CLIMATE CHANGE ADAPTATION INFORMATION FOR IMPROVED AGRICULTURAL PRODUCTIVITY AMONG SMALL-HOLDER FARMERS IN LOWER EASTERN KENYA

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DECLARATION

This thesis is my original work and has not been presented elsewhere for a degree or any other award

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DEDICATION

This work is dedicated to my late father Jeremiah Onyango, my mum Monicah Were and my siblings Willy, Calvince, Mark, Winnie and Cain. Your inspiration and support were great.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS

ALIN	Arid Lands Information Networks
ASALs	Arid and Semi-Arid Lands
ASDSP II	Agricultural Sector Development Strategy Programme
CCCA	County Climate Change Act
CCFs	Climate Change Funds
CFS	Climate Field School
CIDP	County Integrated Development Plan
CMD	County Meteorological Department
ESR	Endogenous Switch Regression
FAO	Food and Agriculture Organization
FIML	Full Information Maximum Likelihood
GDP	Gross Domestic Product
RoK	Republic of Kenya
ICT	Information Communication Technology
IDRC	International Development Research Centre
IL	Intermediate Lowland
IPCC	Intergovernmental Panel on Climate Change
IVR	Interactive Voice Response
KCCCFR	Kitui County Climate Change Funds Regulation
KCCISSP	Kitui County Climate Information Services Strategic Plan
KCCWG	Kenya Climate Change Working Group
KCSAP	Kenya Climate Smart Agricultural Project

KMD	Kenya Meteorological Department
KMO	Kaiser-Meyer Olkin
KNBS	Kenya National Bureau of Statistics
LH	Lower Highland
LM	Lower Midland
MALEP	Makueni Agricultural, Livestock and Extension Policy
MCCAP	Machakos County Climate Change Action Plan
MCCCA	Machakos County Climate Change Act
MCCCP	Machakos County Climate Change Policy
MCCFR	Makueni Climate Change Funds Regulations
MCCISP	Makueni County Climate Information Services Plan
MoA	Ministry of Agriculture
MoE	Ministry of Environment
MDGs	Millennium Development Goals
MVP	Multivariate Probit Regression
NARIGP	National Agricultural and Rural Inclusive Project
NCCAP	National Climate Change Action Plan
NCCFP	National Climate Change Framework Policy
NDMA	National Drought Management Authority
NDEF	National Drought Emergency Fund
OLS	Ordinary Least Squares
PC	Principal Component
PCA	Principal Component Analysis

RMP	Rangelands Management Policy
SDGs	Sustainable Development Goals
SMS	Short Message Services
SPSS	Statistical Package for Social Sciences
UM	Upper Midland
UN	United Nations
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNDP	United Nations Development Programme
VIF	Variance Inflation Factor

DEFINITION OF TERMS

Climate Change: Climate change refers to long term changes in weather patterns of a region identified by the use of statistical tests by the changes in either mean or variability of properties such as rainfall and temperature that persist for a long period usually a decade or longer. It is mainly due to atmospheric and land-use changes (IPCC 2014).

Climate Variability: Variations in the mean state and other statistics of climate on all temporal and spatial scales beyond that of weather events such as standard deviations and other extremes (IPCC 2018).

Adaptation: In relation to climate change, refers to adjustments in both human and natural systems in response to climate stimuli and its effects that make rural communities better able to adjust to climate change and variability, moderate its potential damages, cope with adverse consequences and exploit opportunities that come with climate change (IPCC 2018).

Climate information: In the context of this work entails predictions of expected weather conditions entailing forecasts and warnings.

Adaptation Information/ Agro-advisories: In the context of this work refers area-specific strategies and advisories developed from climate information given to users (farmers) to enable them adjust in response to climate change over given periods for example seasonal agro-advisory.

Adaptive capacity: In the context of this work is the ability of households to evolve, prepare, adjust and accommodate the hazardous effects of climate variability and change.

Policies: In this context are the documents containing intents to achieve climate change adaptation taking the form of strategies, plans, regulations or acts.

Saturation: This is a point at which the data collection process does not offer any relevant or new information (Mason 2010).

Adoption: Use/Uptake of seasonal climate smart technologies disseminated in the form of agro-advisories.

Principal Component: This is a re-expressed data set with uncorrelated new variables obtained after a reduction process in Principal component analysis (Kurita 2019).

Eigen Value: This is the amount of variance explained by the corresponding component multiplied by the number of variables represented in each Principle Components (Kurita 2019).

Institutional arrangements: In the policy context are social and political structures like authorities, partnerships and knowledge sharing forums that shape interaction among policy actors.

ABSTRACT

The effects of climate variability and change on communities are felt across the globe thus adaptation information is sought as a panacea. With the pervasive uncertainty on expected weather patterns amidst climate variability and change, sound decisions are fundamental. As a consequence, this study hypothesized that achieving increased climate-informed adaptation action requires the dissemination of climate change adaptation information. The relevant risk factors and policy domains should be particularly targeted at the sustainability of this course. This study generally aimed at determining the effect of climate change adaptation information on productivity. Specifically, the study characterized the pathways through which farmers in lower eastern Kenya access agro-advisories and the effect of socio-economic characteristics on access to agro-advisories. The study also went ahead to look at the policies that support the dissemination of adaptation information and lastly determined the effect of agro-advisory utilization on food productivity. To achieve these objectives, 400 farming households and 15 key informants were interviewed in lower Eastern Kenya. Thereafter, principal component analysis, multivariate probit regression and endogenous switch regression model were used to analyze the type of agro-advisories received through various pathways, the effect of socio-economic factors and adaptation information effect on productivity respectively. Further, document analysis, thematic analysis and mean ratings were used to determine the effectiveness of the existing policy regimes. Based on the study findings, both Information Communication Technologies (ICT) and face-to face interaction sessions are used to receive agro-advisories. Several factors; gender, age, ownership of phones and radio, occupation of the household head among other factors significantly determined the pathway used to access agro-advisories. On policies, institutional arrangements and funding were the least effective instruments supporting information dissemination. The uptake of adaptation information entailing soil/water conservation and crop/varietal adjustment had a significant positive impact on productivity. The study therefore recommends that other types of adaptation information such as environmental protection are included in agro-advisories, the significant socio-economic factors are considered in the preparation and dissemination processes, policy instruments such as institutional arrangements, expertise and legal frameworks are improved and reinforced to ensure dissemination thus access to agro-advisories in Arid and Semi-Arid Lands (ASALs) and lastly, support that enables use of information such as provision of tolerant seeds are looked into. The findings contribute to the existing body of scientific knowledge particularly on climate change adaptation information as a decision-making tool that should be mainstreamed into farm-level planning. It additionally provides a basis for drawing and reinforcing existing policy regimes towards supporting the generation, dissemination and use of climate change adaptation information to minimize the rising risks in ASALs of Kenya hence enabling farming households across the region to make the best of every season.

CHAPTER ONE
INTRODUCTION

1.1 Background Information

The rising tides of climate change have over the past decades been a global phenomenon causing vulnerability to societies around the world (Schimdt *et al*., 2013; Falco *et al*., 2018; Thomas *et al*., 2019). With these impacts felt in the social, scientific, political and policy domains, it is the most dominating discourse of the 21st century (Olatumile & Tunde, 2019). Of the many sectors affected by climate variability and change, the effects have had a major toll on the agricultural sector particularly the frequency of adverse weather events; floods and drought (Belay *et al*., 2017; Ogenga *et al*., 2018; Malhi *et al*., 2021). Literature is in consensus that the productivity of crops has over time been compromised by climate variability and change with the tropics experiencing extreme losses creating the need to improve agricultural productivity amidst the extreme conditions (Bryan *et al*., 2013; Altieri *et al*., 2015; Kogo *et al*., 2020; Ndalilo *et al*., 2020). The impact of climate change on the yields of top ten global crops; barley, cassava, maize, oil palm, rapeseed, rice, sorghum, soybean, sugarcane and wheat ranges from -13.4% for oil palm to 3.5% for soybean (Ray *et al.,* 2019).

Amongst the most hit regions are countries in Sub-Saharan Africa due to their reliance on rain-fed agriculture as well as inability to adapt effectively because of resource constraints amidst other factors (Ochieng *et al*., 2016). In addition, this limited essential ability is because policy response is often inadequate, interventions are at times introduced without incorporation of local needs and the presence of feeble institutional arrangements (Adu *et al*., 2018). Communities across the region have thus remained livelihood and food insecure statistically at 220 million as of 2016 (Wambogo *et al.,* 2018). However, the United Nations (UN) current projections state that food production needs to double by 2050 to feed the sub-Saharan growing population (FAO, 2017). To achieve this, adaptation and mitigation are considered to be promising.

Adaptation, relatively in its infancy stages, is probably the greatest scope for action to ensure sustained agricultural production amidst climate variability and change (Niles *et al*., 2015; Muchuru & Nhamo, 2019). In the fifth assessment report by the

Intergovernmental Panel on Climate Change (IPCC), there is an emphasis on adaptation opportunities however underutilized they are (IPCC, 2014). To promote effective adaptation particularly in the agricultural sector, it is important to take note of adaptation strategies practised by farmers (Jianjun *et al*., 2015). Farmers are using low-risk adaptive technologies Nyasimi *et al*. (2017) whereas new technologies have the potential to improve their adaptive capacity (Dunnett, 2018). It is evident that farmers are less aware of these technologies. This is necessitated by inadequate information that is properly packaged and timely disseminated for action by farmers thus obstructing adaptation (Abid *et al*., 2015; Agesa *et al*., 2019). Adaptation can be achieved, but this depends on whether or not farmers are aware of technologies that will enable them to adapt. As Jirgi (2009) documents, farmers can only adopt innovations they are aware of.

Usually, adaptation information entails planting dates, irrigation needs, fertilizer application, soil conservation techniques, crop/varietal adjustments among other strategies developed periodically based on critical weather patterns like rainfall- onset, spread and cessation and temperatures (Kumari *et al*., 2016; Jaybhaye *et al*., 2018). Such information is issued to farmers in form of agro-advisories; defined as a set of well-packaged advice issued to farmers by experts through different pathways regarding what they should do or not do to maximize productivity while minimizing losses based on predictable future climatic conditions (Stigter, 2016). Such information enhances the planning of farm activities (Maini & Rathore, 2011). Better farm-level planning translates to improved practices and subsequently yields. Several success stories have been documented on the output for farmers who access and utilize agro advisories (Magwata, 2014; Arunkumar *et al*., 2015; Charkraboty *et al*., 2018; Barett *et al*., 2020).

Kenya's arid and semi-arid regions cover up to about 80% of the land mass in the country and receives slightly below-average rainfall to sustain agricultural production; a situation currently worsened by climate variability (Mutunga *et al*., 2017). Farmers in the country are left gambling between total crop failure and considerable harvest all year round thus worsening the food insecurity situation in the country, specifically among rural livelihoods. Food insecurity is therefore a major problem in Kenya standing at 36.5% across the country (FAO, 2018) with 68% being insecure in the Mt. Kenya region Mutea

et al., (2019), 98.2% insecure in Kilifi and Kitui counties Momanyi *et al*. (2019). Food security status in the country has often led to reliance on external support every year (Makoti & Waswa 2015).

According to United Nations Development Programme (UNDP) report, extreme events such as drought lead to the use of 8.0% of the Gross Domestic Product (GDP) in coping, mitigation and adaptation. The report also states that there is an increased possibility of flooding in the country and extreme drought occurrence further stating that adaptation strategies such as dissemination of climate information, soil and water conservation, crop adjustment practices and environmental protection practices are the way forward for Kenya's agricultural sector (UNDP, 2016).

One of the potent avenues for addressing the risks of food insecurity and poverty among rural livelihoods is placing a national strategy on adaptation measures including adaptation information to guide the farmers in making both strategic as well as tactical decisions at the household level Bryan *et al*. (2013) instead of a response to surprises and making decisions on ad hoc basis (Buurman & Babovic, 2016). The need for access to information has also been outlined by National Climate Change Action Plan (NCCAP).

There have been efforts by Kenya Meteorological Department (KMD) and the Arid Lands Information Network (ALIN) to disseminate climate information through various channels to ensure adaptation but this has not enabled effective access and use of the information. Adaptation remains low as evidenced by various studies as the information has proven to be less actionable, not often location-specific, inappropriately packaged, untimely and sometimes deficient (Kirui *et al*., 2014; Abid *et al.*, 2015; Agesa *et al*., 2019).

Tailored accurate, location-specific, timely-forecast and additional adaptation information have been extensively concluded to be the most appropriate way for enabling farmers to adapt to climate change effects. As documented by Barrett *et al*. (2020) agro-advisories have a greater impact when they are prepared and issued at county levels as compared to issuance at the national level. However, information given to farmers is forecast on rainfall onset and warnings of extreme events such as storms and slides with very limited agro-advisory information which doesn't effectively bridge the adaptation

gap (Ongoma & Shilenje, 2016). Therefore, there is lack of sustainable adaptation measures in Kenya despite increased rainfall variability (Stefanovic *et al.*, 2019).

Information Communication Technologies (ICT) use has evolved to be an appropriate dissemination pathway of information that enables adaptation but according to Ongoma and Shilenje (2016), the information disseminated is quite technical and very brief to allow action by farmers. Mobile M-services for example usually benefits wealthier and educated farmers as opposed to the poor rural population especially women (Krell *et al*., 2020). This creates a foundation for the dissemination of information that is simpler through alternative community-based pathways that would cater for resource-constrained and uneducated farmers. Institutions can shape information dissemination through networking with stakeholders from concerned institutions, resource mobilization and networking to ensure adaptation meets set goals (Ouma *et al*., 2018). Farmers can also get help if messages are sent to them through mobile phones on climate information, advisories and other services promptly and the information designed in such a way that it is location-specific, applicable to a particular season, crop-specific and problem-specific (Gowda & Dixit, 2015).

In Lower Eastern Kenya rainfall and temperature variations have negatively impacted the productivity of major crops grown in the area Omoyo *et al*. (2015) causing severe food insecurity in the counties statistically at 63.5% for Machakos for instance (Robinson & Kithu, 2020). The low yield has also been directly linked to inadequate knowledge of agronomic practices which are cheaper and most appropriate for the resource-constrained farmers in the region (Recha *et al*., 2012). Unfortunately, farmers in the area particularly Makueni, basically receive forecasts as information daily, weekly and seasonally (Muema *et al*, 2018). Kwena (2015) states in his report that semi- arid Eastern Kenya still lacks access to agro-advisories that would enable farmers to shift to more tolerant crop varieties and additional information that will guide farmers. However, receiving agro-advisories is just an initial step to the realization of impacts at the grass-root level. The use of agro-advisory depends on pathway used to disseminate that information Chandre & Dixit (2015) as well as the manner in which this information is accessed, the guidance offered and the interpretation given to the intended user (Wilhite *et al*., 2014). Often,

learned farmers can use information from mass media and extension (Okwu, 2011). Since it is evident the type of information that is usable to literate farmers, it is important to find pathways that enable use for the less literate farmers.

Lastly, Ouma *et al*. (2018) argues that for efficient adaptation to be realized, there is a need to include it in the mainstreaming of policies. The recognition that policies have the potential to stir greater depths in adaptation is needful (Eriksen *et al*., 2011). Further, Kenya needs policy and institutional changes to enhance adaptation (Ziervogel & Ericksen, 2010). Preferably, policy and institutional changes that enhance information flow in adaptation would be extremely useful (Lybbert & Sumner, 2010). Therefore, proactive approaches that combine institutional policy solutions and promising technology options at both the national and community levels would be very influential (Shiferaw *et al*., 2014). Adaptation policy for instance should be channeled towards meeting information needs such as advisories.

Based on this available literature, this study assessed the pathways through which farmers in the study area access timely disseminated location-specific agro-advisories that enable them to adapt and improve productivity. In addition, it highlights the socio-economic environment in which different pathways are accessed. The study also estimated the impact of agro-advisory use on farm-level output. Finally, the study analyzed the existing policy regimes for their effectiveness in supporting the dissemination of climate change adaptation information. Policy-related findings are meant to provide policy makers and other stakeholders with policy options and choices, further information upon which they can anchor their arguments and a rationale for alternative policy selections (Burton *et al*., 2002). These areas formed the basis for this study.

1.2 Statement of the Problem

Climate change has had adverse effects globally thus not exceptional to Kenya. In Kenya, the problem is prevalent in ASALs among rural households who rely on rain-fed agriculture that is dependent entirely on natural resources. Owing to the reliance on rain-fed agriculture, current climate extremes have caused low agricultural productivity leading to severe food and livelihood insecurity. This has deterred the country from achieving its various goals such as the sustainable development goals 1, 2, and 13 on

poverty elimination, zero hunger and climate action respectively. This is because rural areas have the largest population living under poverty lines and food insecurity statistically at 51% of the rural households. This inability of rural farmers to sustain their major source of income has been exuberated by low adaptive capacity. County government in partnership with rural development agencies disseminate seasonal agro-advisories to farmers in the region yet productivity still remains low. This study assessed whether farmers access agro-advisories, the type of this information accessed and equally determined whether agro-advisories improve agricultural productivity. The study narrowed to randomly selected wards in Machakos, Kitui and Makueni Counties of lower Eastern Kenya which are part of ASALs in Kenya to enable effective appraisal.

1.3 Research Objectives

1.3.1 General Objective

To evaluate the effect of climate change adaptation information use on farm-level agricultural productivity by small-holder farming communities in Lower Eastern Kenya.

1.3.2 Specific Objectives

i. To characterize the existing climate change adaptation information dissemination pathways among smallholder farmers in Lower Eastern Kenya.
ii. To assess the effect of selected socio-economic factors on access to climate change adaptation information among smallholder farmers in Lower Eastern Kenya.
iii. To evaluate the effectiveness of existing policy regimes in supporting access to climate change adaptation information among smallholder farmers in Lower Eastern Kenya
iv. To evaluate the effect of up-take of climate change adaptation information on farm-level productivity among smallholder farmers in Lower Eastern Kenya.

1.4 Research Questions

i. What are the existing climate change adaptation information and dissemination pathways used by smallholder farmers in Lower Eastern Kenya?

ii. What is the effect of selected socio-economic factors on the use of different pathways to access adaptation information among smallholder farmers in Lower Eastern Kenya?

iii. How effective are the existing policy regimes in supporting the access to climate change adaptation information among smallholder farmers in Lower Eastern Kenya?

iv. What is the effect of the uptake of climate change adaptation information on farm level productivity among smallholder farmers in Lower Eastern Kenya?

1.5 Justification of the Study

The rural population is vulnerable due to its reliance on rain-fed agriculture which has been adversely affected by climate change (Ochieng *et al*., 2016). The extreme extent of vulnerability has caused poverty and food insecurity subsequently. It is in this situation that the achievement of Sustainable Development Goals (SDGs) has dimmed as the millennium development goals (MDGs) were also deterred (Mwenda *et al*., 2019). Additionally, ASALs experience high rainfall variability incidences which are at times extremely wet and sudden causing floods thus the destruction of agricultural fields and property. With projections of increased variability, the situation is expected to worsen creating the need to disseminate location-specific, timely information that would enable adaptation (Omoyo *et al*., 2015). Kenyan ASALs have been highlighted to be an important contributor to economic growth to enable the realization of vision 2030 goals. Initially, efforts were geared towards mitigation over adaptation, however, adaptation is most likely to benefit rural households of lower eastern Kenya (Muchunku, 2015). This study, therefore, contributes to the IPCC call to improve the adaptive capacity of households through improved access to information services by farmers which has been documented to be limited (IPCC, 2014). The study findings also give up-dated information required by the three Counties under study to facilitate County Integrated Development Plans (CIDP). Farmers are equally likely to benefit from agro-advisories owing to improved productivity and better agricultural related income. The findings of this study will also act as a reference for researchers and stakeholders as they look at dissemination of adaptation information.

1.6 Scope of the Study

The study was carried out in lower Eastern ASALs of Kenya specifically the Counties of Kitui, Machakos and Makueni. The region was chosen because it is one of the areas most affected by climate variability and change yet its population depends on agriculture as the main source of food and livelihood. Also, information collected from both key informants and households was within the geographical location of Kitui, Machakos and Makueni. Interviews conducted with government officials gave information on policy effectiveness in enabling information dissemination.

However, the scope of the study was also narrowed to the information it intended to pursue. The study specifically evaluated the pathways through which farmers get adaptation information for production and not climate information entailing forecasts.

Policies considered are those under implementation for a period and not drafts or policies passed in June 2021.

1.7 Limitations of the Study

The study narrowed to adaptation policies whereas there could be other policies working on information dissemination as well. This study might have generated limited data therefore other evaluations should integrate other related policies working on communication of information such as ICT policy for an entire conclusion.

Besides, the findings are limited to the wards studied due to financial limitation amidst other factors. The outcome may vary with geographical locations away from lower eastern Kenya.

There was also little information on access and use of agro-advisory information in Kenya so the study made most of its references to other countries. A similar problem was also encountered in finding the relationship between agro-advisory uptake and farm productivity in Kenyan literature.

Understanding the drivers to specific pathways of information access is limited to analysis of the selected socio-economic factors included in this study therefore any generalization with any other factors should be done with this limitation in mind.

CHAPTER TWO
LITERATURE REVIEW

2.1 Climate Change Adaptation Information

Adaptation to climate change has been significantly reported as low by most studies. This shows that farmers are either not aware of new technologies or the way the information is packaged and delivered doesn't enable access and use for the majority of the farmers. Sangeetha *et al.* (2016) states that with the spread of mobile use, it can be used as a source of information to create awareness on improved cultivation practices disseminated as agro advisories. However, other pathways may also be useful in the dissemination of climate advisories.

Bendapudi *et al*. (2019) in an Indian study documented that agro-advisory information comprising of the location-specific crop, water, pest and other environmental and organic management interventions were issued to farmers in the local language fortnightly. The pathways used were mobile phones in form of Short Message Services (SMS), television, radio, wall papers and face-to-face interactions. About 88% of respondents in this particular study received information through SMS, 72.5% by television and 55% was from inter-personal interactions between farmers.

Muema *et al*. (2018) found out that 82.96% of farmers used radios, 9% used television, 2% received information from friends and relatives,0.9%,0.45%, 0.45%, 0.45%, 0.45% used peer farmers, cell phones, baraza meetings, printed media and extension services respectively to access climate information in Makueni County. However, agronomic advice received entailed flexible farm operations, crop adjustment factors and seasonal forecast only.

In Machakos, barazas conveyed advisories and alerts to 56% of farmers. The reliability was however dwindling as reported by 65% of farmers. The most accessible climate information was daily weather forecasts received by 97% of farmers through radios. This study only looked at advisory dissemination through barazas while shifting the rest of the focus to climate information entailing forecasts (Gichangi *et al*., 2015).

A study in Kisii-Kenya documented that ICT (68%), extension agents (22%), farmer groups (2%), barazas (3%) and field days (5%) are the major pathways through which farmers receive agro climate information (Wamalwa *et al*., 2016). The above-mentioned studies either did not state the type of agro-advisory received, or did not conduct Principle Component Analysis (PCA) or other methods to document the type of agro-advisories these pathways conveyed to find out what information they are specific to.

2.2 Adaptation Information Access and Socio-economic Factors

Environments in which adaptation information is set for an issue have various unique characteristics that define, how and to what extent information is received. However, all these factors have not been studied for the level of effect on access to adaptation information. However-much information is issued, there is a need to understand the social and environmental context under which the information is issued (Vaughan & Dessai, 2014). In addition, different pathways used to disseminate information determine who can access the information. There is a clear realization that for farmers to adapt to climate change, there is need to make the information practical by either the way it is issued, the language, the population target for example women, as it has been evidenced by numerous studies that they are the most participants in agricultural production yet as Mbevi, (2015) documents, extension agents tend to ignore women. Pathways that will consider this type of group should therefore be considered.

Muchunku (2015) in a Kitui County study looked at the relationship between community seminars and chief baraza and gender and age of respondents. The study findings showed that there was no significant effect of age on the chief baraza pathway but there was a significant effect of the literacy levels on use of the pathway. This study was however specific to opinion leaders and the socio-economic factors considered were gender, age and literacy levels. This did not provide conclusive results on socio-economic factors' effect on different pathways through which households' access information. In addition, Mugi-Ngenga *et al*. (2016) affirms that Kitui farming households have their adaptation-related decisions made by household heads and therefore it is useful to consider relating age, gender, education level amidst other factors to household heads and not just the respondents giving information; a factor this study put into consideration.

In Wajir, pastoralists with low education levels often used radio to access climate information. This was coupled with various reasons such as the availability of the item as well as the fact that vernacular was used enabling a better understanding of the information (Ndavula & Lungahi 2018). Education level having a significant impact on the use of mobile phones in the access to advisories was also reported in a study conducted at southern Indian State of Karnataka (Gowda & Dixit 2015). However, majority of the farmers included in this study were graduates followed by those educated till intermediate level. The findings of this study does not cut across many regions since majority of the farmers are less educated especially in a place like Kenya.

In a different study conducted in Ethiopia and Kenya, ownership/access of ICT tool, extension contact and frequency of extension were significant in determining the use of Short Message Service (SMS), radio and newsletters sources of agro-advisories. Group membership was found to be significant in explaining access to information through Interactive Voice Response (IVR), newsletters and SMS. The study used multivariate regression to determine these factors which does not cater for correlation in the case of simultaneity of use in pathways (Oladele *et al.,* 2018). In a different study, Getnet *et al*. (2014) reported that years of education, age, participation in trainings and the behaviour of pursuing information were significant elements in use of ICT to access information among farmers in Ethiopia.

2.3 Climate Change Adaptation and Policy Regimes

Policy regime is a construct to describe governing arrangements established within complex policy areas to direct disparate interests towards a mutual policy objective with the analytical lens being ideas that instill purpose of the policy, institutional design that regularizes policymaking and integrates elements of multiple policy subsystems and interests that either support or oppose the relevant policies (Henstra, 2017). Schmidt *et al*. (2013) stated that one underexplored area is the role of policy in facilitating adaptation to climate change. United Nations Environmental Programme (UNEP) in their report also strongly emphasizes on policy oriented knowledge of adaptation for either lessons or success (Biesbroek *et al*., 2018). Based on this review it is important to consider a policy approach to climate change adaptation, especially support for information dissemination.

A comparative case study done in India found a deficit in the implementation of climate change adaptation policies. In India, the two policies under study were found to clearly depict the problem, the policy goal was also clearly defined. However, in the implementation, the policies were less effective as several limiting factors were noted thus having a limiting impact on the policy. Some of the problems included lack of adaptive capacity in the implementation context (Dupuis & Knoepfel, 2013).

A comparative analysis on adaptation policies in different countries in Latin America through "incremental perspectivism" showed different perceptions of the respondents on knowledge gaps in the development of adaptation policy. Nearly 80% of the respondents noted deficits in the effectiveness of adaptation policies in the costs and benefits of implementation as well as the measures put in place. The study also found out from 50% of the respondents that weak state capabilities was the main barrier in the adaptation policy monitoring and assessment (Ryan & Bustos, 2019).

In a study conducted in Ethiopia simulating effectiveness of different policy interventions that enable farmers adapt to climate variability and change, the policy interventions that promoted innovated crop varieties appeared effective. The interventions included perfect communication of required technological information through extension, expansion of credit and fertilizer subsidy (Berger *et al*., 2017).

In Kenya, findings show that different climate change adaptation related policies such as the Rangelands Management Policy (RMP) which incorporates the ASALs policy has objectively looked into diversification of livelihood systems in those areas, improved the condition and productivity of degraded lands by providing drought tolerant crops and disseminated agricultural research results to farming communities (Ongugo *et al*., 2014).

From the foregoing cases, there is limited literature on effectiveness of policy regimes in facilitating information dissemination in Kenya. Additionally, few studies narrow to the policy instruments documented to have effect on adaptation policies. This was the motivation of the study.

2.4 Climate Change Adaptation Information Uptake and Farm Productivity

Agro-advisory programmes administered through extension services, group meetings and farmer field schools are usually expected to improve farmers' skills in the production process (Romani 2003). With improved skills, the adoption of new technologies is enhanced thus the link between research and expected change in farmers' behaviour is achieved (Evenson, 2001). The improved skills are translated to better yields and enhanced livelihoods compared to those who are not aware of agro-advisories (Jagadeesh *et al*., 2010; Maini & Rathore 2011). This is usually the ultimate goal of disseminating agro-advisories; to improve efficiency in farm-level production.

A study in Quebec that used propensity score matching to derive the effect of agro-advisories on environmental management practices on farm income found an increasing effect (Tamini, 2011). Similarly, Lapple *et al*. (2012) also found a positive return to group membership. The study estimated gross margins for group members and the case for non-membership among dairy farmers in Ireland. In a different study in Visakhapatnam, findings showed that there was improved growth, quality and yield of cane for farmers who received agro-advisories by 27.8% as compared to farmers who had no access to similar advisories (Kumari *et al.,* 2016). Similarly, in Nigeria, climate information has been reported to improve cropping practices and income among farmers. The findings show that income increases within a range of +1.8% to +1.3% depending on the type of farmer among millet farmers (Roudier *et al*., 2016).

Using propensity score matching, Issahaku *et al*. (2018) found that technologies issued through mobile phones improve productivity for user-farmers by 261.20kg/ha in every season. Similarly, a study in Pakistan reported increase in wheat productivity among farmers who accessed agro-advisories from multiple sources compared to those who accessed from a single source (Elahi *et al*., 2018). The above mentioned studies have major shortcoming of; narrowing to specific crops while agro-advisories advocate for diversification, considering climate information entailing forecasts, looking at effect of agro-advisory from the pathway point of view and not the specific technologies and lastly, using models that do not control for selection bias. These are key aspects this study put into consideration.

In Kenya forecasts and agro-advisories are dissemination by KMD (KMD, 2014; 2014a). However, the economic valuation of these agro-advisories is yet to gain robust valuation in developing countries such as Kenya. In lower eastern Kenya, agro-advisories provide a collection of information to farmers ranging from crop, soil, livestock and environmental management practices disseminated through various pathways. It is against the weaknesses of the above reviewed studies, this study sought to document the effect of agro-advisories accessed and used from various pathways.

2.5 Summary of Research Gaps

The dissemination of agro advisories to farmers is currently an area of interest. However, studies still tend to focus on climate information that entails forecasts and warnings Muema *et al*. (2018); Yohannis *et al*. (2019) which have proved less successful in enabling adaptation and resilience of farming communities. Besides, the environment in which information is disseminated greatly determines who access the information that enables its use for quantifiable impact Vaughan & Dessai, (2014). However, there is limited literature on the effect of socio-economic factors on different pathways through which adaptation information is disseminated. Besides, policies that enforce adaptation play a key role in information access. Yet, the role of policy in adaptation has received little emphasis Dupuis & Knoepfel (2013) with the implementation phase being the major weakness deterring adaptation Ryan & Bustos, (2019). There was therefore need to evaluate the existing policy regimes and document how effective they are in ensuring dissemination of adaptation information as the available literature has looked into provision of seeds and dissemination of research findings (Ongugo *et al*., 2014). There is need to determine their role in information access which includes the ability to incorporate ICT and other platforms such as CFS use in the dissemination of adaptation information as they are widely advocated platforms. Finally, this study sought to estimate the impact of agro-advisories on food productivity which has very little literature in developing countries specifically Kenya.

2.6 Theoretical Framework

For the purpose of this study, climate change adaptation information dissemination and use will be anchored on various theories along the entire value chain. These theories

range from those based on reception of climate related information to uptake of the information. Utilization of information depends on perceived usefulness in reducing risks from climate variability and change, the ultimate goal being to improve productivity.

2.6.1 Theory of Efficient Adaptation

This theory explains how a decision making entity such as a household (firm) responds to climate change. Usually, physical changes in climate variability and change such as temperature and rainfall variations always impact on farmers' decisions. This comes when farmers are aware that they are vulnerable to climate change thus prompting responses in form of adaptation. Impact of climate change should have been seen on production for instance when farmers notice there is reduction in yields and see the need of altering the situation (Mendelsohn, 2012).

Farmers decisions are geared towards maximizing profits or returns as expressed in the following equation:

$$Max\ \pi = P_q Q(Z, C) - \sum P_z\ Z, \tag{2.1}$$

Where $P_q$represents the price of output Q, P_z represents the price of purchased inputs Z, and $Q(Z, C)$ is a production function. In profit maximizing firms, climate enters the production function and alters the relationship between inputs and outputs. The first-order condition for the farm is to equate the price of each input to its marginal productivity as:

$$P_z = dQ\ (Z, C)/dZ \tag{2.2}$$

Where d_Q is the change in output while d_Z is the change in input.

With climate change, firms experience either decrease or increase in yields which triggers changes in inputs as the marginal productivity of the inputs change. In extreme cases, the firm shifts output as well. For example, if increasing temperatures make one output less profitable when compared to another, there is the likelihood of a shift to the profitable output. In such an instance, farmers shift to different crops or animals with the effects of climate change.

In this particular study, the farming households were considered as the firm taking various decisions that would sustain agricultural production amidst varying climatic conditions. The decisions may include shifting to drought tolerant varieties increase of organic fertilizer use among other strategies.

2.6.2 Theory of Diffusion of Innovation

The study was also anchored on the theory of diffusion of innovations. Diffusion is the process by which an innovation or technology is communicated through certain channels over time among members of a social system while innovation is an idea, practice or object perceived to be new to an individual or other unit of adoption (Wani & Ali, 2016). According to the theory, technological innovations have advantage for its potential adopters who utilize information based on awareness. This is also dependent on the relevance of the source and its appropriateness to the farmers (Rogers, 2010). The theory of diffusion of innovation has been emphasized by Adebayo and Oladele, (2012) in explaining adoption of innovations. This theory was used to explain findings on how dissemination of adaptation information from different pathways is accessed by farmers.

2.6.3 Policy Theory

Theory of policy can either be under certainty or uncertainty. Under certainty, to achieve x targets, x instruments are required. According to the theory, structural changes in policies alter the magnitude of response to policies. In addition, when structural changes proposed for a policy enables higher scores in terms of utility, then it is presumed that the change proposed improved the effectiveness of the policy (Brainard 1967). This theory was used to explain the policy instruments considered vital in supporting agro-advisory preparation and dissemination hence access with specific emphasis on how the recommended changes will bring change; in this case, access to agro-advisories.

2.7 Conceptual Framework

Adaptation strategies refer to actual adjustments which ultimately are aimed at enhancing resilience to the observed climatic variability and changes in decision environments (Korir & Ngenoh, 2019). Households vulnerable to climate variability and change usually depend on resource availability, characteristics of the household, social networks, political institutions available as well as the household's environmental context to enable them adapt (Speranza *et al.*, 2014). Pathway through which farmers receive adaptation information were evaluated as well as the household characteristics that enable both access and use of information ultimately.

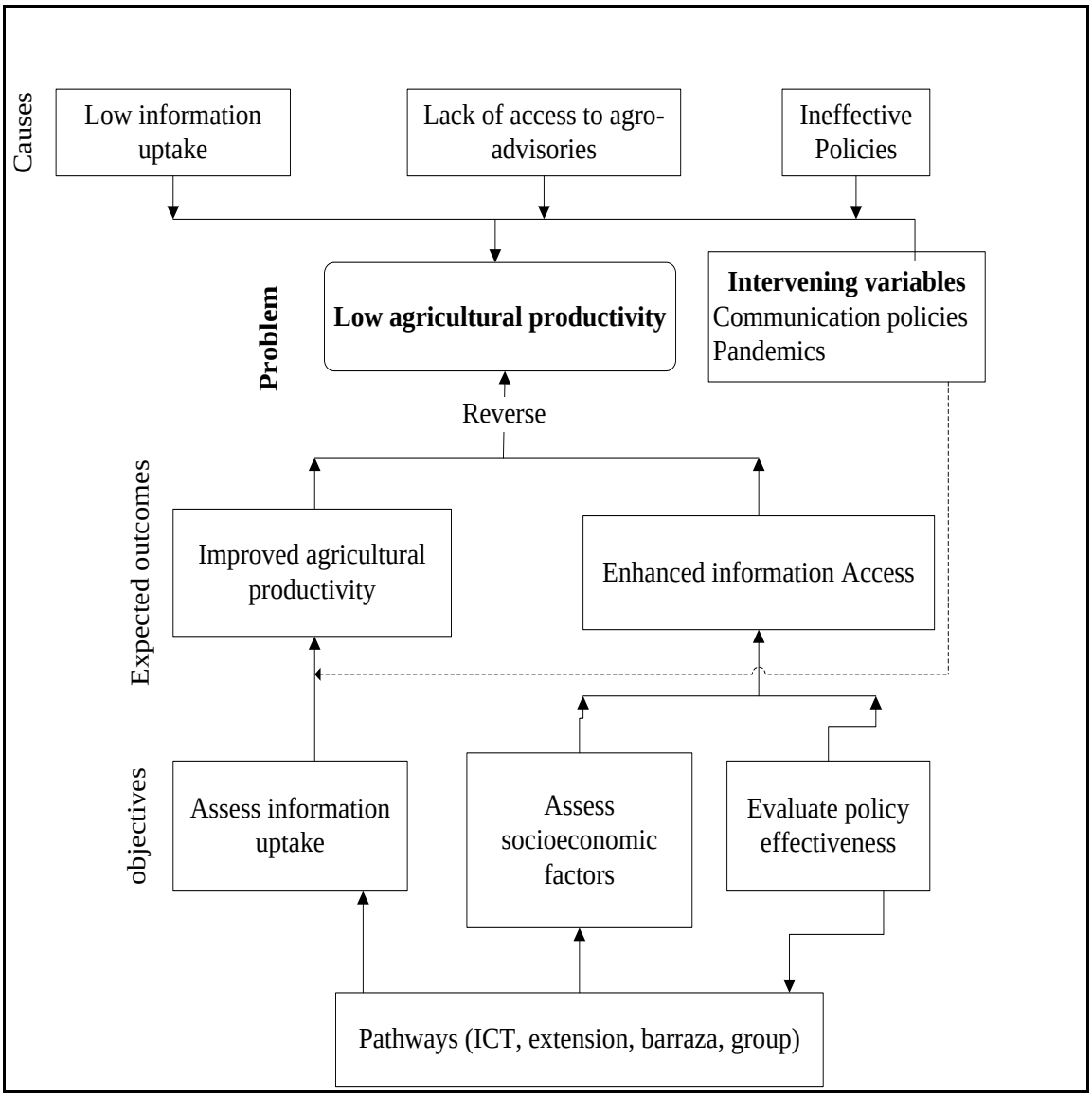

Figure 2. 1 Conceptual Framework

Low information access, ineffective policy implementation to facilitate information access, and low uptake are presumed to be the drivers of low agricultural productivity in Lower Eastern Kenya. This study therefore intervenes to assess the socio-economic environment in which the information is expected to have an impact and to project the productivity expected for the case of uptake of various adaptation strategies disseminated in the region**.**

CHAPTER THREE
METHODOLOGY

3.1 Description of the Study Sites

The study was conducted in Machakos, Makueni and Kitui Counties of Kenya (Appendix II). The three counties lie in the lower eastern region which gradually becomes drier to the East. Makueni County is an ASAL prone to recurrent droughts. It lies between Latitude 1^0 35' and 30 00 South and Longitude $37^0$10' and 38^0 30' East. Towards the lower sides, the rainfall ranges from 300mm-400mm which hardly supports agriculture that is the main economic activity in the County. The major agro zones in the county are Lower Highland (LH) 2, Upper Midland (UM) 2, 3, 4 and 5, Lower Midland (LM) 3, 4 and 5 with the predominant crops being maize, beans, mangoes and vegetables commonly grown in the area (RoK, 2017).

Kitui County is located between latitudes 0°10 South and 3°0 South and longitudes 37°50 East and 39°0 East. It is generally a low lying region experiencing arid and semi-arid climatic conditions. The County experiences unreliable and erratic rainfall that ranges between 250-1050mm yet its economy is largely dependent on agriculture. The entire County's population is thus absolutely food insecure. The County consists of nine agro zones UM 3 and 4, LM 3,4 and 5 and the IL 5 with the major crops being coffee in the UM 3 zones, sunflower, dryland maize, pigeon pea, cow peas and millet (RoK, 2018).

Machakos County lies between latitudes $0^0$45' and $1^0$31' South and longitudes $36^0$45' and $37^0$45' East. Annual rainfall distribution in the County is generally unreliable and unevenly distributed. Common crops grown in the county are maize, beans, pigeon peas and cassava among others. Climate change continues to impact negatively on the general economic growth of the county and particularly in the agricultural sector that depends largely on rainfall (RoK, 2015). The challenge facing the County is on how to maximize on the seasonal rainfall. Despite this challenge, agriculture still contributes to 70% of household incomes. The County is categorized into five agro-ecological zones founded on crop production potential (Jaetzold, 2010). The two Sub-Counties selected for this study Machakos town/Kalama and Kangundo are dominated by LM 3 and 4 with major food crops being maize, beans, pigeon peas and cow peas.

3.2 Research Design

This study adopted a cross-sectional survey design. Both qualitative and quantitative data was gathered. Qualitative information was collected from farming households which was the sampling unit, through questionnaires and face-face interviews. The respondents gave information on access of adaptation information as well as the dissemination pathways through which they received usable information. They also stated whether the information received was practiced in their farms. Qualitative information was gathered from key informants in respect to the effectiveness of the existing policy regimes at the county level.

3.3 Target Population and Sample Size

The study targeted smallholder farming households and key informants of lower eastern Kenya. The sample size for farm-level interviews was determined using (Cochran, 1977) formula:

$$n = \frac{Z^2 pq}{d^2} \qquad (3.1)$$

Where: n = desired sample size

Z = standard normal deviate at the needed confidence level,

P = the estimated proportion of the target population having the characteristics that are desired

q = 1-p =the proportion of population without desired characteristic being measured

d = level of statistical significance established

In this study, the standard deviation was set at 1.96 which tallies 95% level of confidence. Since there was no estimate of the population with characteristics of interest, the assumption was that at least 50% have the desired characteristics. The sample size was thereafter calculated as:

$$n = \frac{(1.96)^2(0.5)(1-0.5)}{0.05} = 400$$

On the other hand, fifteen informants drawn from the government departments including the Ministry of Agriculture (MoA), Kenya Climate Smart Agriculture project (KSCAP); National Drought Management Authority (NDMA); Ministry of Environment, Natural Resources and Climate Change (MoE); County Meteorological Departments (CMD); National Agricultural and Rural Inclusive Project (NARIGP) and Agricultural Sector Development Strategy Programme II (ASDSP II) were interviewed with a specific mandate in policy matters that facilitate climate change adaptation. The interviewees were selected by virtue of competence, experience and knowledge of both the study area, climate change adaptation and policy implementation. The interview aimed to provide qualitative data on the adequacy of existing policy regimes in the timely dissemination of weather-based agro advisories at the County levels. Desktop research was also used to scrutinize and get a clear picture of the policy documents. The fifteen key informants interviewed mirrored from the concept of saturation as stated by (Mason, 2010). In addition, as argued by Dworkin (2012) 5 to 50 participants are considered adequate for any qualitative research depending on factors such as nature of topic, the quantity of useful information obtained from a single participant among other factors holistically referred to as conceptual models.

3.4 Sampling Procedure

The study used purposive sampling in the first step. Multistage sampling was then used procedurally as outlined below:

First, six sub-counties were purposively selected from the three Counties based on the dominant agro zone with specific emphasis on Lower midland zones (Machakos town/Kalama, Kangundo North, Mwingi Central, Kitui South, Makueni and Kibwezi west). One ward was then randomly selected from each sub-county making six wards. In the six wards, a sub-location was randomly selected giving a total of 6 sub-locations. Two villages were then randomly selected from each sub-location giving a total of 12 villages. With the help of assistant chiefs and village elders, the number of households in every village sampled was established and sampling frame prepared. Specific households included in the study were randomly selected from the sampling frame.

Table 3. 1: Households Interviewed

County	Sub-County	No. of respondents
Machakos	Machakos Central/Kalama, Kangundo North	194
Makueni	Makueni, Kibwezi West	115
Kitui	Kitui South, Mwingi Central	91

3.5 Reliability and Validity of the Instrument

Cronbach's alpha was used to measure the internal consistency, accuracy and dependability of questionnaire. A total of 40 questionnaires collected before the actual study were tested. The conformity of the answers to the expected results was confirmed as the reliability coefficient was 0.74 and since the cut-off value for an acceptable coefficient is 0.7 the tool was used for collecting data (Bonett & Wright, 2014). The key informant section was however modified to suit output needs.

3.6 Econometric Models Used in Data Analysis

Data analysis was done using both quantitative and qualitative approaches. Statistical Package for Social Sciences and STATA were used to analyze data in line with the study objectives. The research questions of this study were answered using PCA, MVP, thematic analysis, document analysis and ESR.

3.6.1 Characterizing of Adaptation Information and Dissemination Pathways

Karl Pearson's Principle Component Analysis (PCA) has been used to characterize adaptation information received for each pathway used. This is a data reduction process that condenses original correlated variables into independent variables termed Principal Components (PCs) with each PC having factor loadings referred to as Eigen values (Abdi & Williams, 2010). Varimax rotation with Kaiser Normalization was used parallel to Mairura *et al*. (2007) to confirm the appropriateness of PCA (Field, 2005; Lattin *et al*., 2005). The rotation method enhances loading of smaller number of highly correlated variables for each principle component (Field, 2005). PCA has been used in other characterization studies such as Cherotich *et al*. (2012). Eigen values included were above 0.4 to reduce noise following the assumption that the largest Eigen values contain the most meaningful information (Wold *et al*., 1987). The results have been presented to

show the pathways through which adaptation information is accessed as well as the different adaptation information received.

3.6.2 Socio-economic Factors and Adaptation Information Dissemination Pathways

Pathways used to access climate change adaptation information were multiple. Some of the pathways used to access information found out in this study included radio, mobile, extension, chief barazas and social groupings. These pathways were used by farmers simultaneously. Therefore, the random error components of the different information sources under study were correlated. Multivariate probit model was therefore considered as it allows for related correlation in the use of the five different pathways to access information concurrently (Cappellari & Jenkins (2003). Multivariate probit estimation has been used to assess factors that influence adoption of technologies in other studies (Jenkins, 2011; Mittal & Mehar, 2016; Okello *et al*., 2020).

The model is empirically specified as:

$$Y_{i1} = X_{ij1}\beta 1 + \varepsilon_{i1}$$

$$Y_{i2} = X_{ij2}\beta 2 + \varepsilon_{i2}$$

$$Y_{i3} = X_{ij3}\beta 3 + \varepsilon_{i3} \qquad (3.2)$$

$$Y_{i4} = X_{ij4}\beta 4 + \varepsilon_{i4}$$

$$Y_{i5} = X_{ij5}\beta 5 + \varepsilon_{i5}$$

Where, i= household identification, Y_{i1}=1 if household access information from mobile sources and 0 if otherwise, Y_{i2}= 1, if household access information from radio and 0 if otherwise, Y_{i3}=1 if household access information from groups and 0 if otherwise, Y_{i4} =0 if household access information from Chief Baraza and 0 if otherwise, Y_{i5} =1 if household access information from extension agents and 0 if otherwise, X_i= Vector of factors affecting access to the information pathway, $\beta_j = \beta_1, \beta_2, \beta_3, \beta_4, \beta_5,$ are vector of unknown parameters , and ε_i= is the error term. Instead of running independent probit

models under the assumption that the error terms are jointly exclusive, a multivariate probit model of the form below was used instead;

$$Y_{ij} = X'_{ij}\beta_j + \varepsilon_{ij} \quad (3.3)$$

Where Y_{ij} $(j = 1, \ldots .5)$ represented the five different information pathways used by the ith household $(i = 1, \ldots 400)$, X'_{ij} is a $1 \times k$ vector of observed characteristics that affect the choice result of a household, β_j is a $1 \times k$ vector of unknown parameters and ε_{ij} is the unobserved error term. The assumption was that the error terms (across $j = 1 \ldots, \ldots, n$ options) are multivariate and are normally distributed with mean vector equal to zero.

The unknown parameters in equation (3.3) were however estimated using simulated maximum likelihood which uses Geweke-Hajivassiliour-Keane smooth recursive conditioning simulator process to evaluate the multivariate normal distribution. The simulator feats the fact that a multivariate usual distribution function can be articulated as the product of the serially accustomed univariate normal distribution functions often simply and precisely calculated (Chib & Greenbarg, 1998).

3.6.2.1 Multicollinearity Test

Multicollinearity is the presence of linear correlation between variables Okeyo, (2020) often causing reliability problems with the estimates of a model. Correlation between dependent and predictor variables is obvious, unlike among independent variables which is often undesirable (Daoud, 2017). The presence of multicollinearity causes large standard errors which make it difficult to properly assess the relative importance of the predictor variables (Alin, 2010). Variance Inflation Factor (VIF) is one of the common multicollinearity diagnostic tests (Kumari, 2008; Kim, 2019). When the value is greater than 10, it shows the presence of multicollinearity. Weak or absence of collinearity allows one to carry out regression while in a case where variables are strongly correlated hence multicollinearity, it is eliminated by dropping the variables (Kumari, 2008). For this particular study VIF was used to test multicollinearity (Appendix I).

3.6.3 Effectiveness of Existing Policy Regimes in Facilitating Dissemination of Adaptation Information

The objective was conducted in two aspects. The first part involved analysing key policy documents. Document study is used to explain arguments based on written information evidenced by literature and can either be personal or official. In this study official policy regime documents were scrutinized based on the fact that they adequately provide the governments intent in line with climate change adaptation which includes creating awareness through dissemination of climate adaptation information. Policy document analysis for climate related policies has been conducted in other studies like (Kwena *et al*., 2015; Di Gregorio *et al*., 2016; Ampaire *et al*., 2017). The second part involved interviewing stakeholders and key informants including policy makers drawn from various government departments at the county level. Five policy instruments relevant to climate change adaptation as outlined by Henstra *et al*. (2016) were part of the quantitative information collected. Three aspects of policy effectiveness were considered drawing from Underdal, (2004); no regime case, actual performance and collective optimum. Ordinal scale of 1-5 was used whereby, No regime was represented by 1, values in between represented the actual performance of each instrument according to the current policies and lastly, 5 represents what is achievable by an adequate/effective policy for adaptation labelled as collective optimum. The actual performance was based on key informant judgement. Mean ratings was used to determine the most and least effective instruments in the existing policy regimes and recommendations given. Thematic analysis was also used to show key aspects such as the presence of policies, platform for information dissemination and information sets disseminated.

3.6.4 Effect of Climate Adaptation Information Uptake on Productivity

Assessing the impact of using adaptation information on farm productivity requires that potential endogeneity is accounted for. To avert the occurrence of self-selection bias, adopter and non-adopters of the information are not compared. Instead, using the model, the study derives an estimated impact of information use through conditional expectations which would have occurred if the farmers had not practiced information. This projected outcome is compared with the actual case. The endogenous switching

regression (ESR) method begins by modelling selection of crop/varietal adjustment and soil and water conservation. Thereafter, the outcome of interest which in this case is the value of output per acre is modelled for both adopters and non-adopters of these information sources.

Theoretically, a household uses information received if the expected utility derived from the use (U_1^*) is greater when compared to utility derived from non-use(U_0^*). Use of information is observed but projected utility is unobserved. U is therefore treated as a dichotomous variable whereby $U = 1$ if information is used and $U = 0$ if otherwise. Therefore, the adoption of information decision can be modelled as;

$$U_i^* = Z_{\alpha i} + \varepsilon, \text{with} \quad U_i = 1 \text{ for use and 0 if otherwise} \qquad (3.4)$$

Where Z represents explanatory variables, α is the vector of parameters to be predicted, and ε is a normally spread error term with mean of zero and variance σ_ε^2 .

It is also anticipated that the use of information affects farm productivity. Based on this, a different equation of outcome is modelled for adopters of information and non-adopters

$$y_{1i} = X_{1i}\beta_1 + \varepsilon_{1i} \text{ If } U_i = 1, \qquad (3.5)$$

$$y_{0i} = X_{0i}\beta_0 + \varepsilon_{0i} \text{ If } U_i = 0, \qquad (3.6)$$

Whereby y_j designates value of output for adopters and non-adopters of information, X_j represents explanatory variables while β_j is a vector of the parameters estimated. The selection problem comes in if the error ε in the equation (3.4) is interrelated with the error ε_1 and ε_0 of the aftermath equations (3.5) and (3.6). This simply means that if unobserved factors such as capability and skills affect the choice of adopting adaptation information and farm output, the estimated parameters β_j will turn out biased.

Full Information Maximum Likelihood (FIML) assessment suggested by Lokshin & Sajaia (2004) which simultaneously estimates selection and product equations using the *movestay* command was used. FIML method estimates the selection (use of information) and the outcome (farm productivity) equations to yield steady estimates. ESR requires that a variable considered correlated with adaptation information but has no effect on outcome (productivity) is exclusively restricted. In the first test, probit model is run for

adaptation information, the instruments and other variables. In the second case, as documented by Di Falco *et al*. (2011), a falsification test is carried out to discover whether the instruments played an essential role in production. In this study, farming experience was used as the instrumental variable. It is hypothesized that farming practice over the years shows a long term commitment and interest in farming and therefore could make the farmer to access and put into use innovative information. The variable was therefore considered as a valid selection instrument that is not statistically significant when included in an Ordinary Least Squares (OLS) regression on output per acre.

3.6.4.1 Treatment Effect of Adaptation Information

The endogenous switch regression model was used to relate the expected output of farmers who practice adaptation information received and counterfactual case for members who do not practice information. According to Maddala (1983) the conditional expectations and counterfactual cases are computed as follows:

$$\text{Adopter } E(Y_{1i}|U_i = 1) = X_{1i}\beta_1 + \sigma_{\varepsilon_1\epsilon}\lambda_{1i} \quad (3.7)$$

$$\text{Non-adopter } E(Y_{0i}|U_i = 0) = X_{0i}\beta_0 + \sigma_{\varepsilon_0\epsilon}\lambda_{0i} \quad (3.8)$$

In a parallel fashion, the equation modelled for counterfactual yield for adopters and non-adopters of the information sources is:

$$\text{Adopter counterfactual } E(Y_{0i}|U_i = 1) = X_{1i}\beta_0 + \sigma_{\varepsilon_0\epsilon}\lambda_{1i} \quad (3.9)$$

$$\text{Non-adopters counterfactual } E(Y_{1i}|U_i = 0) = X_{0i}\beta_1 + \sigma_{\varepsilon_1\epsilon}\lambda_{0i}$$

The change in farm output due to uptake (return to adaptation information) was calculated with reference to Carter & Milon (2005); Heckman *et al*., (2001). The change is often referred to as the Treatment on the Treated (TT).

$$TT = E(Y_{1i}|U_i = 1) - E(Y_{0i}|U_i = 1) = X_{1i}(\beta_1 - \beta_0) + (\sigma_{\varepsilon_1\epsilon} - \sigma_{\varepsilon_0\epsilon})\lambda_{1i} \quad (3.10)$$

The average farm output for the non-adopters also referred to as Treatment on the Untreated (TU). This difference in outcome if non-adopters had similar characteristics as those of adopters (Shiferaw *et al*., 2014).

$$TU = E(Y_{0i}|U_i = 0) - E(Y_{1i}|U_i = 0) = X_{0i}(\beta_0 - \beta_1) + (\sigma_{\varepsilon_0\epsilon} - \sigma_{\varepsilon_1\epsilon})\lambda_{0i} \quad (3.11)$$

3.7 Operationalization of Variables

Several studies have demonstrated that these factors such as age, income and education level often predict farmers' decision to make a choice among information sources (Ali & Kumar, 2010; Jenkins *et al*., 2011; Mittal & Mehar, 2016; Okello *et al*., 2020). The table below gives variables that guided the study and their respective measurements. The outcomes stated are predictions of expected outcome.

Table 3. 2: Variables Included in the Study and their Measures

Variable	**Measure**	**Nature Of Variable**	**Expected Outcome**
Access	1=Yes 0=No	Dichotomous	+
Productivity	Value per acre	Continuous	+
Information uptake	1=Yes 0-No	Dummy	+/-
Age of HHH	Years	Continuous	+/-
Gender of HHH	1=male 0=female	Dummy	+/-
Education level of HHH	Level of education attained	Categorical	+/-
Household size	Numbers	Continuous	+/-
Main occupation of HHH	1=Farming 0=non-farming activities	Dummy	+/-
Secondary occupation	1= Casual laborer 0=others	Dummy	+/-
Farm size	Acres	Continuous	+/-
Land ownership	1=Yes 0=No	Dummy	+/-
Household income per month	Kenyan shillings	Continuous	+/-
Food source	1=farm 0= bought		
Farmer experience	Years	Continuous	+
Distance to Market	Kilometers	Continuous	+
Frequency of extension	1= monthly 0=otherwise	Dummy	
Other pathways	1=Friends and agro-vets 0=No	Dummy	
Radio	1=Yes 0=No	Dummy	+
Mobile	1=Yes 0=No	Dummy	+
Baraza	1=Yes 0=No	Dummy	+
Group	1=Yes 0=No	Dummy	+
Extension	1=Yes 0=No	Dummy	+
Effectiveness score			
Expertise	1-5	Likert scale	+
Institutional arrangement	1-5	Likert scale	+
Funds	1-5	Likert scale	+
Legal framework	1-5	Likert scale	+

CHAPTER FOUR

RESULTS AND INTERPRETATION

4.1 Socio-economic Characteristics of the Households

The socio-economic factors considered were related to resources owned by particular households and the characteristics of the household head. The results (Table 4.1) show the socio-economic factors of the sampled household. Majority of the household heads were male headed (81.7%) with a few female headed households (18.3%). This implies that most households in the region are headed by males who are most likely the decision makers on farming.

Most of the household heads were aged between 38-57 years (38.6%), with the youth comprising only 17.6%. Most of the household heads (55.7%) had attained at least primary level of education, implying low literacy levels. Low literacy level could be a hindrance to the understanding and use of agro-advisories. This calls for simplified information in a language that can be easily understood. In addition, information relayed in the local language (Kikamba) would be more preferable for this population. Majority of the household heads (52.8%) have their main occupation as farming. This emphasizes the need to improve agricultural related incomes of these households whose heads rely on farming. Adaptation information is thus vital to the community.

With respect to household monthly income, majority (70.8%) had less than 20,000 Kenyan shillings. This indicates high poverty levels. These farmers would resolve to information sources that are affordable such as attending extension training sessions. Modern ICT could be a challenge to this group of farmers due to the cost of getting information in case of the need for any form of payment. More than half (53.2%) of the households had a range of 4-6 members confirming (KNBS, 2019) findings on an average of 4 members per household in lower eastern Kenya. This number provides arguably enough family labour for farming activities. Most of the households owned 2-3.9 acres of land.

Table 4. 1: Socio-economic Characteristics of the Households

Variables	Frequency/Measure(n=400)	Percentages (%)
Gender		
Male	327	81.7
Female	73	18.3
Marital status		
Married	326	81.5
Not married	74	18.5
HHH age		
18-37	71	17.8
38-57	175	43.8
Above 58	154	38.4
Education level		
Non-formal	27	6.8
Primary	223	55.7
Secondary	111	27.7
Tertiary	39	9.8
Main occupation		
Farming	211	52.8
Other occupation	189	47.2
Secondary occupation		
Casual labourer	203	50.7
Others	197	49.3
Household size		
1-3	79	19.8
4-6	213	53.2
7-9	92	23
11-13	16	4
Income		
Less than 20000	284	70.8
20001-40000	84	21.3
420001-60000	28	7.1
Above 60000	4	0.8
Farm size		
0-1.9	109	27.3
2-3.9	144	36
4-5.9	88	22.1
Above 6	59	14.6

HH- HouseHold, HHH- Household Head

4.2 Institutional Characteristics of the Farming Households

Institutional factors are factors linked to bodies that deliver services such as extension, infrastructure, technology and credit (Ndirangu, 2017). For this study, market distance, CFS trainings and frequency of extension contact were included in assessing adaptation information access. Majority of the households cover 4 to about 8 kilometers to access a market. This is relatively a longer distance that could hinder adaptation especially in the access to drought-tolerant varieties or even physical extension services hence ICT could be suitable. However, extreme cases such as poor radio frequencies may be experienced by farmers who live 8-16 kilometers from markets. Climate field schools were attended by only 24% of the households. This could be linked to the few set-ups in the region. The frequency of extension contact was relatively low for most of the farmers with 91% having no access to extension agents on a monthly basis.

Table 4. 2: Institutional Characteristics

Variable	Frequency/measure	Percentage
Km to market		
Below 4km	128	32
4-<8	162	40
8-16	98	18
CFS attendance		
No	302	75.5
Yes	98	24.5
Frequency of extension contact		
Monthly	36	9
More than a month	364	91

4.3 Characterization of Information Dissemination Pathways

The patterns of climate change adaptation information received by farmers in the area of study were majorly accessed through ICT, extension agents, chief barazas and groups formed by the farmers, whose members were often selected to go for seminars and workshops thus being great trainers to the rest of the group members. Before PCA, Bartlett's test of sphericity was done for each pathway. This is a statistical test for the overall significance of all correlations within a correlation matrix. The test shows whether the information received can be factored. Kaiser-Meyer-Olkin (KMO) measure

of sampling adequacy greater than 0.5 reveals the suitability of PCA. The Principle components for chief barazas and indigenous pathways are not presented due to sampling inadequacy (KMO< 0.5).

4.3.1 Bartlett's Test of Sphericity

Bartlett's test of sphericity was carried out. Three pathways; extension, ICT and groups were highly significant (p< 0.01). KMO test for pathways above 0.5 justifies factoring. However, chief baraza pathway was significant (p>0.01) but its KMO measure (0.328) was less than 0.5 which is the minimum threshold thus showing sample inadequacy. Additionally, the indigenous pathway was non-significant (P>0.01) with a KMO measure (0.210) of less than 0.5. Following the test results, Chief baraza and indigenous pathways are therefore not reduced through PCA hereafter.

Table 4. 3: Bartlett's Sphericity Test

Pathway	KMO	Chi-square	df	sig.
Extension	0.540	430.263	253	0.000
ICT(Radio and Mobile)	0.784	1276.498	253	0.000
Group	0.770	684.604	253	0.000
Chief Baraza	0.328	306.46	253	0.012
Indigenous	0.210	205.134	253	0.451

4.3.2 Climate Change Adaptation Information Accessed through ICT

Table 4.4 shows the PCA results of the model fitted for ICT. The adaptation information services were classified into five Principal Components (PC) which explained 53.66% of the total variance. The PC1 which explained most of the variance (21.84%) indicate that through ICT, most of the farmers receive information about terracing, rainwater harvesting, use of farmyard manure, short-duration crops, crop rotation and intercropping/mixed cropping. The pathway is thus labelled as soil and water management as well as crop adjustment specific.

Table 4. 4: Rotated Correlation Coefficient Patterns for ICT Pathway

Type of information	PC1	PC2	PC3	PC4	PC5
Terracing	0.829				
Rain water harvesting	0.795				
Use of farm yard manure	0.742				
Short duration crops	0.647				
Crop rotation	0.568				
Intercrop/mixed cropping	0.544				
Change in harvesting dates		0.805			
Change in planting dates		0.683			
Change in weeding dates		0.522			
Livelihood diversification			0.635		
Reduced tillage			0.596		
Irrigation			-0.454		
Mulching				0.664	
Improve/increase fertilizer application				0.663	
Drought tolerant crop					0.718
Pest resistant crop					0.638
Variance explained (53.66%)	21.84	9.27	8.12	7.29	7.14

4.3.3 Climate Change Adaptation Information Accessed through Group Pathway

Table 4.5 shows the PCA results of the model fit for groups. Six principal components were obtained which explained 64.91% of the total variance. The PC1 explained most of the variance (24.72%). The largest contribution was from rainwater harvesting, use of

farmyard manure, short duration crop, mulching and terracing in that order. The loadings indicate that through groups, farmers receive quite a wide range of information. The pathway is thus labelled as soil and water conservation and crop adjustment specific.

Table 4. 5: Rotated Correlation Coefficient Patterns for Group Pathway

Type of information	PC1	PC2	PC3	PC4	PC5	PC6
Rain water harvesting	0.789					
Use of farm yard manure	0.769					
Short duration crop	0.748					
Mulching	0.714					
Terracing	0.643					
Intercropping/mixed cropping	0.633					
Drought tolerant crop	0.565					
Change in harvesting dates		0.749				
Change planting dates		0.656				
Change weeding dates		0.650				
Livelihood diversification			0.649			
Irrigation			0.570			
Crop rotation				0.518		
Improve/increase fertilizer use					0.764	
Pest resistant crop						0.447
Reduced tillage						-0.434
Variance explained (64.91%)	24.72	10.55	8.28	8.24	6.84	6.28

4.3.4 Climate Change Adaptation Information Accessed through Extension Agent

Table 4.6 shows the PCA results of the model fitted for extension agents. Six principal components were extracted which explained 56.78% of the total variance. The PC1 which explained most of the variance (13.97%) indicate that through extension agents,

households receive information on changes in planting, weeding and harvesting dates. Additionally, information on fertilizer management and short-duration crops is received. The loadings show that extension agents give a wide range of information. This channel can therefore be labelled as farm operations adjustment and soil fertility management specific.

Table 4. 6: Rotated Correlation Coefficient Patterns for Extension Pathway

Type of information	PC1	PC2	PC3	PC4	PC5	PC6
Change in harvesting dates	0.722					
Change in planting dates	0.604					
Change in weeding dates	0.588					
Improve/increase fertilizer application	0.524					
Short duration crop	0.451					
Irrigation		0.699				
Reduced tillage		0.583				
Intercropping/mixed cropping			-0.421			
Use of farmyard manure				0.501		
Terracing				0.500		
Livelihood diversification				-0.465		
Rain water harvesting				0.483		
Pest resistant crop					0.473	
Drought tolerant crop					0.455	
Crop rotation						0.739
Mulching						-0.530
Variance explained (56.78%)	13.97	11.66	8.81	8.28	7.78	6.28

4.4 Effect of Socio-economic Factors on Choice of Adaptation Information Pathway

Prior to the effect of socio-economic factors on different information pathways, multicollinearity test was carried out (Appendix 1) and correlation was also carried and discussed hereafter.

4.4.2 Selected Patterns for Pathways Used to Access Adaptation Information

The pathways used by farmers were summarized and presented in Table 4.7 as shown below. From the findings, radio was the most accessed single source of information at 27.8%. Seemingly, none of the farmers accessed information from all the five sources. The choice can be attached to accessibility or trust in a particular source that gives satisfaction in receiving information from that particular source as stated by the theory of diffusion of innovation; farmers' use of an innovation is strongly attached to appropriateness and relevance of a source. Groups was the second single most accessed source of information at 9%. Very few farmers (0.5%) access information from four of the pathways simultaneously. Farmers who do not access information confirmed growing the local Kamba variety due to lack of knowledge of other tolerant varieties. This confirms the assumption that an innovation is only adopted out of awareness in the theory of diffusion of innovations.

Table 4. 7: Distribution of Information Pathways

Proportions	Frequency(n=400)	Percentage (%)
Radio Only	111	27.8
Chief Baraza Only	7	1.8
Extension Only	28	7
Mobile phone Only	3	0.8
Groups Only	36	9
Extension and Chief Brraza	6	1.5
Extension and Group	13	3.3
Extension, Group, Mobile phone	1	0.3
Extension, Mobile phone	1	0.3
Groups, Mobile phone	1	0.3
Radio, Chief Baraza	18	4.5
Radio, Chief Baraza, Group	1	0.3
Radio, Extension	42	10.5
Radio, Extension, Chief Baraza	2	0.5
Radio, Extension, Group	15	3.8
Radio, Extension, Group, Mobile phone	2	0.5
Radio, Extension, Mobile phone	9	2.3
Radio, Group	45	11.3
Radio, Group, Mobile phone	1	0.3
Radio, Mobile phone	27	6.8
None of the five	31	7.8

4.4.3 Correlation between Choices of Information Pathways

Correlation coefficients of paired information pathways were run and the results have been discussed below. The farmers' selection of patterns used in adaptation information access had a wide variation as shown in Table 4.7 above. This creates higher chances of correlation between the pathways used in climate change adaptation information access. A test of correlation between the groups was done and the results are presented in (Table 4.8) below. Most of the pairs were significant thus justifying the use of the multivariate probit model. The positive signs show that the pair of pathways are complementary while the negative ones show that the pathways are substitutable. Radio and mobile were the most significant complementary sources ($p<0.05$). It can therefore be argued that farmers who use radio as a source of adaptation information are likely to use mobile as a source

of information as well. Group and radio were also found to be the most significant substitutable pathways of information access ($p<0.01$). An inference can be drawn from this that the pathways used to access information can in a way be complementary, such that once a household receives information from a given source, they tend not to seek information from other sources as presented by radio and extension agents, radio and chief barazas, radio and groups, extension and groups, extension and mobile, chief barazas and mobile and finally mobile and groups.

Table 4. 8: Pairwise Correlation

Information pathways	Correlation coefficient
Radio and Extension agents	-0.115**
Radio and Chief Baraza	-0.067
Radio and Groups	-0.159***
Radio and Mobile phone	0.145**
Extension and chief Baraza	0.001
Extension and Groups	-0.015
Extension and Mobile phone	-0.018
Chief Baraza and Groups	-0.136**
Chief Baraza and Mobile phone	-0.043
Group and Mobile phone	-0.126**

***1% and ** 5% significant level

4.4.4 Socio-economic Factors Affecting Choice of Information Pathways

Multivariate probit regression results showed that several factors influenced the use of different climate change adaptation information pathways. The coefficients show the direction of effect of each predictor variable on the dependent variables. Receiving information from friends and agro-vet owners significantly predicted all the pathways at 1% level of significance. This implies that receiving information from this group of people increases the likelihood of accessing information from radio, mobile, extension, barazas and groups.

Ownership of radio was a significant predictor in the use of radio pathway to access agro-advisories at 1% level of confidence. This implies that ownership of this tool increased the likelihood of accessing information through this pathway. Similarly, the main occupation positively and significantly explained the use of radio pathway. This meant

that household heads that carry out farming as the main source of income are more likely to access information from radio. Further, secondary occupation significantly predicted use of radio at 5% level of significance. This implies that household heads that are casual labourers receive information through radio. Contrary, income significantly but negatively predicted use of radio pathway. This implies that farmers with more income are less likely to access information from radio pathway. Alternatively, farmers with less income access information from radio.

Ownership of radio was a significant factor in explaining information access through mobile at 5% level of significance. This means ownership of the tool increases the likelihood of accessing information through mobile phone. This could be due to the complementarity of the two pathways. Farm size also had a significant positive effect on mobile information access at 5% level of significance. This shows that households with large farms were more likely to access information disseminated through the mobile pathway. Correspondingly, capital significantly explained information accessed through mobile at 5%. This meant that capital intensification increases the likelihood of accessing information from mobile phone. Climate filed schools also significantly determined access to information from mobile source at 5%. The positive coefficient shows that attendance of CFS increases the likelihood of accessing information through this source.

For extension source, ownership of radio, secondary occupation and labuor were significant in explaining access to information through this pathway at 1% and 5% levels of significance. Ownership of radio negatively explained the predicted variable. This showed that households which owned radios were less likely to get information from extension agents. Contrary, the secondary occupation of the household head was a significant negative predictor of extension use. Therefore, households that carry out casual works are unlikely to seek information from the extension pathway. Labour positively predicted use of extension pathway showing that an increase in labour increases the likelihood of using this pathway to access agro-advisories.

The education level of the household head was a significant negative predictor in the use of groups as an information source. This depicts a higher likelihood of less-educated farmers seeking information from groups. Income was a significant positive predictor for

access to information through groups at 1%. This meant that households with more income are likely to access information from groups. Food source also positively corresponded with group pathway at 5 % level of significance. This positive relationship shows that households relying on the farm as the main source of food often access information from groups. Besides food sources, capital also positively and significantly predicted access to information through groups at 5%. This implies that those who invest more in production often access information through groups. Farm size also positively and significantly increased the likelihood of access to information through group source at 1%. Therefore, households with relatively large farms are more likely to access information through groups.

The marital status of the household head positively determined use of chief baraza information source. Married heads are likely to attend barazas and receive agro-advisories as compared to the unmarried, widowed and separated counterparts.

Table 4. 9: Multivariate Probit Results

Determinants	Radio	Mobile	Extension	Groups	Baraza
	B(SE)	B(SE)	B(SE)	B(SE)	B(SE)
Own phone	.117(.223)	.577(.443)	.313(.250)	-.674(.205)***	-.090(.269)
Own radio	1.593(.206)***	.867(.420)**	-.656(.220)***	-.176(.199)	-.226(.273)
HHH Gender	-.086(.331)	-.155(.540)	.060(.401)	-.087(.357)	.571(.448)
HHH Age	.073(.061)	-.078(.074)	.051(.065)	-.095(.060)	-.114(.084)
HHH Marital	-.068(.090)	.049(.148)	.087(.109)	-.113(.100)	.251(.120)**
HHH Education level	-.005(.113)	.245(.131)*	.019(.118)	-.416(.119)***	-.106(.143)
HHH main occupation	.075(.075)**	.104(.098)	-.066(.078)	-.031(.074)	-.162(.103)
Secondary occupation	.179(.076)**	-.086(.106)	-.392(.099)***	.097(.069)	-.203(.113)
HH Size	.099(.103)	-.001(.130)	.052(.109)	.143(.102)	.036(.134)
Income	-.234(.117)**	-.038(.145)	-.219(.129)*	.010(.120)***	-.186(.168)
Food source	.023(.086)	-.097(.111)	-.098(.092)	.150(.083) **	-.136(.116)
Farm size	-.015(.041)	.107(.049)**	.036(.042)	.140(.040)***	-.045(.057)
Land ownership	.150(.272)	-.698(.400)	-.063(.291)	.023(.243)	-.557(.374)
Labour (log)	-.175(.260)	-.758(.324)	.717(.271)**	.062(.255)	.033(.341)
Capital (log)	.107(.233)	.702(.300)**	.119(.250)	.607(.231)**	-.114(.310)
CFS	-.054(.427)	.268(.470)**	#	1.069(.415)*	-.743(.807)
Frequency of extension	-.105(.414)	-.452(.455)	#	-.495(.407)	-1.178(.803)
Pathways of AI access	.302(.087)***	.347(.100)***	.484(.088)***	.251(.084)***	.478(.107)***
Log-Likelihood value					-754.582
Wald test chi*2* (95)					337.44***

***, **, * indicate significance at 1%, 5% and 10% respectively. # are variables that have been dropped to avoid multicollinearity. Likelihood ratio test rho21 = rho31 = rho41 = rho51 = rho32 = rho42 = rho43 = rho53 = rho = 54 =0. Chi2 x^2 (10) = 54.572, p-value = 0.000

4.5 Effectiveness of Existing Policy Regimes

4.5.1 Document and Thematic Results for Policies at the National and County Level

Policies that support climate change adaptation planning at the national level selected for this study were National Climate Change Action Plan (NCCAP) and National Climate Change Framework Policy (NCCFP). NCCAP enforces the legal and policy framework set out by the Paris agreement under UNFCC which has been outlined in the Constitution of Kenya 2010 to contribute towards adaptation. Domestic legislation that guides climate change – Climate Change Act, 2016- provides for the mainstreaming of climate change into sector functions usually implemented at the County levels. NCCAP takes cognizance of the regulations needed to enhance adaptation. However, to date, counties that have enacted climate change fund legislations include Makueni (2015), Garissa (2018) and Wajir (2016) while Garissa, Isiolo, Kitui Makueni and Wajir have at least established Climate Change Funds (CCFs).

Other enabling actions outlined that could support agro-advisory dissemination include; providing climate information services and early warning systems for farmers and communities, promoting technologies and innovation and operationalizing funding. NCCFP extensively reflects government commitment towards integrating climate change in development planning. The policy statements relevant to information dissemination include, putting in place strategies that enable identification, refining and dissemination of climate change information to the public and stakeholders in user-friendly formats, ensure sufficient resourcing of institutions involved in climate change public awareness, facilitate launching and operation of climate change information hub that develops, coordinates, gathers, collates, stores, retrieves and eventually disseminate quality and updated data and information, develop an all-inclusive communication strategy to enhance the dissemination of timely information and research findings that are both credible and reliable.

Lastly, a policy statement on implementing mechanisms that facilitate and support access to climate change information is outlined in NCCFP. NCCAP and NCCFP have been the existing policies implemented at the County levels in form of strategic plans and regulations till recently when the Counties began developing policies at their level.

Specifically, Machakos County has recently developed Machakos County Climate Change Policy (MCCCP) which is less than a year old in action. Additionally, there is Machakos County Climate Change Action Plan (MCCAP). The documents clearly state the County's intentions to improve adaptation like specifying the use of local-area radio to provide meteorological and other climate information services.

Respondent 1 Machakos County: 'Before we had MCCCA, we were using the NCCAP and the strategy. The policy has specific issues on rehabilitation, renewable energy, landfills and in agriculture, we are promoting conservation agriculture through the use of integrated pest management, cover cropping and use of shade nets. We mainly use extension staff and public meetings to disseminate this information while we plan to have a digital platform. The problem is funding. There is equally a need for continuous capacity building of the experts to ensure use of ICT-mediated platform owing to its dynamic nature.

Kitui County has equally made progress in the development of policies related to climate change adaptation which include the Kitui County Climate Change Funds Regulation (KCCCFR) which stipulates that 1% of County funds is set aside for climate change action. The policy however does not clearly outline how these funds are used in climate action, specifically information dissemination. The County equally has a Kitui County Climate Information Services Strategic Plan (KCCISSP) working on information dissemination. The document however basically outlines the generation of weather information, extreme alerts and warnings through community-based intermediaries, SMS and local as well as regional radios without further looking at agro-advisories from these forecasts.

Respondent 2 Kitui County: The main problem is that the previous act did not have direct fund allocation until the NDMA was reviewed in 2021 and National Drought Emergency Fund (NDEF) included. For Kitui County we have got the regulations (KCCCFR*), which was done in 2018 and passed by the County assembly stating that 2% of the budget should be set for climate adaptation but to date this is not consistently implemented.*

Respondent 3 Kitui County: The County does not have a functional Climate Change policy but there is a draft. What is in operation is the KCCCFR, MoE, Kitui

Meteorological Department (KMET) have formed a platform where they usually sent information to farmers through SMS and Radio about the onset of rainfall, in case of extreme events such as drought, flash floods, pandemics like locusts. This is not enough, so more sensitization is required in the County.

In Makueni County, several policies are working on climate change adaptation hence immense progress has been made in line with information dissemination. The policies include; Makueni Climate Change Funds Regulations (MCCFR), Makueni County Climate Information Services Plan (MCCISP) with the most recent being Makueni Agricultural and Extension Livestock Policy (MALEP) approved in early 2021. The MALEP clearly outlines a platform for information dissemination.

Respondent 4 Makueni County: We usually develop a down-scaled forecast or rather a forecast for the County once we receive forecast from the national MET, then call for a County Climate forecast forum/participatory scenario planning workshops where stakeholders who need the information are informed, specifically for agriculture we tell them when rain is likely to be little. From there, we come up with agricultural advisories. These advisories tell farmers in specific wards about first the climate information and then what agricultural activities they should carry out. So if it is maize, we specify this variety…….and the information trickles through extension officers. We also have volunteer climate observers at the village level which the County has purchased phones and are jointly in a WhatsApp group for information sharing. The County has also recruited intermediaries such as pastors and chiefs at ward levels who receive SMS and share during meetings. I get facilitated to give information on Musyi FM every time the season approaches. MET, ASDSP, NDMA have been supportive in the process.

*Respondent 5 Makueni County: Climate-smart is just part of that policy (M*ALEP*) which we formulated last year but approved in February this year. Under this aspect, we have technologies that we are promoting for example Zai pits, farm ponds which has been promoted by the County government by availing back hoe at subsidized prices, zero tillage, use of nets for nurseries. Actually, majority of the farmers have applied though there is a difference in the extent. We downscale weather information together with MET at the start of the season to the County from the national level, and print hard copies in*

three languages; English, Kiswahili and Kikamba and this is disseminated through sub-county agricultural officers to the ward representatives. We have partnered with Safaricom to develop Makueni E-extension as well.

4.5.2 Constraints in the Information Dissemination Process

The most cited hindrances to adaptation and specifically information dissemination across the three counties are resource allocation (funding), failure of climate change adaptation actors to work under climate change unit such that there is uniformity in dissemination, absence of an adaptation policy in the agricultural sector hence reliance on the policy within the MoE which gives little emphasis on agriculture.

4.5.3 Effectiveness Score of Policy Instruments for Adaptation

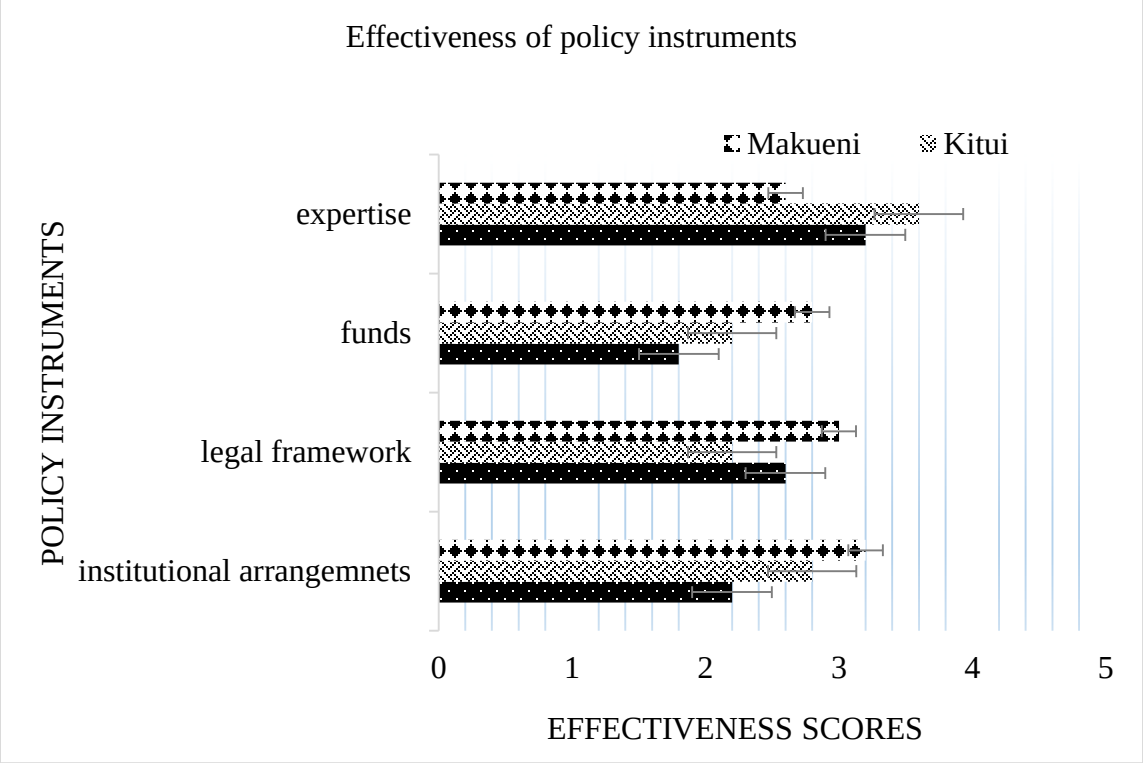

Figure 4. 1 Mean Ratings and Standard Deviation by County

Based on the key expert judgement of the policy instruments relevant to adaptation, funding was the least effective aspect supported by the existing policies followed by legal frameworks supporting the policies, institutional arrangements put in place and the presence of expertise respectively. Makueni County scored highly in terms of the

institutional arrangements put in place by (MALEP, MCCISP, and MCCRF) to support information dissemination followed by Kitui (KCCISP, KCCRF and NDMAA) and lastly Machakos (MCCCP, CCAP). In terms of funding, Makueni County still had the highest scores for effective policies that support funding of climate change activities including information dissemination followed by Kitui and Machakos lastly. The policies of Makueni equally effectively support information dissemination through the presence of a reinforced legal framework as compared to Machakos and Kitui. Lastly, Kitui has more effective expertise for the development and dissemination of agro-advisories as compared to Machakos and Makueni.

4.6 Effect of Uptake of Climate Change Adaptation Information on Productivity

4.6.1 Information Use

The proportion of households using adaptation information they receive are outlined below. The majority of the households practice soil and water conservation practices (78%) as well as crop/varietal adjustment practices (55%), an indication that the respondents within the region are appreciating the need to improve production through the use of weather-based tailored agro-advisories.

Table 4. 10: Information Users

Type	Components	Percentage (%)
Crop/varietal adjustment	Drought-tolerant crops, short-duration crops, pest-resistant crops	55
Soil and water conservation	Rain water harvesting, mulching, terracing	78

4.6.2 Determinants of Adaptation Information Uptake

Several factors determined the use of adaptation information as presented below (Table 4.11). As indicated in the model procedures, experience was included in the first stage of the model executed as an instrumental variable. Age, education level, farm size and experience all significantly predicted use of adaptation information. Age significantly determined the use of information on crop/varietal adjustment at 5% level of significance. Its coefficient was positive implying that an increase in age corresponds to a higher

likelihood of practising this type of information. Similarly, age predicted use of information on soil and water conservation at 5% level of significance. The positive relationship between age and soil and water conservation also shows a higher probability of the aged practising this information, a possible explanation to use of information with increased age is the observation of climate changes over a long period of time hence embracing the need to adjust. Equally, education level positively predicted use of soil and water conservation information at 5% level of significance. The relationship was positive implying that literate household heads are more likely to utilize information on soil and water conservation unlike their illiterate counterparts. This, possibly shows that educated heads understand the deterioration in soil fertility and embrace the need to improve it.

Concerning farm size, the determinant significantly predicted the use of both crop/varietal adjustment and soil and water conservation at 1% and 5% respectively. For crop and varietal adjustment, its coefficient was negative implying that households with small farms are more likely to use the information. This is expected especially for resource-constrained farmers when it comes to the purchase of these seeds. Contrary, the coefficient of farm size was positive for use of information on soil and water conservation. Meaning that households with large farms are more likely to practice this information. A possible explanation for this is because households with large farms invest a lot in the farms hence they practice conservation agriculture to reduce losses.

Lastly, experience significantly predicted use of both crop/varietal adjustment and soil and water conservation practices at 1% and 5% respectively. Their coefficients were however both negative implying that more experienced farmers are less likely to put into use both types of information. This is usually expected as experienced farmers tend to remain adamant to change and often prefer continuing with the practices they have carried out over the years.

Table 4. 11: Probit Results for Information Use

Variables	Crop/varietal adjustment		Soil and water conservation	
	Coefficient	Std. error	Coefficient	Std. error
Constant	1.013	0.811	0.351	0.906
Phone ownership	-0.161	0.192	-0.239	0.239
Radio ownership	0.335*	0.180	0.322	0.209
Age	0.015**	0.007	0.016**	0.007
Education level	0.148	0.097	0.236**	0.111
Household members	0.034	0.086	0.060	0.097
Irrigation	-0.021	0.187	0.148	0.212
Main occupation	-0.162	0.142	0.068	0.171
Capital (log)	-0.096	0.086	0.015	0.097
Farm size	-0.151***	0.034	0.077**	0.042
Income	-0.175	0.107	0.218*	0.122
Experience	-0.026***	0.010	-0.0223**	0.011
Log likelihood	-612.192		-534.66	
Wald chi2(10)	44.55***		25.51***	
Likelihood ratio test	7.16**		7.80**	

***, **, * indicate significance at 1%, 5% and 10% respectively

4.6.3 Uptake of Adaptation Information and Productivity

The effect of adaptation information on users and non-users was determined in the second procedure of the model and the results have been presented below (Table 4.12). Interestingly, the significances and their respective signs for both users and non-users showed significant covariance for both groups, showing how self-selection occurs in a heterogeneous group. This implies that if non-users access adaptation information, the effect will not be the same; they are likely to produce more.

Table 4. 12: Endogenous Switching Regression of Adaptation Information on Output

Variables	Crop/varietal adjustment		Soil and water conservation	
	User	Non-user	User	Non-user
	Coefficient	Coefficient	Coefficient	Coefficient
Constant	9.301***	7.960***	8.954***	9.86***
	(0.668)	(0.621)	(0.536)	(0.876)
Phone ownership	0.447***	0.093	0.310***	0.178
	(0.155)	(0.123)	(0.117)	(0.261)
Radio ownership	-0.169	0.268**	0.021	-0.154
	(0.160)	(0.115)	(0.120)	(0.198)
Age	0.003	-0.001	0.001	0.00
	(0.004)	(0.003)	(0.003)	(0.006)
Education level	-0.151	-0.046	0.177***	0.276**
	(0.086)	(0.057)	(0.059)	(0.133)
Household members	-0.084	0.027	-0.028	-0.052
	(0.072)	(0.057)	(0.052)	(0.108)
Irrigation	0.546***	0.047	0.387***	0.175
	(0.160)	(0.115)	(0.116)	(0.235)
Main occupation	0.077	0.193**	0.134	-0.044
	(0.122)	(0.090)	(0.088)	(0.166)
Capital (log)	0.143**	0.186***	0.181***	-0.055
	(0.072)	(0.056)	(0.054)	(0.092)
Farm size	-0.142***	-0.098***	-0.191***	-0.142***
	(0.033)	(0.025)	(0.021)	(0.049)
Income	0.246**	0.180***	0.203***	0.103
	(0.095)	(0.064)	(0.069)	(0.121)
rho1	-0.840***		-0.925***	
	(0.084)		(0.070)	
rho 0		-0.347		0.362***
		(0.297)		(0.728)
sigma1	0.882		0.746***	
	(0.083)		(0.046)	
sigma 0		0.521***		0.597**
		(0.046)		(0.146)

Standard errors in parenthesis, * at 10%, ** at 5%, *** at 1% significance levels

4.6.4 Impact of Adaptation Information on Output (Ksh/acre): Treatment Effects

The impact of both adoption and non-adoption of adaptation information on farm productivity was modelled and results are presented hereafter. The treatment effects show the outcome of information use on productivity. Households that used the information on crop/varietal adjustment produced 20% more of produce compared to if they had not put into use this information. Correspondingly, households that did not use the information

on crop/varietal adjustment would have produced 12% more if they had practised this information. A similar increment was also observed in households that used information on soil and water conservation who produced 7% more when they used this information. For non-users of the information, they would have produced 9% more if they used the information on soil and water conservation.

Table 4. 13: Treatment Effects

Adaptation information	Sub-headings	Decision		Treatment effects	Treatment effects (%)
		To use	Not to use		
Crop/varietal adjustment	Households that used	26,888.59	22,277.99	TT=4610.6***	20.70
	Households that did not use	24,275.854	21,502.7	TU=2773.154**	12.90
Soil and water conservation	Households that used	27,897.808	25,865.28	TT=2032.528***	7.86
	Households that did not use	23000.022	20,984	TU=2016.022***	9.61

CHAPTER 5
SUMMARY OF FINDINGS, DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary of Results

This sub-section provides a summary of the results outlined in chapter 4 above.

5.1.1 Information Accessed Through Different Pathways

Different information sets were best accessed through different pathways following household responses. Principal component analysis results (Table 4.4) showed that ICT disseminated information on terracing, rainwater harvesting, use of farm yard manure, short-duration crops, crop rotation and intercropping/mixed cropping. The pathway was thus labelled as crop adjustment specific as well as soil and water conservation specific. Groups (Table 4.5) were used to access information such as rainwater harvesting, use of farmyard manure, short duration crop, mulching and terracing. The pathway was thus labelled as crop/varietal adjustment specific and soil and water conservation specific. Through, extension agents (Table 4.6) households received information on change in planting, weeding and harvesting dates, fertilizer management and short-duration crops showing that this pathway is specific to soil fertility and adjustment in farm operations.

5.1.2 Socio-economic Factors Affecting Information Access

5.1.2.1 Pairwise Correlation

Several characteristics were significant in explaining access to information from specific pathways. This shows that regardless of a farmer's socio-economic status, they received information from at least one of the pathways. The pathways were both complementary and substitutable as established after a pairwise correlation test (Table 4.8). The most significant complementary pair was radio and mobile while the most significant substitutable pair was radio and group.

5.1.2.2 Socio-economic Factors Affecting Information Access

Several factors determined access to agro-advisories. Factors such as the ownership of phone, ownership of radio, marital status, education level, secondary occupation, income,

food source, farm size, labour, CFS, capital, and access to information from agro-vet owners and friends all predicted the use of different pathways in accessing climate change adaptation information. Ownership of radio had a negative relationship with access to information from group showing substitution between the pathways. Ownership of radio however positively predicted use of radio and mobile pathways while negatively predicting use of extension pathway. Marital status positively predicted access to information through chief barazas.

For education level, its coefficient showed a negative relationship with group pathway. Similarly main occupation showed a negative correspondence with the extension pathway but positively corresponded with radio pathway. Besides main occupation, income had a negative relationship with radio but had a positive relationship with group. In addition, food sources also had a positive relationship with group. The farm size owned by a household also had a positive relationship with both mobile and group pathways. The predictors labour and capital both had a positive relationship with mobile source. Capital additionally predicted access to information from groups as well. Attendance of climate field schools showed a positive significant relationship with access to information from mobile. Lastly, access to information from agro-vet owners and friends had a positive correlation with all the pathways considered in the study.

5.1.3 Effect of Information Uptake on Productivity

5.1.3.1 Uptake of Information

Most households took up the adaptation practices disseminated to them through various pathways. Specifically, crop/varietal adjusted (drought-tolerant crops, short-duration crops, pest-resistant crops) by 55% while soil and water conservation (rain water harvesting, mulching, terracing) was practised by 78% of the households. Age, education level, farm size and experience in farming determined the use of information on the two technologies. Age had a positive correlation with both crop/varietal adjustment and soil and water conservation. Education level however had a positive relationship with soil and water conservation only. The variable farm size had a positive correlation with soil and water conservation but had a negative relationship with crop/varietal adjustment. Experience showed a negative relationship with both types of technologies.

5.1.3.2 Impact on Productivity

Uptake of different types of information had different effect on farm level food productivity. Households that adopted information on crop/varietal adjustment and soil and water conservation produced 20% and 7% more respectively than they would have produced if they had not used this information. Alternatively, farmers who did not adopt information from on crop/varietal adjustment and soil and water conservation produce 12% and 9% less than what they would have produced if they used information respectively.

5.2 Discussion

5.2.1 Pathways of Information Access

The study narrows to characteristics of the household head because as reported by Mugi-Ngenga *et al*. (2016), most decisions related to adaptation are made by the household heads. Several pathways are also considered to cater across different socio-economic environments as Okwu (2011) and Mbanda-Obura *et al*. (2017) reported that farmers who are better educated, are male-headed and have relatively higher income are most likely to receive information from mass media, unlike their uneducated low-income counterparts. Therefore, this study considered both ICT and face-interactions. Uneducated farmers were able to receive information through face-to-face interactions such as groups.

Different pathways disseminated different sets of agro-advisories to farmers in the region. ICT was specific to crop/varietal adjustment and soil and water management strategies. Through extension agents' pathway, the information received was on adjustment in farm operations and soil and water conservation practices. This could be attributed to the fact that there is currently a lot of emphasis on conservation agriculture and onset of seasons hence the inclination towards this type of information. This partially agrees with Kirui *et al*. (2014) who found out that through extension agents farmers access information on climate hazards and adaptation technologies. The possible explanation to this is that through groups demonstrations are easily organized and some of the soil and water management practices are easier understood by the farmers when demonstrated.

Additionally, farmers are able to learn how the tolerant varieties are grown in the demo plots. This is similar to Tamini (2011) who stated that in Quebec farmers were organized into advisory group clubs where they were guided on best management practices such as management of fertilizer, conservation practices, reducing pesticide use, integrated pest management practices and management, rotation plans and protection of water courses. The findings also concur with that of Nyasimi *et al*. (2017) who documented that through group training farmers were able to access information on irrigation, terracing, traditional and scientific weather forecasts, agroforestry, crop rotation, tolerant varieties thus group was specific to soil and water conservation practices, forestry innovations and environmental conservation practices, cropping innovations and livelihood diversification and weather information services.

5.2.2 Socio-economic Effect on Access to Information

Ownership of phone negatively explained information access through groups. A possible explanation for this is that farmers with phones can access information from the phone. It also shows the substitutability between the two pathways. Ownership of radio positively explained the use of radio and mobile pathways but negatively explained use of extension. The positive relationship between ownership of radio and the use of radio pathway could imply ease of accessing information through the pathway. This is expected as information can be accessed with very little inconveniences within a household. This finding is parallel to that of Oladele *et al*. (2018). However, the positive relationship between ownership of radio and mobile pathway could have generated from the complementarity between mobile pathway and radio pathway. The negative relationship between ownership of radio and extension source could ascribed to substitutability of the two pathways. Marital status positively explained access to information through chief baraza source. This could possibly originate from shared responsibility among married heads enabling them to find time to attend chief barazas unlike the widowed, unmarried or divorced persons.

Education level negatively predicted the use of group source. This shows that less-educated farmers' access information through groups while educated farmers access information through other pathways other than group. This is probably facilitated by the

local dialect delivery method and the possibility to seek clarification from group leader. For educated farmers, there is a better understanding of information from pathways such as ICT. The finding disagrees with Muchunku (2015) who found no relationship of both educated and less educated farmers on the use of face-to-face interactions to access climate information in Kitui. The finding reflects that of Krell *et al*. (2020) which showed that educated farmers are more likely to access information through mobile.

The main occupation had a significant positive relationship with access to information from radio. This possibly reflects convenience for farmers as well affordability of accessing information through radio for farmers. For secondary occupation, its effect was positive for radio but negative for extension. Since household heads that are casual labourers go to work every day, this denies them the chance to attend extension agents training thus hindering access to information through this pathway unlike radios which they can possibly listen to at work places. Income had a negative effect on radio source but had a positive effect on group pathway. The negative effect could be attributed to the fact that higher income enables a household receive information from alternative sources other than radio such as mobile while the positive relationship between education level and groups possibly depicts the cooperative groups often joined by better resource endowed farmers.

Food source had a positive effect on group source. A possible explanation to this is that in groups there are demonstrations such as kitchen gardens and vertical gardens which readily provide vegetables for farmers who depend on farms as the major food source therefore attracting such households to group. Farm size had a positive effect on mobile and group sources. This possibly means that farmers with large farms will access information from the sources due to the enormity of projected loss due to climate change when the farm land is large. Therefore, phones enhance reference during practice while groups improve trust especially when demonstrated. These findings concur with those of Mittal & Mehar (2016) who found a positive relationship between farm size and access to information through face-to-face interactions such as trainings which possibly takes place in groups. Similarly, Muema *et al*. (2018) and Das (2014) supports these findings on a positive relationship between farm size and access to information through ICT. Labour

had a positive effect on extension source. A possible explanation for this could be because the type of information disseminated by extension such as soil and water conservation are labour intensive and with the availability of this labour, households are likely to seek such information.

Capital had a positive relationship with mobile source. Large capital investment is a measure of wealth. Hence, these farmers will sort information from ICT sources as mobile which could easily be referred. However, the positive relationship between capital and group as well would mean a confirmation from the group demonstration before large investments. Additionally, this could be because being part of groups such as those that produce and market may guarantee a marketing procedure hence large investments. According to Yu *et al*. (2017), privileged socio-economic environments enhances the ability to access information through ICT thus explaining access to information through mobile for large capital investors.

Attendance of CFS showed a positive correlation with access to information through mobile phones. A possible explanation for this is the fact that in field schools farmers within groups can make payments for these services thus enabling access. This finding is similar to Krell *et al*. (2020) which documented that farmers belonging to groups are likely to access mobile information services. Das, (2014) also reported a higher probability of trained farmers accessing information through ICT-a function of CFS. Other pathways (friends and agro-vet owners) positively correlated with all the pathways used to access information considered in this study. This denotes how information flows across groups. Farmers easily influence each other to listen to various information sources or trying to source information could be driven by lack of trust in friends this attribute can be supported by Kipkurgat, (2015) findings which documented that there is usually a problem with the relevance of information gotten from fellow farmers hence need to confirm such information from source. This finding is also supported by Jones *et al*. (2000) who argued that agro-advisory accessibility and use is synonymous with farmers' social networks and the groups they are involved in. The involvement in these kind of setups is essential in the access, translation, understanding and ultimate uptake of agro-advisories as supported by Charness & Sutter (2012).

5.2.3 Effectiveness of Existing Policies in Supporting Information Dissemination

Based on the desktop review, the two policies are promising as they provide direction and guidelines at both national and county levels on action plans to enhance climate change adaptation. The dissemination of climate information and technologies is outlined within the documents as part of the policy's statements. However, there are notable weaknesses that reflect ineffectiveness of these policies. For instance, climate change fund legislation has been set, however less than five counties out of forty-seven counties have enacted the same. This possible shows weak legal regulations that do not enforce all the counties put in place climate change funds that could facilitate the development and dissemination process of agro-advisories.

The documents equally provide a reasonable institutional capacity to facilitate information dissemination however it lacks realistic and comprehensive back up that is practically actionable on how the information should trickle and the institutions involved in the process. The three counties rely on extension officers to disseminate information with Makueni being the only county with an ICT-mediated platform called Makueni-Extension. For Machakos, adaptation is only incorporated in the Climate change policy within the Ministry of Environment. The policy therefore, focuses on aspects of the environment such as waste management leaving behind agricultural information dissemination.

In Makueni where there is a policy (MALEP)within the agricultural sector, there is a clear stipulation on a platform, information sets and support by the county government through the provision of back hoes to dig water harvesting structures like farm ponds. On the other hand, policies in Kitui support the dissemination of climate information which needs to be tailored into agro-advisories. Additionally, the legislations available for climate change are equally weak.

5.2.3.1 Effectiveness of Policy Instruments Relevant to Adaptation

Lower eastern Kenya has policies that support climate information dissemination. However, science is in consensus that climate information does not adequately support farm decision making and planning that enhances productivity amidst climate variability

and change. Additionally, the dissemination process to large extent is reliant on extension for example in Machakos County whereas according to this study findings, these face to face interactions should be complemented with ICT. In addition, across the policies, none has set up any knowledge-sharing platform such as climate field school yet according to Sinegar & Crane (2011) farmer schools concept is an appealing mechanism of building adaptive capacity through access and use of climate information. This is equally supported by Hasan & Kumar (2019).

Funding was found to be the weakest policy instrument for adaptation across all Counties. This could be brought about by weak legislations enforcing stipulation of climate change funds for climate change in the annual county budget. The situation is probably further worsened by the absence of a climate change fund board that oversees the use of the funds in climate change adaptation and specifically agro-advisory dissemination. This finding is supported by Nagoda & Nightingale (2017) who stated that there are no good mechanisms to use adaptation funds in the adaptation process in Nepal. Funding as a constraint to adaptation is equally supported by Vij *et al*. (2019).

Institutional arrangements for agro-advisories dissemination was also found to be an instrument that is weakly supported by the existing policies in the region under study. This could be as a result of lack of cooperation between the actors (national and county meteorological departments) as well as users (MoA, MoE, NDMA) of adaptation information. This brings about independent action whereas climate change adaptation requires a multi-stakeholder approach. In addition, the linkages between ward representatives and volunteer climate informants in Makueni for example should be replicated in other counties. Formulating of new institutional arrangements to aid certain aspects of adaptation is equally supported by Franzén *et al*. (2015) while the improvement of linkages between policy actors and the weakness of information disconnect in the institutional arrangements is emphasized by Ampaire *et al*. (2017) in Uganda.

Legal frameworks supporting adaptation are also seemingly weak. This could be brought about by lack of political goodwill from the county government. A weak legal framework

has been reported to be an ineffective aspect of current policies thus hindering adaptation in Nepal (Gaire *et al*., 2015).

5.2.4 Uptake of Adaptation Information and Productivity

Socio-economic factors influenced use of climate change adaptation information. The factors significant were age of the household head, education level, farm size and experience in farming. Age positively influenced the use of crop/varietal adjustment information as well as soil and water conservation information. This possibly results from appreciating the need to adjust from the climatic changes observed over a long time. Farm size had a negative correlation with the uptake of crop/varietal adjustment practices. This possibly arises from resource constraints that disables farming households from purchasing varieties for their large parcels. This contradicts the findings of Issa *et al*. (2016) which found a significant positive relationship between farm size and adoption of improved maize production practices. The finding is also inconsistent with Ali & Erenstein (2017) who reported a positive relationship between farm size and the practise of growing tolerant varieties and shifting to new crops.

Contrary to crop/varietal adjustment, soil and water conservation had a positive relationship with farm size. This could be brought about by the attitude of rain water harvesting for example that is attributed to use beyond the farm or other activities such as watering livestock. The findings relate with Recha *et al*. (2015); Tesfaye *et al*. (2014); Teshome *et al*. (2016) in Tharaka Nithi and Ethiopia respectively. The finding however contradicts that of Muriu-Ng'ang'a *et al*. (2017) which showed a negative effect of farm size on adopting rain water harvesting techniques in Tharaka South, Kenya. For education level, there was a positive relationship between the variable and uptake of information on soil and water conservation. This is attributable to the fact that educated farmers are better informed of climate-related impacts on farming systems hence the need to improve productivity and adaptive capacity ultimately. This is consistent with Husen *et al*. (2017) and Asfaw & Neka (2017) in Ethiopia. Experience had a negative relationship with both practices showing how farmers a reluctant to drop their ancient ways and take up new technologies. This is consistent with Kaloi *et al*. (2020) on the adoption of new rice production technologies.

The treatment effect results showed that adopters of crop/varietal adjustment produced more by 20% while non-adopters would have produced more by 12%. Similarly, adopters of soil and water conservation produced 7% more while non-producers would have produced 9% more if they took up these practices. This finding concurs with Maini & Rathore (2011) which showed a significant increase in yields for farmers who accessed and utilized agro-advisories entailing weather-sensitive crops and seeds such as cereals, onions, millet and cotton in India. The finding also corresponds to Simtowe *et al.* (2019) which reported an increase in yield per acre by 15% among farmers who grow maize tolerant varieties in Uganda. This is similar to Martey *et al*. (2020) who reported a 150% increase in yields for farmers who adopted drought-tolerant maize varieties in Ghana. Similar findings have also been reported by Ogada *et al*. (2020); Khanal *et al*. (2018). A general review by Wolka *et al*. (2018) reports that across 80% of studies in soil and water conservation, yields are reported to increase with the adoption of these practices.

5.3 Conclusions

There is a need to improve the livelihoods of small-holder farmers across arid areas. This can be adequately achieved through the dissemination of agro-advisories by combined efforts of information providers; both private and public. However, salience and relevance are very essential if the gap between the availability of information and usability is to be reduced. Based on the study findings, the study concludes and recommends the following;

Objective 1: Pathways Through Which Households Access Agro-advisories

The pathways used to disseminate agro-advisories in lower eastern Kenya often leave out flood control and drought control which are currently frequent extremes. Other types of information such as livelihood diversification are not stressed by most of these pathways. The information disseminated tends to be soil and water conservation and crop/varietal adjustment with extension being the pathway that incorporated farm operation adjustment information. There is need to incorporate other strategies relevant for adaptation.

Objective 2: Socio-economic Environment and Adaptation Information Access

Access to information is largely dependent on the socio-economic environment in which the information is disseminated. Different household characteristics determines whether or not they access information from various sources. Multiple sources of information enhance access for farmers with different needs. ICT is a widely advocated platform, however, traditional ways of information should not be dropped but complemented as they cover resource-constrained and illiterate farmers who are the majority.

Objective 3: Effectiveness of Existing Policies

The available policies both at the county and national level do not effectively enhance and support the dissemination of agro-advisories to farmers. This is brought about by the weaknesses in various instruments that facilitate information dissemination such as weak institutional arrangements, legal arrangements, inadequate funding as well as a shortage of expertise which do not support information preparation and knowledge sharing.

Objective 4: Impact of Agro-advisory Uptake on Productivity

Agro-advisories guide farm decisions and production process as evidenced by this study. The usability of this information however is still largely dependent on whether it is accessed and whether it is accessed in a form that necessitates utilization. It is evident that agro-advisories improve productivity of crops. Pathways that enhance usability should be prioritized by information providers. Groups largely enhance usability since there are demonstrations especially soil and water conservation techniques.

5.4 Recommendations

Objective 1: Pathways Through Which Households Access Agro-advisories

There is a need to emphasize flood control during the long rains through short term as well as long term solutions that involve both farmers and government agencies. There is therefore the need to package agro-advisories that goes beyond crop/varietal adjustment practices and soil and water management strategies so that farmers benefit from these innovations such as environmental protection practices as well.

Objective 2: Socio-economic Environment and Adaptation Information Access

Information providers should reinforce the factors such as age, gender, occupation, education level, extension access and climate field schools in the planning of agro-advisory dissemination. In addition, these factors also form a basis in the formulation of policies that facilitate agro-advisory distribution. Access to information disseminated through ICT can be improved through the issuance of information from known senders to boost trust, the cost of acquiring information should also be standardized. Additionally, the information should be simplified to enhance understanding and use or otherwise sent in the local language. Institutions such as extension services both traditional and modern should be funded as well as field schools set up across ASAL regions.

Objective 3: Effectiveness of the Existing Policies

In line with policy ineffectiveness, Machakos and Kitui Counties should develop an institutional framework that supports adaptation through links that will enable adaptation information dissemination. Legal frameworks governing the funding of agro-advisory preparation process should be enacted by relevant bodies across the county governments and the country at large. In line with expertise, more experts should be trained to facilitate the timely preparation of advisories. Lastly, county governments should also develop county climate change boards that oversee the funding and use of climate change funds in enhancing various aspects of adaptation with the inclusion of information dissemination while those without climate change funds such as Machakos develop one.

Objective 4: Impact of Agro-advisory Uptake on Productivity

For information use, setups such as climate field schools should be facilitated in arid areas. Such institutions should be funded by the government for the overall benefit of food security and livelihood security in Kenya. The findings of the study show adequacy of climate change adaptation information in improving productivity. It is therefore important to support agro-advisory use through the provision of tolerant seeds, subsidized fertilizers and even irrigation water through the drilling of boreholes. In light of these findings, dissemination of seasonal agro-advisories warrants support from government and non-governmental organizations as well as other rural development agencies.

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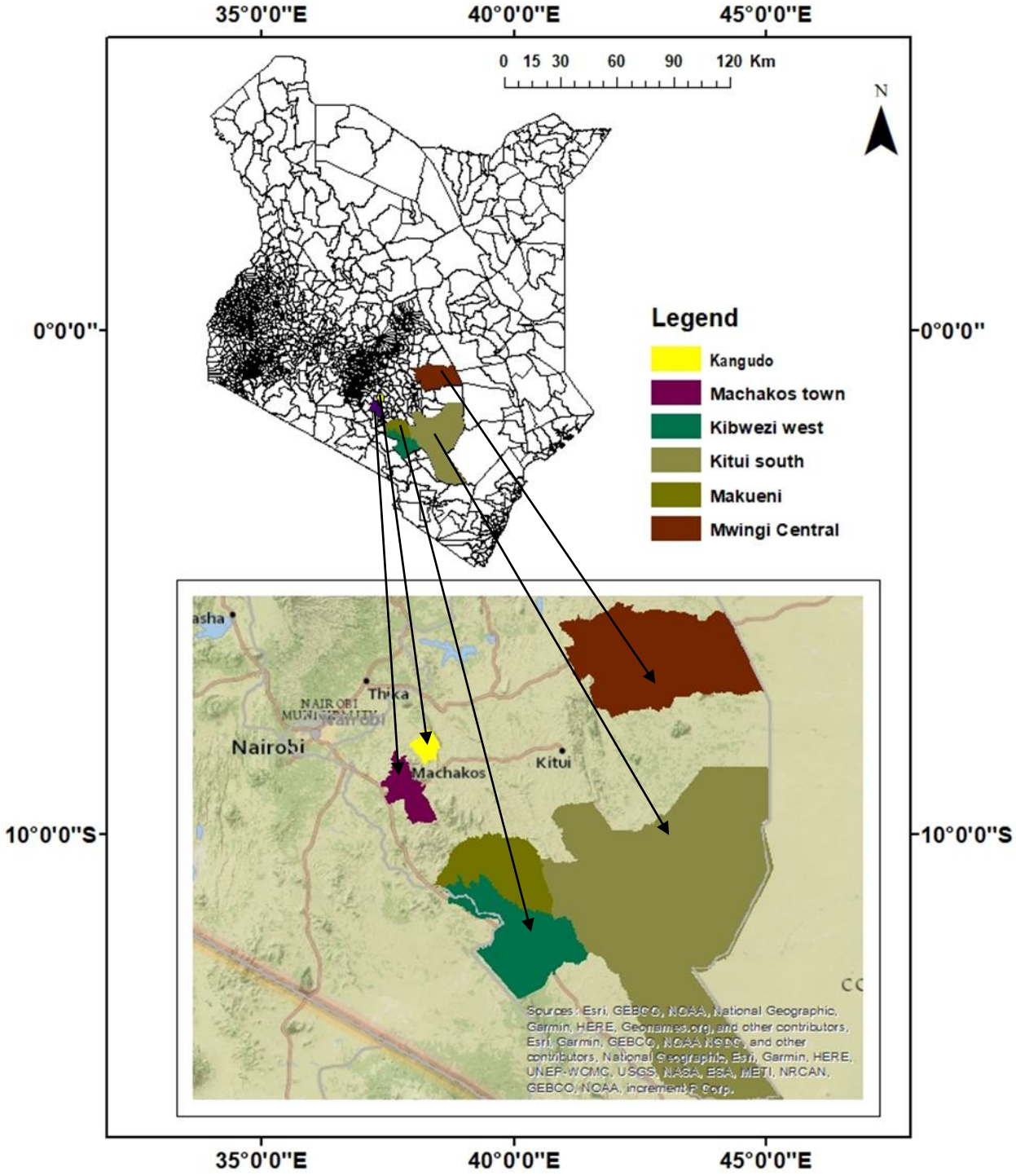
APPENDICES

Appendix I: Multicollinearity test

Variables	VIF
Dependent	
Extension	1.63
Chief Baraza	1.25
Mobile phone	1.45
Group	1.49
Independent	
Frequency of extension Contact	6.02
CFS attendance	5.78
HHH marital status	4.22
HHH gender	4.14
FHH farm size	2.36
Other pathways(friends, agro vets)	2.02
HHH main occupation	1.68
HHH secondary occupation	1.61
Ownership of radio	1.6
HHH education level	1.51
HHH age	1.36
Decision to use AI	1.34
Ownership of phone	1.45
Capital (seeds, pesticides, labor)	1.23
Kilometres to nearest market	1.19
Labour(man hours)	1.18
HH size	1.17
Land ownership	1.13

HH- House Hold , HHH- House Hold Head, AI- Adaptation Information, CFS- Climate Field School

Appendix II: Map of the study area



Appendix III: Questionnaire

CLIMATE CHANGE ADAPTATION INFORMATION FOR IMPROVED AGRICULTURAL PRODUCTIVITY AMONG SMALLHOLDER FARMERS IN LOWER EASTERN KENYA

This survey questionnaire is purely for academic purposes with the objective of **'Assessing the role of climate change adaptation information in enhancing agricultural productivity among smallholder farmers'.** You are assured of confidentiality and this information will only serve the above mentioned purpose for all the views expressed below. Thanking you in advance for your kind cooperation.

SECTION 1

Expert Level Interview: The expert discussion is meant to obtain information on concern towards the access of climate change adaptation information to farmers.

County	
Name of Policy	
Name of key informant	
Position	
Contact	

i. What is the policy focus in line with climate variability and change in the County?
……
ii. By which means do you achieve this? ……..
iii. How would you classify the vulnerability of farmers in the region?
[Not vulnerable] [Quite vulnerable] [Very vulnerable] [Extremely vulnerable]
iv. What are the main adaptation strategies? .....
v. What do you think are the potential limitation of these strategies?
.....
vi. What support do you offer?
……..
vii. What are the existing climate change adaptation information sets?
.....

viii. How is the advisory prepared?

…….

ix. How does the policy facilitate climate change adaptation information preparation, dissemination and monitoring?

…….

x. Does the policy implement the stated goals in achieving climate adaptation information access?

……

xi. Effectiveness score of policy instruments for information dissemination Scale 1-5

xii. Constraints and recommendations towards information dissemination

……

SECTION 2

Household level Questionnaire

Interview Date	**County**	**Sub-County**	**Ward**	**Village**	**No. of HH**

1. Have you heard of climate change?

[Yes] [No]

2. What is climate change in your opinion?

3. Has it affected your farming activities?

[Yes] [No]

4. a) Do you know adaptation?

[Yes] [No]

b) If yes, what is it?

5. How did you know about it?

[Phone] [Radio] [TV] [Computer] [Friends] [Family] [Community leader] [Extension officer] [CFS] [Agricultural show] [Specify any other source……]

6. How long have you lived in the area? ….. [In years]

How long have you carried out farming? … [In years]

7. Does your household own or to either of the following?

[Phone] [Radio] [TV][Computer]

8. a) Is the gadget used to access climate change adaptation related information?

[Yes] [No]

b) If Yes, specify which one is used to access information ….

9. Which other ways do you access information that enable you adapt?

[Chief Baraza] [Extension officer] [CFS] [Agricultural show]

10. Pathways used [see guide below table]

Pathway [1-7]	Type of information accessed [1-23]	Information used 1=Yes 0=No	Season	Location specific	Timing	Reliability

Pathways – [Radio[1], Mobile[2], Tv[3], Chief baraza[4], Extension officers[5], Group[6], Family[7] any other specify …….

Type of information- [Change plant location[1], Irrigation[2], Reduced tillage[3], Intercropping/Mixed cropping[4], Drought tolerant crop[5], Short duration crop[6], Crop rotation[7], Rain-water harvesting[8], Flood control[9], Cover crops[10], Pest resistant crop[11], Drought control[12], Mulching[13], Terracing[14], Change planting dates [15], Change harvesting dates[16], Change weeding dates[17], Use farm yard manure[18],

improve/increase fertilizer use[19], Livelihood diversification[20] Keeping more livestock[21] Change dates and time of pesticide[22] Agroforestry in crop farms[23] any other specify …….

Season- Short [1] Long [2] Both [3]

Location specific

Strongly agree [5] agree [4] no opinion [3] disagree [2] strongly disagree [1]

Timing

Strongly agree [5] agree [4] no opinion [3] disagree [2] strongly disagree [1]

Reliability

Strongly agree [5] agree [4] no opinion [3] disagree [2] strongly disagree [1]

11. What prevents you from accessing information from specific sources? And using the information you access?

(Choices below the table)

Source	Failure of access	Failure of use

Pathways – [Radio[1], Mobile[2], TV[3], Friends[4], Chief baraza[5], Extension officers[6], CFS[7], Agrovets[8], Family[9]

Failure of access- lack of ICT tool [1] cost of information from tool [2] distance to meeting place [3] lack of trust [4] any other reason specify ……..

Failure of use- language [ ] Brief [ ] Technical [ ] Not interested [ ] lack of trust [ ] any other reason specify

12. Do you get any form of adaptation information from friends and agro-vets

Friends [ ] Agro-vets [ ] both [ ]

13. Where do you think most friends and agro-vet owners get the information they share with you from? Community gatherings [ ] Chief barazas [ ] Workshops [ ] Extension officer [ ] Radio [ ] Mobile [ ] specify other sources …..

Do you trust them or refer to those sources?

Trust [Yes] [No]

Refer [Yes] [No]

13. Sex of HHH […] Male=1, Female=0

14. Age of HHH … [Actual age in years]

15. Education of HHH [……] 0=None, 1=Primary, 2=Secondary, 3=Tertiary

16. Farming Experience of HHH […….] 0= ≤ 10, 1= ≥ 10

17. What is the primary occupation of the HHH? [Farming] [Public service] [Self-employment] Casual labourer

18. What is the secondary occupation of the HHH? Farming [ ] Public servant [ ] [Self-employment [ ] Casual labourer [ ] other specify …..

19. Number of HH' members […….] Employed [……] Unemployed [……..]

20. Does the HH' depend on agriculture solely as the source of income? 0=Yes 1=No

21. What is the average household income in a month Ksh? [Indicate income in Kes] …..

22. What is the major income activity of the HHH?

[Farming] [Public service] [Self-employment] Casual laborer

23. Where does your family get most of its food from? Farm [ ] Bought [ ] Both [ ]

What is the distance to the nearest market? …. [In kilometres]

24. What is the total farm size under production…. [Actual farm size in acres]

25. What type of ownership do you have on the land you farm?

Lease [ ] Private [ ] Both leased and private [ ]

26. Have you noticed any changes in agricultural yields from your farm due to climate change? If yes what is it? [Loss] [Gain]

27. Who makes decisions on use of adaptation information received? [HHH] [Man] [Woman] [Any other]

28. How often do you decide to use adaptive measures obtained from different communication technologies? [All the time][Very often] quite often] often] [Once in a while] [Never]

29. Do you discuss with others before making climate change adaptation decisions?[Yes] [No] If Yes, how often do you make the discussions?

30. What is your perception that there is increased rainfall in one of the two seasons in the year?

Increased Rainfall	Season	Perception

1-First season 0-Second season

1- Yes 0- No

31. What conservation measure do you take in the season with increased rainfall? (Multiple)

What do you mainly do with your produce? Sale [ ] Family consumption [ ] both [ ]

Which market do you use for the produce you sell?

Market	Quantity	Price

32. What is the average yield of your staple food crops yearly?

Crop	Acre	Yield	Productivity	Value of output
Legumes				
Vegetables				
Cereals				

33. What kind of inputs do you use in your farming?

Input	Number of Unit	Price(Cost)	Cost per acre
Labour			
Fertilizers			
Other inputs			

34. Which adaptation strategies do you use in your farm from the information you receive?

35. Recommend any help the Government can offer to enable you adapt to climate change and variability

……

……

Thank you for the information