CLIMATE VARIABILITY RISK PERCEPTION ON RAINFED AGRICULTURAL PRACTICES AMONG SMALL-SCALE FARMERS IN EMBU COUNTY, KENYA

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N85/37767/2016

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN ENVIRONMENTAL STUDIES (CLIMATE CHANGE AND SUSTAINABILITY) IN THE SCHOOL OF ENVIRONMENTAL STUDIES OF KENYATTA UNIVERSITY

NOVEMBER 2021

DECLARATION

Declaration by the Candidate

This thesis is my original research work and has not been presented for a degree in any other University or any other award. Apt recognition has been given where reference has been made to the work of others.

Signed: ……………………………………… Date: ……………………………..

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Declaration by Supervisors

We confirm that this thesis has been submitted for examination with our approval as the University supervisors.

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DEDICATION

To my parents Mr. and Mrs. Adiel Nkari Amos whom I am greatly indebted forever for the counsel in life. To our children Cedrick Waswa, Morgan Murimi, and Olivia Omina for being my inspiration. To my beloved husband Boaz Waswa for having great confidence in me and my achievements.

ACKNOWLEDGEMENT

First and foremost, I am grateful to the Almighty God for the blessings and guiding me in all my academic endeavors and for the successful completion of this research work. I am greatly indebted to my supervisors Dr. James Koske and Dr. Evelyn Wemali Chitechi for their enormous support, motivation, and advice during the development, research, and write-up of this thesis. Appreciation also to all the fraternity and members of staff of the Department of Environmental Science and Education who directly and indirectly supported me in the progress of this research work to its successful completion.

My sincere gratitude also goes to the staff members of Embu and Nairobi Metrological Departments, key informants in the land, water, crops, and livestock departments for their support during fieldwork. I am also forever indebted to the entire intellectual community at Kenyatta University, who contributed to my intellectual growth at all stages of this journey, and particularly for listening to me and adding their voice to this work. To all the small-scale farmers who sacrificed their time to respond to the questionnaires, my lead field assistant Dismas Ongoro and the entire team of enumerators for their tireless efforts in data collection, I am very grateful. I wish to thank Mercy Mutua of CIAT for support with digital data collection and to Mr. Kevin Onyango of CIAT, Nairobi for offering great guidelines in data analysis.

My warm and deep gratitude goes to my beloved friend and husband Dr. Boaz Waswa whose academic guidance and faith in me made it possible for me to achieve my goals in presence of other family commitments. To our children Cedrick Waswa, Morgan Murimi, and Olivia Omina, I wish to thank you for your understanding and loyal support during the entire period of the study.

God Bless.

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LIST OF ACRONYMS AND ABBREVIATIONS

AEZs	Agro Ecological Zones
CCAM	Climate Change Adaptation Measures
CEC	County Executive Committee
CIAT	International Center for Tropical Agriculture
EWS	Early Warning Systems
EBC	Embu County
FBOs	Faith-Based Organizations
FGD	Focus Group Discussion
GDP	Gross Domestic Product
GHA	Great Horn of Africa
GHG	Green House Gases
GoK	Government of Kenya
IFPRI	International Food Policy Research Institute
KARLO	Kenya Agricultural Research and Livestock Organisation
KMD	Kenya Meteorological Department
LDCs	Least Developed Countries
NFNP	National Food and Nutrition Programme
NGOs	Non-Governmental Organizations
PMT	Protection Motivation Theory
SPSS	Statistical Package of Social Sciences
SSA	Sub-Saharan Africa
VIF	Variance Inflation Factor

ABSTRACT

Agricultural productivity is a function of climate variability and its associated impact on farming practices and farmers' adaptive capacity. Small-scale farmers in the study area have involuntarily engaged in climate variability adaptation mechanisms. This study was instigated to assess the extent of variation in temperature and rainfall, analyze the economic impact of climate variability on crop and livestock production, examine climate variability risk perceptions, adaptation mechanisms and how they influence rainfed agricultural practices, determine farmer and farm characteristics that influence climate variability perceptions and adaptation, and assess the effectiveness of institutions and information channels in facilitating climate variability adaptation mechanisms and risk perception. The research design involved a descriptive survey that allowed the collection of both qualitative and quantitative data. The sampling procedure involved a multi-stage sampling procedure to obtain 411 respondents, purposive sampling for 10 key informants, and quota sampling techniques to select 5 focus groups. Data were analyzed by the use of descriptive statistics, the Mann Kendall test, Logit regression, chi-square, Likert scale analysis, and the use of variables produced through the Ricardian model and Heckman approach. Results show that there is climate variability and the rise in maximum temperature and rainfall variability are significant at $P<0.002$ with a 0.02ºC increase in temperatures and a 10.2mm decline in rainfall amount per year. Economic impact on crop and livestock production indicated that temperature rise affects crop net revenue negatively and that of mixed farming positively respectively at $p\leq0.05$. Apart from climate variability, other factors were found to influence the net revenue of the three sectors such as distance to the market centers, size of land under cultivation, level of education, and soil fertility. The farmers perceived climate variability as real. The perception was expressed in terms of extreme changes in both rainfall and temperatures. The majority (85.4%) observed the outbreak of crop pests and diseases as a result of climate variability. Whereas 97.6% of the respondents perceived that training and extension services would minimize the negative impact of climate variability on agricultural practices. However, 86.4% attributed the failure to the adaptation of climate change to inadequate time. Perception and adaptation were influenced by gender, social networks, education, extension services, land size, and age. Both formal and informal institutions exist in the study area and among the formal institution cooperative societies were the most influential in the adaptation of climate variability while Departments of Agriculture and Livestock Development were more likely to influence small-scale farmers on climate variability risk perception. Access to credit and extension services were more likely to attract farmers to membership in informal institutions. However, only formal institutions were significant ($P\leq0.05$) in improving farmers' perception and adaptation to climatic variability. Five information channels namely, farmer to farmer, agro Vets, radio, lifetime experience, and school knowledge were more likely to influence farmers' perception and adaptation mechanisms. This study concludes that there is climate variability which leads to an economic impact on agricultural practices and adaptive capacity is influenced by climate change risk perceptions, institutions, and the dissemination of information. This study recommends that the Department of livestock and that of Agriculture continuously provide climate-related information for effective risk perception and adaptation to climate change by small-scale farmers.

CHAPTER ONE: INTRODUCTION

1.1 Background of the study

Climate variability, directly and indirectly, affects the agricultural system that has a predictable influence on the economic system in all the regions of the world (Porter *et al.,* 2014). Studies indicate agricultural productivity is a function of five parameters that characterize rainfall season, namely rainfall onset, final rain dates, rainfall duration, amount, and intensity (Garcia *et al.*, 2007; Parry *et al.,* 2004).

Over 80% of the Sub-Saharan African (SSA) agricultural productivity by small-scale farmers relies on seasonal rainfall (Nyong *et al.*, 2007; Hulme *et al.,* 2001). These regions are characterized by extreme temperatures and changing precipitation regimes that affect the growth and abundance of crops (Parry *et al.,* 2004). According to Connolly-Boutin and Smit (2016), people's ability to rear livestock and grow food has been hindered by extreme droughts. Furthermore, the rainy season onset, heatwaves, and floods have resulted in crop loss and low yields in many African countries (Codjoe *et al.,* 2011). Also, climate variability has been linked to alterations of disease vectors on both plants and animals that pose new risks to food production (Connolly-Boutin and Smit, 2016).

All the societies both developed and developing have their basic adaptive capacity to climate variability vulnerability (Deressa *et al.,* 2008). According to Cooper *et al.* (2008), these adaptation mechanisms are in three categories; risk management choices, in-season alteration of crop and resource management decisions, and reduction of livelihood impacts. Climate variability varies from country to country, and location to location, and therefore some regions are more sensitive to climate-related risks than others (Fahad and Wang, 2018). This influences the type and the level of climate variability adaptation mechanisms implemented by the small-scale farmers (Hoang *et al*., 2014). According to Sanga *et al.* (2013), Gandure *et al.* (2013), Cooper *et al.* (2008), and Olesen *et al.* (2011) adaptation mechanisms range from tree planting, irrigation scheme, use of drought-tolerant crops, change of cultivation practices, the shift of sowing dates, the introduction of new crop and livestock breeds.

Adaptation mechanisms tend to vary within individual farmers of the same location due to farm and anthropogenic factors (Batisani and Yarnal, 2010). These factors affect small-scale farmers' ability to shield themselves from the scathing effects of climate change and variability. According to Gbetibouo (2009) soil fertility status, farm sizes, the land tenure system, and occupation are likely to influence farmers' adaptive capacity. Whereas education, access to credit, gender, age, farmer's income, and presence of extension services have also been cited as determinants to climate variability adaptation mechanisms (Deressa *et al.*, 2009). Agricultural production remains the major source of livelihood for the small-scale farmers in Kenya who over-rely on seasonal rainfall (Herrero *et al*., 2010). Therefore, these determinant factors being location and farmer specific it becomes imperative to promote adaptive capacity among the small-scale farmers that would lead to protected livelihoods and food security.

Farmers' risk perception of climate variability and adaptation mechanisms is another dimension of anthropogenic factors that tend to influence farmers' adaptive capacity (Mase *et al.,* 2017; Juana *et al.*, 2013). According to Rao *et al.* (2011), farmers' ability to manage unreliable precipitation relies on the farmers' perceived risks and dangers posed to their agricultural system. Several studies show variances among individual farmers to climate variability risks which contributes to diverse levels of risk perception (Juana *et al.*, 2013). These levels vary with one's occupation, geographical location, culture, existing policies, knowledge, and experience Rao *et al.*, (2011); Taylor *et al.,* 2014). Small-scale farmers tend to perceive climate variability risks in terms of losses or reduced yields on crop and livestock, and overall cash flow (AEA GROUP, 2018). Information on the impact of farmers' risk perception on climate variability and adaptation mechanisms is integral in instituting effective adaptation options that enhance economic returns (Taylor *et al.,* 2014). Climate information and support services provide awareness and Early Warning Systems (EWS) for disaster preparedness and capacity building towards climate variability (Cherotich *et al.*, 2012). The choices made by the small-scale farmers on the dissemination channels influence their decision-making process on available adaptation mechanisms, how to access and use them to ensure resilience. According to Parikh *et al.* (2007), small-scale farmers are mostly marginalized which increases the transaction costs due to poor communication networks on climate variability, and yet 80% of these farmers contribute to the Gross Domestic Product (GDP) of the country. Many institutions and information channels exist and assist small-scale farmers in the changing climatic conditions (Churi *et al.,* 2012). For instance, use of churches, mosques, funeral gatherings, radio, television, extension services, and market places to pass agricultural-related messages. However, risks associated with climate variability can only be minimized through the presence of effective, well-structured, and accessible agriculture-related information centers (Scott and Lemieux, 2010).

1.2 Statement of the problem

Agriculture in Kenya is predominantly small-scale and rain-fed with only 11% irrigation (Elijah and Odiyo, 2020). Embu County is a region that practices crop and livestock production which is the backbone of its peoples' livelihood and economy. For instance, this sector has created 70.1% employment of Aembu population while 88% of the households are involved in farming activities (Embu County Government integrated Development plan, 2013). According to Kisaka *et al.* (2015), the county experiences crop failure that is related to climate variability. This has affected the net revenues of agricultural production exposing the county to food shortages regardless of the availability of adaptive capacity among the small-scale farmers. With gradual changes in both temperature and rainfall patterns, rain-fed agriculture is threatened. These are the environmental stimuli that cause fear and panic among the farmers. Kellstedt *et al.*, (2008) argue that the farmers go through a perception process that involves awareness, comprehension, and understanding the threats facing agricultural productivity. The farmers then perceive risks associated with climate variability that expose them to the probability of shielding their agricultural practices from the harsh environment (Deressa *et al.,* 2011). Though, risk perception is influenced by the geographical location of the farms, socio-economic factors, farmer's resilience, exposure levels, and structural issues (Limantol *et al.,* 2016; Shackleton *et al.,* 2015). Besides, Ndambiri *et al.,* (2013) underscore the need for institutions and information channels in demystifying the farmers' perceived adaptive capacity, perceived risks, and ability to address determinant factors that influence both adaptation and perception. Furthermore, studies have shown that inadequate information on risks causes exaggerated fears among individuals (Jones *et al.*, 2010).

Studies show human risk perception is as important as adaptation mechanisms, farming practices, institutions, and information channels in enhancing resilience to climate variability (Mase *et al.*, 2017; Mugendi *et al*., 2003). There is scanty knowledge on risk perception of climate variability and how it influences rainfed agricultural practices among small-scale farmers in Embu County. This study was designed to fill this gap.

1.3 Research Questions

This study pursued to respond to the research questions below:

1. In what way has climate varied in Embu County in terms of temperature and rainfall between 1976 and 2016?
2. What is the economic impact of climate variability on livestock and crop production among smallholder farmers in Embu County?
3. How do risk perceptions on climate variability and adaptation mechanisms influence rain-fed agricultural practices among the small-scale farmers in Embu County?
4. How do the farm and farmers' characteristics influence risk perceptions and adaptation of climate variability among small-scale farmers in Embu County?
5. How have institutions and information channels facilitated risk perception and adaptation mechanisms of climate variability among small-scale farmers in Embu County

1.4 Objectives of the study

1.4.1 General objective

The general objective was to examine the risk perception of rainfed agricultural practices among the small-scale farmers of Embu County.

1.4.2 Specific Objectives

1. To assess the extent of variation in temperature and rainfall in Embu County between 1976 to 2016 in Embu County

2. To investigate the economic impact on livestock and crop production by climate variability among small-scale farmers in Embu County
3. To examine the risk perceptions on climate variability and adaptation mechanisms and their influence on rain-fed agricultural practices among the small-scale farmers in Embu County
4. To determine farmer and farm characteristics that influence risk perceptions and adaptation of climate variability among small-scale farmers in Embu County
5. To assess the effectiveness of institutions and information channels in facilitating risk perception and adaptation mechanisms of climate variability among small-scale farmers in Embu County

1.5 Hypotheses

The study was guided by the following hypotheses:

1. There is a significant difference in temperature and rainfall amounts received in Embu County
2. There is a significant difference between climate variables and the economic impact of crop and livestock among the small-scale farmers of Embu County
3. Farm and farmers' characteristics have a significant influence on risk perception and adaptation to climate variability among the small-scale farmers of Embu County
4. There is a significant relationship between institutions and information channels, and risk perception and adaptation of climate variability among the small-scale farmers in the county of Embu

1.6 Significance of the study

This study will benefit farmers, policymakers, researchers, and the general public in different ways. For instance, the findings of the study will help boost resilience and advance the adaptive capacity of small-scale farmers on the negative impacts of climate variability within the county and country. Furthermore, the study findings reveal pertinent information on how climate variability risk perception influences rainfed agricultural practices that policymakers can use and draft policies that will encourage and assist small-scale farmers to cope with the climate change menace effectively. This can enhance resilience to climate change, improve food production, and alleviate poverty among the small-scale farmers of Embu County.

Besides, the outcome of this study will subsidize the prevailing body of information on farmers' risk perception of climate change to agricultural activities. The findings of the study will also deliver a background for upcoming research on education for climate change as a vital instrument for alertness in the entire country. Finally, there is a necessity to mainstream action-oriented policies on climate change at the county level due to decentralized services to the Counties. This research is thus judicious as it will offer a perfect orientation on ways to integrate information and knowledge on climate change into the County's development plans.

1.7 Theoretical and Conceptual Framework

This study is based on Protection Motivation Theory (PMT) which indicates that human beings have a self-protective way when faced with a perceived fear (Rogers, 1975). It is assumed that the presence of fear triggers attitude change (Deressa *et al.,* 2011). These triggers comprise fear messages that inspire individuals to either protect themselves or refrain from activities that bring harm (Ndambiri *et al.,* 2013). The theory posits that individuals assess possible responses by a threat appraisal and coping appraisal process. The threat appraisal process involves the assessment of the severity of the threat and the probability of the threat happening (Grothmann and Patt, 2005). On the other hand, the coping appraisal process involves consideration of the efficacy of the response, response cost, and the perceived ability to enact the coping response. When the coping appraisal is greater than threat appraisal it leads to adaptive response while the opposite leads to a maladaptive response that includes denial and wishful thinking (Kellstedt *et al.* 2008).

The Protection Motivation Theory informed this study's conceptual framework (Figure 1.1). All farmers, small or large-scale, are threatened by climate change and variability especially those who rely on rain-fed agriculture. According to Ogutu *et al.* (2012), 80% of small-scale farmers in Kenya rely on climatic elements such as temperature and precipitation for livestock and crop production. These climatic variables have an economic impact that stimulates the final agricultural output which affects both crop and livestock net revenue which brings panic and fear among the farmers (Kellstedt *et al., 2008).*

Psychologically, the farmers are faced with many thoughts on adaptation and adaptive processes. These farmers have to change their agricultural operations to cope with or minimize the negative effects of climate variability. At this point, the farmers are faced with two perception processes namely risk perception and perceived adaptive capacity.

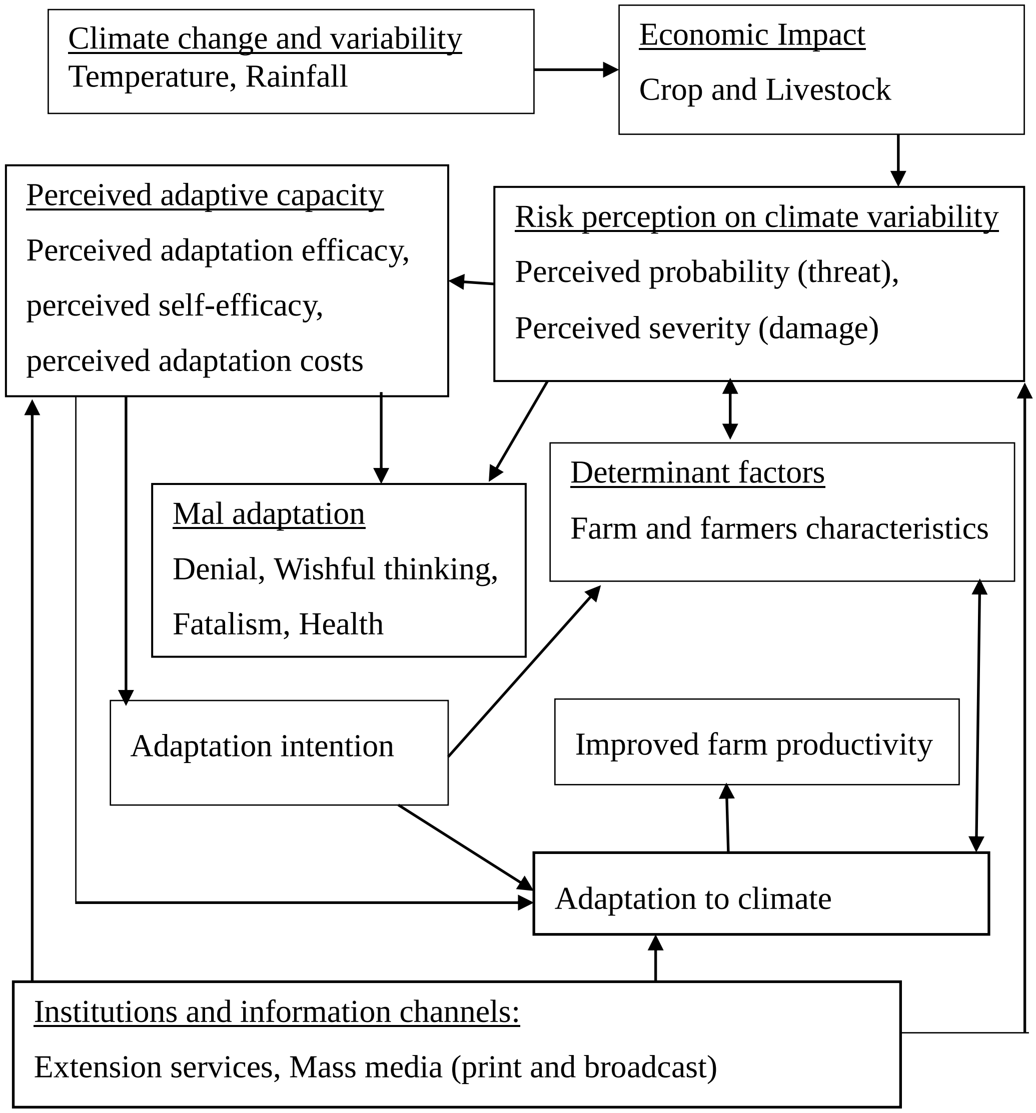

Figure 1: 1: Conceptual framework showing the relationship among the objectives

Source: Adapted from Kellstedt *et al.* (2008); Prager and Posthumus (2011)

The risk perception contains the threat probability and the perceived damage to the rainfed agricultural activities which may result in food insecurity. The perceived probability shows the small-scale farmers' anticipation of being exposed to the risks while perceived severity indicates the small-scale farmers' judgment on how climate variability may impact both crop and livestock (Kellstedt *et al.,*2008).

In the perceived adaptive capacity the farmers appraise their ability to handle and prevent risks associated with climate variability (Grothmann and Patt, 2005). This stage has three components: perceived adaptation efficacy perceived self-efficacy and perceived adaptation costs which commence if a minimum level of risk exists. Then the farmer is faced with two possible responses namely adaptation intention and mal-adaptation. The farmers will accept the available adaptation mechanism after perceiving benefits while on the other hand, the farmer may not accept because the risk perception is high but have a low adaptive capacity which leads to maladaptation (Prager and Posthumus, 2011). Adaptation intention is where the farmers accept available adaptation mechanisms after perceiving benefit. (Limantol *et al.,* 2016, Lee *et al.*, 2015). However, this adaptation intention may be influenced by the farm and farmers' characteristics such as scarcity of capital, land size, age, education levels, and gender (Salamula *et al.*, 2017).

Kellstedt *et al.* (2008) argue that institutional and information channels on agricultural-related messages boot the farmers' ability to adapt to climatic changes. The institutions both formal and non-formal, can improve risk perception, perceive adaptive capacity, and address farm and farmers' characteristics among the small-scale farmers. Jones *et al.* (2010) observed that risk perception by farmers towards climate variability is also a function of agricultural extension services and media. Besides, farmers perceived risks to climate variability and adaptation mechanisms determine the type and the level of adaptive capacity which is directly proportional to the quantity of food produced and hence improved food security (Belay *et al.*, 2017).

1.8 Definition of Terms and concepts

Adaptation – Modification/adjustments made to agricultural practices, processes, and systems to respond to the current and future climate change hence reducing vulnerability

Adaptive capacity – is the ability of a farmer to adjust to possible damage by trying to cope with harsh climatic conditions

Agricultural practices – These are a collection of principles that are applied on-farm production processes to get better agricultural products

Climate change - is any change in climatic elements (temperature and precipitation) over a long time probably above 10 years.

Climate variability –refers to the short-term deviations on seasonal or multi-seasonal timing in climatic variables such as temperature and precipitation.

Effectiveness - is the capability to produce desired results, expected outcomes, or deep and vivid impressions.

Farm profits – refers to benefits accrued when the revenue generated from farm production surpasses the expenses, costs, and taxes

Formal institutions – a group that follow rules and procedures that are formed, communicated, and enforced through channels widely accepted as officials, such as courts, legislatures, and bureaucracies

Non-formal institutions – these are shared informally unwritten rules that are created, communicated, and enforced outside of official channels.

Perception - the process by which information is received and transformed to create a psychological awareness. People perceive the same information differently based on their cultural differences and previous experiences

Rain-fed agriculture – refers to farming practices that depend on the annual rainfall of more than 1150mm and therefore no soil moisture stress with crop growing period of 120 days or more

Resilience – The ability of the small-scale farmers to bounce back after climate change and variability shock on their farms due

Small-scale farmers – describe the rural agricultural producers who use family labor on their farms and focus on subsistence production. Their farms are mostly small and located in marginal or risk-prone environments. Risks include drought and flood, crop and animal disease, and market shocks

Vulnerability - The degree to which a system is unable to cope with, negative impacts of climate change. Also refers to the level at which climate change may harm a system

CHAPTER TWO: LITERATURE REVIEW

2.1 Overview of climate change

The global climate is unprecedentedly changing at a rate not witnessed in recent human history and the associated risks are highly uncertain but real (Adger *et al*., 2003). The farmers' vulnerability to these risks may degenerate ongoing economic and social challenges especially for those who depend purely on rain-fed agriculture (Batisani and Yarnal, 2010).

Climate change refers to a wide range in the statistical description of weather conditions over a long period usually above 30 years (Yang *et al.,* 2015). The global climate is determined by atmospheric, oceanic circulations, earth surface-atmosphere interactions, and solar radiation (Chen and Chen, 2013). Based on Köppen-Geiger climate classification natural vegetation, monthly temperature, and precipitation are used to outline the boundaries of various climate types in the world (Kotteki *et al.,* 2006). For instance, world climate is classified according to the type of vegetation which gives five zones, namely the equatorial zone, the arid zone, the warm temperate zone, the snow zone, and the polar zone (Kotteki *et al.,* 2006). These zones are further subdivided according to the amount of precipitation received and air temperature. Furthermore, the climate in Africa is divided into seven zones that include tropical wet and dry, tropical dry, tropical rainforest, mountain, humid, middle-latitude dry, and Mediterranean (Kotir, 2011).

2.2. Temperature and Rainfall variations

There are global climate variations in terms of changing rainfall patterns, increased temperatures, and extreme weather patterns at various time scales as a result of external and internal forces within the atmosphere (Aming et *al.,* 2014; Plisnier *et al.*, 2000).

2.2.1 Temperature variations

The global trend shows linear warming of about 0.61ºC for the last 140 years which is a clear indication that global surface temperature is changing over time (IPCC, 2007). In North Atlantic and environs, warming was reported first in 1945 while the Northern Hemisphere showed a slight chance of increasing temperatures in 1975 and later in 2000 Southern Hemisphere (Folland *et al.,* 2002). With a slight increase in temperatures, evaporation rates on the ocean surface are very high which leads to an imbalance in global net radiation on the earth's surface.

In the African continent, reports show a hot and dry current that is associated with warmer seasons than it was in the past 30 decades at a rate of 0.5º C per century with June- August and September – November experiencing warmer seasons as compared to December–February, and March-May (IPCC, 2007; Kotir, 2011). Studies show that the 1980s and 1990s were the warmest years particularly 1987 and 1998 (Hulme *et al.,* 2005). The temperature varies within regions and countries, for instance, countries within the Nile Basin experience elevated temperatures of between 0.2 and 0.3ºC while Rwanda has experienced a 0.7 to 0.9ºC temperature increase per decade over the second half of the century (Eriksen *et al.,* 2008).

In Kenya, studies have shown that temperatures rose by 1°C over the past 50 years whereas temperatures are expected to increase gradually to nearly 3°C by 2050 (IPCC, 2007; Nzau, 2013). According to Nzau (2013), Kenyan minimum temperature has increased by 0.7°C to 2.0°C and the maximum by 0.2°C to 1.3°C. These variations largely depend on the region and the season (Nzau, 2013). The temperature variations, unfortunately, expose populations to climate variability effects. Though various studies have focused on the unpredictability of weather events it remains unclear how farmers perceive the risks and adaptation mechanisms to climate change and variability.

2.2.2 Changing patterns of rainfall

Global net radiation imbalances lead to irregular precipitation patterns on earth. For instance in the Northern Hemisphere studies indicate a slight precipitation increase as compared to the subtropical lands where rainfall has decreased in recent decades (IPCC, 2007). In South America, different phases of the El Nino-Southern Oscillation results in significant impacts on monthly and seasonal precipitation amounts owing to irregular water vapor and heat vacillations from the tropical Pacific Ocean to the atmosphere (Grimm and Tedeschi, 2009). In Pakistan, spatial shifts in the rainfall patterns have been associated with atmospheric general circulation in the region (Salma *et al.,* 2012). In many parts of the country, rainfall is unreliable and unpredictable. Furthermore, Khyber Pakhtunkhwa, Sindh, Punjab, and

Baluchistan were hit by heavy downpours in 2010 which damaged crops and 700,000 homes (Salma *et al.,* 2012). According to IPCC (2007), rainfall variability has increased across seasons, annually, and geographically in Asia over the past three decades with declining trends in rainfall patterns in the arid plains and along the coast.

In West Africa, reports indicate a shift in the onset of rainy periods over a decade and a very strong correlation between water scarcity and precipitation variability (Niasse and Coalition, 2014). According to Aming *et al.,* (2014), the Great Horn of Africa (GHA) has experienced an increased number of extreme precipitation events over the last few decades. The East African region displays considerable topographic and climatic variability associated with temporal and spatial bimodal rainfall (Galvin *et al.,* 2004). For instance, North Atlantic Oscillation and El Nino-Southern Oscillation (ENSO) have a large-scale influence on the Tanzanian climate. The country is a transition region for strong ENSO causes a change in rainfall patterns with the Tabora region receiving rainfall less than 700mm annually while regions around Lake Victoria receive above-average rainfall (Mongi *et al.*, 2010). In Kenya, maritime and terrestrial factors influence the climatic conditions with the central highlands and some parts of Rift Valley receiving a high amount of rainfall while the lowland areas receive a low amount of rainfall (Thornton *et al.*, 2009). The high and low amounts of rainfall experienced more often than not are unpredictable and precipitate untold suffering to small-scale farmers as observed by Mongi *et al.* (2010). Though various studies are focusing on unreliable rainfall patterns, little is known on how small-scale farmers perceive this as a risk and by extension how the perception influences rainfed agricultural practices among the small-scale farmers in Embu County.

2.3 Climate variability impact on crop and livestock production

2.3.1 Crop production practices to adapt to climate change

Crop production is one of the agricultural practices that involve the growth and production of food and fiber for commercial and sustenance (Lobell *et al.,* 2011). This practice comprises all the feed sources that are essential to maintain and produce crops. Crop production is associated with tillage which refers to soil preparation by use of hand or machine-powered tools which involves digging, overturning, or stirring of soils. According to Kladivko (2001), there is primary tillage that allows reasonable depth, kills weeds, incorporates organic manure and aerate soils, and secondary tillage that increases soil pulverization and conservation of water moisture by destroying the weed. The choice of any particular tillage depends on the soil, climatic conditions, and the number of years the land has been cultivated (Kladivko, 2001). Besides, sowing involves seeds being put in the soil by either use of hand or machines while planting is putting into the soil an already established plant and ensuring all its roots are covered in the soil (Connor *et al.,* 2011). The farmers' intention of sowing or planting is to ensure adequate crop establishment with the right conditions for growth and yield. Villalobos *et al*. (2016) argue that the critical stages of the agricultural crop are germination, emergence, and early seedling growth which depend on soil moisture content, soil structure, seed viability, and soil temperatures. Bot and Benites (2005) note that there are two main ways of soil enrichment namely, organic and inorganic methods. The organic method involves the use of plant and animal material in the soil that goes through the decomposition process to release nutrients. However, the organic method of soil enrichment alone cannot supply enough quantity of nutrients in the soil and therefore supplement with chemical fertilizers (Pagliai *et al.,* 2004). Besides, Villalobos *et al*. (2016) observed that it is common for a farmer to apply fertilizers containing potassium, phosphorus, and nitrogen on their farms.

Another important practice in crop production is weeding. This is the process of removing unwanted vegetation that grows alongside useful crops in an agricultural field. The weeds tend to compete with crops for space, nutrients, and sunlight hence reducing crop productivity (Metzger *et al.,* 2019). Harvesting is also another practice that involves gathering, cutting, cleaning, sorting, and packing ripe or mature crops by use of hand or machine-powered tools (American Heritage Dictionary, 2007). These crops are then stored for future use to guarantee food security during dry seasons, ensure availability of seeds for the next season, and ensure even and unceasing provisions of raw materials to industries, and equilibrium the demand and supply of agricultural products to ensure stabilized market prices (Sanderson and Adler, 2008).

2.3.2 Climate variability impact of crop production

Globally, crop production depends on five parameters that characterize rainfall season namely rainfall onset, final rain dates, rainfall duration, amount, and intensity (Garcia *et al.*, 2007). However, this practice faces uncertainties as a result of changing climatic conditions such as unreliable rainfall and warming temperatures (Morton, 2007). A study carried out in Pannonian, Central Europe indicates an increase in water deficit affects planting time and limits vegetation physiological ability hence reducing yields (Trnka *et al*., 2010). Furthermore, sowing during spring is rendered impossible as a result of unfavorable weather conditions which reduces the farmers' crop revenue (Van Passel *et al.*, 2017). In Northeast Asia, a slight increase in temperatures coupled with a large increase in rainfall leads to an increase in overall output which translates to increased net revenue on crop production (Kurukulasuriya and Ajwad, 2007). However, in Myanmar, a county in southeast Asia reported a loss in crop productivity which was associated with extreme weather and climate events (Oo *et al.,* 2020).

In Africa, crop production is mainly a function of temperature and rainfall. For instance, in Sub-Saharan Africa and North Africa, 95% and 75% of crop production are rain-fed respectively. Rain-fed agriculture refers to agricultural practices that depend on the amount of rainfall, its distribution, and its effective utilization (Taylor *et al.*, 2014). In South Africa, the impact of climate on sugarcane production shows a non-linear significance of climate on net revenue (Deressa *et al.,* 2005). Cameroon's agriculture net revenue has shown that the farms are averagely profitable regardless of the existing harsh climatic conditions (Molua, 2009). In Kenya, results show crop production is impacted by climate variability although the magnitude of this impact varies from one geographical location to another (Seo *et al.*, 2009; Kabubo-Mariara and Karanja, 2007). With variation impacts, there is a need to determine the crop production economic impact of climate variability on small-scale farmers of Embu county.

2.3.3 Livestock production practices to adapt to climate change

Livestock production involves the keeping of tamed animals in an agricultural setting to provide labor and products, namely meat, eggs, milk, and leather (Mench, 2008). These animals range from cattle, goats, sheep, rabbits, donkeys, poultry, and pigs. Globally livestock production contributes about 70% of livelihood in the rural areas where zero-grazing and free-range are common (Mench, 2008).

In livestock production, many practices are involved. For instance, animal feed management involves modern and traditional livestock feeds. Modern feeds are those produced by selecting and blending ingredients to provide a high nutritive diet and can improve the health of the animal and increase the quality of end products such as meat, milk, and eggs (Gizzi *et al.*, 2004). Besides, traditional feeds include pasture grasses, hay and silage crops, and a variety of grains (Schnabel *et al.*, 2001). Other feeds are obtained from by-products of human foods such as sugar beet pulp, brewers' grains, and pineapple bran and surplus food crops like wheat, fruits, vegetables, and roots (Westendorf and Wohlt, 2002). The quality and quantity of animal feed depend on geographical location, livestock species, and system (Yahav, 2004).

Animal breeding is another livestock practice that involves selecting mates for animals with desired genetic traits, maintaining or improving these traits for future generations (Gamborg and Sandøe, 2005). It involves looking at the genetic value of individual animals such as growth rate, yields like eggs, milk, or meat (Lawrence *et al.*, 2004). This ensures that animals are energetic and able to adjust to climatic changes. Also, these animals need to be protected from pests and diseases to ensure high productivity. According to Dinesh *et al.* (2015) in Africa, 20% of ruminants and 50% of poultry do not reach maturity due to the attack of pests and diseases. It is reported that climate change and variability alter the pest and disease life cycles in animals (Boxall *et al.*, 2009).

2.3.4 Climate variability impact on livestock production

Globally, livestock production and management vary from one agro-ecological zone (AEZs) to another (Rojas-Downing *et al.*, 2017). However, Mengesha (2011) observed that the climatic impact on livestock production is not necessarily a function of AEZs. This makes it difficult to generalize the impact of climate variability based on AEZs. In North America, heat stress ensued in increased morbidity and mortality to livestock which translates to economic losses (Renaudeau *et al.*, 2012). Besides, high temperatures affect forage production that resulting in reduced feed intake. According to Rojas-Downing *et al.* (2017) reduction in animal feed intake leads to a decrease in milk production.

In India, heat stress is reported to have compromised the immune system of poultry that leaving the chicken more susceptible to bacterial infection (Cole and Desphande, 2019). Besides, poultry lacks appetite and experiences diarrhea that farmers assume infection and rush to purchase antibiotics. A study carried out in Africa indicates 80% of poultry farming reared by small-scale farmers is free-range and depends largely on grains from crop yields (Mengesha, 2011). Reduced crop yield results to reduce feed –intake that translates to reduced quality of meat and low egg production.

In East Africa, goats and sheep are affected during extreme weather events because these animals have no mechanisms to resist prolonged dry periods due to feeding and water deficiency (Feleke *et al.*, 2016). This leads to weak and malnourished animals that can't fetch good prices in the market. In Kenyan Coast regions indicate a non-linear significance between livestock net revenue and climate variability whereas a study in Kenyan Arid and semi-arid areas shows a linear correlation between an increase in temperature and livestock production (Wachira, 2017; Seo et al., 2009). The economic impact of climate variability can not be generalized because the magnitude of the effects varies with altitudes. There is scanty information about small-scale farmers' net revenue on livestock production and therefore the study is set to investigate net revenues among the small-scale farmers in Embu County.

2.4 Climate change risk perception and adaptation mechanisms on rain-fed agricultural practices

2.4.1 Climate change risk perceptions

Perception refers to a process in which stimulus or information is received and transformed to generate psychological awareness (Kellstedt *et al.,* 2008). Observation of the small-scale farmers may vary from that of scientists and researchers due to the diverse lens underlying their observation (Nichols *et al.,* 2004). Therefore farmers' perception is formulated based on cultural background, prior experience, and socioeconomic factors whereas scientists are highly based on general conclusions from a certain place with a few variables (Ayal and Filho, 2017). Hence, farmers' claims may or may not concur with the scientific observation and therefore need to comprehend farmers' perceptions of climate variability and the perceived impacts.

Farming is a risky adventure where season-to-season fluctuations of both rainfall and temperatures dictate output and profitability (Rao *et al.* 2011; Mase *et al.*, 2017). Farmers have to decide on what to plant, when to plant, how to plant, what input to utilize, and what crop, water, and soil management strategies to use to avoid massive losses (Rao *et al.*, 2011). The vulnerability of agricultural systems does not depend only on climate change and variability but also on human response to mitigate the adverse impacts (Mase *et al.*, 2017). Therefore the ability of the farmers to handle the changing climate relies on the farmers' perceived risks and dangers posed to the system.

Several studies show that different countries have different exposures to climate change risks which contributes to different levels of risk perception (Juana *et al.*, 2013). These levels vary with one's occupation, geographical location, culture, existing policies, knowledge, and experience (Rao *et al.*, 2011; Taylor *et al.*, 2014). For instance in developed countries like the United States of America, Britain, and Germany perceive climate variability as a far-fetched phenomenon with a moderate risk that impacts geographically and temporally distant people and places (McCarthy *et al.*, 2015). A study carried out in the United Kingdom perceives heavy rainfall and floods as major risks to their day-to-day lives (Taylor *et al.*, 2014).

A study carried out in Africa by Juana *et al.* (2013) indicates that the majority of small-scale farmers in Sub-Saharan African are aware of risks associated with the season-to-season rainfall variability and the presence of warmer temperatures in food production. Nhemachena and Hassan (2007) noted that South Africa, Zambia, and Zimbabwe farmers observed changes in rainfall patterns and frequency of droughts which has resulted in farmers developing various farm-level coping strategies.

A study carried out in Kenyan semi-arid regions indicates that farmers distinguish climate change risks in terms of loss of plants and animals, and a negative impact on the national economy (AEA GROUP, 2018). In Embu County, several studies have highlighted the possible undesirable impacts and future change on agrarian yield as a result of the current climate variability and the urgent need to develop adaptation strategies (Deressa *et al.*, 2009; Eriksen *et al.*, 2005; Mugi-Ngenga *et al*., 2016). Understanding small-scale farmers' risk perception on the trends of climate change, adaptation mechanisms, and factors influencing adaptation to climate change is critical for effective management of the farming sector which this study seeks to address.

2.4.2 Climate variability adaptation mechanisms

Adaptation mechanisms are in three categories as observed by Cooper *et al.* (2008), firstly risk management choices such as the use of crop variety tolerant to harsh climatic conditions, water management investment, mixed farming, and off-farm activities. Secondly, in-season alteration of crop and resource management decisions such as a variation in the dates of planting, tillage type, and harvesting time. Thirdly reduction of livelihood impacts associated with climate change by selling household assets, borrowing, and cutting off daily expenditure of dispensable items.

Globally farmers have advanced knowledge, skills, and management tactics that enable continuous interaction with the environment and the same time buffer against uncertainties induced by climate variability (Cooper *et al.,* 2008). According to Olesen *et al.* (2011), Europe is one of the world's largest producers of fiber and food, experiences climate change which has led them to change the cultivation practices and shifts in sowing dates. In Vietnam, farmers have accustomed their seasonal calendar, irrigated their lands, and introduced new crop and animal breeds to cope with the changing climatic conditions (Hoang *et al*., 2014). Sri Lanka's integration of trees on a farm with crops and livestock contributes to climate change adaptation in this small island nation in South Asia. In Bangladesh, farmers have resulted in having integrated farming systems, crop insurance, use of drought, and salinity tolerant varieties to cope with harsh climatic conditions (Uddin *et al.*, 2014).

In Ghana, farmers diversify their crops, shift the planting dates depending on the onset of rains and others migrate to agricultural favorable areas while in Zimbabwe farmers have resulted into a livelihood and crop diversification as the main climate change coping strategies (Gukurume, 2013; Fosu-Mensah *et al.,* 2012; Rademacher-Schulz *et al*., 2014). Whereas in Benin, farmers plant seed varieties that mature within a short time and non-farm activities like making and selling of crafts (Baudoin, 2014). In Ethiopia, farmers plant early maturing and drought-resistant crop varieties, supplement rainfall by irrigation, and encourage mixed farming to spread the risks (Deressa and Hassan, 2009). Farmers in Gladstone, a South African rural community have resulted in in-field rainwater harvesting which involves the collection of runoff that is stored in the soil profile for crop production (Gandure *et al.,* 2013). In Uganda small-scale farmers have resulted in off-farm activities that supplement farm incomes, use of drought-resistant crop varieties, and migration of the youth to provide remittances to their families whereas in Malawi farmers draw on savings, sell livestock and consume food stocks to cope with the climatic shock (Berman *et al,* 2015; Oyekale and Gedion, 2012). A study carried out in Tanzania indicates that small-scale farmers' soil and water conservation measures, use litter for mulching, increase the number of inorganic fertilizers (Sanga *et al.*, 2013).

In Kenya, smallholder farmers have shifted to mixed cropping, crop diversification, and agroforestry to ensure continuous agricultural productivity (Hoang *et al.*, 2014). Mwang'ombe *et al.* (2011) observed that arid and semi-arid areas mitigate drought by purchasing fodder and seasonal destocking of livestock. A study carried out in Makueni indicate that indigenous knowledge and social networking are necessary adaptation mechanism for the small-scale farmers in Kenya for they allow easy prediction of rainfall patterns and drought frequency (Speranza *et al.,* 2008). Regardless of many evaluated and documented adaptation mechanisms available to the small-scale farmers, food shortage is still a menace in Kenya. This study sort to understand the perception of the adaptation mechanisms in the study area.

2.5 Factors influencing small-scale farmers' perception and adaptation to climate variability

2.5.1 Factors influencing small-scale farmers' perception of climate variability

Farmers directly engaged in farming practices are more probable to experience climate change and thus more inclined to adaptation mechanisms (Spence *et al.,* 2011). Beliefs that climate variation is occurring such as a rise in temperatures and unreliable rainfall patterns affect farmers' decisions to protect the farm (Weber, 2010). Farmers' choices under climatic risk and uncertainty differ according to available information, geographical location, and access to credit (Spence *et al.,* 2011; Limantol *et al.,* 2016).

Globally, there are diverse public opinions about climate change and variability. For instance, Lee *et al.* (2015) observed climate change information, awareness, and risk perceptions are uneven across the world. This uneven distribution of awareness affects the farmers' perception of the dangers linked to climate change. Therefore geographic, national, and cultural factors play a vital part in modeling farmers' level of perception of climate change.

In Sub-Saharan Africa, poor farmers face serious social, cultural, and structural issues to reach climate change information which tends to limit their perception to respond to stress and change (Shackleton *et al.,* 2015). In Ghana, the degree of perception varies as a result of farmers' resilience, exposure levels, and adaptive capacity (Limantol *et al.,* 2016). In Ethiopia, the perception of climate change varies with altitude where farmers in the highlands perceive more climatic variability than those in the lowlands or mid-land (Deressa *et al.,* 2011). This is a result of reduced water availability and soil erosion in the highlands due to erratic rainfall patterns.

In Kenya, a study carried out in Garrisa shows that farmers with more farming experience are likely to shape farmers' climate change perceptions. This is because these farmers have long-term exposure to the changes in temperature and rainfall patterns (Bryan *et al.,* 2013). According to Ndambiri *et al.* (2013), household heads in the Kyuso district (currently within Kitui County) between the age of 31-60years are more likely to perceive climatic change compared to those with 30 years and below. Individual-level on perception varies due to region, geographic and cultural factors, therefore this study is focused on small-scale farmers of Embu country to investigate the key factors that play a role in shaping their perception of climate change.

2.5.2 Factors influencing small-scale farmers' adaptation to climate variability

Globally many agricultural adaptation mechanisms have been suggested to farmers. These adaptation mechanisms are of different types such as micro-level, market responses, institutional changes, and technological developments which range from large to small-scale (Mertz *et al.,* 2009). As observed by Kurukulasuriya *et al.* (2006) governments, firms, and farmers have been involved in decisions on adaptation. However, a study carried out in Hungary indicates a lack of knowledge as the only factor that hinders farmers from adapting to available adaptation mechanisms (Li *et al.*, 2017). According to Reidsma *et al.* (2010), European farmers may not adapt to changing climatic conditions owing to a lack of awareness of various adaptation mechanisms, lack of planning, and lack of motivation by policymakers to create an adaptive environment.

In African countries, rain-fed agriculture is directly affected by climate variability and over time farmers have evolved with adaptation mechanisms although poverty conceals progress (Batisani and Yarnal, 2010; Cooper *et al*., 2008). In South Africa, farmers are likely to adapt to a new technology due to the presence of private land tenure, large land size, and the challenge of soil infertility (Gbetibouo, 2009). Furthermore, in Ethiopia, farmers' gender, education, and availability of credit facilities tend to influence the type and the level of adaptation (Deressa *et al.*, 2009). Eriksen *et al.* (2005) indicated determinants to the adaptation of climate change as a lack of capital, skills, and limited family in both Tanzania and Kenya. However, Mugi-Ngenga *et al.* (2016) noted that in dry zones of Eastern Kenya, farming experience, household size, and education level are the most significant factors that promote the adaptation to climate variability. These adaptation mechanisms are site-specific and the level of adaptation is influenced by many factors that are geographical and anthropogenic related. This study sort to address the farm and farmers characteristics that may hinder effective adaptation to climate change among the small-scale farmers in Embu County.

2.6 Institutions and communication channels on climate change and variability

2.6.1 Institutions on climate change and variability

Institutions are either formal or informal which tend to outline a community or individuals' expectations, behavior, and interactions (Wang *et al.,* 2013). These institutions range from public, civic, and private sectors which include business organizations (Agrawal and Perrin, 2009). The public institutions consist of administrative units and local government whereas civic comprise membership and cooperative organizations. Globally, the UN Framework Convention on Climate Change synchronizes entirely those activities threatened by climate change and accepts adaptation as the paramount way to deal with climate change (Turner and Hannachi, 2010). This convection gives guidelines on the prerequisites to adaptation at global, regional, and local levels to promote sustainable development (Lindseth, 2005). Though the convention campaigns for the miniature organization at local levels to warrant real adaptation to the changing climate, this study delves to find out.

In South Africa, local farming cooperatives pursue active reciprocal links to ensure farmers access information, credit facilities, and exchange labor to overcome climate change shocks (Osbahr *et al.,* 2010). The study distinguished that individuals who invested in social networks have long-term support.

In Kenya, Eriksen *et al.* (2005) observed that informal social capital in conjunction with formal institutions helps to reduce and manage risk related to climate change. Social networks encourage and motivate farmers to adapt to adaptation. This is possible as a result of interactions and visits to members' farms that enable observation and learning of new adaptation mechanisms (Tari *et al.,* 2015). Though in Embu County, slight evidence is acknowledged on the functions of local institutions in determining the results of perception and adaptation to climate change and variability, this study intends to fill this gap.

2.6.2 Information channels on climate change and variability

Globally climate information and support services are critical in providing awareness and Early Warning Systems (EWS) to have disaster preparedness and capacity building towards climate variability (Cherotich *et al.,* 2012). The choices made by the farmers on the dissemination channels influence the access and the use of this climate information and service. Furthermore, smallholder farmers encounter competition in the global marketplace due to a lack of access to communications and information that can be used for decision making and the availability of new markets (Parikh *et al.,* 2007). This has affected the small-scale ability to access advanced forms of mechanization due to low acquisition power. In Mexico, for instance, 80% of the country's population are small-scale and marginalized farmers who have increased transaction costs due to poor communication networks on climate change and variability (Parikh *et al.,* 2007). Therefore including many forms of mechanization because of their small-scale and low acquisition power.

In Africa agricultural messages and knowledge are shared from farmer to farmer although there is inadequate dependability on climate variability information (Churi *et al.*, 2012). However, this information is communicated east through meetings in the village such as churches, mosques, funeral gatherings, and marketplaces. Risks associated with climate variability can adequately be managed by the presence of climate information (Scott and Lemieux, 2010). In Tanzania's smallholder farmers have been reported to have several traditional communication methods that are used in rural areas to access agricultural technologies and climate forecasts (Churi *et al.*, 2012). These methods include village meetings and radio. Although television and extension services are also used to some extent in areas that have electricity and affordability capacity. According to Churi *et al.* (2012), these information channels are affected by a low percentage of extension workers to small-scale farmers, limited finances by both individual farmers and climate change institutions to support farmers' demonstration plots and schools, slow flow of climate variability information to the farmers. Interpersonal channels like farmer to farmer interactions, opinion leaders, and extension agents are reported to be the most common in, Benue State, Nigeria in spreading climate variability information (Okwu and Daudu, 2011). Besides in the category of mass medium Radio was the most accessible for agricultural information while television scored the least mode of communication on climate variability and agriculture this is due to the dependence of electricity which is available in many parts of the rural areas. In Western Kenya, vulnerable farmers are reported to use extension services, radio, and local administration to acquire climate variability information for their agricultural activities (Cherotich *et al.*, 2012). However, in Embu County scanty information is documented on the existence and availability of information channels to pass agricultural and climate change awareness and knowledge among the small-scale farmers, this study intends to fill this gap.

2.6.3 Factors influencing access and utilization of climate change information

Climate change is associated with environmental problems that impact negatively on ecological and social structures this has led researchers to come up with possible solutions. Despite the many studies on climate change, there is a persistent gap between the user, in this case, farmers, and knowledge production, the researcher (Lemos *et al.*, 2012). According to Cash *et al.* (2003), one of the factors that may affect the use of climate change information is the farmers' perception and understanding of climate change and its impacts. This is a result of researchers and users being heterogeneous in the production and utilization of climate information. A study carried out in America shows that the users of the information are likely to deploy climate change information if they perceive it to be timely and relevant (Pagano *et al.*, 2002). Also, the information should be credible and accurate (Cash *et al.*, 2003). Many United States water users resisted new knowledge due to the perceived risks, fear of failure, and unwillingness to change from the well-established routines and knowledge (Rayner *et al.*, 2003; Rice *et al.,* 2009).

In developing countries, lack of flexibility of organizations and institutions on decision making, insufficient technical and human capacity, and inability to access external information constrains climate change information regarding climate change information (Lemos *et al.*, 2012; *Rayner et al*., 2003). According to Oyekale (2015), farmers' access and utilization of climate change information in East and West Africa are hindered by both farm and user characteristics such as level of education, household size, gender, level of degradation of the land, and access to credits. Whereas in Maluga and Chibela villages in central Tanzania cultural issues are singled out as the major influencer of access and utilization of climate change information (Elia *et al.,* 2015). In Zimbabwe farmers' ability to interact with extension service providers, farmer to farmer, field days, and learning-based meetings significantly influence the access and utilization of climate change information on farms (Gwandu *et al.*, 2012). A study in South Africa indicates a top-down approach from researchers to farmers influences the access and utilization of climate change information because there is no relationship between the producers of the information and the end-users (Johnston *et al*., 2004).

In Northern Kenya, illiteracy levels among the arid and semi-arid vulnerable populations have been reported to influence access and utilization of climate change information (Cherotich *et al.*, 2012). Furthermore, micro variability in climate in Northern Kenya weakens the broad-scale of climate forecasting (Luseno *et al.*, 2003). A study carried out in Western Kenya reported that farmers did not trust the daily forecast and did not find the information geographically relevant to the locality whereas the fishermen did not receive climate change information relevant to their operations (Onyango *et al.*, 2012). Scanty information is documented on challenges facing small-scale farmers in a bid to access and utilize climate change information in Eastern Kenya. This study intends to fill this gap by investigating factors influencing access and utilization of climate change information among the small-scale farmers of Embu County.

2.7 Research gaps

With many uncertainties and unpredictability of weather events, there is a need to study how farmers in Embu County perceive the risks and adaptation mechanisms and by extension how the perception influences rainfed agricultural practices in the county.

Climate variability has had destructive effects on agricultural production, especially on crop and livestock practices that rely entirely on rainfall. The magnitude of impact varies from one geographical location to another. Besides, there is scanty information on net revenue on livestock and crop production among the small-scale farmers of Embu County, and therefore this research was set to seal this gap.

Understanding small-scale farmers' risk perception on the trends of climate change, adaptation mechanisms, and factors influencing adaptation to climate change is critical for effective management of the farming sector which this study seeks to address.

With climate variability, small-scale farmers have involuntary embarked on adaptation mechanisms to shield themselves from the scathing effects of the rise in temperatures. These adaptation mechanisms are site-specific and the level of perception and adaptation is influenced by many factors that are geographical and anthropogenic related. Besides, the individual level of perception varies with region, geographic and cultural factors. Therefore, this study sort to investigate the key factors that play a role in shaping the perception and adaptation to climate change among the small-scale farmers in Embu County.

Institutions and information channels are critical in giving awareness and knowledge to small-scale farmers. However, there is scanty evidence documented on the functions of local institutions in determining the outcomes of perception and adaptation in Embu County. Furthermore, there is scanty documentation on the existence and availability of information channels to pass awareness and knowledge to influence perception and adaptation. Besides, little is known on challenges facing small-scale farmers in a bid to access and utilize climate change information in Eastern Kenya, this study intends to fill these gaps.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 The study area

3.1.1 Study location

The study area is located in Embu County within the Kenyan highlands on the eastern foot slopes of Mount Kenya (5199 m above sea level). Embu County has altitudes vacillating from 1080 m to over 4700 m above the sea levels and longitude 37° 3’ and 37° 9’ East, and latitude of 0° 8’ and 0° 50’ South (Figure 3.1).

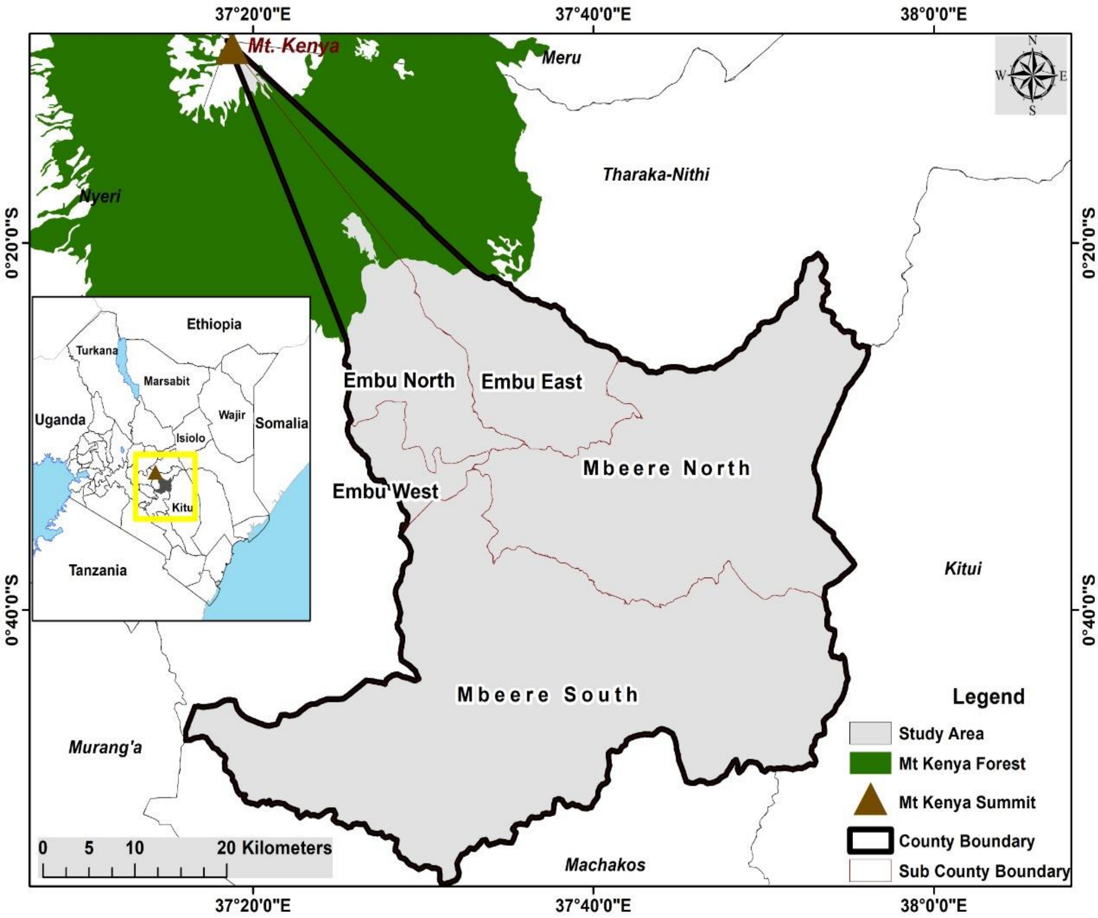

Figure 3:1: Study Area Map

The region occupies an area of about 2,818km^2 and there are five sub-counties namely Embu West, Embu North, Mbeere North, Embu East, and Mbeere South (Embu County Government Integrated Development Plan, 2013). Kirinyaga County borders Embu to the West, Kitui to the East, Machakos to the South, and on the North is Tharaka Nthi.

3.1.1 The study area climatic conditions

Embu county is recorded to collect a total annual rainfall of between 1200 and 1500 mm in two rainy seasons, March to June which is considered as the long rainy season, and October to December as the short rainy season, although the rainfall quantity received varies with altitude. Temperatures range from 12°C minimum in July to a maximum of 30°C in March and September with a mean of 21°C (Ayuke *et al*., 2009). The difference between the minimum and maximum temperatures is due to the extensive altitudinal range of the county. However, there is a localized climate in areas along the Tana River due to the presence of five dams, Masinga, Kamburu, Gĩtaru, Kĩndaruma, and Kĩambere (Embu County Government integrated Development plan, 2013). The presence of favorable temperature and rainfall allows the small-scale farmers of the study area to practice rain-fed agriculture.

3.1.2 Socio-economic activities of Embu County

Agriculture is the pillar and livelihood of the study area because it supports 70.1% of the populace and 87.9% of the homes are directly involved in Agrarian activities. These agricultural activities take about 80% of the total area of Embu County (Embu County Government integrated Development plan, 2013). The county cultivates both cash and food crops. The cash crops include coffee, tea, macadamia, and cotton. However, due to challenges facing cash crops, many small-scale farmers have shifted to food crops such as maize, beans, sorghum, millet, sweet potatoes, cassavas, mangoes, and horticultural crops. In addition, the small-scale farmers rear cattle, sheep, goats, pigs, chickens, ducks, and donkeys.

Owing to the county's vibrant real estate, sand harvesting has lately become a lucrative business. One of the key up-and-coming economic incentives is the upgrading of Embu airstrip to airport status, which is expected to link up the county's agribusiness to an external market.

On the other hand, the county has a high affinity for international and local tourists due to the presence of attractive sites like waterfalls (Nthenge Njeru), caves, and rocky hills for rock climbers, gateway to Mt. Kenya. Furthermore, there is the presence of five hydroelectric power dams that generate hydroelectric power and huge incomes to the County.

3.1.3 Soils and Land Use

Embu County has soils of volcanic origin in the upper midland and higher zones near Mt Kenya which include andosols, ando-humic nitisols, and humic nitisols. In most of the lower midland zones, soils are based on metamorphic basement rocks with volcanic influence with moderate to low fertility (Jaetzold *et al.*, 2006). Table 3.1 shows ten major ecological zones in this county ranging from high-altitude zones with forest cover (UH0) to dry lowland livestock-millet zone (IL5) which are characterized by various land uses as indicated by Jaetzold *et al.* (2006). The county's land-use patterns range from gazetted forests 4.96%, arable land at 59.06%, urban areas at 1.93%, non-arable land at 17.81%, and water mass at 16.20% (Embu County Government integrated Development plan, 2013). Arable land is used for both crop and livestock production. In crop production, the county has three categories; food, industrial, and horticulture crops. The food crops include Irish potatoes, green grams, sorghum, pearl millet, beans, cowpeas, sweet potatoes, cassava, maize, and while the industrial crops are cotton, coffee, tea, and macadamia. On the other hand, horticultural crops are mangoes, bananas, passion fruits, avocadoes, kales, tomatoes, carrots, butternuts, and watermelons. Furthermore, livestock types are cattle, sheep, goats, chickens, rabbits, donkeys, beehives, and pigs.

Table 3. 1: Agroecological Zones and major land use in Embu County

Agro-Ecological Zones	Altitude	Annual Mean Temp °C	Major land use	Annual Average Rainfall
Forest zone (UH0 and LH0)			Forest Reserve	
Lower Highlands (LH 1)	1770-2070	17.7-15.8	Tea-Dairy zone	1750-2000mm
Upper Midland Zone (UM 1)	1590-1830	18.9 – 17.5	Coffee-tea zone	1400 - 1800mm
Upper Midland Zone (UM 2)	1400-1590	20.1-18.9	Main coffee zone	1200-1500mm
Upper Midland Zone (UM 3)	1 280-1 460	20.7-19.6	Marginal coffee zone	1000-1 250mm
Upper Midland Zone (UM 4)	1 280-1 400	20.7-20.0	Sunflower – maize zone	980-1 100mm
Lower Mid land (LM 3)	1 070-1 280	22.0-20.7	Cotton zone	900-1 100 mm
Lower Midland (LM 4)	980-1 220	22.5-21.0	Marginal cotton zone	800- 900mm
Lower Mid land (LM 5)	830-1 130	23.5-21.7	Livestock-millet zone	700-800mm
Lowland (IL 5)	760- 830	23.9-23.5	Livestock-millet zone	640- 780

Source: Jaetzold *et al.*(2006).

3.1.4 Population

According to Embu County Government integrated Development plan (2013) there is a total of 513,363 comprising of 254,303 males and 261,909 females as of the 2009 census who occupy 2,615.2 km^2 excluding 202.8km^2 which is a part of Mount Kenya forest. Out of the total population in this County, 83.8% live in rural areas where agriculture is prominent.

3.1.5. Hydrology

There are six major rivers in this county that include Rupingazi, Thuci, Ena, Kii, Thiba, and Tana. Besides, the county shares some major dams with Makueni and Kitui counties that produce hydroelectric power for the country. These dams are situated along the Tana River and include Kiambere, Gitaru, Kindaruma, Kamburu, and Masinga (Embu County Government integrated Development plan, 2013).

3.2 Research Design

The descriptive survey was employed to implore data on the particular variables. This design was the most apposite for this study as it allowed the assortment of information from individual farmers on risk perceptions, adaptation mechanisms, farm, and farmer characteristics, institutions, and information channels concerning small-scale farmers in Embu County. The survey also allowed observation of the small-scale farmers in a natural and unchanged environment. The data collected provided both quantitative and qualitative in-depth information on the aforementioned parameters.

3.3 Sample Size and Sampling Procedure

The sample size for the study was calculated by the use of a formula by (Yamane, 1967). The formula helps to determine the sample size (n), from a given finite population (N) with a ±.05 level of precision and confidence level of 95%. According to Bryman (2008), a 95% confidence level is the most preferred due to its low variability and enhancement of precision on a higher size of the sample. Below is the formula

$$\frac{N}{N e^2 + 1} = n$$

Where

n represents the sample size of the proportional population

N represents a finite population (106,920)

e is the ±.05 level of precision with a confidence level of 95%

Based on the formula a sample size of 399 was obtained and derived as shown 106,920 / (1+ 106,920 (0.05^2) = 106,920 / 268.3 = 398.5. The study however used a sample size of 411. This was adopted to account for absentee and non-responses.

A multi-stage sampling procedure was adopted that involved purposive, stratified, and random sampling. Purposive sampling was the first stage where five sub-counties were selected within Embu County. This was to ensure equitable distribution of the questionnaires and unbiased responses from the households. The second stage involves the stratified sampling of administrative divisions within the sub-counties to form the substrata. This was to arrive at sampling units with proportional sample sizes for each division by use of the following formula.

$$ni = n/N*411$$

Where **n** is the total number of small-scale farmers in the division, **N** is the total number of small-scale farmers in the study area, and ***ni*** represents the sample size for the division. A simple random sampling technique was the third stage that involved selecting respondents from each division (Table 3.2).

Table 3. 2: Distribution of respondents in five-sub counties in Embu County

Sub – County	**Divisions**	**No. of small-scale farmers**	**No. of questionnaires**	**Percentage (%)**
Embu West	Central	10 866	41	10.2
	Nembure	6 360	24	5.8
Embu North	Manyatta	17 218	64	15.5
Embu East	Runyenjes	16 552	64	15.5
	Kyeni	13 448	52	12.6
Mbeere South	Gachoka	6 818	27	6.7
	Mwea	6 060	24	5.8
	Makima	5808	23	5.6
	Kiritiri	6565	26	6.3
Mbeere North	Evurore	7 830	30	7.3
	Siakago	9 395	36	8.7
	Total	**106,920**	**411**	100

Purposive sampling was used in identifying 10 key informants for the interview. The selection of the informants was founded on the wide knowledge and competency in the field of agriculture and climate change by their academic qualifications and experience in both government and private agencies as shown in Table 3.3.

Table 3. 3: Informant interviewees of Embu County

Type of organization	Respondents
Government department	The office of the County Executive Committee (CEC) for agriculture, livestock, and fisheries
Government parastatals	National Environmental Management Authority official
NGOs	Tuungane tujijenge
Farmers Organization	Gachoka farmers group
	Kathade men association
	Maciara women group
	Neema farmers group

Quota sampling was chosen to generate FGDs participants which comprised 8-12 smallholder farmers. Within the 5 Sub-counties, age cohorts formed the basis of sample size. These cohorts were alienated into 6 clusters with an intermission of 10years. In each cluster, 2 respondents were selected to partake in the focus group discussion.

3.4 Pre-testing research instruments

Pretesting of the data collection tools to determine reliability and validity was done in March 2018 using a randomly selected sample size of 60 small-scale farmers and Agricultural officers. These small-scale farmers were drawn from the five sub-counties of Embu County. As observed by Bryman (2008) the study tool is considered reliable if the respondents answer the questions, in the same way, each time they were asked. Furthermore, the tool is deemed valid, if it measures the concepts accurately. The sampled small-scale farmers and agricultural officials were taken through the research tools which included questionnaires, interviews, and focus discussion questions. They were then requested to give their assessments regarding the clarity and appropriateness of each of the tools. The coefficient of reliability for 30 randomly selected questionnaires was conducted by use of SPSS version 16 and there was a 0.87 value. According to Tchagneno (2020), Cronbach's alpha value above 0.7 is an acceptable reliability coefficient. This indicated a very high relationship between the variables and therefore not affected by random factors. Thereafter all the variables in these questionnaires were taken into account when generating the final tools. All those respondents involved in the pre-testing exercise were not allowed to participate in the final survey.

3.5 Data Collection methods

An exploratory study was done in each of the sub-counties to help to boost clarity in climate variability issues. Data collection instruments included questionnaires, focus group discussions, key informants' interviews, observation sheets, and desktop study.

3.5.1 Questionnaire

The study administered 411 questionnaires. The sections of the questionnaire were aligned with the objectives of the study. The questionnaires captured data on demographic, socioeconomic, risk perception on climate change, factors perceived to influence adaptation mechanisms, and the effectiveness of institutions and information channels in facilitating adaptation mechanisms and risk perception towards climate variability. The questionnaire also included livestock and crop data (species, the stock of livestock owned, livestock products, animals sold, crop yield, and sales) during the period of January 2018 to December 2018.

3.5.2 Focus Group Discussions

Five FGDs were undertaken from each Sub County. These discussions involved small groups of 8-15 people who were led through open-ended discussion guided by a trained leader (skilled moderator). The moderator explained to the group the importance of the discussion and thereafter the discussions were based on an already existing checklist under the objectives of the study (Appendix 3). The key points of the discussions were noted on flip charts and notebooks.

3.5.3 Key Informants Interviews

Actors for these interviews were drawn from both the private and public agencies who have expert knowledge on climate change and agriculture. These interviews were to provide an exhaustive understanding of climate change and its impacts on the agricultural sector within the study area, the role of institutions, and information channels in enhancing climate variability adaptation mechanisms.

3.5.4 Desktop study

A desktop study was done to obtain special data for objectives 1, 3, and 5. Furthermore, objective 1 on the temperature and precipitation data was obtained from the Meteorological department website for Embu County for the 40 years (1976-2016). Besides, objective 3 on the economic impact of climate change and variability on crop and livestock production, the information on prices was obtained from Kenya Agricultural Research and Livestock Organization (KARLO) in Embu offices and institutional websites and test books. Objective five: to identify the effectiveness of institutions and information channels in facilitation knowledge of climate change adaptation mechanisms partially a desk study was undertaken. This included publications, county websites, peer-reviewed journals, and dissertations.

3.5.5 Observations sheet

Observations were made to verify and gain knowledge of the existing cropping strategies on the changing climate and the associated risk on the agricultural practices within the study area. The observations were recorded using a checklist and photographs.

3.6 Description of variables

This study has both independent and dependent variables. The independent variables of the study include climatic variables namely temperature and rainfall that affect crop and livestock production. Besides, perception level and adaptation to the changing climatic condition are also independent variables. This is because small-scale farmers depend on the perception level, and adaptive capacity to shield their production from unreliable rainfall patterns. On the other hand, small-scale farmers' decision to adopt is influenced by the magnitude of the economic impact, the risk perceived, risk behavior, socioeconomic factors (farm and farmers), and availability of institutions and information channels to give information on climate change.

3.7 Data management and analysis

The data in the questionnaires were coded and responses were stored in SPSS software (Version 16) under the assigned folder (Bryman, 2008). Data cleaning followed and later on descriptive statistics were conducted. This included frequencies, means and percentages, and standard deviations where applicable. To test the degree of relationship among independent variables Chi-square was used.

The logit model was adopted to analyze factors influencing net revenue among small-scale farmers. Heckman’s model is a two-stage process that was used to evaluate the influencing factors of climate change adaptation and perceptions as proposed by Maddison (2006). The first stage encompasses small-scale farmers' ability to perceive or not to perceive changes in temperature or rainfall amount, intensity, or duration of a season while the second stage is whether the households adapted to climatic change immediately after they experienced climate change or otherwise. According to Heckman (1976) probit model for sample, selection accepts that there an underlying relationship that exists with a latent equation as shown below;

$$y^{x}_{j} = xj\beta + u_{1j,} \quad (1)$$

Only the binary outcome is observed given by the probit model as

$$y_j^{probit} = (y^{x}_{j} > 0), \quad (2)$$

If $_j$ is observed in the selection equation, then the dependent variable is detected

$$y_j^{select} = (z_j\delta + u_{2j} > 0), \quad (3)$$

$$u_1 \sim N\ (0, 1)$$

$$u_2 \sim N\ (0, 1)$$

$$\text{corr}\ (u_1, u2) = p,$$

Where *x* represents a *k*-victor of regressors which includes explanatory variables with different factors assumed to sway adaptation mechanisms, *z* is an m vector of repressors that include explanatory variables with different factors assumed to affect perception, u_1 and u_2 are error terms. The first stage in Heckman's model is therefore represented in equation (3) which denotes the perception of the household towards climate change. Equation (1) gives the outcome model in the second stage which shows whether the small-scale farmers adapted to climate change and is restricted on stage one which represents the perception of climate change.

Household data was subjected to the Ricardian model which examines the variation of net profits across different farms owned by small-scale farmers. Bozzola *et al.* (2017) argue that this model is the most effective when estimating relationships between net revenue and agro-climatic variables while putting into consideration the adaptive capacity of the farmers. The model, therefore, takes into account both the direct effect of climate on agricultural yields and the indirect influence of farm activities or inputs to varying weather conditions (Van Passel *et al*., 2017). According to Kurukulasuriya and Ajwad, (2007) the approach relies on the net revenue of what the farmer currently receives without putting into account the future returns, discounting, capital, or labor markets.

For the Ricardian model, all the descriptive data were converted to numerical to examine the impact of climate variability on agricultural production. For instance, the gender variable has males (0) and females (1) while marital status has married (1) and unmarried (0).

The age of the respondents ranged from 18 to above 70 years while education level has five categories namely tertiary (1), secondary level (2), upper primary level (3), lower primary levels (4), and no years of formal schooling (5). The occupation was divided into off-farm (1) and on-farm activities (0) while perception level was categorized as yes (1) and no (0).
Land ownership came into three groups: Government land (1), leasehold (2), and privately owned land (3). Years of farming on the same piece of land ranged from 1 - 60years while the adaptation to changing climate conditions was either yes (1) or No (0). The average land under cultivation is 1.38 acres with cases of .05 and 5acres minimum and maximum respectively. Soil fertility was estimated under four groups namely fertile (1), infertile (2), moderate (3), very infertile (4) whereas soil erosivity had five categories: high (1), low (2), moderate (3), very low (4), very severe (5). Access to certified seeds was either a yes (0) or a no (1) then access to media was yes (1) or a no (0). The distance to the nearest market center was between 0.5 to 8kms. Besides, mean rainfall and temperatures for 40 years were used to determine their impacts on agricultural production.

Likert scale analysis was subjected to household data to generate the attitudes and opinions of climate variability and risk perceptions. Besides, a ranking scale was done of the institutions and information channels used in the study area to determine the most preferred in shaping the perception and adaptation to climate change.

Data from FGDs and Key informant interviews were abridged according to themes and relationships and conclusions drawn in line with the study objectives (Elmusharaf, 2012). This information provided an insight into the small-scale farmers' perspectives on the agriculture and climate variability situations in the county.

Rainfall and temperature data from KMD (1976-2016) were subjected to Mann Kendall trend text by use of XLSTAT version 2020 to give variations of time. Rainfall and temperature anomalies were also calculated to show long-term drifts of annual temperature and rainfall using the following two Equations (Tilahun, 2006).

Equation 1 shows Anomalies (positive)

$$RAI = +3\left[\frac{RF - M_{RF}}{M_{H10} - M_{RF}}\right]$$

Equation 2 shows Anomalies (negative)

$$RAI = -3\left[\frac{RF - M_{RF}}{M_{H10} - M_{RF}}\right]$$

Where Rainfall Anomaly Index is represented by RAI, actual rainfall per year is Rf, the mean of the total length of records is M_{RF}, M_{H10} is the mean of 10 highest values of rainfall of the period of record, M_{L10} is the lowest 10 values of rainfall of the period of record.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Introduction

The results of this study are presented in this chapter and the study was guided by five objectives; namely assessment of the extent of variation in temperature and rainfall between 1976 to 2016, analysis of the economic impact of climate variability on crop and livestock production, the examination of how climate variability risk perceptions and adaptation mechanisms influence rain-fed agricultural practices, determination of the farmer and farm characteristics that influence perception and adaptation to climate variability, and assessment of the effectiveness of institutions and information channels in facilitating climate variability adaptation mechanisms and risk perception among small-scale farmers in Embu County. The study made use of primary and secondary data. The primary data was composed of information from 411 farmers, five FGDs, and 25 climate and agricultural experts' key informants whereas secondary data was obtained from KMD and KARLO websites, publications, county websites, peer-reviewed journals, and dissertations. The results are presented in line with the objectives of the study. The first section however presents the socioeconomic characteristics of the respondents.

4.2 Respondents' Socio-Economic characteristics

4.2.1 Age distribution and Gender of the respondents

Out of the 411 respondents, 41% were males while 59% were females (Table 4.1). The majority (67.5%) of the respondents are of 50 years with 27.7% males and 39.8% females. Besides, 3.7% of males and 3.4% of females are above 70 years.

The high percentage of respondents of both males and females witnessed mirrors a study carried out that shows that farming is a source of livelihood and employment in the study area (Embu County Government integrated Development plan, 2013). However, the high percentage of female respondents in the study is an indicator that females are more likely to be self-employed in the agricultural sector compared to males (Mnimbo *et al.*, 2016). Van den Broeck and Kilic (2019), noted a trend of males across rural and urban areas in off-farm employment as compared to females.

Table 4. 1: Respondents' age distribution and gender in Embu County

Age (yrs.)	Gender					
	Male		Female		Total	
	(n)	(%)	(n)	(%)	(n)	(%)
18-30	30	7.3	31	7.54	61	14.84
31-40	45	10.95	70	17.03	115	27.98
41-50	39	9.49	63	15.33	102	24.82
51-60	28	6.81	49	11.92	77	18.74
61-70	11	2.68	16	3.9	27	6.57
>71	15	3.65	14	3.4	29	7.05
Total	**168**	**40.88**	**243**	**59.12**	**411**	**100**

4.2.2 Marital status of the respondents

The study sought to find out the marital status of the respondents. The results show that the majority (84.91%) of the respondents were married while 12.41% were single status. A few (1.46%) of the respondents were widowed while 1.22% were separated (Table 4.2).

Table 4. 2: Respondents' marital status in Embu County

Marital status	n	%
Married	349	84.91
Widower/widow	6	1.46
Separated	5	1.22
Single	51	12.41

Before the promulgation of the new Constitution of 2010, Kenyan women were not recognized as rightful owners of the land (Gaafar, 2017). This resulted in the majority of women being married to be able to access land for agricultural purposes (Ngeywo *et al.*, 2015). Besides, marriage provides farmers with family labor due to the presence of parents and their offspring and enhances the sharing of agriculture-related information and knowledge (Ozor *et al.*, 2015). Furthermore, marriage brings balance among farming households which promotes climate change adaptation mechanisms (Umunakwe *et al.*, 2014).

4.2.3 Household Type and decision making in the study area

From the results, there were three major types of households associated with the decision-making of the farming activities within Embu County. These are male-headed and a decision-maker (9.20%), female-headed and a decision-maker (16.10%), and dual (male and female) as decision-makers (74.7%) (Figure 4.1).

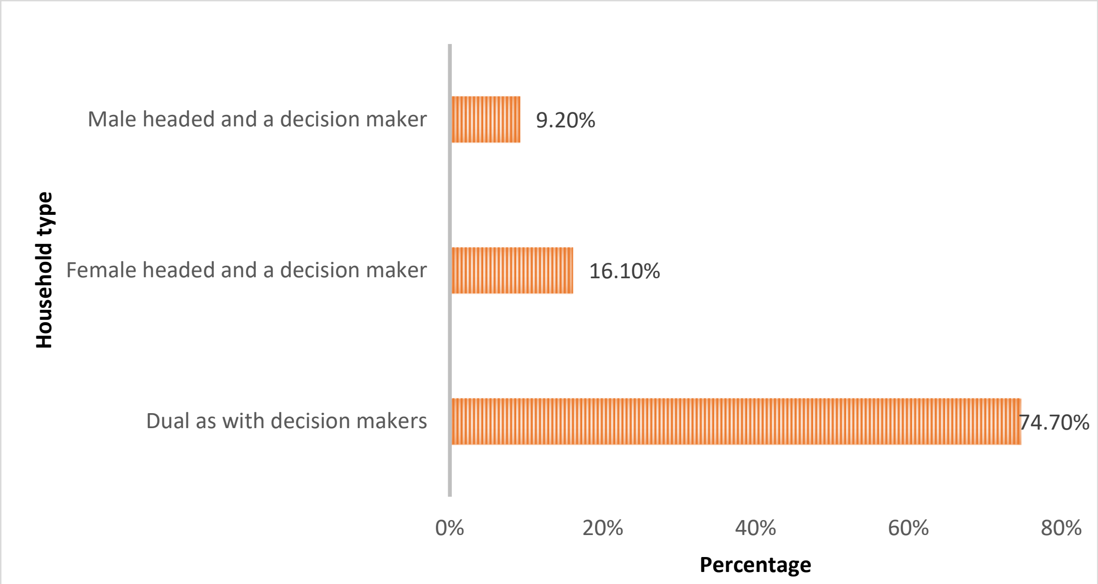

Figure 4:1: Household head type and decision-makers in Embu County

The majority (74.7%) of the household interviewed have both males and females as decision-makers on farming activities. This is a contrast to the study carried out in Kisii County by Wamalwa (2017) and in Embu County by Sibiko *et al.* (2017) that indicates 86% and 67% of households are male-headed respectively and most decisions being done by men. According to Deressa *et al.* (2008), male-headed decision-makers were more likely to plant trees and change crop planting dates to shield them from the scathing effects of rising temperatures and unreliable rainfall.

4.2.4 Household composition of the respondents

Out of 411 respondents interviewed only 4.38% (n= 18) live alone which are the elderly and single status respondents. On the other hand, 19.71% have more than 6 family members in one household with an average number of 4 members per household (Table 4.3).

Table 4. 3: Respondents' house composition in Embu County

House hold size category	Members in the household		Members of the family under 18yrs		Members of the family over 18years		Members of the family assisting in farm activities (over 18yrs)	
	n	%	n	%	n	%	n	%
≤1	18	4.38	212	51.58	26	6.33	59	14.35
2	44	10.71	112	27.25	201	48.91	236	57.42
3	86	20.92	57	13.87	101	24.57	65	15.82
4	94	22.87	25	6.08	54	13.14	30	7.3
5	88	21.41	5	1.22	19	4.62	13	3.16
> 6	81	19.71	0	0	10	2.43	8	1.95
Total	**411**	**100**	**411**	**100**	**411**	**100**	**411**	**100**

On the other hand, 51.58% of the respondents have one member of the family under 18years of age that depends on them followed closely by 27.25%, (n=112) with 2 dependents. The maximum number of dependents is 5 which represents 1.22% of the respondents. The results indicate a level of dependence for food, shelter, and clothing for the members of the household below 18 years. Furthermore, 48.9% and 24.6% of the respondents interviewed had 2 and 3 dependents above 18 years respectively. These results indicate a level of dependence by these members of the household unless they support themselves in on-farm and off-farm activities. In contrast, 57.42% of the respondents have 2 members of the family above 18 years assisting in the farm activities followed distantly by 15.82%, (n= 65) and 14.35% (n=59) with 3 and 1 dependents, respectively (Table 4.3). Household These results are supported by Shackleton and Hebinck, (2018) who indicate that many small-scale farmers use family members to provide labor in the fields. However, the amount of food intake depends on the dependency ratio of each household. The smaller the family size the lesser food consumed within the household and also the better the nutritional status of that food (Olayemi, 2012).

4.2.5 Education level of the respondents

The respondent's level of education was investigated and five categories were established: respondents with no formal education, lower primary education are those with less than 5 years in formal schooling, upper primary education are those with above 5-8 years in primary school, secondary schooling, and tertiary education. The highest percentage (32.1%) of females and 15.8% of males had attained upper primary education while 15.3% females and 15.5% males had secondary education. The study revealed that 9% females and 4.6% males had spent less than 5 years in a formal schooling curriculum and 1.46% of the respondents had not attained any formal education training. On the other hand, more males (4.14%) had attained tertiary education as compared to females (1.95%). This indicates a diversity of education levels in the study area which may influence awareness, comprehension, and understanding of climate change.

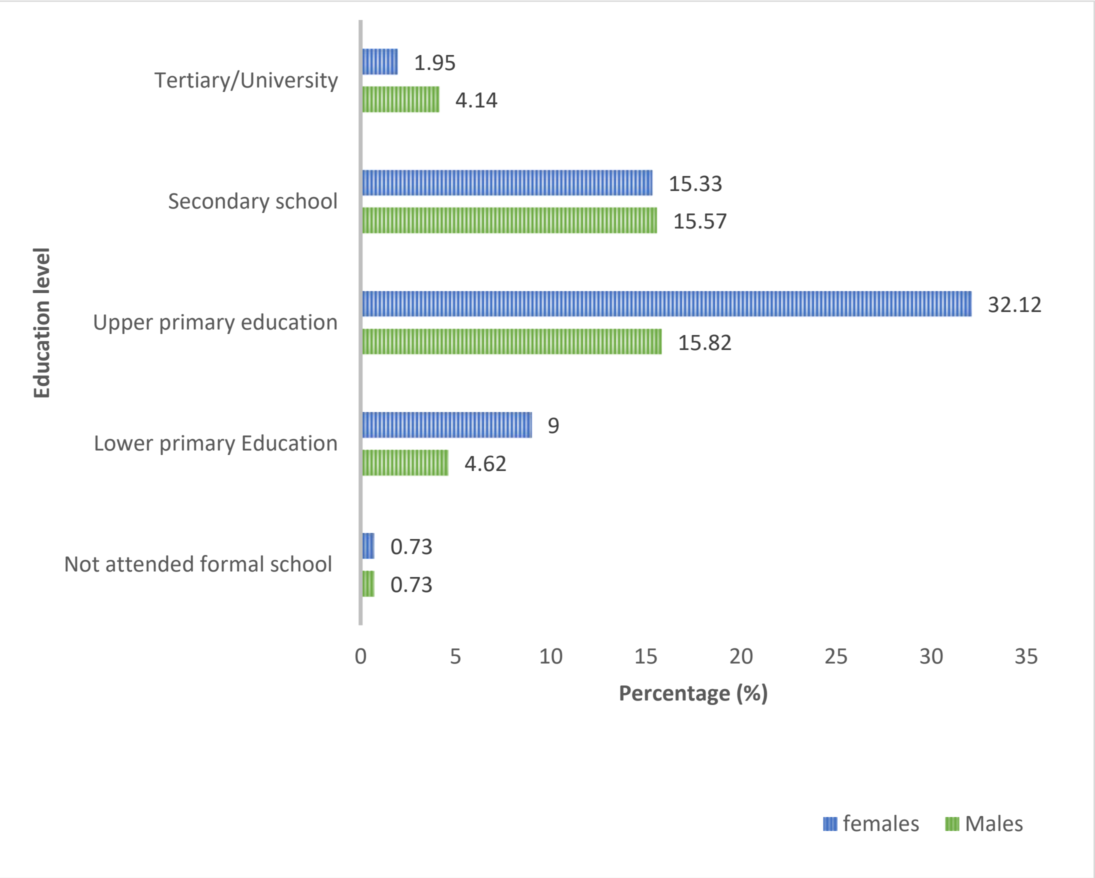

Figure 4:2: Educational level of Respondents of Embu County

Silvestri *et al.* (2012) note that household heads with higher levels of schooling are more likely to take up climate change adaptation mechanisms. Furthermore, education enhances the human capacity to adapt and improve perception towards climate change and variability (Deressa *et al.*, 2011). Opiyo *et al.* (2016), indicate that higher education level leads to better plans, access, awareness, and knowledge of early warning signs for effective adaptation to climate change.

4.2.6 Household labor specialization

Children of the respondent over 18 years were reported to assist in several farm activities where weeding (65.09%) was the common activity the members of the family assisted (Table 4.4).

Table 4. 4: Labor specialization by the family members in Embu County

Farm activities	Frequency (N=106)	Percentage (%)
Herding	45	42.45
Planting	63	59.43
Digging/tillage	18	16.98
Weeding	69	65.09
Manure application	1	0.94
Harvesting	17	16.04
Irrigation	1	0.94

Other farm activities included the planting of crops (59.43%), herding of the family livestock (42.45%), tillage (16.98%), harvesting (16.04%), irrigation (0.94%), and manure application (0.94%). The results show that households in Embu County engage family members in the provision of farm labor. According to Cooper *et al.* (2009), the agricultural sector is a major contributor to employment in rural areas. However small-scale farmers use family labor and rarely quantify it to reflect the actual wage rate per family member (Seo *et al.*, 2009). While Ozor *et al.* (2015) observed that the presence of family labor may lead to climate change and variability adaptation.

4.2.7 Land and Farm size

The majority (38.2%, n=157) of the respondents have 1 acre, 8.5% have 3 acres, 2.9% have 4 acres of land (Figure 4.3). The average farm size was 1.38 acres. About 12.01% of small-scale farmers with one acre and below reported renting neighbors' land to increase the land size under cultivation contrary to those farms with more than 2 acres.

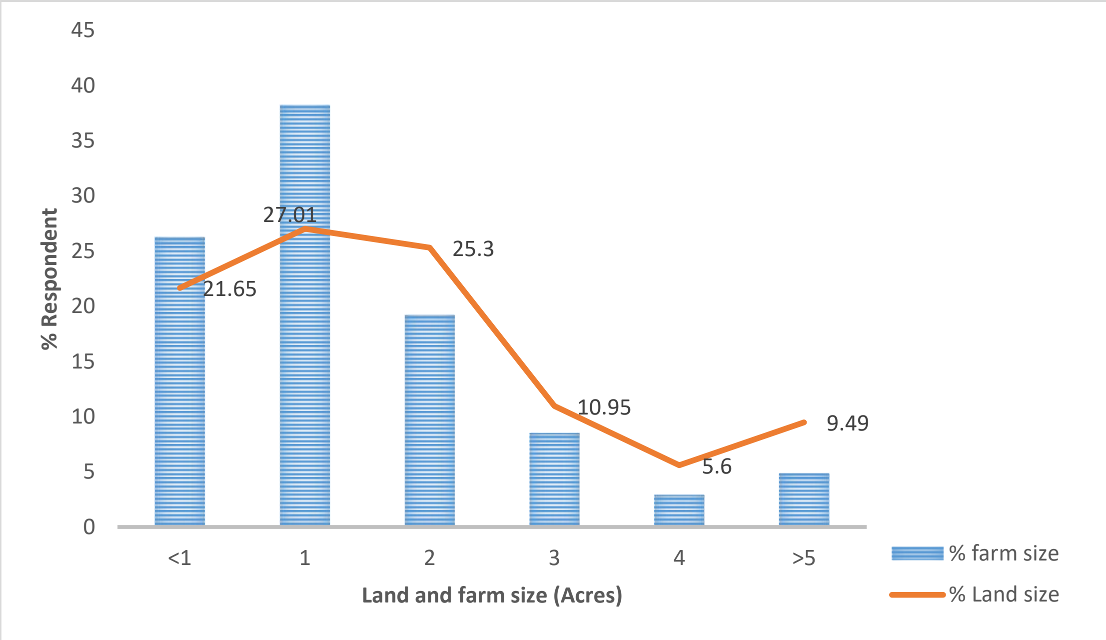

Figure 4:3: Land and farm size of respondents of Embu County

These findings concur with many studies carried out in Kenya that indicate small-scale farmers own small pieces of land between 0.2 to 2 acres (Wamalwa, 2017). The farm sizes are getting smaller in acreage year by year due to an increase in the human population which exerts pressure on the agricultural land of the county (Ngeywo *et al.*, 2015). According to Deressa *et al.* (2011), there is no significant relationship between land size and climate change adaptation mechanisms. This is because adaptation is location-specific and therefore precise characteristics of a farm dictate the basic adaptation method to climate variability. However, Kuponiyi *et al.* (2010) argue that land size influences the farmer's ability to perceive climate variability. Okonya *et al.* (2013) note that the smaller the size of land under cultivation the more the farmer’s perceptive level to climate change.

4.2.8 Respondents years in farming

The majority (30.65%) of the respondents in Embu County have been farming for over 20 years while 17.52% for between 16-20 years and 15.82% for 11-15 years (Table 4.5). This indicates that the majority of the respondents have been practicing farming for a long time. About 36.01% of the respondents have been farming for 10 years and below. This indicates that the young generation is venturing into farming activities.

Table 4. 5: Years of farming by Respondents in Embu County

Years in farming	No	%
Below 5	69	16.79
6-10	79	19.22
11-15	65	15.82
16-20	72	17.52
Over 20	126	30.65
Total	**411**	**100.00**

As observed by Kuponiyi *et al.* (2010) there is a linkage between years in farming and better perception of climate change and variability. Ndambiri *et al.* (2012) argue that farmers with more years in farming observed extensive changes in temperature and drought. However, Silvestri *et al.* (2012) indicate that years in farming for small-scale farmers do not influence adaptation mechanisms to climate variability. This could be because adaptation to climate variability is site-specific and may only be influenced by farm characteristics (Deressa *et al.*, 2011).

4.2.9 Land ownership

The results show the most dominant land ownership type was the privately owned land constituting 91% where the small-scale farmers either inherit from their fathers or purchase. There were, however, 3.41 % of respondents who leased or rented land for agricultural purposes. Besides, 5.6% of the respondents used government land for cultivation. According to Fosu-Mensah *et al.* (2012), farmers with privately owned land are more likely to promote climate change adaptation compared to those with leased land. This is because land security encourages long-term investments such as water and soil conservation measures to shield crops from harsh climatic conditions. These views are also echoed by Roco *et al,* (2014) who state that land tenure security promotes investment decisions that increase the probability to implement climate change coping strategies.

4.2.10 Main Sources of Income

The main source of income is from farm activities with 90.51% and only 9.49% relying on off-farm activities in Embu County. The farm activities range from crop to diversification to livestock breeds whereas off-farm income came from salaried civil servants, carpentry, and shopkeeping. From the results, it is clear that most small-scale farmers of Embu County depend directly on agricultural activities for their livelihood. As observed by Ozor *et al.* (2015) mixed farming and off-farm occupation are already forms of adaptation to climate change. This is because small-scale farmers can spread risks across many activities to help them to manage the changing climatic situations. Opiyo *et al*. (2016) note that the availability of farm income helps the farmers to adapt to climate change. The income of a small-scale farmer is a representation of material wellbeing and it can absorb innovation towards climate variability (Deressa *et al*., 2009).

4.2.11 Respondents' access to credit facilities

The respondents reported minimal access to credits on their farms for improvement. Only 15.82% (n=65) respondents can access credit facility while the majority (84.18%, n=346) have never accessed credit to improve their farms. Out of the 15.82% (n=65), 6.08% (n=25) are males who are landowners and custodians of land ownership documents. High-interest rates attached to the total principal borrowed also discourage small-scale farmers from applying for a credit facility (Wamalwa 2017). According to Quagrainie *et al.* (2010), there is a need for commercial and government lending organizations to invest in farming activities to boost productivity. According to Deressa *et al*. (2009) and Fosu-Mensah *et al*. (2012), there is a positive correlation between credit availability and acceptance of climate change adaptation strategies by small-scale farmers.

4.3 Variation in temperature and rainfall (1976 to 2016)

4.3.1 Variation in temperature from 1976 to 2016

The data for temperature witnessed in the study area between 1976 and 2016 was obtained as secondary data from KMD. The graph obtained from the trend analysis is presented in Figure 4.4. The maximum mean temperature around the county was 24.6ºC with a standard deviation (σ) of 0.73 and 0.58 variance (σ2) with linear regression analysis of Y = 0.0235x + 24.119 was obtained. With 0.341 Kendall's tau and P-value of 0.002. The positive slope in the regression analysis indicates that the annual maximum temperatures over the 40 years were slightly increasing with about 0.02ºC. Besides, descriptive analysis shows a minimum mean temperature of 14.2ºC with a 0.42 standard deviation, 0.18 variance (σ2), and linear regression analysis of Y = 0.0125x +13.936. With Kendall's tau of 0.365 and P-value of 0.001. The positive slope indicates a slight increase of 0.01ºC in annual minimum temperatures over the 40 years. These findings show there is a rise in both minimum and maximum temperatures per year. The results assert the research hypothesis that there is significant variation in temperature for the period of 1976 to 2016.

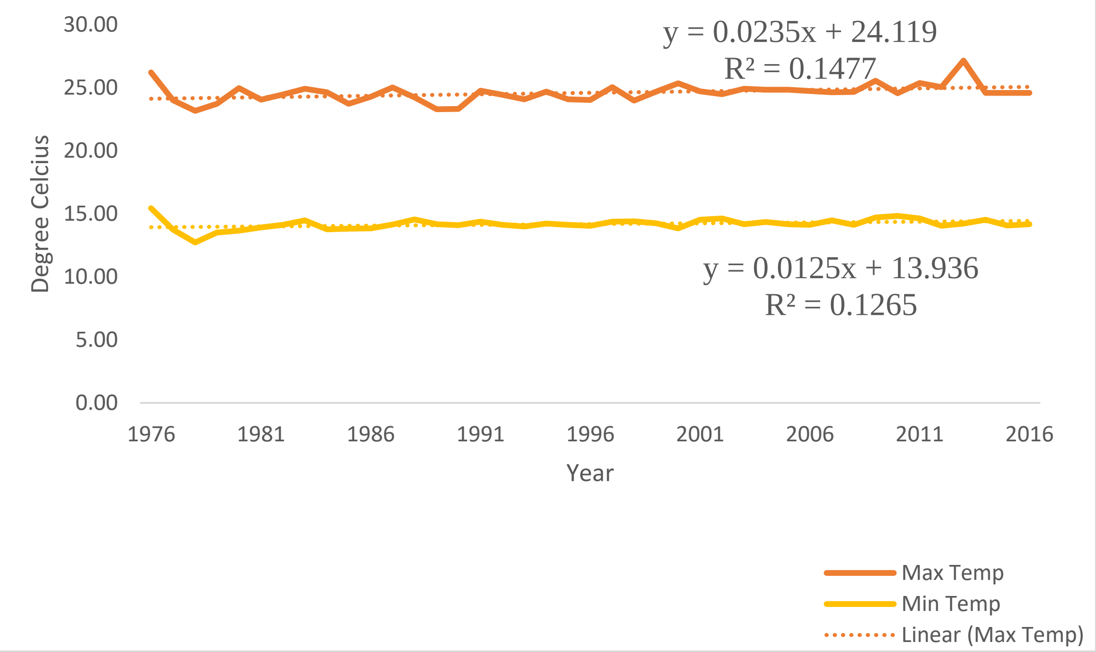

Figure 4:4: Trend Analysis of minimum and maximum temperatures for 40 years

In Kenya, it is estimated that the temperatures will increase gradually to nearly 3℃ by 2050 (IPCC, 2007). (Nzau, 2013) noted 1℃ increases in temperature in Western Kenya for the past 50 years. There is a slight variation in the temperature increase for the western region and eastern region of the country due to their geographical locations.

Annual mean minimum temperature anomalies throughout the 40 years for the county were computed and presented in Figure 4.5. This shows a tremendous deviation from the mean temperature. For instance, 1986 recorded a negative deviation which means that the minimum temperature that year was very low. From 2001 to 2011 there was a positive deviation which indicates that temperatures were higher than the annual mean. This was followed by a negative deviation in 2012 and a positive one in 2013. This kind of anomaly is also recorded in the Rift Valley region and is associated with the El Nin˜o–Southern Oscillation (ENSO) phenomenon which is a principal cause of global interannual climate variability (Linthicum *et al.*, 1999).

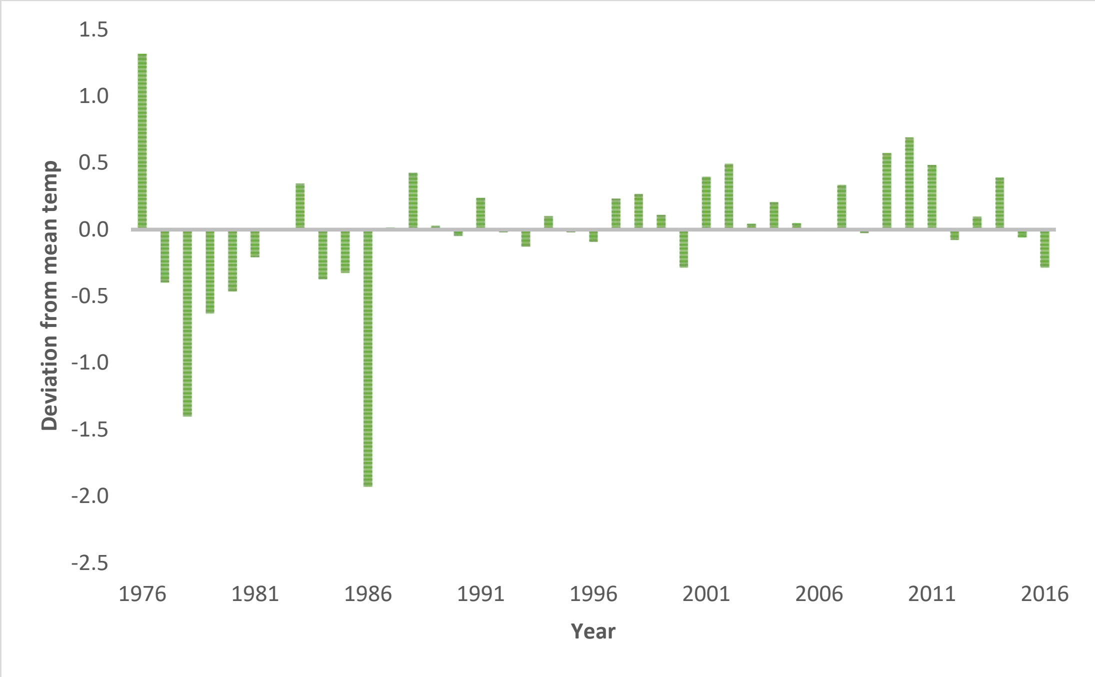

Figure 4:5: Annual mean minimum temperatures anomalies for Embu County from 1976 to 2016

The observed maximum temperatures in Figure 4.6 reflected anomalies between 2003 and 2016 however the largest anomaly is seen in 2013 with a positive 2.6. This indicates a rise in temperature beyond the recorded annual mean for the 40 years.

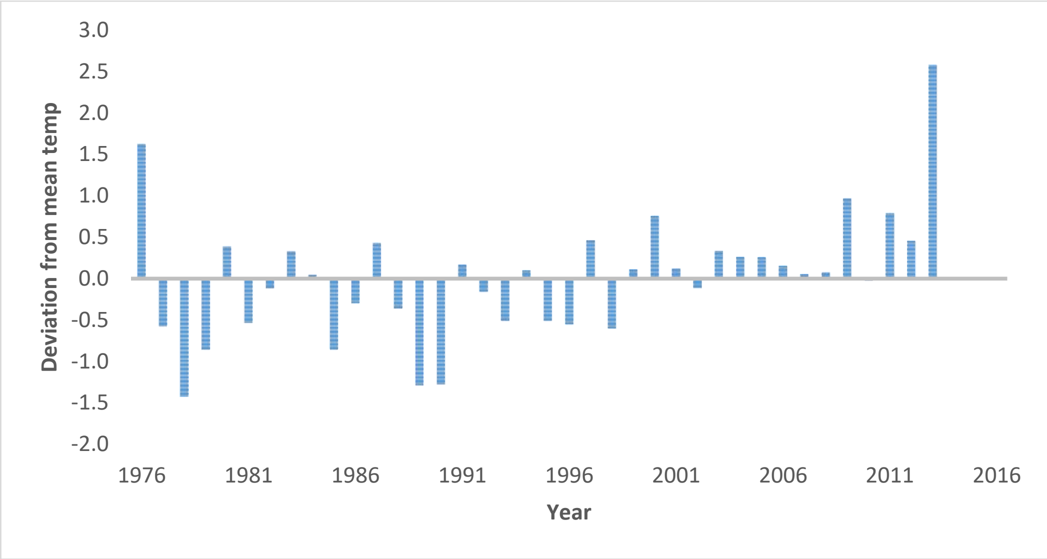

Figure 4:6: Annual mean maximum temperatures anomalies for Embu County from 1976 to 2016.

The other extreme anomalies were recorded in 2008, 2011, and 2012 with deviations from the mean temperature of 0.8, 0.6, and 0.4, respectively. A study carried out in semi-arid areas of Kenya shows year-to-year variations in annual mean maximum temperature (Gichangi et al., 2015).

According to Folland *et al.* (2002) increase in temperature elevates the intensity and frequency of drought. In sub-Saharan Africa, people's ability to rear livestock and grow food has been hindered by extreme droughts (Connolly-Boutin and Smit, 2016). Raise in temperatures change disease vectors (Chen *et al.*, 2006). Also increased temperature causes deterioration of food quality especially perishable foods such as fruits and vegetables (Connolly-Boutin and Smit, 2016).

4.3.2 Variations in rainfall for the period between 1976 to 2016

The descriptive analysis shows Embu County with a mean rainfall amount of 355.3cm (3553mm) with a standard deviation of 81.57 and a variance of 6653.96. The linear regression analysis (Y = -1.0171x +376.65) indicates that there is a slight decline in the amount of rainfall over the last 40 years (Figure 4.7). This means the annual total amount of rainfall has decreased by about 1.02cm (10.2mm) per year which results in rainfall variability in the county.

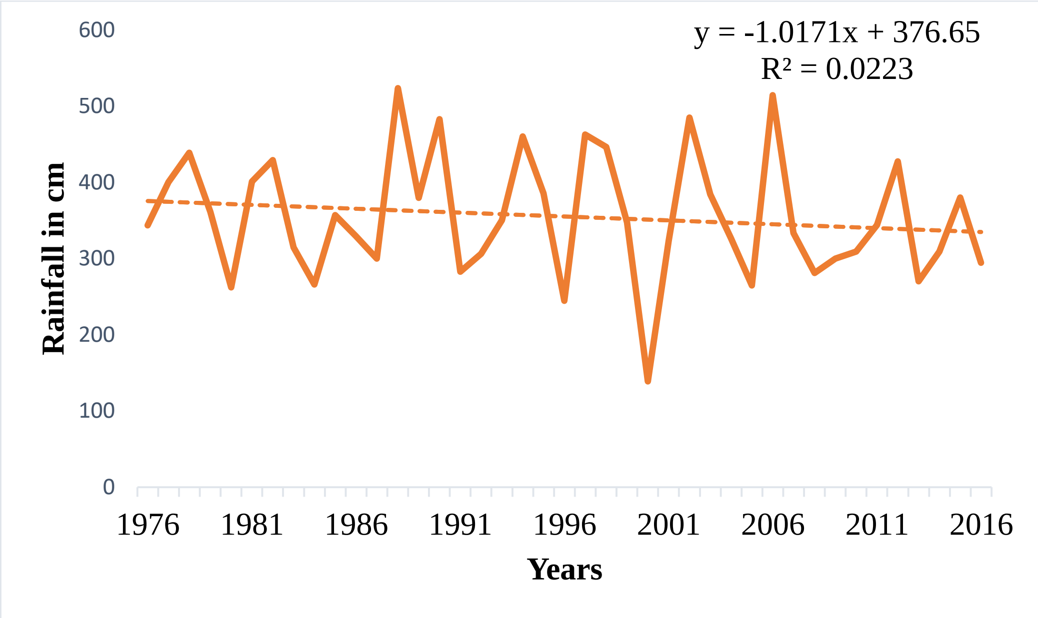

Figure 4:7: A linear relationship rainfall amounts over 40 years

As observed by Hulme *et al.* (2005) inter-annual rainfall variations are a common phenomenon in Africa and according to Kisaka *et al.* (2015), rainfall variability is manifested in delayed onset, short length, and cessation of rainfall. Olayide and Alabi, (2018) linked rainfall variations with food insecurity, especially where the small-scale farmers depend on rain-fed agricultural systems. As observed by Trnka *et al*. (2010), increased water deficit on agricultural fields affects planting time and limits vegetation physiological ability hence reducing yields. Besides, climate variability modifies the pervasiveness of pests and diseases resulting in reduced food supply (Asif *et al.*, 2010; Adégnandjou and Dominique, 2018).

After analysis of rainfall anomalies for 40 years, it was observed that 2000/2001 had the highest rainfall deficit followed by other short durations of rainfall anomalies such as 2005/2006, 2009/2010, 2012/2013, and 2016 (Figure 4.8). Mann Kendall's test indicated a Sen's slope of -0.2 and was statistically significant at 0.0028. These results assert the research hypothesis that there is significant variation in rainfall for the period of 1976 to 2016 in the study area. The FGDs confirmed droughts that affected both crop and livestock production within the above-mentioned years. In contrast, the county has experienced higher rainfall events in 1988/1989, 2002/2003, and 2007/2008. These events were noted by the respondents in terms of the presence of floods, mudslides, and seasonal rivers.

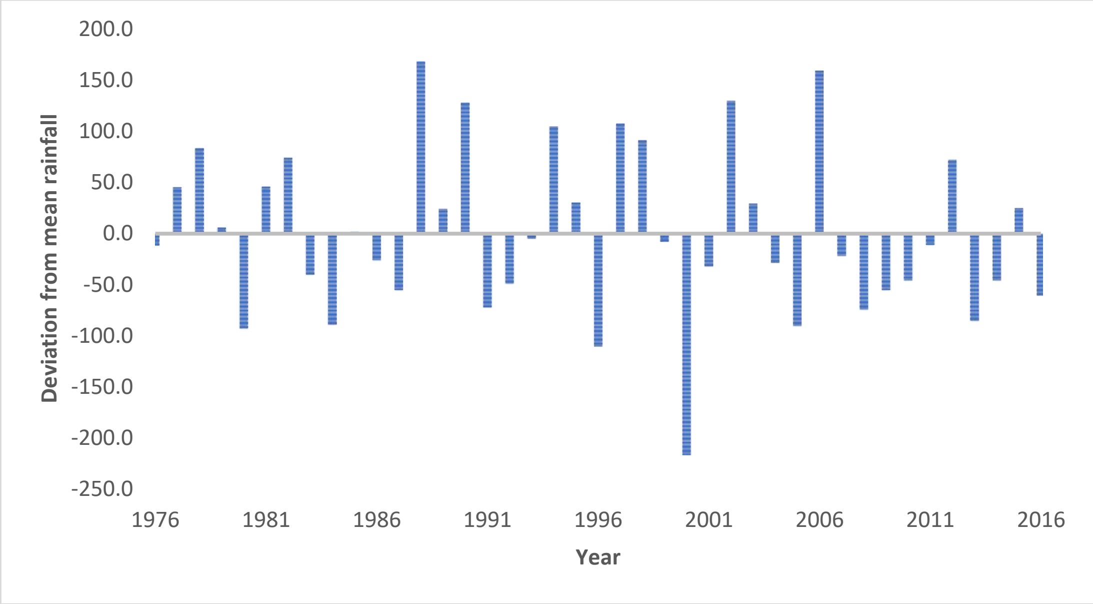

Figure 4:8: Annual rainfall anomalies for Embu County from 1976 to 2016

According to Kisaka *et al.*, (2015) rainfall patterns have become unreliable with a short rainy season moving from mid-October to late October and early November. This shift becomes worrisome to the small-scale farmers who find it problematic to time their farming activities for instance planting crops.

Small-scale farmers can relate to this dryness because of precipitation anomalies which directly influence the soil moisture conditions on the farm. According to Kisaka *et al.*, (2015) rainfall patterns have become unreliable with a short rainy season moving from mid-October to late October and early November. This shift becomes worrisome to the small-scale farmers who find it problematic to time their farming activities for instance planting crops.

4.4 Economic impact of climate variability on agricultural production

Descriptive variables were converted into numerical to examine the impact of climate variability on agricultural production. These variables were used in the Ricardian analysis to generate net revenue for the crop, livestock, and mixed farming. In terms of livestock production, the mean revenue had Ksh –25,563.08 with a standard deviation of 22746.42, minimum revenue of Ksh -117,820.00, and a maximum of Ksh. 52,240.00. The negative signs in both mean and minimum revenue show that many of the small-scale farmers in Embu County have higher expenditure than income. The farmers are more likely to pump all the cash from other sources to livestock production but are not able to generate a profit. This could be because livestock production is a long-term investment and profit generation may take time before it's realized. Below is a typical livestock production scenario presented verbatim from a small-scale farmer in one of the FGDs conducted.

> *"………….I invested in 2 cows aged 5 and 9 months at the end of 2017 and for the last 12 months, I have been feeding with green forage from my farm and purchasing from neighbors. I also supplement with commercial animal foods from agro Vets and hay from a company about 4kms from my homestead"*

This scenario is a pointer of how small-scale farmers are spending on a farm practice that may not give them immediate output and if not well managed and monitored leads to food insecurity in the region.

On crop production, maize and beans were the only crops used in this economic analysis because they play an important role as food staples within the county and contribute greatly to the Kenyan Gross Domestic Product (GDP) (Katungi *et al.*, 2011; Kisaka *et al*., 2015). There was a mean net revenue of Ksh 37,057.39 with a standard deviation of 22697.80, minimum revenue of Ksh 955.00, and a maximum of Ksh 93,120.00. This indicates that on average small-scale farmers are benefiting from crop production. The majority of the small-scale farmers in the County rarely use hired labor and therefore opportunity cost for family labor was considered in the economic analysis. The family labor was reported to assist in five major crop production activities namely land preparation, planting, weeding, fertilizer/manure application, and harvesting. According to Posadas-Domínguez *et al.* (2014) family labor directly influence farm productivity which translates to more farm income.

On the Mixed farming (livestock and crops) net revenue on average was negative Ksh 13,300.70 with a standard deviation of 22876.60, minimum of Ksh-99,160.00, and a maximum of Ksh. 70,406.00. The negative signs in both mean and minimum net revenue are a result of the negative sign in livestock production. This indicates that when the two farming practices are combined then the small-scale farmers are making losses. According to Van Passel *et al.* (2017) Economic impact analysis is assumed to be influenced by various independent variables that range from climatic conditions, adaptive capacity, geographical location, farm, and farmer characteristics. However, there are many other variables affecting farm revenue at the national level that could indirectly affect the net revenue of the small-scale farmer. For instance agricultural policies, taxes, technology, and trade (Seo *et al.*, 2009).

4.4.1 Factors that affect livestock net revenue of the small-scale farmers

Small-scale farmers reported rearing cows, goats, sheep, chickens, ducks, donkeys, and pigs. However, the study focused on cows, chickens, sheep, and goats to examine the impact of climate variability was used. Table 4.6 shows the Ricardian analysis.

The results show that four variables are likely to influence livestock production within a confidence level of 5%. These variables include adaptation to climate variability, gender, access to media, and size of land under cultivation. Adaptation is likely to positively influence livestock net revenue because respondents reported having invested in mechanisms such as the purchase of fodder, storage of excess fodder for future use, purchase of animal supplements, use of drought resistance forage, and rearing of animal breeds that cope with climatic conditions. This implies that the livestock production sector is shielded from direct climatic fluctuations in terms of temperature and rainfall variations.

Table 4. 6: Independent variables and Livestock Net Revenue in Embu County

Variables	Unstandardized Coefficients		
	B	Std. Error	t-test
(Constant)	-27197.5	2298.55	-11.83
Precipitation (mm)	-2.29	4.90	-.46
Mean max Temp ºC	-31592.32	65292.85	-.48
Gender	8083.34*	2173.91	3.71
Age	10271.41	5297.67	1.93
Education	-83757.52	70618.31	-1.18
Marital status	-60134.53	85279.21	-.705
Occupation	-629857.78	341151.81	-1.84
Land ownership	-215404.76	180431.37	-1.19
Year of farming	-6511.86	6444.625	-1.01
Adaptation	17271.96*	4338.49	3.98
Land under cultivation	-2942.13*	1148.53	-2.56
Soil fertility	28930.13	93947.66	.308
Soil erosivity	-3715.20	80529.32	-.046
Hired labor	428243.55	333362.94	1.28
Microcredit	-436977.10	831092.37	-.526
Chama	54407.79	310561.21	.175
Extension services	307165.31	728621.88	.422
Distance to market	62811.62	215207.68	.292
Access to media	-22902*	8886.24	-2.57

F (4,406)	13.02
Prob>F	0.000
Root SQ	221519.60
VIF	2.123
N	411

Also, the gender of the respondent was more likely to influence positively the economic benefits of livestock production because males were more into livestock production compared to the females in the study area. Livestock production is a tedious activity that requires farmers to ferry fodder and water for cattle, goats, and sheep within the hilly region that characterizes the study area.

Besides, access to media was more likely to improve the farmers' net revenue on livestock rearing. The respondents reported accessing climate-related information from various local media outlets. Different media channels provide relevant climate-related information that may have assisted the livestock farmers to decide on how to improve the management of the sector.

The small-scale farmers of Embu County have an average land size of 1.38 acres which is allocated for many uses. The farmer's ability to set aside a sizeable piece of land for livestock production positively influences the final net revenue. The reasons could be due to the availability of land to plant forage and also enough space to increase the number of animals. It was noted that the small-scale farmers use crop vegetative parts after harvesting as animal fodder and therefore more cultivation space directly translates to more fodder

These findings are in agreement with a study carried out in the Coastal region of Kenya that indicated a non-linear relationship between climate variability and net revenue on livestock production (Wachira, 2017). On the other hand variations in farm sizes significantly influences agricultural productivity (Kabubo-Mariara and Karanja, 2007). In terms of gender in the livestock production sector, Kurukulasuriya and Ajwad (2007) argue that households headed by males are more profitable due to the availability of manual labor which is associated with the male gender.

4.4.2 Factors that affect crop production net revenue of the small-scale farmers

Table 4.7 shows all the variables that may affect crop production net revenue however only five were found to be statistically significant at $p \leq 0.05$. Annual temperature fluctuations were found to be likely influencers of net revenue for crop production. This implies that an increase of 1ºC of temperature per year would lead to a reduction of crop net revenue. This is because crop production depends on cycle patterns of both temperatures and rainfall for growth and development. A rise in temperatures leads to increased evapotranspiration which leads to the poor performance of crops and hence reduced yields or total crop failure.

Table 4. 7: Independent variables and crop Net Revenue in Embu County

Variables	**Unstandardized Coefficients**		
	B	Std. Error	**t-test**
(Constant)	26470.74	5797.06	4.56
Precipitation (mm)	.01	.09	-.56
Mean Max temp^o C	-365.23*	205.10	1.78
Distance to market	-72.00*	786.48	-0.09
Extension services	-286.34	3633.57	-.07
Chama	-1466.54	1565.07	-.93
Microcredit	1441.14	3993.60	.36
Soil erosivity	-571.75*	1358.30	-0.42
Soil fertility	-207.89	392.37	-.53
Land under cultivation	9071.07	3464.25	2.61
Adaptation	-28691.64*	4068.86	-7.05
Years of farming	-119.12*	120.24	-0.99
Land ownership	-199.74	567.65	-.35
Occupation	-6287.22*	3361.90	-1.87
Marital status	-308.75	355.39	-.86
Education	173.94	283.06	.61
Age	185.75	109.49	1.69
Gender	552.39	361.06	1.53
Land under cultivation	6346.34*	1055.53	6.01
F (8,403) 22.06		VIF -------------4.12	
Prob>F 0.000			
Root MSE 19465.33			
R Square .277			
N 411			

Distance to the nearest market to sell crop produce was negatively influencing the crop net income of the small-scale farmers of Embu County. This implies that the longer the distance to the nearest market place the lesser the net income attached to crop yields. This is because long distance increases the costs of travel to purchase farm inputs such as fertilizers, crop seeds, and pesticides. An increase in transportation costs would directly affect the crop's net revenue.

Land characteristics may influence the final crop yields and hence crop net revenue. For instance, soil erosivity was statistically significant in the study area. Soil erosivity is a measure of the impending ability of the soil or land to erode by agents of erosion which is determined by the rainfall-runoff factor and the slope of the land among other factors. This implies that small-scale farmers' ability to manage and control soil erosion translates to better soils in terms of soil nutrients, water holding capacity, and soil aeration. These soil characteristics render a better chance for crop growth and development that may increase crop production.

Adaptation is statistically significant which means inadequate or lack of shielding crops from extreme climatic conditions leads to loss of income. This then implies that the use of different adaptation mechanisms leads to better crop yields that translate to increased incomes. This is because adaptation strategies like the use of drought-tolerant crops, early maturing varieties, and water, and soil conservation measures may protect the crops from fluctuating rainfall and temperatures.

As observed by Gbetibouo (2004) rise in temperatures influences plants' marginal water balance which affects plant growth and development. Therefore small-scale farmers have to adapt to the changing climatic conditions for better crop yields (Shakoor *et al.,* 2011). Furthermore, Benhin (2008) reports that soil characteristics such as soil type may also influence crop net revenue depending on their erosivity levels. In terms of distance to the nearest market center Buckmaster, (2012) argues that smallholder farmers have to struggle with poor roads and high transportation costs when making production decisions while Kurukulasuriya and Ajwad (2007) reported an increase in crop net revenue returns when farmers increase land under cultivation. However, Seo *et al.* (2009) indicate that in the future climate variability may not directly affect crop net revenue as a result of the presence of capital, better technology, and change in consumption patterns of many countries.

4.4.3 Factors that affect Mixed farming net revenue of the small-scale farmers

Mixed farming net revenue involved a combination of net revenue for crop and livestock production. Table 4.8 shows all the variables that were considered during the analysis however only 6 of them were statistically significant with a confidence level of 5%. These variables were temperature, education, soil fertility, microcredit, extension services, and distance to the nearest market center.

Table 4. 8 Independent variables and Mixed farming Net Revenue in Embu County

Variables	Unstandardized Coefficients		
	B	Std. Error	T-test
(Constant)	-445721.18	159432.14	-2.79
Precipitation	.66	.42	1.57
Temperature	10813.15*	5316.92	2.03
Gender	8694.56	6755.02	1.28
Age	196.57	332.19	.59
Education	-11661.86*	5481.18	-2.12
Marital status	4731.10	6718.25	.70
Occupation	-11205.18	8884.79	-1.26
Land ownership	5507.68	10786.11	.51
Years of farming	720.67	490.19	1.47
Adaptation	-22717.18	18187.35	-1.24
Land under cultivation	-92658.47	65480.51	-1.41
Soil fertility	23495.89*	7497.57	3.13
Soil erosivity	761.53	6854.98	.11
Micro credit	-139448.98*	76514.19	-1.82
Chama	54678.40	30076.21	1.81
Extension services	165619.96*	69323.58	2.38
Distance to market	48842.35*	20868.07	2.34
F (8,403) 4.22			
Prob>F 0.000			
Root MSE 22272.21			
R Square .068			
N 411	VIF ……………..3.21		

The temperature has a positive effect when crops and livestock production are combined. This implies that a small-scale farmer of Embu County is more likely to increase net revenue with a rise in the temperatures for when crop production and livestock rearing are on one piece of land. This could be because diversification of farm activities ensures the spread of risks across available enterprises.

The education level of the head of the household was significant and this means that farmers with an education level below upper primary (less than 5years schooling) are more likely to negatively influence the combined net revenue compared to those farmers with secondary education and above. This implies that for small-scale farmers to actively be involved in mixed farming a certain minimum level of education is paramount. If the household head has a higher education level there is a likelihood of easier adaptation to changing climatic conditions which creates an opportunity to increase net revenue. Soil fertility is more likely to influence mixed farming positively for the small-scale farmers in Embu County. This implies that the farmers who can manage and conserve soil fertility are in a better position to improve their farm income compared to those with poor soil quality. On the other hand farms with good soil fertility promotes animal forage and soil organisms that are chicken food.

On the other hand, access to microcredit by small-scale farmers is more likely to boost their mixed farming enterprises as compared to those with no access. This is because access to microcredit strengthens the farmer’s purchase power in terms of fertilizer, seeds, certified seeds, vaccination services, and feed management. Also, the farmer can install soil and water conservation methods to improve the fertility of the topsoil and humidity which are prerequisites to crop production.

Extension services to the mixed farming enterprise may influence positively the number of yields generated by a small-scale farmer of Embu County. This implies that those farmers who receive extension services from agricultural-related institutions are more likely to boost their overall agricultural yields. As reported by the respondents' extension services providers offer technical advice, provide knowledge and skills, supply farm inputs, and pass new ideas from research stations to the farmers.

Distance to the nearest market centers also may influence the net revenue of the mixed farming enterprise. This implies that the small-scale farmers' cost of transport to and from the market may increase depending on the distance covered which directly affects the net revenue. According to Buckmaster (2012), smallholder farmers have increased the cost of production as a result of poor roads and long distances to the marketplace to either purchase farm inputs or sell farm produce.

According to Ochieng *et al.* (2016) temperature has both negative and positive effects depending on the type of crops and geographical location of the farms. Small-scale farmers can increase net revenue by diversifying farm activities that reduce the downside risk associated with climate variability (Ochieng *et al.,* 2016). For instance, farmers with mixed farming can use manure on their farms for better soil fertility whereas crop residue is used as animal feeds for the livestock (Seo *et al.,* 2009). Besides farmers with mixed farming have learned the art of swapping back and forth between crops and livestock making them more resilient to changing climatic. hence increasing net revenue (Deressa *et al.,*2008). Huong *et al.* (2019) point out that the education level of the head of a household determines the level of adaptation to climate variability.

Besides, small-scale farmers can cope with the changing climatic conditions if they shift to drought resistance livestock and crop species, irrigation, and change farm types (Seo *et al.,* 2009). All these adaptation mechanisms will require the availability of funds in form of microcredit. In terms of soil nutrient loss and degradation Barrett and Bevis (2015) associate it with low crop productivity that affects both crop yields and livestock quality. Access to extension services can positively strengthen farmers knowledge and skills concerning new varieties, pest control monitoring, farming techniques, weather, and market information (Huong *et al.*, 2019)

4.4.4 Marginal effects of climate variability on agricultural net revenue

Table 4.9 shows the marginal effects of the climate variables on different agricultural practices with a confidence level of 5% from Chi-Square analysis.

Table 4. 9: Climate variability marginal effects on agricultural net revenue in Embu County

Climate variables	Crop	Livestock	Integrated
Rainfall	0.00	0.37	0.40
Temperature	-1002.81*	3690.60	4444.55*

According to the results, the temperature is the only climate variable that has statistical significance to both crop and integrated net revenue with a coefficient of -1002.81 and 4444.55 respectively. In terms of crop production, a 1ºC increase in annual temperature may result in a decrease of about Ksh 1002.81 net revenue. The results show that a 1ºC increase in temperature results in an increase of about Ksh 4,444.55 net revenue of mixed (Table 4.9). This implies that an upsurge in temperature could have both negative and positive effects on different farming activities. From the results, there is a significant relationship between climate variability and the economic impact of crop and livestock among the small-scale farmers of Embu County and therefore the research hypothesis was accepted. These findings are supported by Ochieng *et al.* (2016) who reported that climate variability can have both negative and positive effects on agricultural net revenue depending on the type of farm activity and geographical location. Furthermore, the Kenyan Coastal region has been reported to have declined crop net revenue as a result of increased temperature (Wachira, 2017). Whereas Kabubo-Mariara and Karanja (2007) reported that high summer temperatures are detrimental to crop farming as compared to winter temperatures. Gbetibouo (2004) reported that an increase in temperature by 2ºC decreases the final agricultural output by 25%. However, Lobell *et al*. (2011) conclude that agriculture net revenue is not only a function of climate variability but of the geographical location of farms, soil types, and anthropogenic factors.

4.5 Risk perception of climate variability and adaptation mechanisms

From the Likert Scale analysis majority of the respondents (67.64% and 28.22%) at least agreed that climate change and variability are real and negatively impact farm activities and productivity (Figure 4.9).

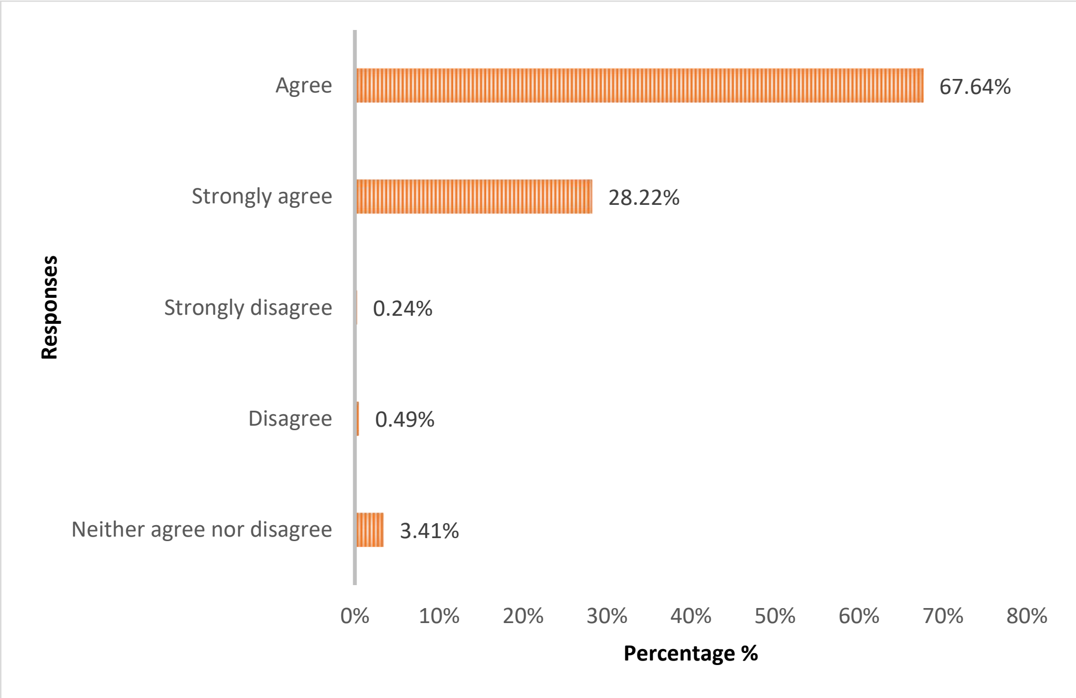

Figure 4:9: Respondents' opinions on climate change and variability in Embu County

About 82.73% and 3.89% perceived an increase and decrease in temperature respectively whereas a total of 13.38% of the respondents were not aware of any temperature change (Table 4.10). On the other hand, 82.73% were aware of the change in the amount of rainfall per season while 17.27% were for the contrary opinion. Furthermore, the majority of the interviewed respondents (95.62%, 0.73%) indicated the frequency of floods had decreased or no flood. A total of 30.9% of respondents indicated observing rains fall within a very short time while 29.2% reported heavy rains within a short time. On the frequency of floods 95.62%, 3.65%, and 0.73% reported no floods, increased occurrence, and decreased flood respectively. The high percentage of not witnessing floods could be as a result of reduced amounts of rainfall and rainfall intensity that was not enough to evenly saturate the soils to an extent of flooding. This perception agrees with the trend analysis of rainfall anomalies that showed extremely low rainfall during the 2000/2001rainy seasons.

Table 4. 10: Respondents' perception of climate variability attributes

Perception and knowledge of climate change Attributes		Frequency (n)	Percentage (%)
Temperature	Increase	340	82.73
	Decrease	16	3.89
	No change	55	13.38
Rainfall amount	Increase	70	17.04
	Decrease	270	65.69
	No change	71	17.27
Rainfall Intensity	Short rains and for a very short time	127	30.9
	High rain and for a short time	120	29.2
	Short rains and for a long time	139	33.82
	No change	25	6.08
Floods Frequency	Increase	15	3.65
	Decrease	3	0.73
	No flood	393	95.62
Drought occurrence	Increase	74	18
	Decrease	18	4.38
	No change	318	77.37

About 77.37% of the respondents reported no change in drought occurrences. This could be because 51.83% had less than 15years of farming experience and may not have noticed the drought phenomena and how they affect agricultural productivity. However, the results of trend analysis on temperature indicated that maximum temperatures had more anomalies between 2003 and 2016 however the largest anomaly was seen in 2013, 2008, 2011, and 2012.

A Key Informant in the Agricultural Department in Embu County was aware of the abnormal distribution and timing of the rainfalls per season. The Key informant perceived rainfall outside the normal rainy seasons to be more frequent and increased rainfall in some months and decreased in other months. These findings were also in line with those reported by the five Focus Group Discussions (FGDs) in the study area. Besides, key informants in the Water Department Office attributed a low groundwater table to prolonged dry seasons. This was in agreement with the trend analysis of rainfall anomalies where short durations of rainfall were recorded such as 2005/2006, 2009/2010, 2012/2013, and 2016 that could directly affect the quantity of the water bodies.

On risk perception of agricultural productivity, 45.01% and 85.4% of the respondents agree and strongly agree that climate variability led to crop failure and yield decline respectively (Table 4.11). When the respondents were asked about the disappearance of some crop variety 73.48% neither agreed nor disagreed while 9.26% agreed and strongly agreed, and 17.28% disagreed and strongly disagreed. The findings also revealed that 57.42% of the small-scale farmers agreed that climate variability is responsible for many pests and diseases associated with crop production within the study area.

Table 4. 11: Climate variability risk perception of agricultural productivity in Embu County

Particulars	Agree and Strongly agree (%)	Neither agree nor disagree (%)	Disagree and Strongly disagree (%)
Crop failure	45.01	0	54.99
Crop yields have declined	85.4	0.49	14.12
The disappearance of crop variety	9.26	73.48	17.28
An outbreak of crop pests and diseases	57.42	1.22	41.36
An outbreak of livestock pests and diseases	8.27	48.66	43.06
Insufficient quality pasture	14.6	40.04	14.00
Poor quality pasture	7.3	3.76	20.31
Low milk and meat production	14.35	82.73	2.92
Death of livestock	5.36	73.0	21.9

On livestock production, above 40% of the respondents neither agree/ strongly agreed nor disagree/strongly disagreed on the outbreak of animal pests and diseases, poor quality, and insufficient pasture and death of livestock. This could be because many of the interviewed small-scale farmers indicated livestock production as a secondary enterprise was not very keen on the issues affecting the sector.

Six major climate variability adaptation mechanisms were perceived to be of importance by the small-scale farmers (Table 4.12). The six are drought-resistant crops, irrigation, change of planting date, agroforestry, extension services, and non-farm activities. About 82.73%, 62.05%, and 97.56% of the respondent believe that the use of drought-resistant crops, irrigation schemes, and the presence of extension services could assist them to deal with the changing climatic conditions respectively. On the other hand, 37.96% and 14.6% believed that Agroforestry practices and changing of planting dates would protect them from the scathing effects of oscillating temperatures and boost their awareness of the available adaptation mechanisms. About 42.84% assume that with income diversification they can reduce dependency on climate-related livelihood.

Table 4. 12: Climate variability adaptation mechanisms as perceived by small-scale farmers in Embu County

Particulars	Agree and Strongly agree (%)	Neither agree nor disagree (%)	Disagree and strongly agree
Drought resistant crops	82.73	0.49	16.79
Irrigating farm plots	62.05	2.68	35.28
Change planting dates	14.6	9.98	75.42
Agroforestry	37.96	21.65	40.39
Training and extension services	97.56	0.49	1.95
Focus more on non-farm activities	42.83	24.33	32.85

Several barriers were perceived to be hindering the acceptance and implementation of climate variability adaptation mechanisms (Table 4.13).

Table 4. 13: Factors influencing climate variability adaptation mechanisms as perceived by small-scale farmers of Embu County

Particulars	Strongly agree (%)	Agree	Neither agree nor disagree (%)	Disagree	Strongly disagree (%)
Lack of Extension services	49.88	20.92	5.35	10.71	13.14
Limited farm land	19.22	0.73	2.19	22.87	54.99
Lack of farm inputs	16.79	20.19	37.96	10.46	14.6
Lack of timely forecasting	51.34	2.19	29.93	12.41	4.14
Lack of enough Time	35.04	51.34	6.33	5.6	1.7
Lack of finances	75.67	5.11	0.49	9.73	9

The majority of the respondents (75.67%) strongly agreed that lack of finances creates a barrier to adapting the climate variability mechanisms. Lack of timely forecasting was also a barrier that was strongly agreed upon by 51.34% whereas

29.93% neither agreed nor disagreed. Furthermore, limited land as a barrier scored 19.22% for those who strongly agreed and 0.73% for those who agreed. Lack of necessary land inputs on the other hand scored 36.98% while 53.53% agreed that lack of timely weather forecast may contribute to failure to implement the available mechanisms. Other barriers that featured prominently were lack of time (86.38%) and lack of financial resources (80.78%) to implement the identified adaptation mechanisms.

Small-scale farmers perceive climate variability as real. The variability was classified in terms of increase and decrease in temperatures, rainfall intensity and amount, droughts, and floods experiences. The farmers also believe that agricultural activities and productivity are affected by climate variability which leads to agricultural losses. Small-scale farmers have in mind suitable climate variability adaptation mechanisms to be employed on their farms. However, many factors tend to limit their ability to comprehend and implement these mechanisms. This implies that small-scale farmers take time to analyze their ability and identify possible limitations before implementation. According to Ayal and Filho (2017) ability to adapt to climate variability depend on the farmer's perception of both the climate-related risks and available adaptation mechanisms. As observed by Kellstedt *et al.* (2008) farmers go through a risk perception process that involves the perception of probable threats and damages, assessment of their ability and existing opportunities, and adaptation costs in terms of time, effort, and money which is then followed by intention to adapt or not adapt. Mertz *et al*. (2009) and Leiserowitz, (2006) notes that risk perception of climate variability adaptation mechanisms provides a better position for farmers to decide on what and how to shield their agricultural activities. Furthermore, the eagerness to shield from extreme climatic conditions depends on the existence of a minimal level of risks and the ability to adapt (Prager and Posthumus, 2011). Therefore the type and the level of adaptation depend on the farmers' perceived risks to farming activities (Dang *et al.*, 2014).

4.6 Farm and farmer characteristics that influence perception and adaptation to climate variability

When using the Heckman model to determine the factors influencing perception and adaptation to climate change farm and farmer characteristics become the explanatory variables. This involves both independent and dependent variables. The independent variables are assumed to affect perceptions of climate change and show the extent of adaptation.

4.6.1 Farm and farmer characteristics influencing the perception of climate change

The Heckman model shows two outcomes; adaptation and perception (Table 4.14). The column of the selection model indicates the variable considered and their significance levels. The results indicate gender ($p \leq 0.1$), education levels (tertiary, secondary and upper primary) ($p \leq 0.05$), and social network ($p \leq 0.05$) were statistically significant. This indicates that the research hypothesis that states that farmers' characteristics have a significant influence on the perception of climate variability among the small-scale farmers of Embu County was accepted.

Male-headed households ($p<0.05$) are more likely to perceive climatic change than female-headed households. This is because male-headed households have a better chance to attain information and new technology as compared to their counterparts (Ndambiri *et al.,* 2013). Bryan *et al.* (2013) are in support that training and capacity building is associated with a better perception of climate change. This would benefit the female-headed households within the county towards perception and adaptation to climate change.

About the education level of the respondents, the study established a likelihood of farmers with tertiary, secondary, and upper primary education levels are more like to perceive climate change than the less educated farmers (Table 4.14). This is because more educated farmers are more likely to be exposed to more information and have an enhanced appreciation of changing climate.

Table 4. 14: Factors influencing perception on climate change among the small-scale farmers of Embu County

	Adaptation model			Selection model		
Explanatory variables	**Par. estimate**	**S.E**	**Marginal effects**	**Par. estimate**	**S.E**	**Marginal effects**
Gender	0.035	0.061	0.582	-4.684*	162.381	0.001
Age (years)						
18-30						
31-40	-0.118**	0.052	-2.240			
41-50	-0.148**	0.055	-2.651			
51-60	-0.102*	0.060	-1.682			
61-70	-0.138*	0.083	-1.654			
>71	-0.109	0.086	-1.264			
Education level						
No formal education						
Tertiary	0.056	0.171	0.331	-4.503**	0.720	-6.25
Secondary	0.033*	0.153	0.224	-3.964**	0.569	-6.96
Upper primary	0.099	0.153	0.651	-4.284**	0.520	-8.23
Lower primary	0.077	0.148	0.526	-4.167		
Social network	-0.026	0.041	-0.626	-0.357**	0.430	-0.83
Access to media	0.013	0.040	0.335	-0.401	0.419	-0.98
Household size	0.015	0.010	1.542			
Access to credit	0.064*	0.045	1.412			
Off-farm income ksh						
10,000 and below						
11,00-20,000	-0.009	0.043	-0.216			
21,000-30,000	-0.033	0.068	-0.492			
31,000-40,000	0.080	0.117	0.691			
41,000 – 50,000	-0.062	0.164	-0.384			
51,000 and above	0.335	0.291	1.152			
On-farm income						
Ksh 10,000 and below						

11,000 - 20,000	0.006	0.037	0.178			
21,000 - 30,000	-0.007	0.056	-0.130			
31,000 - 40,000	0.104	0.105	0.983			
41,000 - 50,000	-0.186	0.165	-1.132			
51,000 and above	0.265	0.278	0.953			
Distance to the market	-0.040**	0.017	-2.310			
Extension services	-0.057**	0.049	-1.172	-0.497	0.422	-1.18
Land under cultivation	-0.057**	0.017	-4.470			
Constant	0.207	0.193	1.070	11.629	1562.38	0.01
lambda	0.326	0.591	0.55			
Wald chi2(27)=64.2						
Prob > chi2 = 0.0001						

Source: Analysis from household interviews

*Significant at 10% ($p < 0.1$)

**Significant at 5% ($p \leq 0.05$

Ofuoku (2011) observed a likelihood increase in appreciation of climate change with an increased number of years in school among the farmers. Further, Ndambiri *et al.* (2013) noted that higher education exposed farmers to more information on climate change.

Furthermore, social networks which are informal mechanisms in the study area to acquire and pass climate-related information among farmers was significant (Table 4.14). This implies that small-scale farmers are more likely to be influenced to perceive climate change by the existence of social interaction. According to Katungi (2006), early adopters slowly circulate information about new technology through sparse social networks that enable perception. Besides, Kristiansen (2004) argues that social networks strengthen individuals' attitudes and bring a commitment to work hard to reduce the risks.

4.6.2 Farm and farmer characteristics influencing the adaptation to climate change

The results of the outcome model are presented in Table 4.15 shows the factors influencing adaptation (Adaptation Model). The explanatory variables such as age, secondary school education levels, credit availability, extension services, size of land under cultivation, and distance to the market centers were found to be significant ($p<0.05$). This indicates that the research hypothesis that states that farm and farmers' characteristics have a significant influence on the adaptation of climate variability among the small-scale farmers of Embu County was accepted.

Table 4. 15: Factors influencing climate change adaptation mechanisms among the small-scale farmers of Embu County

	Adaptation model			Selection model		
Explanatory variables	**Par. estimate**	**S.E**	**Marginal effects**	**Par. estimate**	**S.E**	**Marginal effects**
Gender	0.035	0.061	0.582	-4.684*	162.381	0.001
Age (years)						
18-30						
31-40	-0.118**	0.052	-2.240			
41-50	-0.148**	0.055	-2.651			
51-60	-0.102*	0.060	-1.682			
61-70	-0.138*	0.083	-1.654			
>71	-0.109	0.086	-1.264			
Education level						
No formal education						
Tertiary	0.056	0.171	0.331	-4.503**	0.720	-6.25
Secondary	0.033*	0.153	0.224	-3.964**	0.569	-6.96
Upper primary	0.099	0.153	0.651	-4.284**	0.520	-8.23
Lower primary	0.077	0.148	0.526	-4.167		
Social network	-0.026	0.041	-0.626	-0.357**	0.430	-0.83
Access to media	0.013	0.040	0.335	-0.401	0.419	-0.98
Household size	0.015	0.010	1.542			
Access to credit	0.064*	0.045	1.412			
Off-farm income						
10,000 and below						
11,00-20,000	-0.009	0.043	-0.216			
21,000-30,000	-0.033	0.068	-0.492			
31,000-40,000	0.080	0.117	0.691			

41,000 – 50,000	-0.062	0.164	-0.384			
51,000 and above	0.335	0.291	1.152			
On-farm income						
10,000 and below						
11,000 - 20,000	0.006	0.037	0.178			
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41,000 - 50,000	-0.186	0.165	-1.132			
51,000 and above	0.265	0.278	0.953			
Distance to the market	-0.040**	0.017	-2.310			
Extension services	-0.057**	0.049	-1.172	-0.497	0.422	-1.18
Land under cultivation	-0.057**	0.017	-4.470			
Constant	0.207	0.193	1.070	11.629	1562.38	0.01
lambda	0.326	0.591	0.55			
Wald chi2(27)=64.2						
Prob > chi2 = 0.0001						

Source: Analysis from household interviews

*Significant at 10% ($p < 0.1$)

**Significant at 5% ($p \leq 0.05$

Concerning age, the findings show household heads between the age of 31 and 70 years are influencers of adaptation to changing climate. This indicates that almost all age groups were active in minimizing the climate change effects on agricultural fields. According to Ajuang *et al.* (2016), middle-aged farmers are likely to adapt to changes.

The education level was categorized into five groups which included no formal education, lower primary, upper primary, secondary and tertiary education (Table 4.15). The head of households with the secondary educational level was found to be a statistically significant variable in adaptation to climate change. This implies that household heads with more than 10 years of schooling are in a superior position to comprehend any knowledge on adaptation. This implies that for better resilience there is a need to strengthen the education sector among the farmers (Opiyo *et al*. 2016).

The findings show that access to credit was statically significant in influencing adaptation (Table 4.15). This implies that ease of access to credit facilities by the small-scale farmers in the study area is likely to influence investment in strategies to mitigate impacts of climate change such as the use of drought-tolerant seeds and the adoption of climate-smart technologies. Opiyo *et al*. (2016) observed that access to credit facilities enables farmers to capitalize on the creation of inputs for adaptation. Besides, access to cash enables households to diversify their livelihoods which is a form of adaptation. According to Hassan and Nhemachena (2012), households with more financial resources can use all available information to adapt to climate change.

Distance to the market center was found to be significantly influencing households' adaptation to climate change (Table 4.15). This implies that an increase in distance to the market center negatively influences the adaptation. This is because access to the market centers provides an avenue for the farmers to purchase inputs and sell their produce thus earning income for farm diversification. Farmers with easy access to the market are motivated to purchase certified seeds, fertilizers, and irrigation equipment (Belay *et al.*, 2017).

Access to extension services was another explanatory variable that was significant to adaptation (Table 4.15). This implies that access to extension services leads to improved and better adaption to climate change. This is because extension services are important as a source of information for small-scale farmers in the study area on farming activities and climate-related information. Extension education motivates and increases the likelihood of farmers implementing an adaptation mechanism (Belay *et al*., 2017).

The size of land under cultivation was also considered and the results showed that it is statistically significant to adaptation (Table 4.15). This implies that as the land size increases there is a probability of farmers adapting to climate change. This is because land size increases the probability of mixed farming which translates to diversification (Mugi-Ngenga *et al.,* 2016)

4.7 Institutions and information channels in climate change and variability

4.7.1 Formal institutions in climate-related information

The small-scale farmers were asked to list all the formal institutions they have interacted with in one way or another in the last 5 years concerning farming activities. The majority of the interviewed (97.32%) indicated they have interacted with Faith-Based Organizations (Table 4.16). These organizations are managed and registered under different church denominations within the study area. Those reported interacting with Non-Governmental Organizations (NGOs) were 74.21%. These two are closely followed by Cooperatives and Department of Agriculture with 69.83% and with 59.61% respectively. Department of Livestock Development had 31.39% while Development partners had 24.33% of respondents indicating a significant interaction. Ministry of land had the least number (1.46%) of respondents who had interacted with this office in the last 5 years.

Table 4. 16: Formal institutions utilized by small-scale farmers in Embu County

Formal institutions	%	n	X^2 P-value	
			Adaptation	Risk Perception
Department of Agriculture	59.61	245	NS	0.013
Department of Livestock Development	31.39	129	0.001	0.040
Development partners e.g. marketers	24.33	100	0.001	NS
Non- Governmental Organization	74.21	305	NS	NS
Faith-Based Organization (FBOs)	97.32	400	NS	NS
Cooperatives	69.83	287	0.014	NS
Ministry of land	1.46	6	NS	NS

*NS – Not Significant

The results in Table 4.16 indicate that the Department of Livestock Development, Development partners, and Cooperatives are statistically significant at $P \leq 0.05$ for influencing adaptation to climate change. Besides, the Department of Agriculture and the Department of Livestock development were significant $P \leq 0.05$ for influencing risk perceptions among the small-scale farmers of Embu County towards climate change. This confirms the research hypothesis that asserts that there is a significant association between risk perception, adaptation, and institutions among the small-scale farmers in Embu County

There was a significant relationship between the Department of Agriculture and small-scale farmers' risk perception ($p<0.001$) towards climate variability. This implies that small-scale farmers in Embu County are more likely to get influenced by what and how they perceive the climate-related risks towards their farming activities and productivity. This could be because the farmers reported getting extension services and visiting demonstration centers on the methods to adapt to the fluctuating climatic variables although the actual implementation was yet to occur.

Risk perception and adaptation of climate variability mechanisms were statistically significant to the Department of Livestock and Development at $p<0.040$ and $p<0.001$ respectively. This implies that the Department was influential in improving farmers' opinions and adaptation to changing climatic conditions. According to the interviewed farmers, veterinary services are provided to livestock at the farm level and therefore more advice is sought on how to feed and manage the animals.

Development partners in agricultural and climate-related fields were significant to adaptation ($p<0.001$) of climate variability by the Embu small-scale farmers. The development partners comprised individual marketers of different agricultural yields such as maize, beans, eggs, milk, and meat. This implies that the small-scale farmers were more likely to adapt to climate change and variability when the marketers give them advice on what and how to protect the agricultural crop for better yields and improved market value.

There was a significant connection between cooperatives and adaptation of climate change and variability ($p<0.014$). As explained by farmers these cooperatives assist in marketing farm produce and provide an easy avenue for microcredit. This suggests that small-scale farmers would probably implement adaptation mechanisms when information is passed by cooperatives. The reason may be because these farmers look forward to selling their farm produce to the same institutions and therefore will tend to follow the instructions given. On the other side, the microcredit given to the farmers motivates them to adapt to climate change and variability to be able to repay the loans.

These findings were confirmed by the Key Informant and FGDs respondents who were quick to note that the Department of Agriculture and Livestock Development provides extension services. Below is a scenario from Key Informant;

……… the office is mandated to provide extension services to livestock farmers however we only visit farms within our vicinity due to inadequate personals and funds to send our officers to the field. Therefore, the farmers who need our services have to travel to our offices for assistance.

According to Key Informants, these institutions play several roles such as the creation of awareness, provision of credit facilities, marketing strategies, extension services, capacity building, and enhancement of land adjudication.

Table 4. 17: Initiatives of the formal institutions in the agricultural sector of Embu County

Institution	Role
Department of Agriculture	Give awareness on the available farm inputs in the market e.g. fertilizers, hybrid seed
	Provides extension services to the small-scale farmers
Department of Livestock Development	Provided information and services to the Livestock farmers e.g. the best medicines to control pests and diseases, Artificial Insemination
Development partners (e.g. marketers)	Provide market information e.g. the prices of different farm products
	Capacity building for farmers and officials
Non- Governmental Organization	Provide information and awareness to the farmers on market issues
	Provided farm inputs at subsided rates
	Financial support
	Promotes new crops varieties and animal breeds
Faith-Based	Deals with soil and water conservation programs e.g.

Organization (FBOs)	organic farming
	Encourages in forest conservation: afforestation and reforestation
	Promotes new crops varieties and animal breeds
Cooperatives	Enable market accessibility to the farmers
	Credit facilities
	Value-adding on the farm produce
Ministry of land	Enhances land adjudication and settlement

This implies that the institutions have clearly defined roles on how to assist the farmers to improve their risk perception and shield their farming activities from the scathing effects of rising temperatures. As observed by Islam *et al.* (2017), extension service officials ought to visit the small-scale farmers on their farms for the effective dissemination of agricultural information. Therefore Islam and Nursey-Bray (2017) conclude that failure to visit farmers at the farm level results in insufficient information that is not adequate for adaptation to climate change and variability.

4.7.2 The role of informal institutions in climate-related information

Out of 411 respondents interviewed 71.05% are not members of any farmer organization whereas 28.95% (n=118) are members. These farmers' organizations provide several benefits as reported by the respondents. For instant access to credit (56.31%) and the need to learn new methods of farming (52.94%) had the highest percentage of respondents (Table 4.18).

Other benefits included access to extension service (27.74%), marketing of agricultural produce (23.53%), and access to farm inputs (12.60%). There was a significant difference between access to credit, access to extension services, market facilitation, farmer's organization, and new ways of farming ($p \leq 0.05$) in Embu County. This implies that farmers are more likely to join these organizations for various benefits.

Table 4. 18: Benefits of farmer organization on small-scale farmers in Embu County

Benefits	n	%	X^2 P<0.05
Access to credit	67	56.31	0.000
Access to extension services	33	27.74	0.000
Facilitates the market for agricultural produce	28	23.53	0.009
Learn new methods of farming	63	52.94	0.001
Access to inputs	15	12.60	NS

According to respondents, the farmer organization is closer to their vicinity which makes service delivery faster as compared to the formal institutions. A Key informant indicates that;

> *"……………………farmers' organization have shorter bureaucratic procedures and therefore farmers can access credit faster than the formal institution. The organizations are within the locality of the farmers and therefore marketing of agricultural produce is done on time especially the perishable ones"*

This finding suggests that farmers' organizations are very effective in assisting farmers to adapt to the climate variability and therefore can be used to link the persistent gap amid information generators and the farmers. Besides, farmers' organizations assist to facilitate microcredits to individual farmers (Quagrainie *et al*., 2010). According to Chen'gole *et al.* (2008), the availability of credit facilities may result in a better decision on the type and the degree of adaptability to climate variability. Furthermore, farmers are in a better position to gain knowledge about farm prices and possible marketing strategies because of the presence of collective bargain (Barham and Clarence, 2008).

4.7.3 Marginal effects on institutions on climate-related risk perception and adaptation mechanisms

The marginal effects of formal and informal institutions were analyzed and only formal institutions were statistically significant about climate variability risk perception and adaptation mechanisms employed by the small-scale farmers with P-values ≤0.05. (Table 4.19).

Table 4. 19: Marginal effects of climate-related institutions in Embu County

	Coefficient	
Dependent variables	**Informal**	**Formal**
Climate variability risk perception	0.004	-0.065*
Adaptation mechanisms	0.051	0.094*

*P-value ≤ 0.05

This indicates that the presence and engagement of formal institutions in various agricultural activities promote the farmer's resilience levels towards climate variability. Adaptation to climate variability is only possible if grounded on comprehensive information on farmers' requirements and concerning their geographical location. On the other hand, formal institutions are more likely to negatively influence the farmers' risk perception. This is because farmers' perception is not only formulated by constant interaction with experts but also on other factors like cultural background, prior experience, and socioeconomic factors (Ayal and Filho, 2017). The findings on adaptation concur with a study that shows that knowledge precedes action and therefore emphasis on farmer-tailored services promotes shielding of climate variability on the agricultural activities (Naab *et al.*, 2019). Farmer organizations (Chama) are not statistically significant and this could be because of a lack of central coordination. These organizations are productive if well organized and managed from a central point (Barham and Clarence, 2008).

4.7.4 Information channels on climate change and variability in Embu County

Use of Radio and Nature (lifetime experience) had an equal number of respondents (59.37%) who reported the two channels as the most used when in need of agricultural information (Table 4.20). These were closely followed by 49.88% of respondents who obtained climate change information from other farmers within their vicinity. Use of Televisions and County extension providers scored 25.06% and 22.63% respectively. Agro vet shops (18.25%) are also involved in giving farmers information on the crop variety, pest and diseases, fertilizer application, and other farm chemical use. Other respondents indicated getting information from the Agricultural show (3.65%) that are held annually whereas 2.92% of respondents get information from the demonstration centers organized by formal institutions within the County Use of teachers in schools and reading books or newspapers scored 0.49% and 2.43%, respectively.

Table 4. 20: Climate variability information channels in Embu County

Information channels	**(%)**	**(n)**	**Coefficients**	
			Adaptation	**Risk perception**
From other farmers	49.88	205	0.0394*	-0.0123
Extension provider	22.63	93	0.0378	-0.0018
From agricultural shows	3.65	15	0.0508	-0.0769
Demonstration centers	2.92	12	-0.0397	0.0217
Field days	3.89	16	-0.0171	0.0420
Agro Vet shops	18.25	75	0.0175*	-0.0047
From books/newspapers	2.43	10	0.0531	0.0400
Radio	59.37	244	-0.0388*	-0.0172
TV	25.06	103	-0.0090	0.0057
Internet	4.62	19	-0.0784	0.0276
From teachers in school	0.49	2	0.5338*	-0.0207
Nature	59.37	244	-0.0637*	0.0059*

* Significant $p \leq 0.005$

These results concur with those of the Key Informants that indicated that information on the weather forecasts is communicated through government-owned print or and mass media. The print media comes in either English or Kiswahili language in form of newspapers, booklets, and bulletins while the mass media is in form of Radio and Television which are the majority among the small-scale farmers because of the availability of Kiembu language channels with farming information.

Marginal effects of twelve (12) information channels show farmer to farmer, agro Vets, radio, nature (lifetime experience) and knowledge obtained from teachers in school were statistically significant with a P-value ≤ 0.05. This implies that regardless of many information channels existing in the study area only five made an impact on the adaptation aspects. Farmer to farmer communication is likely to influence adaptation mechanisms because the farmers may feel comfortable watching and asking questions from fellow farmers who had succeeded in implementation.

Furthermore, the Agro Vet shop is statistically significant which implies that the small-scale farmers are more likely to be influenced to the adaptation to climate variability. This is because small-scale farmers reported getting assistance on the type of crop variety, when to plant, type of fertilizers, pesticides, type of livestock feeds, vaccination services, and pests and disease control methods. Besides, the use of radios was likely to influence small-scale farmers to adapt to climate change. This implies that households with radios and listening to farming and climate-related information are more likely to get influenced to shield themselves from harsh climatic conditions. The farmers reported relying on radio to get information on the type of animal breeds to keep, feeding management, and zero-grazing options.

Climate-related information obtained from the formal school curriculum was also significant. This implies that the formal school curriculum is equipped with climate-related information that can influence small-scale farmers to adapt to the changing climatic conditions. Nature or lifetime experience was also significant and this implies that small-scale farmers headed by elderly people are probably likely to both perceive risks and implement adaptation mechanisms to climate variability. These results confirm the research hypothesis that there is a significant association between risk perception, adaptation, and information channels among the small-scale farmers in Embu County.

According to Kellstedt *et al.* (2008), information on climate change has lately become widely available although still far-fetched by many small-scale farmers in developing countries. However small-scale farmers can get agricultural information from agronomists hired by farm goods and services companies or independent farm consultants (Raymond and Robinson, 2013). According to Mugi (2014), small-scale farmers have relied on indigenous knowledge for centuries which has helped them to predict harsh climatic conditions and design adaptation mechanisms for resilience. While another study shows radio as the major climate change communication channel for small-scale farmers (Oyekale, 2015). Knowledge dissemination is effectively shared from farmer to farmer within their local geographical locations (Cunningham *et al.,* 2015). However, Anderson *et al.* (2009) observed that adaptation by small-scale farmers can be reinforced through diverse channels.

4.7.5 Access and utilization of climate change and variability information on agricultural practices

The majority of the respondents (55.47%) indicated receiving climate change information and applying it to various agricultural activities whereas 44.53% who received the information did not use it. This implies that not all information passed to the farmers is applied in the farming activities and therefore the farmer may have all the required information to adapt to climate variability and yet continue being vulnerable.

In livestock production, 228 respondents reported having used climate change and variability information whereas 69.3% used the information to improve the livestock pastures and or feed management (Table 4.21). This included sourcing for better fodder for animals that led to an increase in milk and meat production, the purchase of quality commercial feeds, integrating high-quality animal fodder with crop production, and storage of these fodder for later use. Other respondents (32.02%) reported having reduced the livestock herd size due to increased drought to ensure the animals are within the carrying capacity of the available land.

Table 4. 21: Livestock production and utilization of climate variability information in Embu County

Information	Frequency (n=228)	Percentage (%)
Reduce the livestock herd size	73	32.02
Improve the pasture or feed management	158	69.3
Relocation or migration of the herd	8	3.51
Vaccination/Animal health management	35	15.35
Change of animal type	13	5.7
Intensive/Zero grazing	4	1.75

This is distantly followed by 15.35% of the respondents who have used climate change and variability information on bettering animal health. This information included animal vaccination especially on poultry production, artificial insemination for cattle, and animal drugs to deal with pests and diseases. A mere 5.7% of the respondents have changed the type of animal their rear on their farms due to exposure to climate change and variability information. These small-scale farmers indicated to have purchased cattle breeds that can cope with extreme weather conditions while 3.51% of respondents have the information on how and when to move the animals from one piece of land to another for better management of the herd size. However, this percentage of the respondents was found within those farmers who have more than 6 acres of land. Information on intensive zero-grazing was reported by 1.75% of the respondents.

In crop production, the information received was used to select crop varieties (42.11%) that would cope with climate variability while 35.09% used this information to purchase the farm inputs like the seeds and fertilizers (Table 4.22).

Table 4. 22: Crop production and utilization of climate variability information in Embu County

Information	Frequency (n=228)	Percentage (%)
Planting date	48	21.05
Variety selection	96	42.11
Mixed cropping	39	17.11
Input use (seeds, fertilizer)	80	35.09
Harvest time	3	1.32
Others (Storage, Soil testing, Pest control Irrigation)	2	0.88

The climate change information was critical for 21.05% and 17.11% of the small-scale farmers who received the information on planting dates and need to have mixed cropping, respectively. About 1.32% indicated that climate change information assisted them to harvest their crops on time before they were damaged by the extreme weather conditions whereas 0.88% reported how climate change information assisted them in pest control and storage of produce. This implies that small-scale farmers in Embu County are willing to use climate variability information when packaged in a way that there can interpret.

Marginal effects show statistical significance between the utilization of livestock production information and adaptation ($p \leq 0.05$) (Table 4.22). However, the influence was negatively affecting animal management. This indicates that regardless of the access to this kind of information the animal management didn’t directly benefit from it. On the other hand, utilization of both livestock and crop production did not influence the small-scale ability to perceive climate-related risks.

Table 4. 23: Marginal effects of information use on adaptation and climate variability risk perception

Use of received agriculture-related information	Adaptation	Risk perception
Received information on animal management	-0.0676*	0.0040
Received information on crop management	0.0349	0.0166

About 44.53% and19.71% of the respondents did not make use of the climate variability information on their livestock and crop production respectively. Several reasons were given as shown in Figure 4.10. About 19.75% and 13.11% of the respondents did not understand the information given on crop and livestock production respectively. Also, 24.69% and 13.66% of the respondents did not trust the source of the information they were getting for crop and livestock production, respectively. Besides, 16.05% of the respondents dealing with crop production and 8.2% of livestock farmers indicated that they did not know how and where to apply the available management options. Limited resources were reported by 17.28% and 30.05% of crop and livestock farmers, respectively. These limited resources include inadequate funds, land, inputs for crop farmers, and human labor to try the given management options.

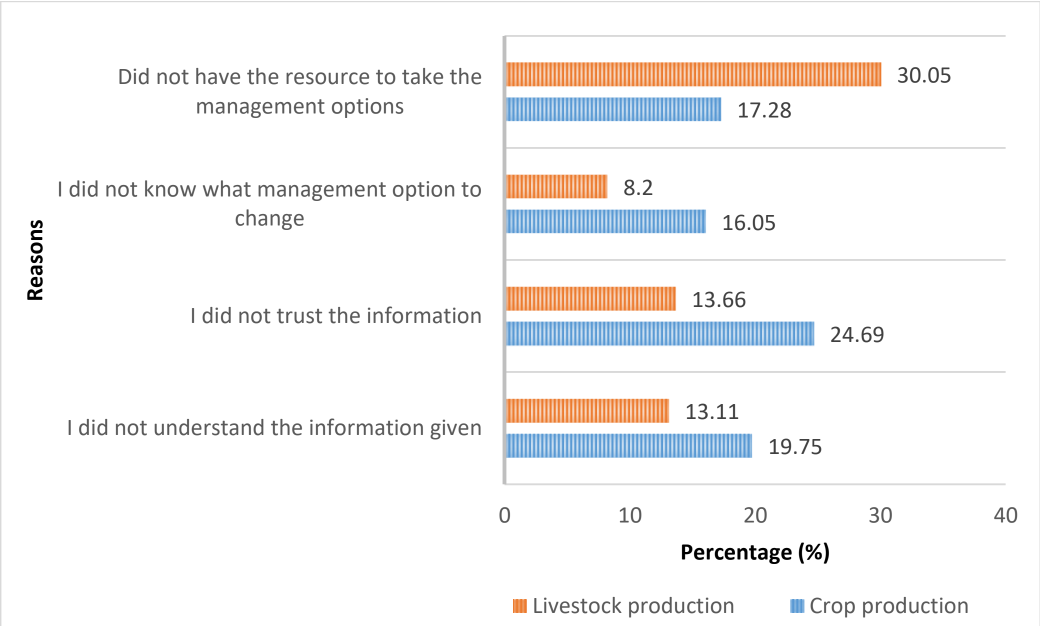

Figure 4:10: Reasons for not utilizing the climate variability information both crop and livestock production in Embu County

This implies that the small-scale farmers are willing to utilize the climate information passed to them although there are limiting factors beyond their reach that affect their ability. As observed by Srinivasan *et al.* (2011) effective utilization of climate information to succeed in the current climate risks and implement adaptation mechanisms to face future changes is paramount. Different regions are at different stages of launching climate information application systems however common limitations range from farmers' opinions and understanding of climate change to socioeconomic issues (Cash *et al.*, 2003). According to Pagano *et al.* (2002) users of information are likely to deploy it if they perceive it to be timely and relevant. On the other farmers go through a process of evaluation on the credibility and accuracy of the information before the implementation (Cash *et al.*, 2003). Many information users tend to resist new knowledge due to fear of failure and unwillingness to change from the well-established routines and knowledge (Rayner *et al.*, 2003; Rice *et al.*, 2009). Also, users assess information attributes such as authentic, responsive, flexible, dependable, usable, and timelines that affect small-scale farmers' ability to utilize the available information (Asrar *et al.*, 2013).

CHAPTER FIVE: SUMMARY, CONCLUSION, AND RECOMMENDATIONS

5.1 Summary

The study established that the maximum mean temperature around the county is 24.6ºC with a slight rise of 0.02ºC and statistically significant at $P<0.001$ while the minimum mean temperature was 14.2ºC with a 0.01ºC rise per year over 40 years and $P<0.001$. On the other hand, the rainfall amount showed a fluctuation with about 10.2mm per year for 40 years with the worst anomaly noted in the year 2000 with 216.6 deviations from the mean.

On the economic impact of climate change on livestock and crop production, the results show that temperature and rainfall do not directly affect livestock production net revenue. However, the lack of availability of climate variability mechanisms influenced the net revenue of this sector. For instance, if the livestock sector was shielded from extreme temperatures there was the likelihood of the farmers to increase the net income. Other factors like gender, size of land under cultivation, and access to media were found to be important influencers in the final net revenue for the small-scale farmers in Embu County. On the other hand crop, production net revenue was directly affected by an increase in temperature per annual. For instance, a 1ºC increase in temperature led to a loss of Ksh 365 per year. Besides, small-scale farmers' ability to protect the crops under cultivation from the scathing effects of temperature and irregular rainfall was more likely to affect the net revenue. However other factors such as distance to the nearest market center, soil erosivity, years of farming, occupation, and size of land under cultivation were found to statistically influence the net income of this sector. In terms of mixed farming temperature rise of 1ºC per year was more likely to increase net revenue because the farmers tend to diversify farming activities that may have different climatic needs. Furthermore, other farms and anthropogenic factors such as level of education, soil fertility, access to microcredit, availability of extension services, and distance to the nearest market center were most likely to also influence the net income.

On the risk perception, the results indicated that small-scale farmers have a perception of climate variability being real and which was expressed in terms of change in temperatures and rainfall amount, rainfall intensity, frequency in drought, and floods. The farmers' associated crop failure, decline in yield, outbreak of crop and livestock pest and diseases, insufficient and poor quality of pasture, low milk and meat production, and death of livestock to climate variability. Small-scale farmers believed that the use of drought-resistant crops, irrigation schemes, change of planting dates, use of agroforestry, availability of extension services, and non-farm income would alleviate the climate-related risks. However, extension services, farm inputs, timely weather forecast, time, finances, and land space were cited to be barriers to the perceived adaptation mechanisms.

On the farm and farmers’ characteristics influencing perception and adaptation to climate variability, variables such as access to credit, secondary school education, age brackets of 61-70years which are significant at $P \leq 0.1$ whereas age brackets of 31-50 years, extension services, size of land under cultivation, and distance to the market centers were significant at $P \leq 0.05$. These variables influenced how small-scale farmers adapt to climate variability. Besides, the gender of the household head, social networks, and education level of the tertiary, secondary, and upper primary were found to be significantly influencing the household's perception of climate change. All these variables were significant at 5% ($P \leq 0.05$).

On the institutions and information channels, the results showed that Embu County has seven formal institutions that directly and indirectly provide climate-related information. These institutions include the Department of Agriculture, livestock development, development partners, NGOs, FBOs, cooperatives, and the ministry of land. Their roles range from the creation of awareness, provision of credit facilities, marketing strategies, extension services, and capacity building to land adjudication. Among these institutions Department of Livestock Development, Development Partners, and Cooperatives were most likely influencers in climate variability adaptation mechanisms while the Departments of Agriculture and livestock development were more likely to influence small-scale farmers on climate variability risk perception. On the other hand, the farmers have formed informal institutions that assist them to access credits, learn new methods of farming, provision extension services, marketing, and access to farm inputs. Provision of credit, access to extension services, marketing, and new farming methods were more likely to attract small-scale farmers to join these organizations. However, the marginal effects showed that only formal institutions are more likely influencers on both climate variability adaptation mechanisms and risk perception. Twelve information channels were identified by the small-scale farmers to be useful in conveying climate-related information. These channels include farmer to farmer, extension providers, agricultural shows, demonstration centers, field days, Agro Vet shops, learning resources, radio, TV, internet, teachers in schools, and natural knowledge. Farmer to farmer, Agro Vet shops, Radio, teachers in school, and natural knowledge were more likely to influence the farmers on climate variability adaptation mechanisms. On the livestock production, the farmers utilize climate-related information to reduce livestock herd size, improve pastures, relocate herd to climate favorable locations, vaccination options, type of animals, and zero-grazing management. The crop production utilization of climate-related information range from planting dates, variety selection, mixed cropping, inputs requirement, harvest time, and irrigation options. However, some farmers did not use climate-related information obtained due to lack of proper understanding, lack of trust from the source, lack of management options to change, and limited resources.

5.2 Conclusion

Based on the findings, the following conclusions were drawn

There is climate variability in Embu County in terms of temperature and rainfall amounts. The temperatures were rising per year while the rainfall amounts declined significantly for 40 years. These variations are also seen by the use of deviation from the mean of the minimum and maximum temperatures and the amount of rainfall.

Climate variability especially the temperature rise has an economic impact on crop and livestock production in the study area. Crop production is negatively impacted by an increase in temperature which reduces the net revenue whereas mixed farming is positively impacted hence an increase in net revenue. Apart from climate variability other factors like gender, size of land under cultivation, nearest market center, soil erosivity, years of farming, and occupation were found to influence agricultural net revenue.

Small-scale farmers have the opinion that climate variability is occurring and have risks and fears that they have associated with the temperature and rainfall variations.

These farmers have in mind suitable climate variability adaptation mechanisms although the ability to implement them depends on the existence of a minimal level of risks.

Small-scale farmers have explanatory variables that significantly affect their perception of climate change. These variables include the gender of the household head, social networks, and education level of the tertiary, secondary, and upper primary.

Besides, adaptation to climate change by small-scale farmers is influenced by access to credit, secondary school education, extension services, land size under cultivation, and distance to the market centers, and age brackets of 31-50years and 61-70years.

Many formal and informal institutions exist in the study area. However, only formal institutions are more likely to influence small-scale farmers' ability to perceive climate variability risks and opt for adaptation mechanisms. Furthermore out of the twelve information channels identified by the farmers only five are more likely to influence climate variability adaptation mechanisms. While life experience was the only channel significant to risk perception on climate variability. On the access and utilization of climate-related information, small-scale farmers are in a position to implement although many barriers were cited.

5.3 Recommendations

Based on the conclusions above, the study recommends the following;

County Government of Embu through the Department of Agriculture to put into consideration farmers' perceptions in agricultural policies to enable effective adaptation to climate change by small-scale farmers. Furthermore, the policymakers in this department to consider farm and farmer characteristics that affect perception and adaptation among the small-scale farmers for effective adaptive capacity.

There is a need for the County in conjunction with agricultural and climate-related institutions such as KMD to enable co-learning to raise awareness and disseminate information to small-scale farmers through extension services, T.Vs, Radios, the internet, and newspapers.

The County governments through the Department of livestock, Department of agriculture, and cooperatives to be strengthened with funds to ensure effective extension services to the small-scale farmers. Besides, the departments to prepare climate-related information that could be broadcast on T.Vs, Radios, and in the county's newspapers. During agricultural shows, demonstration centers, and field days this information could be given to the attendees to ensure continuous awareness. There is a need also to involve Agro Vet shops in giving updated climate-related information to their customers to improve the perception of climate change.

The small-scale farmers' net revenue could be increased if the Department of agriculture provide information and awareness on value-added agriculture, market chains for farm produce, and storage options. Besides, there is a need to provide livestock breeds and crop varieties that are favorable to the current climatic conditions in Embu County to ensure survival and increased productivity.

5.4 Areas of further research

i. More research on climate change risk perceptions process in the County to understand the farmers and the duration taken by the farmers to implement adaptation mechanisms
ii. More research on economic impact analysis that includes all farming activities (food crops, cash crops, and livestock), long term investment, and inclusion of family labor as expenditures

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APPENDICES

Appendix 1: Variables in crop and livestock economic analysis in Embu County

Variable	**Mean**	**Std. Dev.**	**Min**	**Max**
Precipitation (mm)	3550.3	817.17	1372.22	5280.56
Max Temperature (ºC)	24.61	.73	23.18	27.18
Gender (0/1)	.59	.49	0	1
Age (yrs.)	45.70	14.81	18.00	95.00
Education Levels (1to 5)	2.73	.82	1.0	5.0
Awareness level (0/1)	.98	.147	0	1
Marital Status (0/1)	.85	.35	0	1
Occupation (0/1)	.09	.29	0	1
Land ownership (1 to 3)	2.85	.48	1	3
Years of farming (years)	18.60	13.50	1.0	60.0
Adaptation (0/1)	.07	.260	0	1
Land under cultivation (acres)	1.38	.98	.05	5.00
Soil fertility (1 to 5)	2.88	.90	1.0	5.0
Soil erosivity (1 to 4)	2.80	.73	1.00	4.00
Access to Certified seeds (0/1)	.89	.31	0	1
Hired labor (0/1)	.03	.16	0	1
Irrigation (0/1)	.97	.17	0	1
Access to microcredit facility (0/1)	.84	.36	0	1
Member of Farmer organizations (0/1)	.71	.45	0	1
Access to extension services (0/1)	.67	.46	0	1
Distance to the market (Km)	2.45	1.26	.50	8.00
Access to media (0/1)	.01	.12	.00	1.00
Livestock Net Revenue (Kshs)	-25563.08	22746.42	-117820.00	52240.00
Crop Net Revenue (Kshs)	37057.39	22697.80	955.00	93120.00
Mixed farming Net Revenue (Kshs)	-13300.70	22876.60	-99160.00	70406.00

Appendix 2: Explanatory variables used in Ricardian Model in Embu County

Dependent variables	**Units**	**Respondents who experienced climate change (%)**	**Respondents who did not experience climate change (%)**
Perception of climate change	1 = yes, 0 = no	97.8	2.2
Independent variables	**Units**	**Mean**	**Std. Deviation**
Gender of the household head	1 = female, 0=male	0.591	0.492
Age of the household head (years)	18 – 30	0.153	0.002
	31 – 40	0.281	0.004
	41 – 50	0.258	0.006
	51 – 60	0.189	0.009
	61 – 70	0.073	0.012
	≥ 71	0.077	0.014
Households size	Continuous	4.175	1.664
Education levels	Tertiary =1,	0.067	0.002
	secondary =2,	0.310	0.004
	upper pry =3,	0.481	0.006
	lower pry = 4,	0.142	0.009
	no formal Edu. = 5	0.014	0.012
Marital status of the respondents	1 = Married, 0 = not married	0.851	0.358
Type of occupation	1 = On-farm, 0 = non-farm	0.092	0.293
Land ownership	Government land =1	0.064	0.010

	Leasehold = 2	0.037	0.040
	Private land =3	0.914	0.100
Years in farming	Continuous	18.602	13.501
Land under cultivation	Continuous	1.383	0.984
Off-farm income	Below 10,000		
	11,00-20,000	0.018	0.028
	21,000-30,000	0.023	0.014
	31,000-40,000	0.319	0.039
	41,000 - 50,000	0.130	0.153
	51,000 and above	0.192	0.124
Farm income	Below 10,000	0.129	0.113
	11,00-20,000	0.012	0.106
	21,000-30,000	0.036	0.138
	31,000-40,000	0.018	0.011
	41,000 - 50,000	0.101	0.123
	51,000 and above	0.210	0.115
Access to certified seeds	Yes = 1, no = 0	0.106	0.309
Access to hired labor	Yes = 1, no = 0	0.037	0.166
Access to the credit facility	Yes = 1, no = 0	0.842	0.367
Social network	Yes = 1, no = 0	0.714	0.456
Extension services	Yes = 1, no = 0	0.676	0.467
Distance to the market	Continuous	2.453	1.269
Access to media	Yes = 1, no = 0	0.701	0.453

Source: Authors' analysis from respondents

Appendix 3: Farmers' Questionnaire

My name is Ruth Kangai from Kenyatta University researching the climate variability risk perception and rain-fed agricultural practices among farmers in Embu County, Kenya**.** This study is chaste for educational purposes**.** I kindly appeal to you to collaborate and assist to answer the questions below so that I conclude this research successfully. The data received shall be clandestinely stored and used only for educational purposes. I appreciate you for taking the time to answer the questions.

I. Demographic data

1.1 Name ---

1.2 Sub County ---

1.3 Division --

1.4 GPS Coordinates ---

1.5 Gender of the respondent

[1] Male

[2] Female

1.6 Age ---

1.7 What is your highest level of Education --

[1] Education at the lower primary

[2] Education at the upper primary

[3] Secondary school

[4] Tertiary/University

[5] Others (specify) ---

1.8 Household composition

Particulars	**Numbers**
How many people currently (last 3 months) belong to this household	
How many of these household members under 18 years	
How many are above 18 years	

1.9 Do your children (if any) assist in the farming activities

[1] Yes [2] No

1.10 If yes, in which farm activities

[1] Herding

[2] Planting

[3] Digging

[4] Weeding

[5] Others (specify)

1.11 Which is your occupation

Main occupation	**Other occupation**
[1] Farming (crop and livestock] [2] Salaried employment [3] Off-farm (self-employed) [4] On-farm casual laborer (**assisting other farmers** [5] Off-farm casual laborer [6] Other specify	Farming (crop and livestock] [2] Salaried employment [3] Off-farm (self-employed) [4] On-farm casual laborer (**assisting other farmers** [5] Off-farm casual laborer [6] Other (Specify)

1.12 Range of income per month in Kshs

Respondent	**Spouse (if any)**	**How much of this money is put directly into farming activities**
[1] Less than 10,000 [2] 11,000 – 20,000 [3] 21,000 – 30,000 [4] 31,000 – 40,000 [5] 41,000 – 50,000 [6] 51,000 and above [7] Other (Specify)	[1] Less than 10,000 [2] 11,000 – 20,000 [3] 21,000 – 30,000 [4] 31,000 – 40,000 [5] 41,000 – 50,000 [6] 51,000 and above [7] Other (Specify)	[1] Less than 10,000 [2] 11,000 – 20,000 [3] 21,000 – 30,000 [4] 31,000 – 40,000 [5] 41,000 – 50,000 [6] 51,000 and above [7] Other (Specify)

1.13 How big is your farm size (Acres) ------------------------

1.14 Land ownership status

[1] Private

[2] Leasehold

[3] Communal land

[4] Government land

[5] Others (specify)

II. Climate variability and Rain-fed agricultural practices

2.1 How many years have you been farming on this farm --------------------------------

2.2 What acreage of your farm is under cultivation --------------------------------------

2.3 Farming activities involved on your farm?

[1] Livestock rearing

[2] Food crop

[3] Cash crop

[4] Mixed farming

[5] Agroforestry

[6] Other (Specify)

2.4 How is your farm in terms of soil fertility?

[1] A big problem with infertile

[2] Slight problem with infertile

[3] Moderate

[4] Slightly fertile

[5] Very fertile

2.5. How is your farm in terms of soil erosion?

[1] Soil erosion is severe

[2] Soil erosion high

[3] Moderate

[4] Soil erosion is low

[5] Soil erosion is very low

2.6 Do you used treated seeds on your farm?

[1] Yes

[2] No

2.7 What is the average labor use per acre on your farm (adult days)? -----------------

2.8 How many kgs of seeds do you use per acre annually? -----------------------

2.9 How many bags (50kg) of fertilizer do you apply per acre annually? --------------

2.10 How many kgs of organic manure do you apply per acre (Kg) annually?

2.11 Do you use hired labor on your farm on Livestock production? [1] Yes [2] No

2.12 Do you use hired labor on your farm on crop production?

2.13 What is the total distance (Km) to the nearest market center? ------

2.14 List of the animals kept on the farm --

2.15 List major activities involved in livestock production

2.16 The table below is on the agricultural income from crop production. Please fill

a. Revenue on crop production

Crops	**Acres of land**	**Yields in Kgs**	**Unit price in Kshs**	**Total in Kshs**
Total				

B Expenses on crop production

Activities and inputs	**Particulars**	**Land size in acres**	**Cost per unit in Kshs**	**Total in Kshs**
Total Revenue				

2.14 The table below is on the agricultural income from Livestock production. Please fill

a. Revenue on the production of livestock

Livestock	**Particulars**	**Price per Unit**	**Numbers in totals**	**Total in Kshs**
Total Revenue				

b. Cost of production on livestock

Production activities and inputs	**Particulars**	**Per Unit cost (Ksh)**	**Total Quantity**	**Total Cost (Kshs)**
Total Revenue				

2.15 Floods and droughts in the areas

	Has this area experienced the following	If YES what measures did you put in place to protect	Which crops have helped you during this period	How often do the following occur

	in the last 5 years				
		Crops?	Animals?		
Drought	[1] Yes [2]No	[i] Drought resistant crop variety [ii] Planting trees [iii] Use of early maturing crop variety [iv] use of early warning systems [v] credit facilities [vi] extension and training [vii] Early planting [viii] Others (specify)	[i] improved local variety [ii] Livestock insurance scheme [iii] regular vaccination [iv] planting fodder [v] abandoning livestock keeping [vii] Change of food [viii] Others (specify)	[i] Cassava [ii] sorghum [iii] millet [iv] maize [v] beans [vi] sweet potatoes [vii] mangoes [viii] oranges [ix] yams [x] Others (Specify)	[i] every season [ii] after every one season [iii] after every 2 seasons [iv] after every 3 seasons [v] after every 4 seasons [vi] after every 5 seasons [vii] others (specify)
Floods	[1] Yes [2]No	[i] Water harvesting e.g. tanks, water pans [ii] Installation of solid fences [iii] Early warning systems [iv] Others	[i] Installation of solid fences [ii] Early warning systems [iii] Others (specify)	[i] Cassava [ii] Sorghum [iii] Millet [iv Maize [v] Beans [vi] Sweet potatoes [vii] Mangoes [viii]	[i] Every season [ii] After every one season [iii] After every 2 seasons [iv] After every 3

		(specify)		Oranges [ix] Yams [x] Banana [xi] Pigeon peas [xii] green grams [xiii] Others (Specify)	seasons [v] After every 4 seasons [vi] After every 5 seasons [vii] Others (specify)

2.16 What factors hinder you from adapting to the changing climate?

[1] Lack of information about proper adaptation mechanism

[2] Lack of finances

[3] Limited farm land

[4] Lack of timely forecasting information on expected climate change

[5] Lack of necessary farm inputs

[6] Lack of enough time to implement the strategies

[7] Poor infrastructure

[8] Market influence

[9] Weather conditions

[10] Others (specify)

2.17 Microcredit and small-scale farmers

Have you accessed microcredit for your farm activities	How much per season (Ksh)	What are some of the institution that gives microcredit to farmers
[1] Yes [2] No		[1] Kenya Cooperative Creameries [2] Brookside [3] Aspen [4] Superior Highland [5] Caritas [6] Mkulima bora [7] Lugendo Alliance [8] Gakungu) [9] Banks [10] Care Kenya

		[11] Others (specify)

2.18 Farmers' organizations or 'chamas'

Which farmers' organizations or 'chamas' have you heard about in this area?	Which one of these organizations or Chama do you belong to	What benefits have you obtained from the farmer's organization?	Reasons for not belonging to any organizations
		[1] Credit accessibility [2] Information access from extension services [3] Facilitates the market for agricultural produce [4] Educates the farmers [5] Other (specify)	[1] lack of interest [2] lack of registration money [3] Distance involved [4] Others (Specify)

III. Climate variability risk perception

3.1 Indicate the degree of agreement on climate change being real

[1] Strongly agree

[2] Agree

[3] Neither agree nor disagree

[4] Strongly disagree

[5] Disagree

3.2 For the last 10 years, what have you observed that makes you conclude climate variability is occurring?

Climate variables	**Perception**
Temperature	Increase Decrease No change
Rainfall amount	Increase Decrease No change
Rainfall intensity	High rain and for a short time

	Short rains and for a long time Short rains and for a very short time No change
Floods	Increase Decrease No change
Drought	Increase Decrease No change

3.3 In your opinion what causes climate change

[1] Supernatural power

[2] Deforestation

[3] Pollution

[4] Others (Specify)

3.4 Do you think climate change has affected your farming activities

[1] Strongly agree

[2] Disagree

[3] Neither agree nor disagree

[4] Agree

[5] Strongly disagree

3.5 What effects would you say climate change has had on your farming activities

[1] Crop failure

[2] Crop yields have declined

[3] Disappearance of crops

[4] The outbreak of crop pests and diseases

[5] The outbreak of livestock pests and diseases

[6] Pasture is insufficient for my animals

[7] Poor quality pasture

[8] Death of livestock

[9] Change in cropping patterns

[10] Low milk and meat production

[11] Other (Specify)

3.6 Rank the above (3.6) effects of climate change on agricultural production

Effects of climate change on agricultural production	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly Disagree**
Crop failure					
Disappearance of crops					
The outbreak of crop pests and diseases					
The outbreak of livestock pests and diseases					
Poor quality pasture					
Death of animals					
Pasture is insufficient for my animals					
Crop yields have declined					
Low milk and meat production					

3.7 Do you agree on the following causes of food shortage in your household?

Particulars	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**
Prolonged changes in weather patterns (temperature and rainfall)					
Pests and diseases (crops and Livestock)					
Poor farming methods					
Poor access to credit facilities					
Others (specify)					

3.8 In your opinion what are some of the positive impacts of climate change?

[1] Adequate water due to floods

[2] Increased yields

[3] Learning of new farming methods

[4] Increased pastures

[5] No positive effects

3.9 What are the most important adaptation measures for mitigating climate change in your opinion?

IV Institution and Information channels

4.1 Rate yourself using 1-5 to select a response that shows your knowledge of climate change

[1] Expertise in knowledge

[2] Indigenous information (through experience)

[3] Some knowledge

[4] Minimal knowledge

[5] No knowledge

4.2 Where does your farming practices information come from?

[1] From other farmers

[2] From extension services provider

[3] From agricultural shows

[4] Demonstration centers

[5] Field days

[6] Agro Vert shops

[7] From books/newspapers

[8] Radio

[9] TV

[10] Computers or cellphones

[11] In school

[12] Traditional knowledge)

[13] Other (Specify)

4.3 Farm management and new information

	Did you use the information provided	If NO, Why you were not able to use the information	If YES, Which management decision did you change on your farm in response to the

			information?
Animal management	[1] Yes [2] No	[1] I did not understand the information given [2] I did not trust the information [3] I did not know what management option to change [4] did not have the resource to take the management options [5] Others (specify)	[1] Livestock herd size [2] Pasture or feed management [3] relocation or migration of the herd [4] Other (specify)
Crop management	[1] Yes [2] No		[1] Planting date [2] Variety selection [3] Mixed cropping [4] Input use (seeds, fertilizer) [5] Harvest time [6] Other (specify)

4.4 Did you receive training on the use and interpretation of climate information?

[1] Yes

[2] No

4.5 From whom did you receive the training?

[1] Government agricultural extension or met office

[2] Commercial/private company

[3] Local implementing partners

[4] Family members or expert within the community

[5] Other (specify)

4.6 Was there any other support from this organization?

[1] Yes, full financial support

[2] Yes, partly financial support

[3] No other support

4.7 How often do you meet for training and extension services in a year?

4.8 What information do the extension officers offer to you about climate change

[1] To plant our crops early

[2] Give a proper spacing of the crops when planting

[3] introduction of new varieties of crop

[4] Soil/moisture conservation practices

[5] Land preparation

[6] Fertilizer/input use

[7] Irrigation

[8] Livestock management

[9] Others (Specify)

4.9 How as the information received influenced your farm management practices -

Appendix 4: Interview Guide

1.0 Institution data

1.1 What institution do you work for?

1.2 How many years have you operated in this organization/department?

2.0 Climate variability risk perception

2.1 Would you say climate variability is taking place in this area? --------------------

2.2 If yes what have you observed in the last 10 years?

2.3 Are these observed attributes a concern to the smallholder farmers of this area? If yes explain --

2.4 Do you think human activities are accountable for climate change?

2.5 Do you think the concerns about climate change and its effects have influenced farmers to adapt? ---

3.0 Impact of climate change on agricultural practices

3.1 Have you observed smallholder farmers change farming practices in response to climate change effects? ---

3.2 If yes what changes? --

3.3 What current practices are smallholder farmers undertaking to mitigate the negative effects of climate change? ---

3.4 What factors are hindering smallholder farmers from practicing adaptation mechanisms to climate change and variability? ----------------------------------

4.0 Institution and information channels

4.1 Do you know of extension workers who assist the farmers in this County? ----

4.2 As an organization is there provisions in the agriculture sector policies that support innovation and adaptation of climate variability mechanisms? If yes in what way?

4.3 Do research institutions encourage feedback from farmers? ----------------------

4.4 Do the small-scale farmers know the benefits associated with adaptation to climate change? ----------------------------------

4.5 If yes what benefits are they familiar with? -------------------------------------

4.6 As an organization is their provisions in the agriculture sector policies that support innovation and adaptation of climate variability mechanisms ------------

4.7 If yes in what way --

4.8 As an organization have you ever funded small-scale farmers to implement climate variability adaptation mechanisms?------------------------------- If not why?

4.9 If yes has the funding enhanced the climate variability adaptation mechanisms among the small-scale farmer? ---

4.10 Do you receive the climate change information ?--------------------------------?

4.11 Do you consider the information accurate and reliable to small-scale farmers? -

4.12 Do you disseminate this information to farmers? --------------------

4.13 If yes, do you disseminate it in the form you receive it? ---------------------------

4.14 If not do you package it? ---

4.15 If you package it, how do you package this information for the small-scale farmers?

4.16 Is the information disseminated timely? --

4.17 What channels do you use to disseminate the information? ------------------------

4.18 Are these information channels effective in delivering the information to farmers?

4.19 To what extent has this information reached the small-scale farmers --------------

4.20 Are the small-scale farmers using the information passed to them on their farms

4.21 If not why ---

4.22 Does the information they receive of any implication for their management options

Yes [ ] No [ ]

4.23 If yes, what management options ---

4.24 List the policies that ensure actual adaptation measures in the county?

Appendix 5: Focus Group Discussion guide

1.0 Climate variability risk perception

1.1 Would you say climate variability is taking place in this area? ---------------------

1.2 If yes what have you observed in the last 10 years ----------------------------------?

1.3 Are these observed attributes a concern to the smallholder farmers of this area? If yes explain --

1.4 in what way are farming practices affected by the climate change attributes

1.5 Do you think the concerns about the change in climate attributes and their effects have influenced farmers to climatic change adaptation mechanisms?

2.0 Impact of climate change on agricultural practices and adaptation mechanisms

3.1 Have you observed smallholder farmers change farming practices in response to climate change effects? ---

3.2 If yes what changes? --

3.3 What current practices are smallholder farmers undertaking to mitigate the negative effects of climate change? --

3.4 What factors are hindering smallholder farmers from practicing climate change and variability adaptation mechanisms?

4.0 Institution and information channels

4.1 Have you seen extension workers assisting farmers in this County? ---

4.2 As an organization is there provisions in the agriculture sector policies that support innovation and climate variability adaptation mechanisms? If yes in what way?

4.3 Does this research institution encourage feedback from its information users? ----

4.4 Do the small-scale farmers know the benefits associated with adaptation mechanisms? ------------------------------------

4.5 If yes what benefits are they familiar with? --

4.6 As an organization, are their provisions in the agriculture sector policies that support innovation and climate variability adaptation mechanisms ----------------

4.7 If yes in what way ---

4.8 As an organization have you ever funded small-scale farmers on climate variability adaptation mechanisms? ------------------------------- If not why? ------

4.9 If yes has the funding enhanced the climate variability adaptation mechanisms among the small-scale farmer? --

4.10 Do you receive the climate change information? ------------------

4.11 Do you consider the information accurate and reliable to small-scale farmers? -

4.12 Do you disseminate this information to farmers? --------------------

4.13 If yes, do you disseminate it in the form you receive it? ----------------------------

4.14 If not do you package it? --

4.15 If you package it, how do you package this information for the small-scale farmers?

4.16 Is the information disseminated timely? ---

4.17 What channels do you use to disseminate the information? ------------------------

4.18 Are these information channels effective in delivering the information to farmers?

4.19 To what extent has this information reached the small-scale farmers -------------

4.20 Are the small-scale farmers using the information passed to them on the farms -

4.21 If not why --

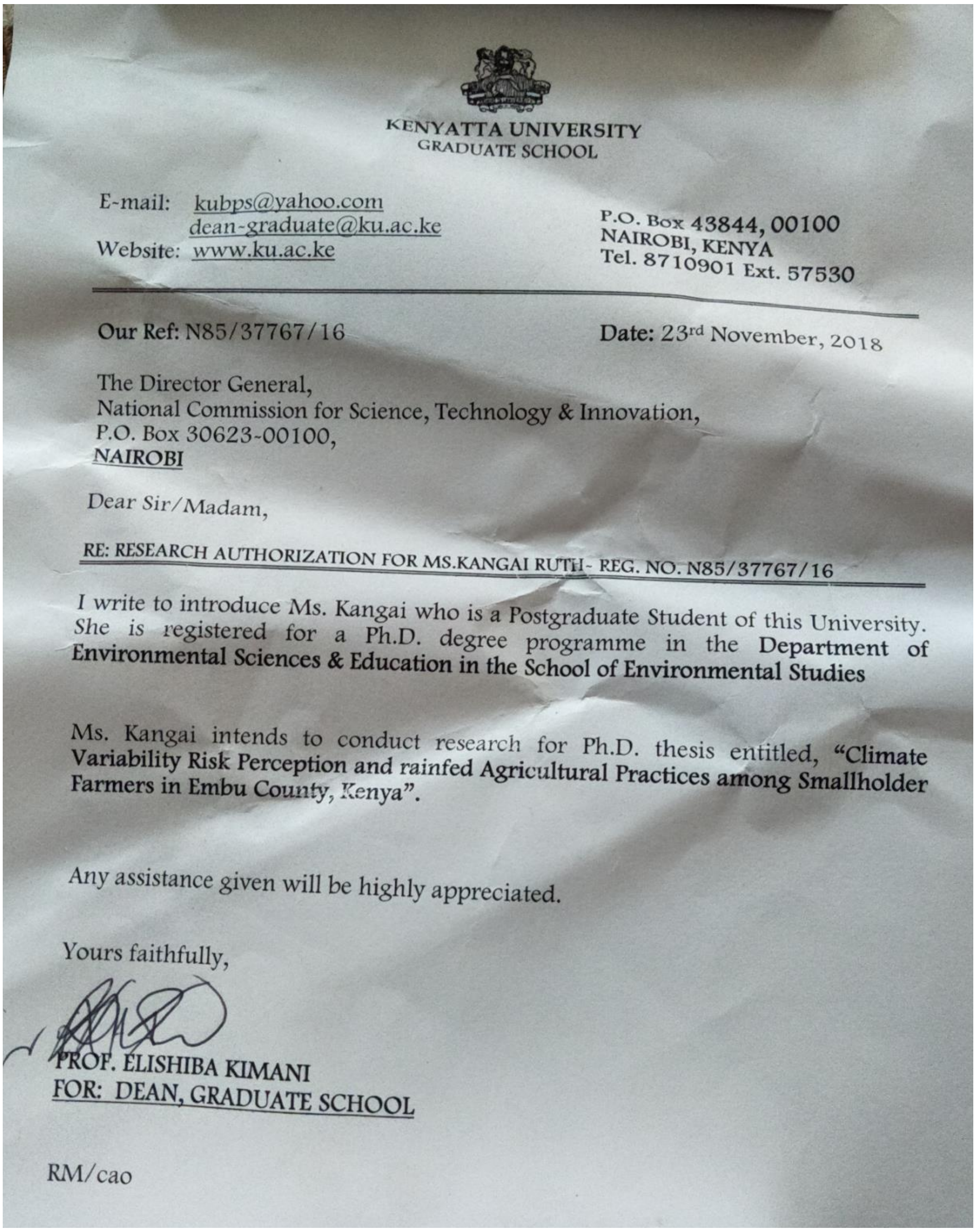
Appendix 6: FGDs and Questionnaires field photographs

Plate 4. 1: Focus Group Discussions with Embu West Sub-County small-scale farmers

Plate 4. 2: Focus Group Discussions with Mbeere North Sub-County small-scale farmers

Plate 4. 3: Research Assistant Administering a questionnaire to a farmer at her home

Appendix 7: Postgraduate Research Authorization



KENYATTA UNIVERSITY
GRADUATE SCHOOL

E-mail: kubps@yahoo.com
dean-graduate@ku.ac.ke
Website: www.ku.ac.ke

P.O. Box 43844, 00100
NAIROBI, KENYA
Tel. 8710901 Ext. 57530

Our Ref: N85/37767/16

Date: 23rd November, 2018

The Director General,
National Commission for Science, Technology & Innovation,
P.O. Box 30623-00100,
NAIROBI

Dear Sir/Madam,

RE: RESEARCH AUTHORIZATION FOR MS.KANGAI RUTH - REG. NO. N85/37767/16

I write to introduce Ms. Kangai who is a Postgraduate Student of this University. She is registered for a Ph.D. degree programme in the **Department of Environmental Sciences & Education in the School of Environmental Studies**

Ms. Kangai intends to conduct research for Ph.D. thesis entitled, **"Climate Variability Risk Perception and rainfed Agricultural Practices among Smallholder Farmers in Embu County, Kenya".**

Any assistance given will be highly appreciated.

Yours faithfully,

PROF. ELISHIBA KIMANI
FOR: DEAN, GRADUATE SCHOOL

RM/cao

Appendix 8: NACOSTI Research Authorization letter

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY AND INNOVATION

Telephone:+254-20-2213471,
2241349,3310571,2219420
Fax:+254-20-318245,318249
Email: dg@nacosti.go.ke
Website : www.nacosti.go.ke
When replying please quote

NACOSTI, Upper Kabete
Off Waiyaki Way
P.O. Box 30623-00100
NAIROBI-KENYA

Ref. No. **NACOSTI/P/19/38397/27205**

Date: **14th January, 2019**

Ruth Kangai Adiel
Kenyatta University
P.O. Box 43844-00100
NAIROBI

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on ***"Climate variability risk perception and rain-fed agricultural practices among smallholder farmers in Embu County, Kenya"*** I am pleased to inform you that you have been authorized to undertake research in **Embu County** for the period ending **14th January, 2020.**

You are advised to report to **the County Commissioner and the County Director of Education, Embu County** before embarking on the research project.

Kindly note that, as an applicant who has been licensed under the Science, Technology and Innovation Act, 2013 to conduct research in Kenya, you shall deposit **a copy** of the final research report to the Commission within **one year** of completion. The soft copy of the same should be submitted through the Online Research Information System.

GODFREY P. KALERWA MSc., MBA, MKIM
FOR: DIRECTOR-GENERAL/CEO

Copy to:

The County Commissioner
Embu County.

The County Director of Education
Embu County.

National Commission for Science, Technology and Innovation is ISO9001: 2008 Certified

Appendix 9: NACOSTI Research Permit

THIS IS TO CERTIFY THAT:
MS. RUTH KANGAI ADIEL
of KENYATTA UNIVERSITY , 0-100
Nairobi,has been permitted to conduct
research in *Embu County*

on the topic: *CLIMATE VARIABILITY RISK PERCEPTION AND RAIN-FED AGRICULTURAL PRACTICES AMONG SMALLHOLDER FARMERS IN EMBU COUNTY, KENYA*

for the period ending:
14th January,2020

Permit No : NACOSTI/P/19/38397/27205
Date Of Issue : 14th January,2019
Fee Recieved :Ksh 2000

...Kangai...........
Applicant's Signature

....
Director General
National Commission for Science, Technology & Innovation

Appendix 10: Embu County Research Authorization letter

REPUBLIC OF KENYA

THE PRESIDENCY

MINISTRY OF INTERIOR AND CO-ORDINATION OF NATIONAL GOVERNMENT

Telephone: Embu 0202310839
FAX 30040
Email: ccembu@gmail.com
When replying please quote

COUNTY COMMISSIONER
EMBU COUNTY
P.O.BOX 3-60100
EMBU

Ref: EBU.CC/ADM/3/37/VOL.11/ (278)

19th February, 2019

All Deputy County Commissioners
EMBU

RE: RESEARCH AUTHORIZATION

Please be informed that **Ruth Kangai Adiel, Research Permit No. NACOSTI/P/19/38397/27205** of **Kenyatta University, Nairobi** has been authorized to carry out research in your Sub County for a period ending **14th January, 2020.**

Her research is based on **"Climate variability risk perception and rain-fed agricultural practices among smallholder farmers in Embu County".**

Kindly accord her the necessary assistance.

AMBROSE K. NJERU
FOR: COUNTY COMMISSIONER
EMBU COUNTY

Copy to.
Ruth Kangai Adiel

Appendix 11: Kenya Meteorological Department (KMD) data request form

FORM NO. 768 (7/97)

REPUBLIC OF KENYA
MINISTRY OF ENVIRONMENT & MINERAL RESOURCES
KENYA METEOROLOGICAL DEPARTMENT
Dagoretti Corner, Ngong Road, P. O. Box 30259-00100 GPO, Nairobi, Kenya,
Telephone: 254-20-3867880-5, Fax: 254-20-3876955/3877373,
Mobile: 0724-255153/4
E-mail: drector@meteo.go.ke, directormet@yahoo.com,
Website: www.meteo.go.ke

INFORMATION/DATA/SERVICES REGISTRATION FORM
Please fill this form in triplicate
NO. 756412

Date: 12/03/2019 **STATION NAME:** ....
PART I *(To be filled by the Applicant)*

Applicant's Name: RUTH KANGAI ADIEL

Address: P.O. BOX 4267 – 00100 NBI

Name of Institution: KENYATTA UNIVERSITY

Type of Date required and period: (1) Rainfall – minimum – maximum (10 day) (2) Temperatures – minimum – maximum (10 day interval) climatic

Purpose for which data is required: For PHD write up.

Station/s or area: EMBU COUNTY & SURROUNDING stations.

Declaration:
I hereby undertake that I shall use the data for the declared purpose(s) only and that I shall not by way of trade or otherwise, lend, resell, hire out or otherwise circulate it in any form without the Department's prior authority, and shall deposit with the Department one copy of the publication arising from the use of the data.

Sign: [signature] Date: 12/03/2019

Part II: ***(Reserved for Official use only)***
Name of Receiving Officer: C. O. Mahonga

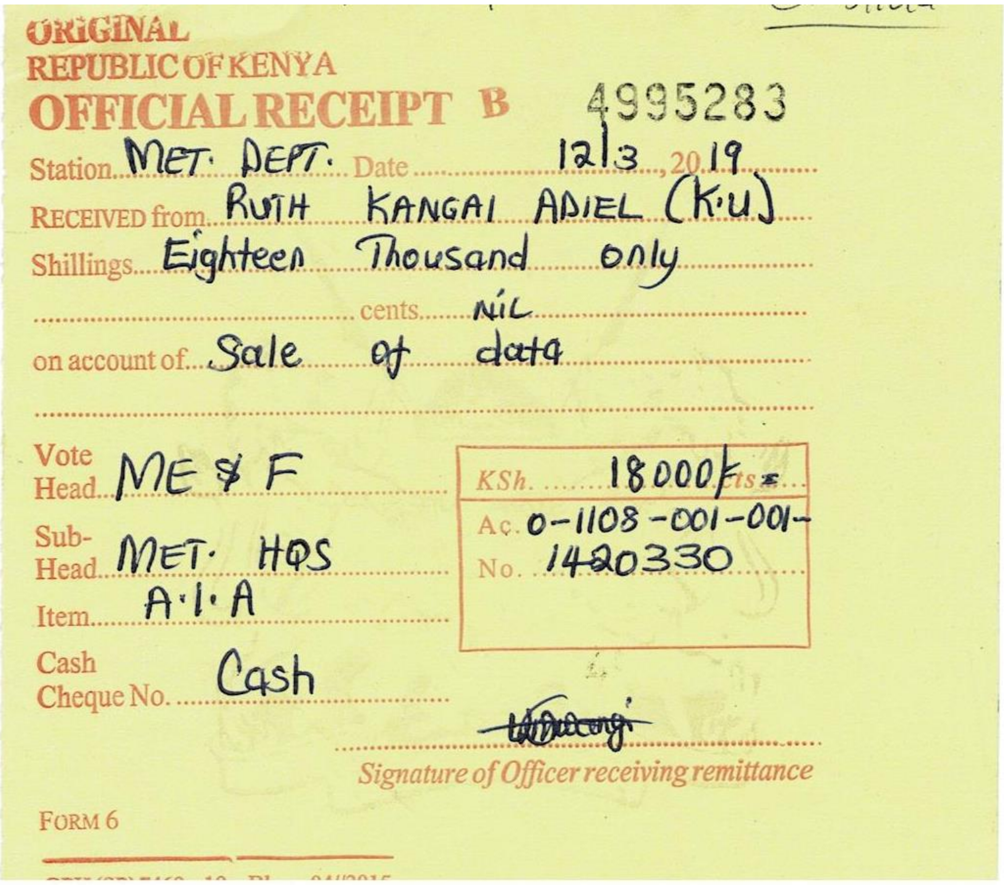
Designation & Signature: Hocm

Comments ....

Part III: ***(Reserved for Official use only)***
Proforma Invoice No. .... Amount: Kshs. 18,000/=
Receipt No. B 4995283 Amount: Kshs. 18,000/=

Part IV: ***(Reserved for Official use only)***
Data Collected by.................. Date: .... Issued by ....
Comments of issuing Officer:..

Appendix 12: Kenya Meteorological Department (KMD) payment receipt



ORIGINAL
REPUBLIC OF KENYA
OFFICIAL RECEIPT B 4995283

Station MET. DEPT. Date 12/3, 20 19
RECEIVED from RUTH KANGAI ADIEL (K.U)
Shillings Eighteen Thousand only
cents NIL
on account of Sale of data

Vote Head ME & F	KSh. 18000/= Cts
Sub-Head MET. HQS	A/c. No. 0-1108-001-001-1420330
Item A.I.A	
Cash Cheque No. Cash	

Signature of Officer receiving remittance

FORM 6