-born livestock diseases (IPCC, 2001). Climate change will lead to low productivity (draught power, milk and meat) due to the increased amount of carbon dioxide that reduces the amount of protein available from vegetation and the out-break of new pests and diseases, for example ticks, snails and other pests. Studies show that milk and meat production will be reduced following the stress on grazing lands (IPCC, 2001). As regards agriculture projected reductions in yield in some countries could be as much as 50% by 2020, and crop net revenues could fall by as much as 90% by 2100, with small-scale farmers being the most affected (Boko *et al.*, 2007).

Although climate change is not expected to directly affect the tree species significantly in the short term due to the fact that these dry land tree species can survive in a wide range of climatic conditions, like all living things trees are not immune to the effects of climate change. In the long run trees must be assisted to adapt to climate change. Wanton destruction of these species for firewood must be controlled to avoid further loss of biodiversity. Shrubs are important drivers of local ecological processes such as alteration of thermal soil regime (Sturm *et al.*, 2001) and thus need to be included in regional studies of climate change. A higher shrub cover may lead to increased soil shading, thereby reducing the energy input into the soil (Blok *et al.*, 2010). Uncontrolled exploitation coupled with climate variability and change is threatening the biological diversity of these shrubs. This study therefore sought to find out the effects of climate variability on food supply/crop yield, livestock production and water availability in Laikipia west sub-County. The study also sought to characterize spatial agrobiodiversity of woody trees and shrubs in Laikipia west sub-County.

2.7 Adaptation to Climate Variability and Change

Climate variability and change is a global phenomenon, while adaptation is largely site-specific. A common disadvantage for local coping strategies is that they are often not documented, but rather handed down through oral history and local expertise. As site-specific issues require site specific knowledge, experience has shown that identified adaptation measures do not necessarily translate into changes because there are context-specific social, financial, cultural, psychological and physiological barriers to adaptation (IPCC, 2007). It is therefore very important to clearly understand what is happening at community level, because farmers are the most climate-vulnerable group.

According to FAO (2008), the current farming systems in the world today are adapted to local climate due to climate variability. What constitutes extreme weather depends on geographical location. For instance, temperatures considered extreme in a region would be considered normal in other regions. Adaptation is critical in protecting livelihoods and food security in many developing countries. It involves all actions aimed at coping with drought that cannot be avoided and at reducing their negative impacts.

In many areas, farming may adapt to increases in extreme temperature events by shifting to practices already used in warmer climate. Although uncertainties around these projections are considerable, adaptation to extreme events is considered a priority, given the potentially high costs of damages from extreme weather and climate variability (Van Dorland *et al.,* 2011). A critical issue is how to raise an adequate level of concern among individuals, policy makers, and broader decision makers in companies and organizations so that adaptation to extreme events becomes mainstream practice. Even though some decision makers are proactive about adaptation to extreme events, it seems to be a low urgency and low priority policy option for many others (Bulkeley, 2010).

Adaptation to climate change involves changes in agricultural management practices in response to changes in climate conditions and often involves a combination of various individual responses at the farm-level. This approach is considered likely to reduce the effects of long-term changes in climate variables on agriculture. Indeed, throughout human history, societies have adapted to natural climate variability by altering settlement and agricultural patterns and other aspects of their economies and lifestyles (Burton *et al.*, 2006). In the coming decades, climate scientists are predicting increasingly dry conditions in much of sub-Saharan Africa (Styslinger, 2011**)**. This makes adapting to climate change in the agricultural sector a critical issue for households in these areas including Laikipia West sub- County.

In an effort to cushion against food insecurity, water unavailability and biodiversity loss which are some of the effects of climate variability the agro-pastoral farmers have evolved a number of response/adaptive strategies. Societies have a long record of adapting to the effects of weather and climate through a range of practices including crop diversification, irrigation, water management, disaster risk management, and insurance. However, climate variability and change present new risks which are often outside their range of experience, such as effects related to drought, heat-waves, accelerated glacier retreat and hurricane intensity (Agrawala & Cane, 2002). Frequent drought and occasional flash floods are the main challenges facing residents of Laikipia West sub- County (Huho *et al.,* 2010). Economic, social, environmental and health impact of drought and household and community preparedness to drought in Laikipia west sub-County is not well understood. Even so, there is information sharing by different actors through early warning system, while meteorological department strives to provide sub county specific observatory information to farmers (MoALF, 2017).

Most studies show some level of acceptance by people's acceptance of the changing climate conditions hence the struggles to live with the effects. Most of the adaptation strategies are not pursued alone by the households but jointly as a menu of options. This is similar to findings from other studies on household level adaptation, for example, identified changing crop type, planting time, and conservation measures and diversified income as the key households' adaptation done in 13 arid and semi-arid divisions (Byran *et al.*, 2011). A similar study done in Tharaka County in 2008, also identified engaging in wage labor, reliance on food aid and livestock diversification as the main strategy (Smucker *et al.*, 2008). Individual perception on climate variability leads to different household and community response/ adaptation strategies. Farmers have diverse agricultural practices which include use of organic pesticides, agro - forestry (ATPS, 2013), use of local seeds which they believe are better adapted than exotic seeds, crop diversification, minimum tillage, mulching, collecting water in ponds and earth dams for irrigation, and changing their planting times based on rainfall forecasts (Pradhan *et al.*, 2017). However, farmers are reactive dealing with short term challenges rather than being proactive to handle long term problems. This reactive behavior can be attributed to low information access and low understanding of mitigation and adaptation options. Increasing human pressures on land combined with climate change are likely to push dryland populations further beyond their limits to adapt, requiring site-specific technological solutions to strengthen their resilience and adaptive capacities (IPCC, 2019). This study therefore sought to find out the response strategies currently employed by agro-pastoral farmers in Laikipia West sub-County to cope with the effects of climatic variability.

2.7.1 Types of response strategies to climate variability

Over the years, farmers have developed strategies through which they respond to climate variability. These response strategies can be autonomous, private and planned or public sector response strategies. When response to climate variability is through actions taken by non-state agencies such as farmers, communities, organizations, firms or a combination of any; then it is referred to as private adaptation. According to Bruin (2011), response may include changing crop species, staggering planting dates, changing management practices, changing irrigation system and selecting different cropping technologies. Public adaptation is achieved the efforts of local, regional, national government or both. This is achieved through the provision of infrastructure and institutions that reduce the negative impact of climate change. These response strategies may include introduction and development of irrigation infrastructure in dry areas, Improvement and development of effective transport or storage infrastructure, land use arrangements and property rights, water shed management institutions (World Bank, 2010).

Planned response initiatives are also often not undertaken as stand-alone measures, but are embedded within broader sectoral initiatives. Since response strategies to climate variability and barriers to response are local specific, identified response measures may not necessarily translate into changes, (Aemro *et al.*, 2012). Response can also be viewed as proactive or reactive depending on the time it is undertaken. If it is undertaken before the climate variability phenomena, then it is proactive and if it is carried out after the impact is felt then it is reactive. Reactive adaptation strategies, addresses effects of climate change after they have been experienced, while proactive adaptation strategies are engaged in anticipation of climate change (Bruin, 2011). In crop production**,** reactive response strategies may include control of soil erosion as a result of floods, construction of irrigation dams in response to drought, improving soil fertility in response to erosion, development of new varieties which can adapt to prevailing conditions, shifting planting time due to unreliable rainfall. Proactive response strategies on the other hand involve the development of adaptable species and research and development. However. in order to enable agro-pastoral farmers to respond to climate variability, the government should provide the necessary support and conducive environment for response (Gbetibouo, 2009). This study therefore sought to find out the response strategies currently employed by agro-pastoral farmers in Laikipia West sub-County to cope with the effects of climatic variability.

2.7.2 Climate variability response in agropastoral systems

Climate variability is currently affecting many parts of the world as manifested through the frequency of extreme events like drought and floods. Response can be defined as adjustment in natural or human systems in resulting from actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of response can be distinguished, including anticipatory, autonomous and planned (IPCC 2007).

Responding to the weather and climate is a characteristic of all human societies, but climate variability is presenting new and increasing challenges. Smallholder farmers all over the world including Kenya, use a range of options to respond to the negative effects of climate variability. Response to climate variability can either be through adaptation or mitigation. Adaptation is motivated from local priorities or regional risks and it helps reduce the impact of climate variability in the short to medium term. In Kenya, different stakeholders have initiated off-farm adaptation that include extension services and capacity building initiatives for famers on how to improve and manage their livestock and crops (MoALF, 2017). According to MoALF, similar efforts have been cascaded at county level to increase resilience through promotion of high drought resistance crops and tolerant breeds, as well as training and research. On the other hand, mitigation is concerned about solving the root cause of climate variability through reducing the sources of greenhouse gases.

Mitigation is concerned about controlling the cause of climate variability while adaptation is concerned about controlling climate variability effects (Bewuket, 2009). The time-lagged nature of climate variability implies that the currently observed climate variability is as a result of the greenhouse gas emission that was experienced in the past. This implies that the effects of current greenhouse gas emission will also lag into the future. As a result, focusing on mitigation alone will not address the inevitable impacts of currently observed climate variability (Anyoha *et al.*, 2013). Mitigating and adapting to climate variability requires collective action of different stakeholders to derive multi-disciplinary approaches to address the situation. Research shows that a variety of climate variability adaptation forms (operational, technical, and financial) have been taken by diverse stakeholders (farmers, climate change agencies, organizations, and governments) at local, regional and international levels (Paradhan *et al.*, 2015). These stakeholders have recognized the important role of agriculture in contribution to, and mitigation of climate variability.

Response measures are being implemented by a range of public and private organizations through policies, investments in infrastructure and technologies, and behavioral change (Adger *et al.,* 2007). Farmers in developing countries are already using their existing experience, knowledge and resources to manage climate risks on their own account and these actions are not easily distinguished from a range of other factors (social, demographic and economic) influencing livelihood decisions and development trajectories (Adger *et al.*, 2003). Planned response initiatives are also often not undertaken as stand-alone measures, but are embedded within broader sectoral initiatives. Since response strategies to climate variability and barriers to response are local specific, identified response measures may not necessarily translate into changes (Aemro *et al.*, 2012). This underlines the importance of understanding local dimensions of climate variability so as to develop response measures that are appropriate in mitigating adverse consequences of climatic variability. In Kenya, government continues to develop elaborate strategies to handle climatic challenges through national adaptation plan and national climate change that is reviewed every five years. Development practitioners and stakeholders in climate change, however, call for involvement of public and stakeholders involvement in climate change mainstreaming and developing of policy interventions at county level (GROOTS Kenya, 2018). Similarly, other suggest that county governments should streamline their current plans and strategies while assess the gaps on climate change adaptations mechanism at local level (Opiyo, 2014).

In order to, enhance relevant policies towards tackling the challenge that climate variability is posing on farm households which have little response capacities, it is necessary to have knowledge of the response choices and factors affecting the response methods to climate change. According to Olarinde *et al.* (2014), failure to implement response options and poor agricultural performances by many African farmers has been blamed on lack of information and resources. Southern Africa for example, has early warning units and meteorological departments, but the information does not reach all intended users. Response policy measures need to consider how information concerning adaptation measures, forecasts, and production cycles can best reach farmers to help them respond to changes in climate. Agro-pastoralism has encouraged integration of more livestock in agricultural systems. This complements their sources of income and also improves crop production through incorporation of the animal manure which improves soil fertility. There is increasing agreement among scientific research that agro-pastoralism make significant contributions to local, national and regional economies. Agro-pastoralism is more productive per hectare than commercial ranching and sedentary livestock keeping in similar environmental conditions, and the high productivity of livestock in pastoral systems not only supports millions of pastoralists but also contributes significantly to other sectors of national and regional economies of Africa (Hesse, 2009). This study therefore sought to find out the response strategies currently employed by agro-pastoral farmers in Laikipia West sub-County to cope with the effects of climatic variability.

2.8 Theoretical and Conceptual framework

2.8.1 Theoretical framework

The ecosystem services framework provides a way to analyze the vulnerability of livelihoods to changes in both stocks and flow of natural capital. This framework groups ecosystem services as: provisioning services (ecosystem products e.g. food, fiber and water); supporting services (necessary for production of other ecosystem services e.g. soil formation, nutrient cycling and photosynthesis); regulating services (including processes such as climate stabilization, erosion regulation and pollination) and cultural services (non- material benefits from ecosystems e.g. recreation, spiritual fulfillment and cognitive development). If, as the framework suggests, livelihoods are ultimately dependent on ecosystem services derived from stocks of natural capital, then a sustainable livelihood must maintain critical stocks of natural capital (Ekins *et al.,* 2003). This suggests that to assess the viability of adaptation/response options, it is necessary to determine whether they threaten critical levels of natural capital and long-term viability of associated ecosystem services. Indicators with thresholds have been developed for a range of ecosystem services to date (Schroder *et al.*, 2004) and using a chosen climatic base-line, they could be adjusted and used to help ensure that adaptation does not simply put off or create new problems. This study analyzed only 2 provisioning ecosystem services i.e. water availability, and food supply/crop yield.

2.8.2 Conceptual framework

The study examined the effects of climate variability on provisioning ecosystem services and the response strategies adopted by the agro-pastoral communities in Laikipia West sub-County. The conceptual framework that guided this study, was adapted from the Ecosystem services framework as a strategic tool to better understand the interaction between ecosystems, climate variability and response strategies. The predominant effects on ecosystem services provision are through environmental changes as a result of climate variability. The figure below outlines the conceptualized inter-relationships in the key variables involved in the proposed study. It has been developed by the researcher on the basis of the research objectives. The study considered the dependent variable to be provisioning ecosystem services i.e. water availability and food supply. This was influenced by the independent variables which were climatic variability (temperature and rainfall variability and Response strategies).

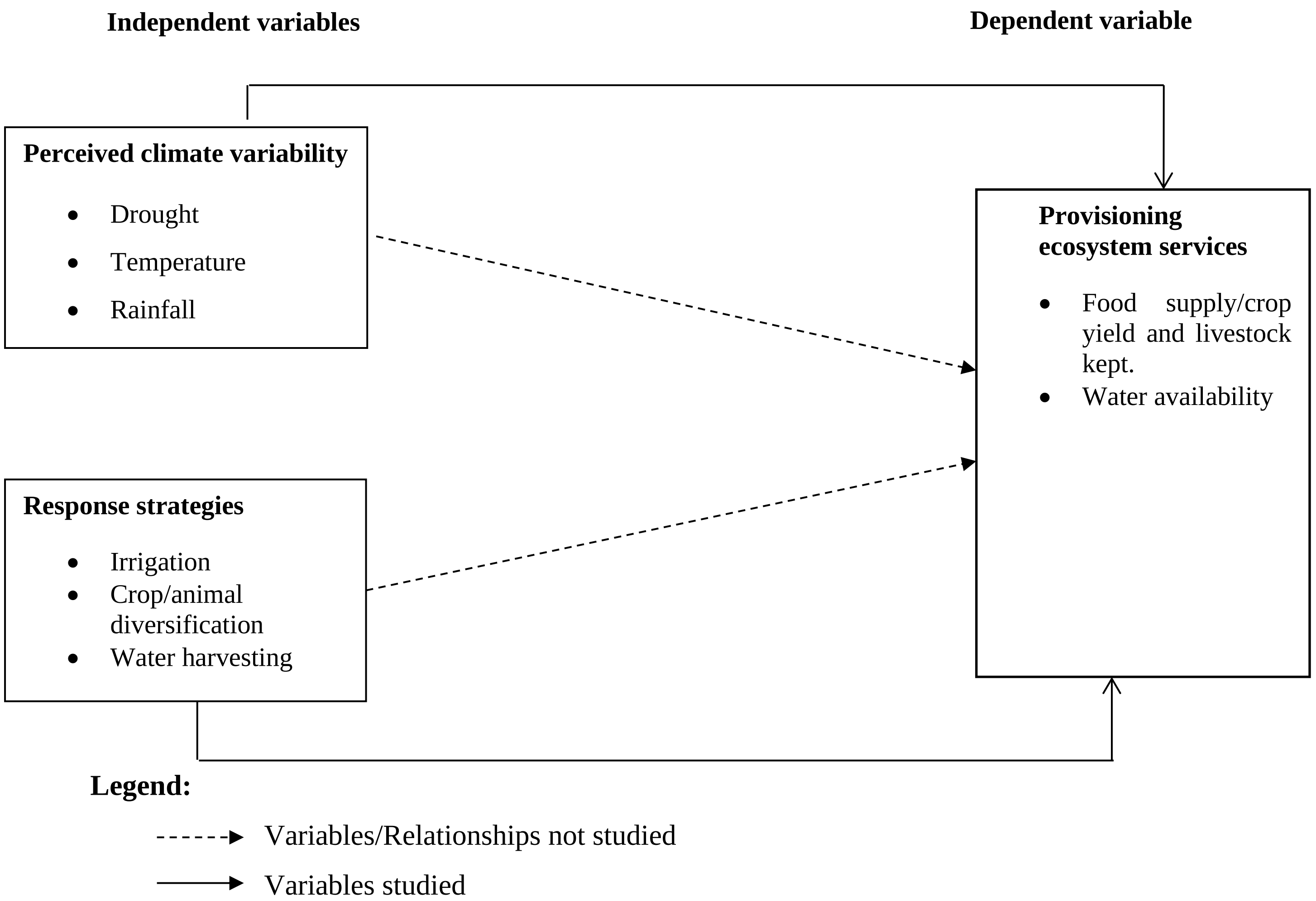

Figure 2. 1: Conceptual Framework on Effects of Climatic Variability on Provisioning Ecosystem Services in agro-pastoral systems in Laikipia West sub- County.
Source: Millennium Ecosystem Assessment (2003).

CHAPTER THREE
RESEARCH METHODOLOGY

3.1 Study area

Laikipia West sub-County is located to the north-west of Mount Kenya. The sub county extends between longitudes 36.2^o East and 36.7^o East and latitude 0.1^o North and 0.8^o North as shown on figure 3.1 and an area of 3891 km^2. The altitude of the sub- catchment varies between 1,000m and 2,600 m above sea level (Thenya *et al.*, 2011). The sub- catchment falls administratively in Laikipia West sub-County and has three divisions namely; Ngarua, Rumuruti and Olmoran. The sub- County has a population of 224,431 and 55,705 households. The sub-County has 6 wards namely: Olmoran, Githiga, Igwamiti, Marmanet, Salama and Rumuruti township (IEBC, 2017).

The sub-County has two distinct climatic zones: humid and semi humid region. Daily temperatures vary with altitude and season; mean temperatures generally range within 22-26°C, minimum temperature (6-14°C) and maximum temperature (35°C). Due to the sub-County leeward position (North West) of the Mt. Kenya, it is comparatively dry despite its location on the Equator. The spatial distribution and the temporal variability of rainfall are strongly influenced by Mt. Kenya and Aberdare Ranges. Precipitations also vary greatly in terms of time and amount along the same gradient. The rains primarily fall in two seasons; the main wet season occurs during April-May, often accounting for 80% of total annual rainfall, while a second wet season occurs in October-November (Laikipia CIDP, 2013).

Even though the population growth in Laikipia has not kept pace with forecasts in the mid-nineties (as stated in Wiesmann 1998: 93), the dispersion of small-scale farms and plots into more marginal areas, continuously advances. Partly as a consequence of this, 8.4% of the land is currently under cultivation, most of which is concentrated in Laikipia west sub-County and around the County's administrative and commercial Centre. The land use systems in Laikipia are strongly reflected by population dynamics in the sub-County. In the upper region intensive maize, wheat and beans farming is practiced as well as rearing of dairy animals. In the lower regions agro-pastoralism and pastoralism is practiced. Irrigation farming has also been practiced in the lower region where tomatoes and onions are grown. Most immigrants moving to Laikipia are Kikuyu peasants from high potential regions in Central Province who continue their habitual systems of rain-fed mixed farming in their new home area (GLOPP, 2007).

The main crops grown include wheat, maize, beans, potatoes and vegetables. Maize takes about 51per cent of the total planted area. Crop farming is mainly undertaken in the south western parts of the county due to favorable weather conditions (Laikipia CIDP, 2018). Efforts are now been put in place to promote the resistant crops such as millet, sorghum, sunflower and black beans (dolichos). There is an emerging trend of increased horticulture production both at large-scale and small-scale levels. This constitutes production of cut flowers, tomatoes, French beans, Aloe, chilies and water melons. There are also pockets of pineapple farms, orange trees and coffee bushes (Laikipia CIDP, 2013).

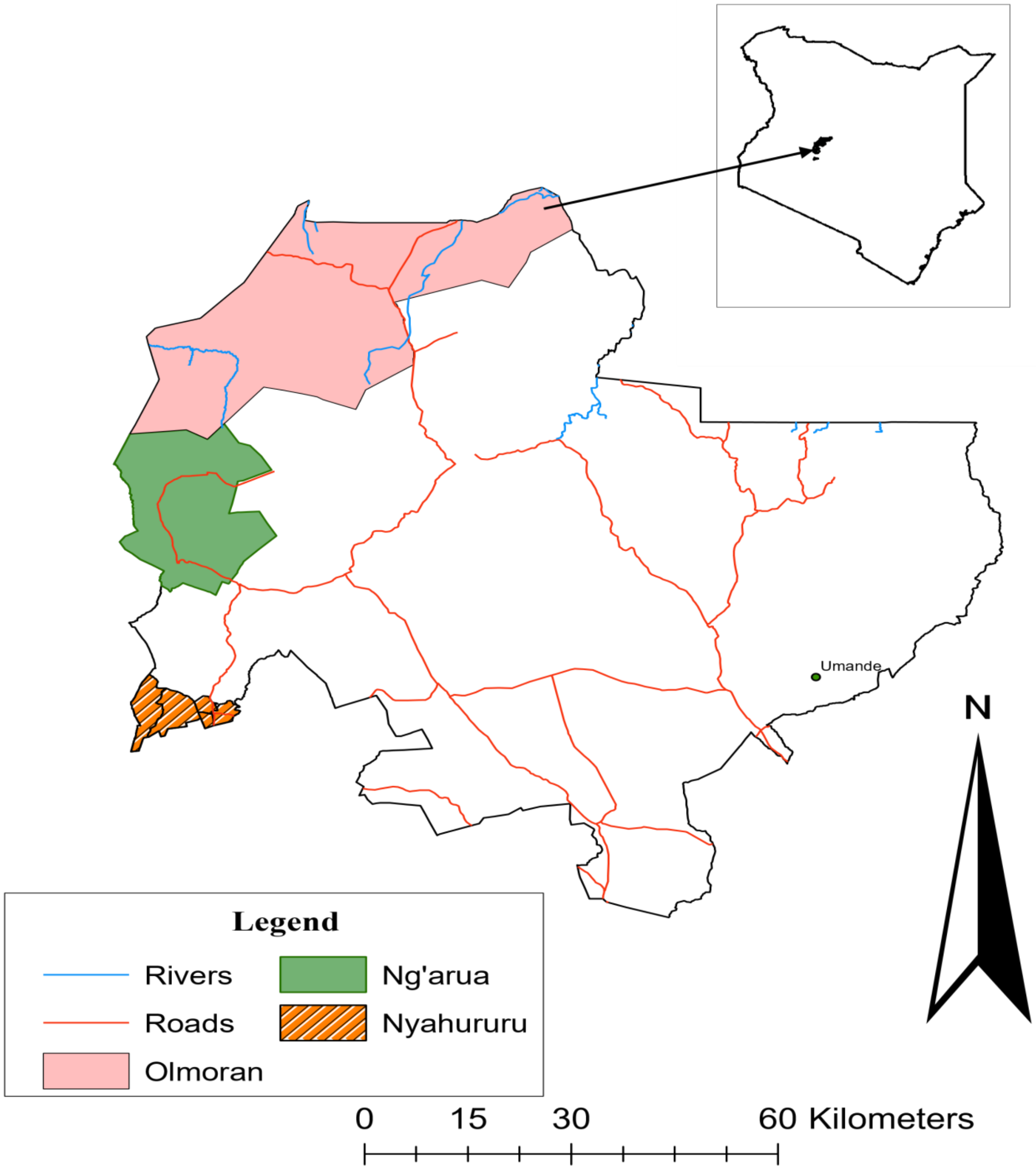

Figure 3. 1 Map of the study area showing the three wards that were surveyed.

Source: World Resource Center (2013)

3.2 Sampling procedure

The sub- County has a population of 224,431 and 55,705 households (KNBS, 2010). The study used a multi-stage sampling technique. Laikipia County was selected purposefully because of its vulnerability to climate variability. The County is composed of 3 constituencies namely; Laikipia East which has 5 wards, Laikipia West which has 6 wards and Laikipia North which has 4 wards. Laikipia West Sub-County was selected purposefully because of the fragile environment and vulnerability of the area to drought and majority of the people are agro-pastoral farmers as shown by the livelihood zones map of Laikipia County (FAO, 2009) regardless of whether the household is headed by women or men. Three wards Igwamiti in Nyahururu division, Olmoran in Olmoran division and Githiga in Ng'arua division were purposefully selected for the study. Finally, the households were randomly selected from a list of households provided by the subcounty Agricultural officers. A sample of agro-pastoral farmers was taken as representative of the county's smallholder farmers population. The target population was the maize, cattle and goat farmers. The population data were obtained from the area agricultural offices in the three selected wards as 19,219 farm households. The key informants in this study were sought from the Ministry of Agriculture Livestock, Forestry Department as well as Laikipia West community leaders; 5 from each of these sectors (agriculture, livestock, forestry and community leaders) were interviewed.

3.3 Sample size determination

Stratified random sampling was used to obtain the sample from 3 wards: Igwamiti, Olmoran and Githiga. For uniformity purposes, proportionate stratified sampling method was used to ensure all the divisions are represented in the study. Stratified random sampling was used to select agro-pastoralists from each stratum. The sample size was determined using the following formula by Bowley's (1977) quoted in Nzelibe (1999) proportion sample formula assuming a 95% confidence interval as shown:

$$S_{total} = \frac{N}{1+N(e)^2}$$

Where; S_{total} = total sample size of all respondents

N = total population of farming households in Laikipia west sub-county (19219)

1 = constant

e = level of significance (confidence interval of 95%)

Hence replacing the values into the formula gives

$S_{total} = \frac{19219}{1+19219(0.05)^2} = 391.844$

$S_{total} \approx 392$

Table 3. 1: Total and sampled households according to Wards in Laikipia West sub-County

Laikipia West Wards	Total households	Sampled Households
Githiga	11,581	240
Igwamiti	4,683	98
Olmoran	2,955	62
Total	**19,219**	**400**

Source (KNBS, 2009)

Three wards – Igwamiti, Githiga and Olmoran agro-pastoral farmers in Laikipia West sub County were randomly selected for the study. The sample size for each ward was calculated using probability proportional to size from the identified wards as shown.

$\frac{p}{N} \times S_{total}$

Where; p = population of the individual ward

N= total population of the three wards

S_{total} = Total sample size (392)

This gives the sample sizes for the three wards as follows

Igwamiti = $\frac{11581}{19219} \times 392$ = 236.116 ≈ 236 ± 4= 240 households.

Githiga = $\frac{4683}{19219} \times 392 = 95.52$ ≈ 96 ± 2=98 households.

Ol Moran = $\frac{2955}{19219} \times 392 = 60.27$≈ 60 ± 2=62 households.

A total of 400 households were interviewed but after data cleaning only 394 households' data was analyzed. The 20 key informants were interviewed based on their field of specialization. It was essentially a qualitative interview which was conducted using interview guides that listed the topics and issues to be covered during a session. It was conducted in an informal atmosphere, resembling a conversation between acquaintances.

To evaluate the effects of climate variability on tree and shrub species in Laikipia West sub-County, systematic quadrat method was applied. Systematic sampling used quadrats that are spaced as widely and evenly as possible. Sampling was done at farm level. From each randomly selected farm in each ward, quadrats were systematically established in systematically selected fields. The quadrats were established as follows: Shrubs $10m^2$ and trees $20m^2$. Along each transect sample, quadrats were laid at an interval of 50m. In each sample quadrat different species observed and their composition recorded in a data sheet. A total of 9 transects were put, each with 2 quadrats resulting to 18 plots for all wards. Therefore, 3 transects were established in the each of the three wards along which 2 quadrats were laid at equal intervals of 50m along these lines resulting to 6 plots in each ward. This was accomplished by a combination of measurement and spacing.

3.4 Data and collection methods

Primary data was collected by interview method using semi-structured questionnaires and key informant interviews. Pre-testing was done to ensure that the questionnaire and the key informant interview guide were reliable and necessary adjustments made. Tree and shrub species data was collected using quadrats and transects through systematic quadrat sampling.

3.4.1 Questionnaire Administration

A questionnaire was administered to the selected respondents (agro-pastoral farmers) to elicit the desired information. I selected three research assistants and trained them to assist me in the data collection process and questionnaire administration especially due to their respective vernaculars and familiarity with the area and people. If, the respondent was literate and desired to fill the questionnaire, I allowed this but also ensured that a research assistant was available to explain or clarify any question that was not clear to the respondent. I was to recheck such a questionnaire and seek further clarification in places not properly filled. I recorded such clarification on the relevant sections in the questionnaire. The use of questionnaires enabled the respondents to be honest and remain anonymous in their responses (Kothari, 2008). Under normal circumstances, I administered the questionnaires personally during the survey in a language in which the respondent was comfortable and did the recording of the answers. The use of this approach ensured direct contact between the research assistant or I and respondent, a factor which facilitated elaboration of aspects that may have not been easily understood by the respondent. The procedure enabled the research assistant or I to ensure that the questionnaire was completed before leaving the respondent to minimize cases of incomplete questionnaires.

3.4.2 Key Informant Interviews

Key informant interviews involved interviewing a selected group of individuals who were likely to provide needed information, ideas and insights on a particular subject. Key informants were selected because they had knowledge on the area of study that could be solicited by the interviewer. These Key informants included individuals from the Livestock, Agriculture, and Forestry ministries as well as community leaders at Laikipia west sub-county level. I subtly probed the key informants to elicit information and take elaborate notes, which were later developed. In case, all relevant items were not covered in a session, I went back to the key informants.

Key Informant Interviews were used to collect data on community and household preparedness to climate variability and adaptation determinants to the same. Key informant interviews complemented the survey research. The key informants in this study were sought from the Ministry of Agriculture and Livestock, Forestry Department as well as Laikipia West community leaders; 5 from each of these sectors (Agriculture, Livestock, Forestry and Community leaders) were interviewed.

3.4.3 Quadrats and Transects.

The quadrats were established as follows: Shrubs $10m^2$ and trees $20m^2$. Along each transect sample, quadrats were laid at an interval of 50m. In each sample quadrat different species observed and their composition recorded in a data sheet. A total of 9 transects were put, each with 2 quadrats resulting to 18 plots. In order to determine the tree and shrub species diversity in Laikipia West sub-County, Simpsons Diversity index was used. The species composition was determined by counting each species within a quadrat. Relative frequency was as well determined by the proportion of quadrats in which a species is present.

3.5 Validity and Reliability of Research Instruments

Pre-testing of questionnaires was done with 20 agro-pastoral farmers' households in Nakuru County similar to the study area to find out if the questionnaire was able to yield the expected outcome. This study also involved multiple data collection methods namely: secondary data as well as questionnaires and systematic quadrat method were used to confirm consistency in the data. The result of the pre-test indicated a reliability coefficient of 0.9 for the whole instrument using the Guttman split-half reliability index. The questionnaire was found to be a reliable instrument for collecting data in the field (Howitt & Cramer, 2003).

3.6 Analytical technique

The computer-based statistical package for social sciences (SPSS Version 20.0) was used for data analysis to yield descriptive and inferential statistics. Coding of questionnaires and observation schedules was done to enable data entry, cleaning and analysis. After cleaning the data, N reduced from 400 to 394.

The collected data was analyzed using both quantitative and qualitative techniques. For tree and shrub species (biodiversity) data, Microsoft excel statistical package was used to compute the Simpson's diversity index and to compute species richness, relative frequency and Menhinick's index. All the quantitative data collected was analyzed using the Statistical Package for Social Sciences (SPSS). Frequency counts, means and percentages were computed for all quantitative data, and results presented using frequency distributed tables, bar graphs and pie charts. All statistical tests were conducted at the 0.05 level of significance. Qualitative data were analyzed using qualitative techniques, which basically involve establishing the categories and themes, relationships/patterns and conclusions in line with the study objectives (Gray, 2004). The data analysis matrix is presented in Table 3 below.

Table 3.2: Method of data analysis by research objective

Objectives	Data required and Source	Measurable Indicators/ Variables	Methods of data collection, analysis and tools
1.0 To determine household perception on climate variability in Laikipia West sub-County.	***Data requirements:*** Rainfall and Temperature variability trends. ***Data source***: Household survey and KII.	• Rainfall variability trends • Temperature variability trends	***Data collections***: Household survey ***Data analysis and tools:*** Descriptive statistics (frequencies and percentages).
2.0 To characterize and analyze spatial agro-biodiversity at farm level.	***Requirements:*** Agro-biodiversity data ***Source***. Household survey and Systematic quadrat sampling method.	• Types of crops grown and livestock kept. • Woody trees and shrubs.	***Data Collections***: Household survey and systematic quadrat sampling method. ***Data Analysis and tools:*** Descriptive statistics Menhinick's index and Simpson's diversity index.
iii) To assess the effects of climate variability on provisioning ecosystem services (food supply, water availability)	***Data requirements***: Household responses on perception to effects of climate variability on provisioning ecosystem services. ***Data source***: Household survey.	• Water availability. • Food supply/Crop yield.	***Data collections***: Household survey. Data ***analysis and tools***: Descriptive statistics (frequencies and percentages)
4.0 To examine the response strategies and mechanisms currently used by agro-pastoral farmers to cope with effects of climatic variability	***Data requirements:*** household perceptions on response strategies and or mechanisms. ***Data source***: household survey.	• Income diversification. • Storage of water. • Livestock/ crop diversification. • Drought tolerant crops/animals.	***Data collections***: household survey, and KII ***Data analysis and tools***: Descriptive statistics (percentages and frequencies)

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the results arising from data analysis. The results and discussion are presented according to the objectives of the study namely: to determine household perceptions on climate variability in Laikipia West sub-County, to characterize and analyze spatial agro-biodiversity of woody trees and shrubs as well as crops and livestock at farm level, to assess the effects of climate variability on provisioning ecosystem services (food supply/crop yield and water availability) and to examine the response strategies and or mechanisms currently used by agro-pastoral farmers to cope with effects of climatic variability.

4.2 Socio-economic Characteristics of Respondents

This section presents results on age, education level, gender, marital status, family size, and land tenure as well as landholding size of the respondents.

4.2.1 Age and Gender Distribution of the Respondents

All age groups in this survey were found to be active and participating in agro-pastoral farming/agro-pastoralism. The /maximum age of the agro-pastoral farmers was 97 years, while the minimum was found to be 24 years. The mean age of an agro-pastoral farmer in Laikipia west sub-County was found to be 51.05 years. This is contrary to the average age of a Kenyan farmer which is put at 57 years (Momanyi *et al.*, 2012). Results of this study reveal that almost all the age groups participated i/n the study as shown in Table 4.1: persons aged over 55years (32.2%), 46-55years (28.9%) and 36-45 years (28.2%) constituted the majority of sampled households. Engagement of this category in agro-pastoralism demonstrated that the involvement of younger people (10.66%) in farming was increasing. This can be attributed to the rising levels of overall unemployment in Kenya, which was reported at 12.7% in the year 2006 (KNBS, 2007) and at 40% in the year 2009 (Krishnamurthy & Dejan, 2009).

A total of 394 households were interviewed of whom 63.9% were male and 36.1% female respondents. Men were more than the women in all the sampled wards (Igwamiti, Githiga and Olmoran) probably because, traditionally they are the heads of the households and only in their absence do women head the households on a part-time basis.

Table 4.1: Age distribution of the respondents in Laikipia West

		Age Group					Total
Ward	**Gender**	**18-24**	**25-35**	**36-45**	**46-55**	**Over 55**	
Igwamiti	Male	1	13	39	45	42	140
	Female	0	8	34	29	24	95
	Total	1	21	73	74	66	235
Githiga	Male	2	8	20	16	17	63
	Female	0	3	6	8	13	30
	Total	2	11	26	24	30	93
Olmoran	Male	0	3	10	12	23	48
	Female	0	4	2	4	8	17
	Total	0	7	12	16	31	65
	Grand total	**3(0.8%)**	**39(9.9%)**	**111(28.2%)**	**114(28.9%)**	**127(32.2%)**	**394(100%)**

Female headed households were not common. Temesgen *et al.* (2009) found that male-headed households adapt more readily to climate because they have more access to improved technology, information on climate, credit and extension services than female headed household. A study by Campbell *et al.* (2002) on household livelihoods in semi-arid areas has shown similar results of both male and female gender involvement in farming activities as a response to meeting livelihood needs occasioned by the harsh environment in ASALs. Studies by Ndegwa *et al.* (2010) and Ndungu *et al.* (2004) have also shown that males and females equally participate in farming with differences only in the farming activities they are engaged in. Farming activities that are manually demanding for example: irrigation, land preparation and spraying are dominated by males; while females handle activities requiring precision like sorting, planting, picking, grading and packaging (Ndegwa *et al.*, 2010).

4.2.2 Marital Status and Family Sizes

In terms of marital status of the agro-pastoral farmers interviewed in Laikipia West sub-County, 281 out of 394 (71.6%) were married while 42 out of 394 (10.7%) were single, 61 out of 394 (15.5%) widowed and 9 out of 394(2.3%) were divorced as shown in Table 4.2. The results are in agreement with Kenya Demographic and Health Survey (2003) that describes Kenya as a marrying society and that almost everyone had done so by age 40-44 (Kenya Demographic and Health Survey, 2003).

The mean number of family members over 18 years of age per household in Laikipia West sub-County was 2.63 persons, while for family members under 18 years of age per household was 2.19 persons. Therefore, the mean number of family members per household was 4.82 persons. However, the average family size for Kenya is 4.4 compared with the average for less developed countries of 2.17 while, for Sub-Saharan Africa, it is 5.6 based on average number of surviving children per woman (female over 15 years) (Haupt & Kane, 2002).

Table 4.2: Marital status of Respondents in Laikipia West

	Igwamiti		**Githiga**		**Olmoran**		**Total**	
Marital status	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**
Married	166	70.2	65	69.9	51	78.5	282	71.6
Single	30	12.8	11	11.8	1	1.5	42	10.7
Divorced	7	3	1	1.1	1	1.5	9	2.3
Widowed	33	14	16	17.2	12	18.5	61	15.5
Total	**236**	**100**	**93**	**100**	**65**	**100**	**394**	**100.0**

4.2.3 Education Levels of the Respondents

A descriptive analysis of the education level of the respondents in the study area was summarized in frequency distribution as shown in Table 4.3. Results of this study showed that majority (49.5%) of the respondents had primary school education. As the level of education increased, the number of respondents with such qualifications decreased accordingly with 34.0% having secondary education, 8.9% having attained tertiary education and only 2.5% university education. Education is a significant income diversification strategy that is critical to climate variability and change adaptation. These results imply that majority of the dairy farmers may lack adequate formal education which is a prerequisite to better modern farming technologies. In addition to this, the level of education of the household head can influence the kind of decision that may be made on behalf of the entire household with regard to farming technologies. More educated farmers are likely to make better decisions as well as quickly adopt new technologies in farming as compared to their less educated counterparts. The results showed that significantly more males than females had tertiary and university education. These low levels of education can be attributed to high dropout at primary level especially for girls (Glennerster *et al.*, 2011).

Table 4.3: Education level of respondents in Laikipia West sub-County.

	Igwamiti		Githiga		Olmoran		Totals	
Level of education	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**
Informal	2	0.9	8	8.6	10	15.4	20	5.1
Primary	112	46.8	48	51.6	35	53.8	195	49.5
Secondary	97	41.6	25	26.9	12	18.5	134	34.0
Tertiary	20	8.6	8	8.6	7	10.8	35	8.9
University	5	2.1	4	4.3	1	1.5	10	2.5
Total	**236**	**100**	**93**	**100**	**65**	**100**	**394**	**100.0**

4.2.4 Land Tenure and Size

Land tenure plays an important role in agricultural production. Majority (87.1%) of the agro-pastoral farmers are individual land owners with title deeds, while individual land owners without title deeds were 3.0% and a few owned community land (0.5%) and family owned land (8.4%). Results of landholding size presented in Table 4.4 shows that the average size of total cultivated land owned by the agro-pastoral farmers was 4.4 acres with farmers having the smallest size of land owning 0.5 acres and the largest owning 50 acres. This is in agreement with the findings of Jayne *et al.* (2003) who noted that the average landholdings in the small farm sector ranges between 5 and 7 acres in Kenya. The larger proportion of respondents (84.3%) had farms measuring below 5 acres (Table 4.4). Agro-pastoral farmers in the sub-county need to maximally invest on the available land to increase production because land for expansion is limited. This finding is supported by Ogola *et al.* (2011) that small land size is an indication that intensive farming is the only option to enhance production.

Demands on the land for economic development and pressures from a burgeoning population are leading to an influx of "immigrant" farmers into the arid and semi-arid lands of Kenya (Muyanga & Jayne, 2012). In Laikipia West sub-County, this influx of farmers from neighboring high potential counties is leading to more land fragmentation and declining household farm sizes (Laikipia CIDP, 2013).

Table 4.4: Land holding size

	Igwamiti		Githiga		Olmoran		Totals	
Land size	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**
Below 5	201	85.2	81	87.1	50	76.9	332	84.3
6-10	25	10.6	10	10.8	14	21.5	49	12.4
11-15	1	0.4	2	2.2	0	0	3	0.8
16-20	2	0.8	0	0	0	0	2	0.5
Above 20	7	3	0	0	1	1.5	8	2.0
Total	**236**	**100**	**93**	**100**	**65**	**100**	**394**	**100.0**

Mean = 4.4027, Standard deviation = 4.556, Min = 0.25, Max = 50.00, Range = 49.75

4.3 Household Perceptions of Climate Variability in Laikipia West sub-County.

Respondents were asked to provide information on their perception of increased frequency of droughts, decreased rainfall amounts, extended dry spells and change in rainfall distribution as shown in Table 4.5. The results imply that, most agro-pastoral farmers in Laikipia West sub-County perceived that, climate variability was characterized by extended dry spells (85.8%) with decreased rainfall amounts (91.1%), increased frequency of droughts (61.9%) and increased change in the distribution of rainfall (54.6%) over the last 20 years.

Respondents also opined out that, climate variability predominantly led to increased incidences of pests and diseases (78%). At least 34% of respondents said that climate variability had contributed to a decrease in growing periods. These results were corroborated by key informants who observed that, severe droughts such as those of 1984 and 2009 led to loss of livestock and crops. Through, key informant interviews, the agricultural experts and farmers concurred that in the 1970's and 1980's, rainfall was more predictable and regular in season but this is not the case now. They stressed that decline in agricultural production was as a result of low and unpredictable rainfall, increased temperatures, failure to predict the on-set of rainy season using traditional indicators/indigenous knowledge and coupled with lack of information of the current soil fertility status in Laikipia West sub-County. These findings are in agreement with Gbetibouo (2009), who stated that 97% of the respondents in the Limpopo Basin had observed changes in rainfall patterns over the last 20 years, and 81% noticed a decrease in the amount of rainfall or a shorter rainy season. Research findings are also upheld by, Dore (2005) who revealed that wet regions are increasingly experiencing higher levels of precipitation, and arid areas are witnessing reduced levels and becoming drier.

Table 4.5: Household perceptions on Indicators of climate variability

	Igwamiti		**Githiga**		**Olmoran**		**Totals**	
Climate variability Trends/indicators	Freq.	%	Freq.	%	Freq.	%	Freq.	%
Climate variability indicators								
Extended dry spells	190	80.9	86	92.5	62	95.4	338	85.8
Windstorms	64	27.1	1	1.1	25	38.5	90	22.8
Increase in rainfall amounts	9	3.8	8	8.6	8	12.3	25	6.3
Decrease in rainfall amounts	224	94.9	78	83.9	57	87.7	359	91.1
Change in rainfall distribution	133	56.4	34	36.6	48	73.8	215	54.6
Frequent drought	146	61.9	54	58.1	44	67.7	244	61.9
Increase in frost	13	5.5	6	6.5	4	6.2	23	5.8
Effects of climate variability								
Increase in growing period	18	7.6	0	0.0	7	10.8	25	6.3
Decrease in growing periods	98	41.5	5	5.4	32	49.2	135	34.3
Increased frequency of floods	7	3.0	2	2.2	4	6.2	13	3.3
Decreased frequency of floods	35	14.8	5	5.4	26	40.0	66	16.8
Occurrence of pests and diseases	196	83.1	52	55.9	59	90.8	307	77.9

According to studies by Kuria (2009) and Macharia *et al.* (2012), the main indicators of climate change were changes in rainfall patterns, rise in temperatures, low rainfall, drying of rivers, low crop yields increase of frost due to low temperatures and increase of droughts. The surge in occurrence of pests and diseases in the study site of Kuria (2009) and the Macharia *et al.* (2012) sites may have been as a result of the rise in temperature.

Key informants repeatedly state that, rainfall patterns and amounts are key indicators of climatic variability because of crop yields and livestock production that are dependent on rainfall. These findings are consistent with Berger (1989), Haile (2005), Lobell and Burke (2008); and Mortimore (1989) in Laikipia, Ethiopia, Africa and West Africa, respectively.

A study by URT (2005) concluded that, the impacts of climate variability are manifested by floods, droughts, erratic rains and extreme events. They revealed that famine resulting from either floods or drought has become increasingly common since the mid-1990s and is undermining food security. Climate variability and change are likely to intensify drought and increase potential vulnerability of the communities to future climate variability and change especially in the semi-arid regions, where crop production and livestock keeping are critically important to food security and rural livelihoods.

Through key informant interviews, the agricultural experts and farmers concurred that in the 1970's and 1980's, rainfall was more predictable and regular in season but this is not the case now. They stressed that decline in agricultural production was as a result of low and unpredictable rainfall, increased temperatures, failure to predict the on-set of rainy seasons using traditional indicators/indigenous knowledge and coupled with lack of information of the current soil fertility status in Laikipia West sub-County.

Table 4.6: Changes in Mean Temperature, onset of long rains and annual rainfall over the last 20 years

Ward	Change in Temp (%)	Change in onset of long rains (%)	Change in annual Rainfall (%)
Igwamiti	97.0	97.0	98.3
Githiga	100.0	100.0	98.9
Olmoran	100.0	100.0	100.0
Total	**98.2**	**98.2**	**98.7**

Nearly all respondents mentioned that, they had experienced change in temperature, onset dates of long rains and annual rainfall amounts in the study area had changed (Table 4.6). Similar observations have been reported by various scholars studying, for instance intra-seasonal factors, such as the timing of the onset of first rains affecting crop-planting regimes (Tennant & Hewitson, 2002), length and distribution of period of rain during the growing season (Mortimore & Adams, 2001), and the effectiveness of the rains in each precipitation event (Usman & Reason, 2004), are the real criteria that affect the effectiveness and success of farming. Recha *et al.* (2013) reported that, persistence of below normal rainfall is a great risk to people's livelihood in Tharaka district in Kenya, where majority of people have been left vulnerable to hunger and famine. IPCC (2007) reported that changes in rainfall amount and patterns also affect soil erosion rates and soil moisture, both of which are important for crop yields.

Table 4.7: Observed changes in number of hot days, rainfall patterns, number of rain days, Effect of climate variability on planting time.

Observed changes	Categories	Freq.	Percent	Chi-square	Df	P-value
Number of hot days	Stayed the same	3	0.8	134.061	2	.000
	Increased	342	86.8			
	Declined	42	10.7			
Rainfall patterns	Drier	379	96.2	176.780	2	.000
	Wetter	10	2.5			
	No change	5	1.3			
Number of rain days	Stayed the same	2	0.5	169.273	2	.000
	Increased	17	4.3			
	Declined	370	93.9			
Effect of climate variability on planting time	Stayed the same	5	1.3	103.000	2	.000
	Earlier	69	17.5			
	Later	313	79.4			

The distribution of the respondents' opinion on observed changes in the number of hot days over the last 20 years was found to vary (Chi-square value = 134.061, P-value = 0.001) with majority of the respondents (86.8 %) indicating that the incidence had increased in the study area. About 10.7 % argued that it had declined, while only a few of them believed it had stayed the same (0.8%) as shown in Table 4.7. These results agree with Mwangangi *et al.* (2012) whom in their baseline household survey in Makueni, Kenya noted that the number of hot days had drastically increased as a result of climate change.

Majority (93.9%) of the agro-pastoral farmers felt that the number of rain days had significantly declined over the last 20 years, only a few (4.3%) felt that it had increased and the rest (0.5%) stated that it had stayed the same as shown in Table 4.7. The findings by Gbetibouo (2009) in the Limpopo Basin also corroborate these findings. He found out that 97% of the respondents in the study area observed changes in rainfall patterns over the last 20 years, and 81% noticed a decrease in the amount of rainfall or a shorter rainy season. The results of this study uphold the findings of a study conducted by Dore (2005) which revealed that wet regions are increasingly experiencing higher levels of precipitation, and arid areas are witnessing reduced levels and becoming drier. He attributed the precipitation patterns and variance to climate change and ocean currents.

Majority (96.2%) of the agro-pastoral farmers felt that it had become drier, while the rest 2.5% perceived that it had become wetter and 1.3% said there were no changes in the rainfall patterns over the last 20 years as shown in Table 4.7 Similar results were reported by Maddison (2006) whereby, a significant number of farmers in eleven African countries believed that temperatures had increased and that precipitation had declined. Majule *et al.* (2008) also reported the same.

The time of planting is very important for it gives the plant an opportunity to mature before the dry spell. Majority (79.4%; n=313) of the farmers planted later due to the effects of climate variability, while other farmers (69%; n=17.5) planted earlier and only a few (1.3%, n=5) planted at the same planting times as shown in Table 4.7. One of the key informants seconded this by stating that, “before March-August, October-December were the normal rainy seasons but this has changed especially October-December, it only rains for 3 weeks. This has made it difficult to predict when to plant”. Another key informant said that, “we have stopped practicing seasonal planting, because it is sometimes useless and does not pay off. We used to plant in March, and that would be it. Now we plant and plant again. We now waste time, money and energy on planting and land preparation”. These results are in agreement with that of Mary and Majule (2009) where, the majority of farmers declared that, rainfall onset has changed because they used to plant crops in October/November but nowadays they have to plant in December/January.

4.4 Characterization of agro-biodiversity at farm level.

This section presents results of the spatial distribution of agro-biodiversity and natural biodiversity in Laikipia West sub-County. These shall include livestock, crops, trees and shrub species found on household farms.

4.4.1 Livestock Distribution in Laikipia West sub-County

The study reveals that the most commonly kept livestock by households are chicken (85.6%), cattle (76%), goats (49%) and sheep (44.9%). When livestock ownership, was analyzed by study sites, it emerged that cattle and chicken were still the most common as shown in Table 4.8. It is significant to note that, the percentage of households owning livestock at Olmoran was above 60% - with the exception of donkeys and rabbits. Across all study sites, donkeys and rabbits are the least owned livestock. The high ownership percentage of livestock at Olmoran can be attributed to the fact that, it is the driest area and livestock keeping was more resilient to climate variability than crop farming.

Table 4.8: Number of percentage of farmers engaged in livestock farming

	Igwamiti		**Githiga**		**Olmoran**	
Livestock	**Freq.**	**Percent**	**Freq.**	**Percent**	**Freq.**	**Percent**
Sheep	85	37.4	49	52.7	39	60.0
Cattle	180	79.3	69	74.2	44	67.7
Goats	108	47.6	41	44.1	41	63.1
Chicken	185	81.5	81	87.1	62	95.4
Donkeys	15	6.6	1	1.1	3	4.6
Rabbits	28	12.3	2	2.2	1	1.5

The study further sought to find out changes in livestock numbers and the results are shown in Table 4.9. Results from data analysis showed that more than half of the respondents across the four study sites recorded an increase in chicken numbers. In general terms, it is evident from the results that of the main livestock (cattle, sheep, goats and chicken) in Laikipia West sub-

County, most respondents indicated cattle numbers were on the decline while fewer respondents indicated goat numbers were on the decline.

It is also significant to note that at Olmoran, goats were reported to be on the increase (44%); while a majority of the respondents at Igwamiti indicated cattle was on the increase (38%). It is possible that at Igwamiti, a relatively high potential area, most households are resulting to dairy farming as a way of diversifying income. The relative increase in goats at Olmoran can be attributed to the resilience of goats to drought which is frequent in ASAL, than other livestock such as cattle and sheep. These results are in agreement with Kangalawe and Lyimo (2013) that, as a result of climate variability and its impact on availability of water and pasture, many farmers now put an emphasis on small stocks whose water and fodder requirements are small, as expressed by 37.5% of the respondents. The small stocks include: goats, sheep as well as chicken.

Table 4.9: Livestock changes in numbers

	Igwamiti		**Githiga**		**Olmoran**	
Livestock	**Increasing (%)**	**Declining (%)**	**Increasing (%)**	**Declining (%)**	**Increasing (%)**	**Declining (%)**
Sheep	22.5	5.7	23.7	8.6	40.0	7.7
Cattle	38.3	32.6	11.8	39.8	16.9	47.7
Goats	31.7	7.9	19.4	17.2	44.6	9.2
Chicken	49.3	15.9	54.8	5.4	67.7	12.3
Donkeys	0.9	0.0	0.0	1.1	1.5	1.5
Rabbits	5.3	1.3	0.0	0.0	0.0	0.0

4.4.2 Crop Production in Laikipia West sub-County

The main crops grown in Laikipia West sub-County were: maize, beans, Irish potatoes, wheat and vegetables, although a few agro-pastoral farmers grow bananas, millet, cassava, cowpeas and garden peas. The main abandoned crops over the last 20 years were found to be pyrethrum and coffee.

Table 4.10: Number of percentage of farmers engaged in crop farming

	Igwamiti		Githiga		Olmoran	
Crop	**Freq.**	**Percent**	**Freq.**	**Percent**	**Freq.**	**Percent**
Maize	230	97.5	90	96.8	63	96.9
Beans	170	72.0	76	81.7	58	89.2
Irish potatoes	164	69.5	18	19.4	15	23.1
Kales	82	34.7	16	17.2	6	9.2
Fruit trees	30	12.7	32	34.4	35	53.8
Tree tomatoes	27	11.4	0	0.0	4	6.2
Bananas	10	4.2	21	22.6	9	13.8
Tomatoes	6	2.5	28	30.1	7	10.8
Cassava	1	0.4	11	11.8	3	4.6
Wheat	55	23.3	9	9.7	4	6.2
Garden peas	10	4.2	2	2.2	1	1.5
Cowpeas	10	4.2	2	2.2	2	3.1

Table 4.10 shows the results of crops grown in Laikipia West sub-County by study sites. In all the three wards (Igwamiti, Githiga and Olmoran), all the agro-pastoral farmers set aside large portions of farms to plant maize and beans. However, Irish potatoes were planted more in Igwamiti ward (69.5%) as compared to Githiga ward (19.4%) and Olmoran ward (23.1%). More agro-pastoral farmers in Igwamiti set aside large portions of their farms to plant kales, wheat and tree tomatoes, as compared to those in Githiga and Olmoran wards as shown in Table 4.10. The attitude that food is equivalent to maize limits the adoption of other crops such as sorghum, cassava, cowpeas and green grams that are well adapted to variable climate. According to Brooks *et al.* (2009), for many farmers one way of dealing with increasing droughts is to plant drought tolerant crops such as: cassava, millet, sorghum, cowpeas and green grams. However, most of the crops which were traditionally consumed are sometimes considered “the poor man’s crop” which can put some off cultivating them.

Table 4.11 shows the reported decline or increase in in acreage of the major crops cultivated in Laikipia West sub-County. The majority of the agro-pastoral farmers were decreasing the acres of land set aside for maize farming as shown in Igwamiti (52.5%), Githiga (48.4%) and Olmoran (75.4%) wards. However, acres of land set aside for beans farming was increasing in

Olmoran ward (50.8%) and decreasing in Igwamiti and Githiga wards (43.2% and 24.7%) respectively. Growing of other crop types were increasing in all the wards as shown in Table 4.11. The majority (55.3%%) of the respondents in Laikipia West sub-County reduced the size of acres set aside for maize as well as beans farming (36.0%) and were instead increasing the acres of their farm on growing Irish potatoes (31.2%) and fruit trees (13.2%) as a result of climate variability and change as shown in Table 4.11.

Regional predictions suggest that 10% of grain production in East Africa may be lost by 2080 because of climatic variations and changes manifested in the increase of temperature and decline of rainfall. However, the impact of climatic change on crop production varies considerably between regions and countries, and between types of agricultural production (Parry *et al.*, 1999). With regard to Tanzania, for instance, Mwandosya *et al.* (1998) argue that climate change and variations will have more impact on maize production than root crops. The impact of climate change on food production is also likely to be more pronounced in the central part of the country than in other zones in Tanzania.

Table 4.11: Crops Declining/Increasing in acreage

	Igwamiti		**Githiga**		**Olmoran**	
Crop	**Increasing (%)**	**Declining (%)**	**Increasing (%)**	**Declining (%)**	**Increasing (%)**	**Declining (%)**
Maize	28.8	52.5	20.4	48.4	13.8	75.4
Beans	10.2	43.2	19.4	24.7	50.8	26.2
Irish potatoes	47.0	9.7	5.4	4.3	10.8	3.1
Kales	13.6	1.3	5.4	2.2	4.6	0.0
Fruit trees	5.1	0.4	12.9	5.4	46.2	1.5
Tree tomatoes	2.5	1.3	7.7	0.0	0.0	0.0
Bananas	0.8	0.8	5.4	6.5	6.2	1.5
Tomatoes	1.3	0.0	20.4	4.3	4.6	3.1
Cassava	0.0	0.0	2.2	0.0	0.0	0.0
Wheat	17.8	3.4	3.2	2.2	3.1	0.0
Garden peas	1.3	0.0	1.1	0.0	1.5	0.0
Cowpeas	0.4	0.0	0.0	0.0	0.0	0.0

However, it must also be borne in mind that forecasters do not always predict the changes and variations of rainfall over time and space absolutely correctly. Similar observations have been made by Ingram *et al.* (2002), who stated that climate change and the failure to forecast the changes and variability correctly had negatively affected agricultural production in Burkina Faso.

4.4.3 Factors considered in the choice of crop grown and livestock kept.

The study sought to find out the various factors considered by the agro-pastoral farmers before deciding the crops grown and livestock kept. These factors were food security, drought tolerance, producer price, price of inputs and seasonal forecasts as presented in Table 4.12.

Table 4.12: Factors considered in choice of crops grown/livestock kept

Factors considered	**Wards**	**Frequency**	**Percent** (%)
Food security	Igwamiti	206	87.3
	Githiga	68.0	73.1
	Olmoran	58.0	89.2
	Total	332	84.3
Drought tolerance	Igwamiti	72	30.5
	Githiga	44	47.3
	Olmoran	43.0	66.2
	Total	159	40.4
Producer price	Igwamiti	153	64.8
	Githiga	42.0	45.2
	Olmoran	19.0	29.2
	Total	214	54.3
Price of inputs	Igwamiti	60	25.4
	Githiga	29	31.2
	Olmoran	42	64.6
	Total	131	33.2
Seasonal forecasts	Igwamiti	12.0	5.1
	Githiga	9	9.7
	Olmoran	29	44.6
	Total	50.0	12.7

Most of the agro-pastoral farmers considered food security before deciding on the crops to grow and livestock to keep in the three wards (Igwamiti, Githiga and Olmoran wards). Drought tolerance (66.2%) and seasonal forecasts (44.6%) were considered more in Olmoran ward because it is a drier area as compared to Igwamiti (30.5% and 5.1%) and Githiga wards (47.3% and 9.7%) respectively. Igwamiti experiences a cooler climate but it gets drier towards Githiga and even drier in Olmoran ward. Majority (85.8%) of the respondents considered certain factors before deciding on the crop/livestock to keep, only a few (14.2%) of them did not consider any of the factors. Among the factors considered majority (84.3%) considered the food security before deciding on the crop/livestock to keep, others also considered producer price (54.3%) drought tolerance (40.4%), then price of inputs (33.2%) and only a few (12.7%) considered seasonal forecast before deciding on the crop/livestock to keep as shown in Table 4.12. According to Okoti *et al.* (2013) growing crops and keeping livestock well adopted to local conditions as well as drought tolerance is a key element to responding to the threat to food security from climate variability and change.

4.4.4 Characterization of Agro-biodiversity of Woody Trees and Shrub Species

There were 28 woody tree species and 15 shrub species encountered in Laikipia West sub-County at farm level as shown in Table 4.14 and Table 4.15

Table 4.13: Showing the diversity characteristics to be obtained

Characteristics	Tool
Species diversity	Simpsons Diversity index (excel) D=1-(Ʃn(n-1)/N(N-1)) n> the total number of trees of a particular species N=the total number of trees of all species
Species richness	Menhinick's index D=s/√N Where; s-number of different species N- total no. of individual species

Table 4.14: Tree species composition, diversity, richness and relative frequency.

Tree Species	Total	Species Diversity	Species Richness	Relative Frequency
Acacia mellifera	2		19.79	0.33
Acacia tortilis	9		9.33	1.48
Acacia nilotica	60		3.61	9.87
Acacia xanthophloea	2		19.79	0.33
Croton megalocarpus	68		3.39	11.18
Grevelia robusta	65		3.47	10.69
Cupressus lusitanica	127		2.48	20.89
Pinus patula	4		14	0.66
Olea Africana	12		8	1.97
Eucalyptus saligna	140		0.8	23.03
Erythrina abyssinica	2		2.37	0.33
Azadirachta indica	1		19.79	0.16
Dombeya goetzenii	2		28	0.33
Ficus thonningii	1		19.79	0.16
Juniperus procera	33		28	5.43
Eriobotrya japonica	4		4.87	0.66
Podocarpus latifolius	12		14	1.97
Terminalia brownie	3		8.08	0.49
Acacia mearnsii	5		16.16	0.82
Mangifera indica	14		12.52	2.30
Callistemon citrinus	27		7.48	4.44
Macadamia integrifolia	6		5.39	0.99
Vangueria madagascariensis	2		11.43	0.33
Citrus limon	2		19.79	0.33
Psidium guajava	1		28	0.16
Malus domestica	1		28	0.16
Carnegiea gigantean	2		19.79	0.33
Euphorbia candelabrum	1		28	0.16
TOTAL	**608**	**0.87**		

Trees and shrub diversity were determined using species richness, composition, relative frequency and Simpson's diversity index as shown in Table 4.14 and Table 4.15.

Table 4.15: Shrub species composition, diversity index, richness and relative frequency.

Shrubs Species	Total	Species Diversity	Species Richness	Relative Frequency
Clerodendum johnstonii	3		8.66	0.47
Myrsine Africana	15		3.87	2.33
Cassia didimobotrya	115		1.39	17.88
Carrisa edulis	26		2.94	4.04
Croton dichogamus	10		4.74	1.56
Justidia flava	46		2.21	7.15
Rhus natalensis	20		3.35	3.11
Acacia gerardii	98		1.52	15.24
Euphorbia tirucalli	5		6.71	0.78
Leucas martinicensis	4		7.5	0.62
Cyathula schimperiana	2		10.61	0.31
Psiadia Arabica	14		4.01	2.18
Tarconanthus camphorates	1		15	0.16
Solanum betaceum	40		2.37	6.22
Acokanthera oppositifolia	244		0.96	37.95
TOTAL	**643**	**1**		

Analysis of characteristics of trees and shrubs is summarized in Table 4.13, Table 4.14 and Table 4.15. There were 28 tree species and 15 shrub species encountered in Laikipia West sub-County. Results of data analysis show that shrubs are more diverse as compared to tree species. This may be attributed to human activities such as: cutting down of trees for firewood, poles, construction amongst others as shown in Plate 1. These results are in agreement with results by Tape *et al.* (2006) using oblique aerial photographs and remote sensing Normalized Difference Vegetation Index (NDVI) show that there has been an increase in shrub cover over the past 50 years in northern Alaska. The alder, willow, and dwarf birch have been increasing, with the change most easily detected on hill slopes and valley bottoms. Shrub expansion has also been reported in Canada, Scandinavia, and parts of Russia. Blok *et al.* (2011) attributes this growth to climate change with the main climate drivers for shrub growth being early summer temperature and summer precipitation. Warming is occurring more rapidly in the Arctic than anywhere else in the world.

Plate 1: Firewood extraction

4.5 Effects of Climate Variability on Provisioning Ecosystem Services (Food Supply, Livestock Production and Water Availability)

The study sought to find out the effects on climate variability on food supply, water availability as well as agro-biodiversity maintenance of trees and shrub species.

4.5.1 Effects of Climate Variability on Food Supply

The study intended to find out the effects of climate variability. The results of data analysis showed that crop yield had declined in the last 20 years as indicated in Table 4.16.

Table 4.16: Crop yield changes in the last 20 years

Changes in crop yield	Wards	Frequency	Percent (%)
Improved	Igwamiti	22	9.3
	Githiga	2.0	2.2
	Olmoran	1.0	1.5
	Total	25	6.3
Remained the same	Igwamiti	3	1.3
	Githiga	0	0.0
	Olmoran	0	0.0
	Total	3	0.8
Declined	Igwamiti	208.0	88.1
	Githiga	91.0	97.8
	Olmoran	64	98.5
	Total	363.0	92.1

Causes of changes in crop yield	Ward	Frequency	Percent (%)
Soil fertility	Igwamiti	92	39.0
	Githiga	18	19.4
	Olmoran	40	61.5
	Total	150	38.1
Rainfall	Igwamiti	85.0	36.0
	Githiga	28.0	30.1
	Olmoran	42	64.6
	Total	155.0	39.3
Drought	Igwamiti	156	66.1
	Githiga	83.0	89.2
	Olmoran	55.0	84.6
	Total	294	74.6
Pests and diseases	Igwamiti	153.0	64.8
	Githiga	52.0	55.9
	Olmoran	49.0	75.4
	Total	**254.0**	**64.5**

Majority (92.1%) of the respondents experienced decline in crop yields in the last 20 years. Respondents reported that the main causes of decline in crop yields/food supply in Laikipia west Sub-County were drought (74.6%), pests and diseases (64.5%), rainfall (39.3%) and soil fertility status (38.1%) as shown in Table 4.16. Farmers perceived that there has been an increase in pests and disease due to increase in temperatures for instance, stalk borers (*Calidea dregii)* and Maize *Lethal necrosis* disease. According to the key informants in 2014, many farmers had almost total failure on maize yields as a result of drought and the maize *Lethal necrosis* disease. The IPCC reported that, an increase in average temperature will adversely affect crops, especially in semi-arid regions, where already heat is a limiting factor of production (IPCC, 2007). Increased temperature also increase evaporation rates of soil and water bodies as well as evapotranspiration rate of plants, and increase chances of severe drought. It means that with warmer temperatures plants require more water.

Given the over-dependence on rain-fed agriculture by a majority of farmers living in rural areas, climate variability has been one of the major limiting factors of agriculture production, thus resulting in food insecurity. Droughts and floods have been reported to cause failure and damage to crops and livestock - leading to chronic food shortages (Kangalawe & Liwenga, 2005; Liwenga *et al.*, 2007). Studies conducted by Rosenzweig *et al.* (2002) revealed that changes in rainfall patterns and amounts have led to loss of crops and reduced livestock production in the United States. As the planet warms up, rainfall patterns shift, and extreme events such as droughts, floods, and forest fires become more frequent. This will result in poor and unpredictable yields, thereby making farmers more vulnerable, particularly in Africa (UNFCCC, 2007).

The two most important climatic elements determining the localization and occurrence of pests and diseases appear to be temperature and moisture. In general, pests and disease vectors do better when the temperature is high under conditions of optimum water supply. Climate variability and change may increase the incidence of pests and diseases. FAO (2007) reported that changing temperatures and rainfall in drought-prone areas are likely to shift populations of insect pests and other vectors and change the incidence of existing vector-borne diseases in both humans and crops.

4.5.2 Effects of Climate Variability on Water Availability

The study sought to find out if there were changes in water quality and quantity as well as distance to the water source over the last 20 years. Majority (62.6%) of the respondents in Laikipia West sub-County felt that there were changes in both water quality and quantity over the last 20 years, however a few (32.4%) felt there were no changes as shown in Table 4.17.

Table 4.17: Changes in water quality and quantity over the last 20 years

Ward	Frequency	Percent (%)
Igwamiti	145	61.7
Githiga	55	66.3
Olmoran	59	90.8
Total	**259**	**62.6**

Most of the agro-pastoral farmers in all the wards in Laikipia West sub-County agreed that the distance to the water source had declined. However, with regards to water amounts only respondents in Githiga ward (63.8%) felt that it had increased, the others in Igwamiti and Olmoran wards felt that water amounts had declined (53.1% and 61.4% respectively) as shown in Table 4.18. This was because many agro-pastoral farmers in Githiga ward had access to borehole water as compared to Olmoran and Igwamiti wards. Responding to water scarcity stress and the threat of declines in crop yields require farm level intervention such as rainwater harvesting and establishing small-scale water reservoirs on farmlands (Osman-Elasha, 2010).

Table 4.18: Changes in distance to water source and water amounts over the last 20 years

Nature of changes	**Ward**	**Response**	**Freq.**	**Percent (%)**	**Chi-square**	**df**	**P-value**
Distance to water source	Igwamiti	Declined	129	87.8	196.286a	2	.000
		Remained the same	6	4.1			
		Increased	12	8.2			
	Githiga	Declined	48	78.7	57.082a	2	.000
		Remained the same	9	14.8			
		Increased	4	6.6			
	Olmoran	Declined	29	47.5	24.820a	2	.000
		Remained the same	2	3.3			
		Increased	30	49.2			
	Total	Declined	206	78.6	231.086a	2	.000
		Remained the same	17	6.5			
		Increased	46	17.6			
		Total	269	100.0			
Water amount	Igwamiti	Declined	78	53.1	50.245a	2	.000
		Remained the same	10	6.8			
		Increased	59	40.1			
	Githiga	Declined	13	22.4	24.862a	2	.000
		Remained the same	8	13.8			
		Increased	37	63.8			
	Olmoran	Declined	35	61.4	28.737a	2	.000
		Remained the same	2	3.5			
		Increased	20	35.1			
	Total	Declined	126	48.1	78.443a	2	.000
		Remained the same	20	7.6			
		Increased	116	44.3			
		Total	**262**	**100.0**	**61.153a**	**2**	**.000**

Table 4.19: Changes in water availability in the last 20 years

Changes in water availability	Categories	F	%	Chi-square	Df	P-value
Changes in amount of water	Declined	146	33.7	92.170	2	0.000
	Remained the same	20	5.3			
	Increased	116	31.0			
Changes in the distance to water source	Declined	219	54.1	253.809	2	0.000
	Remained the same	17	4.5			
	Increased	46	12.1			

Results of this study showed that, the amount of water available has declined as perceived by 33.7% of the respondents in Laikipia West sub-County as shown in Table 4.19. This may be due to the decrease in the amount of rainfall as stated by majority of the respondents. However, majority (54.1%) of the respondents perceived that the distance to the water source had declined. This may have been due to majority (77.2%) of the agro-pastoral farmers having access to borehole water.

According to IPCC (2019) rainfall changes and variations significantly affect agriculture and the availability of water for socioeconomic activities including water for domestic use, crop and livestock production, particularly in arid and semi-arid areas in developing countries. Decreased rainfall, for example, is likely to reduce the water available for crops and livestock, the key economic activities of most rural populations in developing countries where rain-fed agriculture is dominant. Globally, however, the potential for food production is projected to increase with increases in local average temperatures ranging from one to three degrees centigrade. Above this temperature range, however, food production is projected to decrease. At lower latitudes, especially in seasonally dry and tropical regions, crop productivity is projected to decrease even with small local temperature increases (1 to 2°C), which will increase the risk of hunger.

4.6 Response strategies and mechanisms currently used by agro-pastoral farmers to cope with effects of climatic variability.

Results in Figure 4.1 show that crop diversification (85.0%), use of fertilizer and manure (83.5%), pesticides (74.9%) and herbicides (66.2%) are the lead response strategies to low crop yields among agro-pastoralists in Laikipia West sub-County. These findings are contrary to the findings of a study done in Yatta County, Kenya were most farmers (76.5%) planted drought tolerant crops and practiced charcoal burning (52.9%) as adaptations to the effects of climate variability (Mburu *et al.*, 2015).

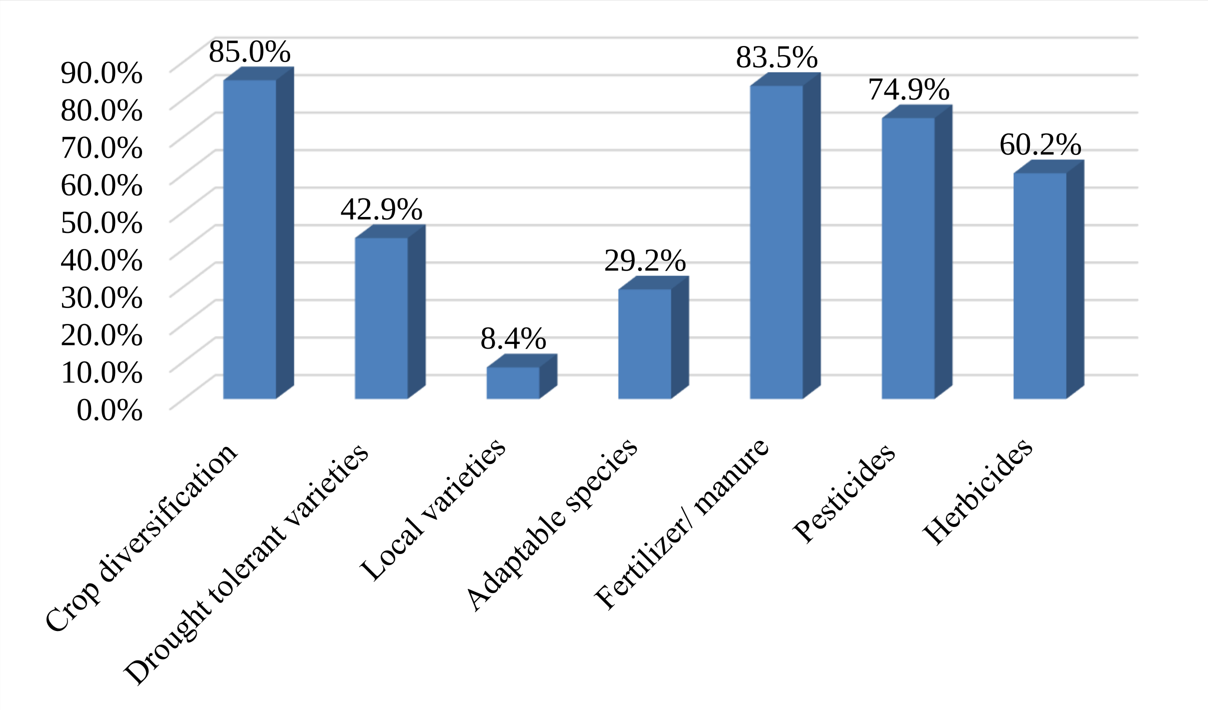

Figure 4.1: Agro-pastoral farmers' response Strategy to low yields/crop failure

Results in table 4.20 presents response strategies by study sites.

Table 4.20: Response strategies to low yields/crop failure

Response strategy	Ward	Freq	Percent (%)
Diversification	Igwamiti	223	94.5
	Githiga	66.0	71.0
	Olmoran	46.0	70.8
	Total	335	85.0
Drought tolerant varieties	Igwamiti	81	34.3
	Githiga	45.0	48.4
	Olmoran	43.0	66.2
	Total	169	42.9
Local varieties	Igwamiti	19.0	8.1
	Githiga	7.0	7.5
	Olmoran	7.0	10.8
	Total	33.0	8.4
Adaptable species	Igwamiti	59.0	25.0
	Githiga	14.0	15.1
	Olmoran	42.0	64.6
	Total	115.0	29.2
Fertilizer/Manure	Igwamiti	198.0	83.9
	Githiga	75.0	80.6
	Olmoran	56.0	86.2
	Total	329.0	83.5
Pesticides	Igwamiti	193.0	81.8
	Githiga	47.0	50.5
	Olmoran	55.0	84.6
	Total	295.0	74.9
Herbicides	Igwamiti	170.0	72.0
	Githiga	24.0	25.8
	Olmoran	43.0	66.2
	Total	**237.0**	**60.2**

4.6.1 Diversification of Crops

An investigation was carried out in order to establish whether the agro-pastoralists used diversification as a response strategy to low yields or crop failure. On analyzing this item, results showed that 85% of the respondents practiced this response strategy (Table 4.20). This showed that the agro-pastoralists had indigenous knowledge that a diversified portfolio of crop products would ensure that farmers do not suffer complete ruin when the weather is unpredictable. The respondents mentioned traditional maize varieties; Irish potatoes, sweet potatoes; and beans as the main crops they grow together. According to Altieri (1999) diversity of crops both in time and space is a traditional strategy to promote diversity in income sources, minimize risks, production stability, reduced insect pest and disease incidence, efficient use of labor, increased production with limited resources and maximization of returns under low levels of technology. Crop diversity can result in higher total yields per hectare than mono cropping, even when yields of individual components are reduced. Mixtures result in more efficient use of light, water and nutrients by plants of different height, canopy structure and nutrient requirements.

Crop diversification is intended to give a wider choice in the production of a variety of crops in a given area so as to expand production related activities on various crops and also to lessen risks related to climate variability and change (Njeru, 2013). However even crops that are indigenous in one area or improved varieties of the same may not always prove to be suitable in other areas though the areas may appear to be ecologically the same. For example, Hulme *et al.* (2001) cites a case in Ethiopia where higher yielding sorghum varieties were introduced to increase food security and income for farmers and rural communities. When weather and other conditions were favorable, the modern varieties proved a success. However, in some areas complete crop failures were observed, whereas local varieties, with a higher variance of traits, were less susceptible to the frequent droughts. The loss of an entire crop was considered by the farming community as more than offset by the lower, average yields of the local variety that performed also under more extreme conditions. According to the Convention on Biological Diversity (CBD), in some places there will be acceleration in the loss of the genetic and cultural diversity already occurring in agriculture as a result of global climate change. This loss will also be evident in crops and domestic animals. A 2.5°C rise in global temperature would determine major losses: between 20 and 30 per cent of all plant and animal species could face a high risk of extinction. Ecosystems and species display a wide range of vulnerabilities to climate variability and change, depending on the imminence of exposure to ecosystem-specific critical thresholds. Local and rare breeds of livestock and plant/crop species could be lost as a result of the impact of climate variability and disease epidemics. Biodiversity loss has global health implications and many of the anticipated health risks driven by climate variability will be attributable to a loss of genetic diversity (CBD, 2007).

4.6.2 Use of Fertilizer/Manure

Soil fertility was expected to be a key factor in crop production. On analysis the results showed that 83.5% of the respondents used either chemical fertilizer or manure as a response strategy to climate variability (Table 4.20). This high percentage may explain that the response strategy was popular and acceptable by the community.

From the key informants' interview, it was noted that the soil fertility status of Laikipia West sub-County was not known and therefore, the agricultural extension officers and experts were not sure on whether they were giving out the right fertilizers to the farmers.

From the survey, it came out that the agro-pastoralists perceived soil fertility in terms of the soil colour (67.4%), crop yield (94.1%), weed growth (46.8%), colour of crop (53.4%), and crop growth rate (51.7%). They employ different indicators of knowing whether the soil is fertile or not. The major indicator mentioned by agro-pastoralists was crop yield (94.1%). A variety of soil fertility management techniques practiced by agro-pastoralists in the study area include application of farmyard manure, mixed cropping, planting leguminous crops, very few agro-pastoralists practiced fallow cropping and opening of new fields. The reasons given by agro-pastoral farmers on why they used the strategy concur with the scientific definition of soil fertility as the status of a soil with respect to its ability to supply elements essential for plant growth without a toxic concentration of any element to enhance productivity (Deenik, 2005).

Table 4.21: Response Strategy to low rainfall

Response Strategy to Low rainfall	Frequency	(%)
Irrigation	149	37.8
Livestock production	203	51.5
Migration	5	1.3
Open up larger fields	1	0.3
Use of greenhouses	2	0.5
Water management practices	162	41.1
Response Strategy to Late onset of rains		
Change of crop variety practices	264	67.0
Change of crop variety practices	227	57.6
Response Strategy to few number of rain days		
Water management practices	163	41.4
Short season crops practices	225	57.1

4.6.3 Irrigation

The study intended to find out whether; irrigation was practiced as a response strategy to low rainfall. The proportion of respondents reporting this practice was relatively small (37.8%) showing that irrigation was not a common practice in the study area as shown in Table 4.21. This may have been so because many (77.8%) respondents relied on rain water for irrigation use yet rainfall amounts had decreased and only a few (23.2%) relied on borehole water for irrigation use as shown in Table 4.1. The majority of crops grown under irrigation are: tomatoes, cabbages, arrow roots, kales amongst others. There is an emerging trend of increased horticulture production both at large-scale and small-scale levels. This constitutes production of cut flowers, tomatoes, French beans, Aloe, chilies and water melons (Laikipia County Development Plan, 2013).

The results are in agreement with Kangalawe and Lyimo (2013) stated that irrigation or wetland cultivation was practiced close to wetlands as a means of reducing the impacts of drought and high temperatures in the soil since wetlands are relatively cooler and moisture than upper fields. However, poorly developed irrigation facilities limit this practice to only small plots. The proportion of respondents reporting this practice was relatively low (18.8%), indicating that irrigation is not common practice in Manyoni and Shinyanga Rural Districts of Tanzania. In some places, especially in these dryland areas, even wetland cultivation may not be reliable in ensuring sustainable livelihoods especially if they dry up early in the season.

4.6.4 Livestock Production

During low rainfall, majority (51.5%) of the respondents resulted to livestock production as response strategy due to its lower demand on water availability as shown in Table 4.21. While, such a practice has guaranteed a livelihood for the respective households in times of low rainfall and crop failure due to unreliable climatic conditions, they have also been a cause of environmental degradation through overgrazing. Farmers experience shows that as a result of climate variability and its impact on availability of water and pasture, many agro-pastoral farmers now put an emphasis on small stocks whose water and fodder requirements are less. This is expressed by 36.0% of the respondents decreasing cattle stocks and only 10.2 % decreasing goat stocks as well as 6.8% sheep stocks. These results are in agreement with Kangalawe and Lyimo (2013) that farmers experience shows, however, that as a result of climate variability and its impact on availability of water and pasture, many farmers now put an emphasis on small stocks whose water and fodder requirements are small, as expressed by 37.5% of the respondents. The small stocks include: goats, sheep as well as chicken.

Plate 2: Livestock rearing in Laikipia West

4.6.5 Migration

Migration was practiced by minority (1.3%) of the respondents as shown in Table 4.21, therefore in the study area (Laikipia west sub-County), mobility as a response strategy was almost non-existent. The low mobility can be attributed to land tenure system, with individual land ownership with title deeds. With this kind of land ownership, there is limited mobility and much confinement.

4.6.6 Harvest and store water practices

This study investigated whether, rain water harvesting was used as a response strategy during the late onset of rains. The results after analysis showed that only 57.6% of the respondents used the strategy as shown in Table 4.21. This average practice could be linked to the findings on land ownership which showed that majority of the respondents in the study area owned land privately, while, ATPS (2013) observes that the potential of rain water harvesting in providing water supplementation to increase crop yield and reduce the risk of crop failure is very high. Respondent agro-pastoral farmers practising this technique, reported improved food security in their households. These findings agree with the results of an evaluation of rainwater harvesting techniques conducted in Laikipia District that showed road runoff water utilization for crop production is already improving yields (Kihara, 2002).

Plate 3: Rain water harvesting

According to Ngigi (2009) agricultural water management is one of the best bets for adapting agricultural production to climate variability and change. Water management can be improved through a diversity of options such as shallow wells, boreholes and rainwater storage. Nonetheless, the ecological effects of these options need to be investigated.

4.6.7 Short season crops practices

The growing season, which is the period of each year when crops can be grown, was expected to be an important coping strategy in order to take advantage of the decreasing rains when available. The study revealed that growing of short season crops was practiced by 57.1% of the respondents Table 4.21. During the questionnaire administration and key informant interviews; maize, kales and tomatoes were mentioned as the crops of choice used under this strategy. Further probing on maize seed used revealed that the type of seeds used were the improved varieties but not the "traditional/ local" varieties and similarly for the other crops. This could therefore be said to be a popular coping strategy. Love, Noble and Parkinson (2009) the growing season is usually determined by climate and elevation, and in agriculture the crop selection. Location, temperature, daylight hours (photoperiod), and rainfall, may all be critical environmental factors. In hot climates, such as the study area, the growing season is limited by the availability of water, with little growth in the dry season. It is often possible to greatly extend the growing season in hot climates by irrigation. However, it was expected that the option of taking advantage of the rainy season. A short season is considered to be anything below 110 days and any crop that matures within such a period is considered a short season crop. The Convention on Biological Diversity (2007) gives about 7,000 as the plant species that have been cultivated for food since agriculture began about 12,000 years ago. This number of species has been reducing overtime courtesy of plant breeding efforts and currently only about 15 species supply about 90% of human food. The crops referred to as traditional are among these remaining species. The term traditional varieties should therefore be understood to mean those varieties adopted since the colonial period but not hybrid (improved) varieties rather than varieties originating from the area.

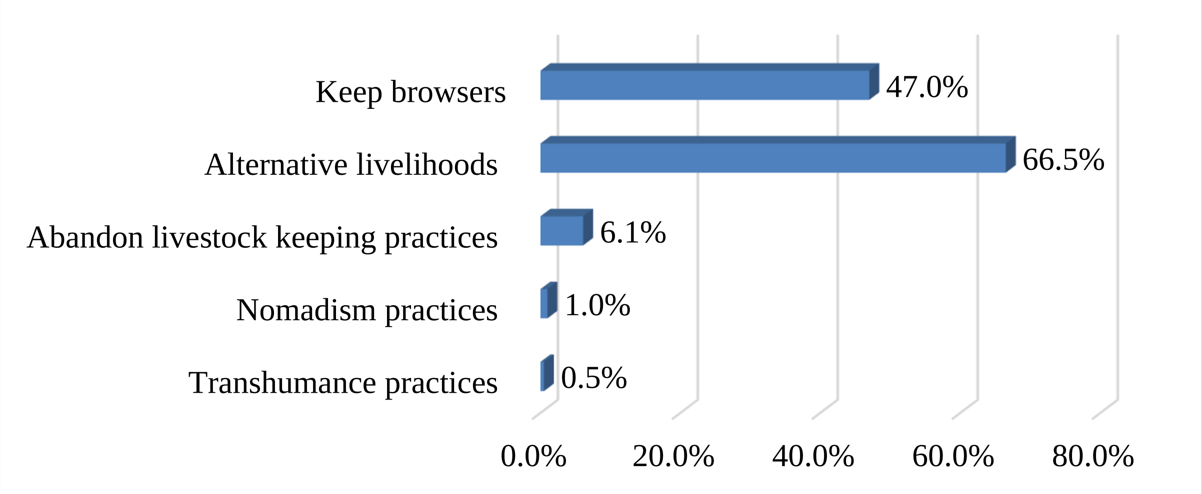

Figure 4.2: Response strategy to increased droughts

4.6.8 Keeping of browsers in the herds

It was expected that agro-pastoralists would adjust their herds in terms of species to take advantage of a specific species capacity to utilize available resources. Species refer to types such as cattle, sheep or goats. Figure 4.2 shows that 47% used this as a response strategy because they were more resilient to droughts and secondly, they have a higher reproduction rate (average gestation period for goats is 150 days) than that of cattle (average gestation period for cattle is 280 days). Thus, browsers replaced the lost herds during severe and extreme droughts quicker than cattle.

PFE, IIRR and DF (2010) argue that pastoralists are changing their species composition from grazers (cattle and sheep), to browsers (camels and goats) to reduce risk and insure against natural as well as human-made shocks. They continue to argue that camels and goats easily adapt themselves to changes in pasture. The number of goat has been increasing at a higher rate than cattle in Laikipia County in general. Between 1999 and 2001 for instance, UNEP and GoK (2006) observe that the overall rise in livestock numbers by 4.1 percent in the county was caused by increased number of browsers since cattle population declined by 26.9 percent. Similar trends have been observed among the pastoralists in Sub-Saharan Africa (Toutain *et al.*, 2010). For instance, the Borana pastoralists in Ethiopia have reduced the number of cattle while at the same time increasing the shoat population in their herds (Akillu & Catley, 2010). While increase in livestock numbers causes overgrazing, the feeding behavior of shoats accelerates the loss of vegetation cover. The ecological impact of the overgrazing is loss of biodiversity.

4.6.9 Planting of drought tolerant crop varieties

The results of this study showed that almost half of the respondents (42.9%) were planting drought tolerant crops such as: sorghum, cassava, millet, and maize varieties as a response to crop failure as shown in Table 4.22. The results are in agreement with the Laikipia County Development Plan (2013) that efforts are now being put in place to promote the drought resistant crops such as millet, sorghum, sunflower and black beans (dolichos).

Table 4.22: Response strategy to infertile soils and poor crops

Response Strategy to Infertile soils	F	(%)
Fallow cropping	50	12.7
Opening new field	4	1.0
Response Strategy to poor crops		
Changing enterprise	111	28.2
Drought tolerant varieties	183	46.4
Intercropping	255	64.7

Other studies show that in the recent years agricultural experts and food agencies like World Food Program (WFP) have raised the issue on the need for Kenya to shift focus from crops like maize and beans to drought tolerant crops (Kandinate, 2011). A study by IRIN (2011) in Mbeere South District indicated that faced with increasingly unreliable rains, farmers in this area have started growing drought-tolerant crops to meet their food and subsistence needs instead of the staple maize. Farmers in other marginal areas of Kenya are also adopting these drought tolerant crops albeit slowly.

Table 4.23: Response strategy to severity of floods

Response Strategy	Freq.	(%)
Flood control infrastructure	35	8.9
Movement of populations	0	0.0
Conservation of flood plains	41	10.4
Terracing	106	26.9
Tree planting	339	86.0

Majority (86.0%) resulted to tree planting as a response to severity of floods, built terraces (26.9%), conserved flood plains (10.4%) and flood control infrastructure (8.9%) as shown in Table 4.23. From Table 4.23, it is evident that the respondents had never experienced severe floods resulting to them having to move from the area.

4.6.10 Mixed Cropping

Mixed cropping is practiced by 74.6% of the respondents (Table 4.24). Note that, the percent compares very closely with, the percentage of those who have practiced crop diversification as a response strategy. This implies that those who practiced mixed cropping did so as they practiced diversification. In modern science mixed cropping is also known as inter-cropping or co-cultivation. It is a type of agriculture that involves planting two or more types of crops simultaneously in the same field (Hirst, 2013). In general, the theory is that planting multiple crops at once will allow the crops to coexist either symbiotically or non-competitively together. Possible benefits of mixed cropping are to balance input and outgo of soil nutrients, to keep down weeds and insect pests, to resist climate extremes (wet, dry, hot, cold), to suppress plant diseases, to increase overall productivity and to use scarce resources to the fullest degree. While modern science refers to it as a theory, to the agro-pastoral farmers in the study area, it is a practice. When farmers employ multiple cropping or polyculture systems, they can adapt to local conditions, and sustainably manage harsh environments and meet their subsistence needs without depending on mechanization, chemical fertilizers, pesticides or other technologies of modern agricultural science. Indigenous farmers tend to combine various production systems as part of a typical household resource management scheme. The practice of multiple cropping systems enables agro-pastoral farmers to achieve several production and conservation objectives simultaneously. Furthermore, polycultures exhibit greater yield stability and less productivity declines during a drought than in the case of monocultures. These types of ecological studies suggest that more diverse plant communities are more tolerant to disturbance and more resilient to environmental perturbations (Vandermeer, 2002).

Table 4.24: Response Strategy to loss of biodiversity and insect pollinators

Response Strategy to Loss of Biodiversity	**Freq.**	**(%)**
Tree planting	332	84.3
Mixed cropping	294	74.6
Pasture reseeding	16	4.1
Mixed farming	280	71.1
Response Strategy to Insect Pollinators		
Water harvesting	187	47.5
Tree planting	243	61.7
Mixed cropping	222	56.3
IPM principles	39	9.9

According to a study in Manyoni District of Tanzania, mixed cropping was commonly practiced where cereals (maize, sorghum), legumes (beans) and nuts (groundnuts) are grown together. From discussions with farmers, it was noted that they have wide field knowledge on advantages of mixing crops with varying attributes in terms of maturity period (e.g. maize and beans), drought tolerance (maize and sorghum), input requirements (cereals and legumes) and end uses of the product e.g. maize as food and sunflower for cash (Mary & Majule, 2009). The study revealed that farmers diversify crop types as a way of spreading risks on the farm (Orindi & Eriksen, 2005). Crop diversification can serve as insurance against rainfall variability.

Tree Planting

Majority (83.5%) of the respondents practiced tree planting as a response strategy to loss of biodiversity as shown in Table 4.24. The agro-pastoralists and key informants stated that majority of the trees were being planted now unlike in the past when there was a lot of deforestation. This agrees with the study findings that the vegetation quality had declined as well the vegetation structure.

Plate 4: Tree planting on farmlands

Other response strategies practiced by the agro-pastoral farmers were opening up of larger fields (0.3%), nomadism practices (1.0%) and transhumance (0.5%). This was because of the private land ownership and land sedentarization which limited mobility as shown in Table 4.22, Table 4.23 and Table 4.24.

The space for mobility for nomadic pastoralists is, however, rapidly diminishing and pastoralists the world over are increasingly suffering from land and natural resource dispossession. Pastoralists are being evicted from areas which they have lived in and utilized for centuries in order to make way for sedentary farming, large-scale commercial farming, natural resource extraction, environmental conservation initiatives, commercial wildlife hunting and tourism development (IWGIA, 2009).

CHAPTER FIVE
CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

i). The study established that the agro-pastoral farmers of Lakipia West sub-County perceive rainfall and temperature to be decreasing and increasing respectively. Respondents further reported that droughts had increased and was experienced after three years unlike in the past every ten years. The perceived decrease in rainfall was reported to have negatively affected the production and management of different crops and livestock. The observed decline in crop productivity/yield in the study area is multifaceted partly due to climate variability and change.

ii). The characterization of agro-biodiversity at farm level showed that shrubs were more diverse than trees.

iii). Majority of the agro-pastoral farmers kept poultry and browsers as they required less feed for survival during these times of climate variability and change. The study concluded that climate variability resulted to decline in food supply/crop yields and water availability had increased yet its amount declined.

iv). Majority of the agro-pastoral farmers practiced several response strategies to cope with the effects of climate variability such as: Crop diversification, use of fertilizers/ manure, keeping of browsers, mixed cropping, harvesting and storage of water practices, irrigation, amongst others. Few of the agro-pastoral farmers planted drought tolerant crop varieties and the use of greenhouses.

5.2 Recommendations

i). There is need to is needed to compare the actual climate variability trends with those perceived by the community since the study only focused on perceived climate variability trends.

ii). Stakeholders need to plan for sensitization of agro-pastoral farmers on the different indigenous and exotic trees species available as well as provide tree seedlings of the same for the farmers to plant in their farms.

iii). Climate variability having negatively affected provisioning ecosystem services like food supply/crop yield and water availability. The study recommends that, there is need for sensitization on climate smart agricultural practices that would increase food supply sustainably.

iv). Stakeholders should promote the adoption of drought tolerant varieties through trainings and improving agro-pastoral farmers access to information concerning such crops. There is also need to improve accessibility to affordable credit facilities to enable agro-pastoral farmers implement capital intensive strategies including irrigation and green houses. Policy makers should also consider modern and efficient water saving delivery systems in the area given the varying and changing climatic conditions and incidences of water scarcity.

5.3 Suggestions for future research

While this research only focused on perceived climate variability, further research may compare the actual climate variability trends with those perceived by the community. This will assist in comparing facts and perceptions for better adaptation to the effects of climate variability in Laikipia west sub-County.

Further research should be conducted on the effects of human activities on provisioning ecosystem services and how specific trees and shrubs will respond to the predicted changes in climate in Laikipia west sub-County.

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APPENDICES

Code _ _ _ _

Appendix 1: Survey Questionnaire

Questionnaire for: Effects of climate variability on provisioning ecosystem services among agro-pastoral systems of Laikipia west Sub- County Kenya.

No………

Dear sir/ madam

My name is Merculine Maoncha a postgraduate student at Egerton University, Njoro Campus. In partial fulfilment of the requirements for the Master of Science in Natural Resources Management, I am conducting a research entitled: "***Effects of climate variability on provisioning ecosystem services among agro-pastoral systems of Laikipia West Sub - County, Kenya***". I would like to kindly request for your assistance to provide information, by filling in the questionnaire provided below, as your views are considered important to this study. Please note that your participation is voluntary and that any information given will be treated with utmost confidentiality and will only be used for the purpose of this study.

Sub-County: ________________________ Ward: _____________________________

Village: ____________________________ Date: ________________________________

Enumerator: __________________________

SECTION A: RESPONDENT INFORMATION

A.1 Information of the household head

1. Name of household head ………………………………………………………………
2. Name of respondent if not the household head…………………………………………
3. Occupation of household head and other livelihood sources ______________________

Household information: **Gender of household head**	**Age in Yrs.**	**Marital status**	**Level of Education**	**Household size** (People living in the homestead over the last one year)	**Source of energy most frequently used** (Can tick more than one)	**Source of water** (Can tick more than one)
1=Male 2=Female		1=Married 2=Single 3=Divorced 4=Widowed	1=Primary 2=Secondary 3=Tertiary 4=University	1.Over 18 years 2. Under 18 years	1= Wood 2=Charcoal 3=Kerosene 4=Gas 5=Solar 6=others	1=River 2=Bore–hole 3=Tap water 4= Rain water 5=Roof catchment 6=Water pan 7=Spring 8=Other (Specify)

A2. Land tenure system

Tenure	Tick
1. Freehold with certificate/title	
2. Freehold without certificate	
3. Communal	
4. Family	
5. Lease	
6. Others (specify)	

A.3 Land use information

	Size in Acres
Land holding size	
Land use	
1. Homestead	
2. Woodlot	
3. Subsistence crops	
4. Cash crops	
5. Livestock /grazing	
6. Other *(specify)*	

A4. Livestock Information

List down all Livestock kept in the farm in order of importance

S/No	Current	Which animals have shown declining numbers	Which animals have been increasing in numbers	Which animals have been abandoned	Which animals have emerged since 1990?
1					
2					
3					
4					
5					

B. CROPPING ENTERPRISES AND CROPPING SYTEMS

B.1 List down all crops grown now and state any changes in crop enterprises and cropping systems over the last 20 years:

S/No	Current	Which crops have shown increasing acreage	Which crops have shown declining acreage	which crops have been abandoned	Which crops have emerged since 1990?
1					
2					
3					
4					
5					

SECTION C: IMPACT OF CLIMATE VARIABILITY IN PREVALENT FARMING PRACTICES

Awareness

C1**)** Have you noticed any changes in mean temperatures over the last 20 years?

Yes [ ] No [ ]

If Yes explain i.e. has the number of hot days stayed the same, increased or declined**?**

1. Stayed the same [ ] 2. Increased [ ] 3. Declined [ ]

C 2) What changes in the rainfall patterns have you noticed in the last 20 years?

1. Drier [ ] 2. Wetter [ ] 3. No change [ ]

C3**)** Have you noticed any long term changes in mean annual rainfall over the last 20 years?

Yes [ ] No [ ]

If yes Explain i.e. has the number of rain days stayed the same, increased or declined?

1. Stayed the same [ ] 2. Increased [ ] 3. Declined [ ]

C4) Have you noticed any changes in the onset of long rains in the last 20 years?

Yes [ ] No [ ]

If yes, how has this affected planting times?

1. Stayed the same [ ] 2. Earlier [ ] 3. Later [ ]

C5**)** What in your opinion are the causes of climate variability?

Causes	
1. Excessive cutting down of trees	
2. Overgrazing	
3. Burning of farm wastes	
4. Others (*specify)*	

C6**)** What extreme events have you experienced in your area in the last 20 years?

Event	**Year of occurrence**	**Impacts**
1.Strong winds		
2.Elnino rains		
3.Severe drought		
4.Floods		
5.Livestock loss		
6.Others (specify)		

- *If event occurred more than once, indicate all the years*

C7) In your opinion, has the yield of your crops improved/ declined since you started farming?

1. Improved [ ] 2. Remained the same [ ] 3. Declined [ ]

C8) What do you think caused the above changes?

1. Soil Fertility [ ] 2. Rainfall [ ] 3. Drought [ ] 4. Pests and Diseases [ ]

C9) What have you done to improve on the yields on your farm?

a) ………………………………………………………
b) ………………………………………………………
c) ………………………………………………………
d) ………………………………………………………

SECTION D: POTENTIAL IMPACTS OF CLIMATE VARIABILITY ON ECOSYSTEM SERVICES (*Water availability and agro-biodiversity*).

D1) What are the sources of water for domestic, crop and livestock use?

	Uses		
Water sources	**Domestic**	**Crop/ Irrigation**	**Livestock**
River 2=Bore–hole 3=Tap water 4= Rain water 5=Roof catchment 6=Water pan 7=Spring 8=Other (Specify)			

D2) Have you noticed any changes in water quality and quantity over the last 20 years

Yes [ ] No [ ]

D3) If yes, has the quality and quantity stayed the same, increased or declined?

	Water quality/ quantity	Changes		
		Reduced	Remained the same	Increased
1.	Distance of water source from the home			
2.	Amount of available water			

D4) Have you noticed any changes in vegetation cover over the last 20 years?

Yes [ ]   No [ ]

If yes indicate the trend i.e. has the cover stayed the same, increased or declined?

		Changes		
	Vegetation cover	**Declined**	**Remained the same**	**Increased**
1	Vegetation quality			
2	Species composition			
3	Vegetation structure			
4	Invasive species			
5	Alien/exotic species			

SECTION E: HOUSEHOLD ADAPTATION PRACTICES AND LIVELIHOOD RESPONSE STRATEGIES AS INFLUENCED BY CLIMATE VARIABILITY IN ECOSYSTEMS SERVICES

E1. What are the farmer's response strategies to climate variability?

	Livelihood Strategy CROPPING	**Response Strategies**	
	Low yields/Crop failure		Tick
		Diversification of crops grown	
		Drought tolerant varieties	
		Local varieties	
		Adaptable species	
		Application of fertilizers/ manure	
		Use of pesticides	
		Use of herbicides	
	Low rainfall		
		Irrigation	
		Livestock production	
		Migration	
		Open up larger fields	
		Use of greenhouses	
		Water management practices	
	Late onset of rains		
		Change crop variety	
		Harvest and store water	
	Few number of rain days		
		Water management practices	
		Short season crops	
	Increased Droughts	Transhumance	
		Nomadism	
		Abandon livestock keeping	
		Alternative livelihoods	
		Keep browsers e,g goats/ sheep	

Appendix 2: Key Informants Interview Guide

Think of the Effects of Climate Variability and Change on provisioning ecosystem services (food supply, water availability and agro-biodiversity maintenance) and Response Strategies used to cope by Agro-pastoral farmers in Laikipia West Sub-County. Use your experience to answer the following questions.

1) Have you noticed any changes in mean temperatures over the last 20 years?

a) Has the number of hot days changed?

2) What changes in the rainfall patterns have you noticed in the last 20 years?

a**)** Have you noticed any long-term changes in mean annual rainfall over the last 20 years?

b) Has the number of rain days changed?

3) Have you noticed any changes in the onset of long rains in the last 20 years?

a) How has this affected planting times?

4) What are the indicators of climate change in your area?

5) Do you train and/ offer extension and training to the agro-pastoral farmers?

a) Do you think the farmers implement this in their farms?

b) What are some of the response strategies employed by farmers?

6) Has water availability increased or decreased and why is this the case?

7) What crops are currently grown and which ones were grown in the past but abandoned?

8) What livestock are currently kept and which ones were kept in the past but abandoned?

Appendix 3: Woody Trees Found in Laikipia West Sub-County

Trees	Scientific name	Local name (Kikuyu)
Silky oak	*Grevelia robusta*	Mukima
Bluegum	*Eucalyptus saligna*	Munyua-mai/Mubau/Muringamu
Kenya croton	*Croton megalocarpus*	Mukinduri
Podo	*Podocarpus latifolius*	Muthengera
African pencil cedar	*Juniperus procera*	Mutarakwa
Neem tree	*Azadirachta indica*	Muarubaini
Umbrella thorn	*Acacia tortilis*	Mugaa
White galled acacia	*Acacia seyal*	Mugaa
Fever tree/Naivasha thorn	*Acacia xanthophloea*	Mureera
Lucky-bean tree	*Erytrina abyssinica*	
Black plum/Java plum	*Syzygium cuminii*	
Mexican cypress	*Cupressus lusitanica*	Mutarakwa/Muthithinda
Tree euphorbia	*Euphorbia candelabrum*	Githuri/kibubungi/muthuri
Nandi flame	*Spathodea campanulata*	
Whistling pine	*Pinus patula*	
Dombeya tree	*Dombeya goetzenii*	Mukeu
Brown olive	*Olea europaea spp.africana*	Mutamaiyu
Magic guarri	*Euclea divinorum*	Mukinyai
Arjun tree	*Terminalia brownie*	
Tommy atkins mango	*Mangifera indica*	Mwembe
Bottle brush	*Callistemon citrinus*	
Loquat	*Eriobotrya japonica*	Murungati/Murukwati
Guava	*Psidium guajava*	Mubera
Apple	*Malus domestica*	
Lemon	*Citrus limon*	Marimau
Pepper tree	*Schinus molle*	Mugaiti
Giant forest fig	*Ficus thonningii*	Mugumo
Red-hot poker tree	*Erythrina abyssinica*	Muhuti
Red thorn	*Acacia gerrardii*	Muthi
Black wattle	*Acacia mearnsii*	Muthanduku
Macadamia nut	*Macadamia tetraphylla*	Mukandania
Wild medlar	*Vangueria madagascariensis*	Mubiru
Tree tomato	*Solanum betacea*	Raimbina

Appendix 4: Shrubs Found in Laikipia West Sub-County

Shrub	Scientific name	Local name
African boxwood	*Myrsine Africana*	Mugaita
Carandas plum	*Carrisa edulis*	Mupage/Mukawa/Ngawa
Croton	*Croton dichogamus*	Kererwa
Candle bush	*Cassia didymobotrya*	Mwenu/Mwinu
Finger euphorbia	*Euphorbia tirucalii*	Kariaria/Ndaru/Nyanjoe
Natal rhus	*Rhus natalensis*	Muthigiu
Arrow poison tree	*Acokanthera oppositifolia*	Kiururu/Mururu/Ndichu
Prickly pears/cactus	*Opuntia vulgaris*	Muhurathi
Camphor bush	*Tarchonanthus camphoratus*	Muriricua
Hibiscus	*Hibiscus fuscus*	Mugere
Sticky psiadia	*Psiadia Arabica*	Mwenda-thigo/Mwenda-nguiko
Yellow justicia	*Justidia flava*	
Honey Acacia	*Acacia mellifera*	Muthingira/Uitie
Wild tea bush	*Leucas martinicensis*	
Forget me not	*Cyathula schimperiana*	Maramata

Appendix 5: Uses of Different Tree and Shrub Species in Laikipia West Sub-County

Use	Species	Parts used
Food	*Citrinus limon, Mangifera indica, Eriobotrya japonica, Carrisa edulis, Rhus natalensis, Opuntia vulgaris.*	Fruits, leaves
Firewood	*Terminalia brownii, Lantana camara, Acacia tortilis, Croton megalocarpus, Acacia mearnsii.*	Stem, branches
Domestic tools	*Terminalia brownii, Acacia Senegal, Mangifera indica, Acacia mellifera, Juniperus procera.*	Stem, branches
Herbal medicine	*Solanum incanum, Azadirachta indica, Acacia senegal, Terminalia brownii, Carrisa edulis, Citrus limon, Psiadia Arabica, Juniperus procera.*	Bark, fruits, stem, roots, branches.
Fencing	*Acacia mellifera, Lantana camara, Euphorbia tirucalli, Acacia tortilis, Acacia brevispica, Dovyalis caffra, Croton megalocarpus, Juniperus procera.*	Stem, branches, whole plant
Honey	*Acacia senegal, Acacia nilotica, Acacia mellifera, Acacia tortilis, Terminalia brownii.*	Stem, branches, flowers.
Fodder	*Lantana camara, Terminalia brownii, Acacia spp.*	Leaves, fruits, bark
Poles	*Terminalia brownii, Eucalyptus spp., Acacia spp., Markhamia lutea, Dalbergia melanoxylon, Acacia mellifera, Croton megalocarpus. Acacia mearnsii.*	Stem

Appendix 6: Key Data Analysis Outputs

Frequency Table

EXTENDED DRY SPELLS

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	NO	56	14.2	14.2	14.2
	YES	338	85.8	85.8	100.0
	Total	394	100.0	100.0	

WINDSTORMS

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	NO	302	76.6	76.6	76.6
	YES	92	23.4	23.4	100.0
	Total	394	100.0	100.0	

INCREASE IN GROWING PERIOD

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	NO	367	93.1	93.1	93.1
	YES	27	6.9	6.9	100.0
	Total	394	100.0	100.0	

DECREASE IN GROWING PERIODS

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	NO	257	65.2	65.2	65.2
	YES	137	34.8	34.8	100.0
	Total	394	100.0	100.0	

INCREASE IN RAINFALL AMOUNTS

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	NO	367	93.1	93.1	93.1
	YES	27	6.9	6.9	100.0
	Total	394	100.0	100.0	

DECREASE IN RAINFALL AMOUNTS

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	NO	33	8.4	8.4	8.4
	YES	361	91.6	91.6	100.0
	Total	394	100.0	100.0	

CHANGE IN RAINFALL DISTRIBUTION

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	NO	177	44.9	44.9	44.9
	YES	217	55.1	55.1	100.0
	Total	394	100.0	100.0	

INCREASED FREQUENCY OF FLOODS

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	NO	379	96.2	96.2	96.2
	YES	15	3.8	3.8	100.0
	Total	394	100.0	100.0	

DECREASED FREQUENCY OF FLOODS

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	NO	326	82.7	82.7	82.7
	YES	68	17.3	17.3	100.0
	Total	394	100.0	100.0	

OCCURENCE OF PESTS AND DISEASES

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	NO	86	21.8	21.8	21.8
	YES	308	78.2	78.2	100.0
	Total	394	100.0	100.0	

FREQUENT DROUGHT

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	NO	149	37.8	37.8	37.8
	YES	245	62.2	62.2	100.0
	Total	394	100.0	100.0	

INCREASE IN FROST

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	NO	369	93.7	93.7	93.7
	YES	25	6.3	6.3	100.0
	Total	394	100.0	100.0	

NPar Tests

Chi-Square Test

Frequencies

HAS THE NUMBER OF HOT DAYS STAYED THE SAME INCREASED OR DECLINED

	Observed N	Expected N	Residual
STAYED THE SAME	3	129.0	-126.0
INCREASED	342	129.0	213.0
DECLINED	42	129.0	-87.0
Total	387		

CHANGES IN RAINFALL PATTERN NOTICED IN THE LAST 25 YEARS

	Observed N	Expected N	Residual
DRIER	378	131.0	247.0
WETTER	10	131.0	-121.0
NO CHANGE	5	131.0	-126.0
Total	393		

HAS THE NUMBER OF RAINDAYS STAYED THE SAME INCREASED OR DECLINED

	Observed N	Expected N	Residual
STAYED THE SAME	2	129.7	-127.7
INCREASED	17	129.7	-112.7
DECLINED	370	129.7	240.3
Total	389		

HOW HAS ONSET AFFECTED PLANTING TIME

	Observed N	Expected N	Residual
STAYED THE SAME	5	98.5	-93.5
EARLIER	69	98.5	-29.5
LATER	313	98.5	214.5
NOT APPLICABLE	7	98.5	-91.5
Total	394		

Test Statistics

	HAS THE NUMBER OF HOT DAYS STAYED THE SAME INCREASED OR DECLINED	CHANGES IN RAINFALL PATTERN NOTICED IN THE LAST 25 YEARS	HAS THE NUMBER OF RAINDAYS STAYED THE SAME INCREASED OR DECLINED	HOW HAS ONSET AFFECTED PLANTING TIME
Chi-Square	134.061[a]	176.780[b]	169.273[c]	103.000[c]
df	2	2	3	3
Asymp. Sig.	.000	.000	.000	.000

a. 0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 98.3.

b. 0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 131.0.

c. 0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 98.5.

Appendix 7: Published Paper(S) Abstract

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Response Strategies by Agro-Pastoral Farmers to Effects of Climate Variability in Laikipia West Sub-County, Kenya

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Authors' contributions

This work was done in collaboration between all authors. Authors MRM, GOO and CWR designed the study, while author MRM performed the statistical analysis, wrote the protocol, wrote the first draft of the manuscript and managed literature searches. Authors GOO, CWR and LWN supervised and managed the research. All authors read and approved the final manuscript.

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ABSTRACT

Aims: This study assessed the effects of Climate variability on Agro-pastoral farmers' livelihoods and response strategies.
Study Design: The study employed a social survey research design, to examine household perceptions on climate variability and response strategies by agro-pastoral farmers to climate variability.
Place and Duration of Study: The study was conducted in Laikipia West region, between August 2015 and March 2016.
Methodology: A questionnaire was administered to 400 agro-pastoral farmers and interviews were held with 20 key informants from relevant institutions. Data was processed and analysed using descriptive statistics and chi-square test.
Results: The study findings revealed that, agro-pastoralists perceived that rainfall had decreased while temperatures had increased. The main response strategies employed by agro-pastoralists were: crop diversification, use of both organic and chemical fertilizers, planting drought tolerant crops and tree planting.
Conclusion: Agro-pastoral farmers in Laikipia West Sub-County are engaging in various response strategies to climate variability. There are fundamental changes in livelihoods such as crop diversification, rainwater harvesting, irrigation, mixed cropping, mixed farming, keeping of browsers and tree planting. However, currently there is promotion of drought tolerant crops, use of greenhouses, fallow cropping amongst others. There is need for integration of scientific and traditional ecological knowledge as well as climate smart agriculture for better adaptation to the effects of climate variability.

Keywords: Climate variability; response strategies; agro-pastoral farmers; coping; Laikipia West Sub-County.

Appendix 8: Research Permit from NACOSTI

EGERTON UNIVERSITY

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NAKURU TOWN CAMPUS COLLEGE

16th June, 2014

The Acting Secretary/CEO
National Commission for Science Technology and Innovation
P. O. Box 30623 – 00100
NAIROBI – KENYA

RE: Acceptance of the Science, Technology and Innovation Research Grant

Your letter of 6th June refers.

I hereby accept the above grant of Kenya Shillings **Two Million Three Hundred Thousands Only (Ksh 2,300,000)** towards our project titled "*Enhancing Response Mechanisms of Small holder Farmers to Impacts of Climate and Environmental Variability in Laikipia and Narok Counties of Kenya*".

I have attached all the relevant documents as requested in the letter.

I wish to sincerely thank NACOSTI for these funds.

Thank you.

Prof. Lenah Nakhone Wati (PhD)
Principal Investigator

c.c. Vice-Chancellor
Egerton University

DVC (R&E)
Egerton University

LNW/mk

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