AN ASSESSMENT OF ADAPTATION MEASURES TO CLIMATE VARIABILITY BY SMALLHOLDER FARMERS IN SOUTH SAKWA WARD, SIAYA COUNTY, KENYA

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C50/71413/2014

A Research Project Submitted in Partial Fulfilment of the Requirements for the Award of the Degree of Master of Arts in Environmental Planning and Management of the University of Nairobi, Kenya

November 2022

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DECLARATION

This research project is my original work and has not been presented for a degree or publication in any other institution

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This research project has been submitted with our approval as the University supervisors

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ACKNOWLEDGMENT

My appreciation goes to my project supervisors, Prof Samuel Owuor and Dr. Isaac John Ndolo for their support, guidance and encouragement till the completion of this project. Your patience in guiding me throughout this exercise is highly appreciated. I also wish to thank the University of Nairobi, and in particular, the Department of Geography, Population and Environmental Studies, for giving me a conducive environment to undertake my postgraduate studies. To the Chairman of the Department, Dr. Boniface Wambua, and all the academic and support staff, including my classmates, friends and colleagues – Thank you all. I am further indebted to my partner Eric S. Ayany and children Victoria and Bellah for their encouragement and support throughout this process. I am thankful to the Climate Change Directorate and Siaya County Climate Change Department for allowing me to interview farmers, collect data, and conduct interviews for this research project. Finally, I am grateful to the many other individuals whom I interacted with as I undertook this research project.

Table of Contents

List of Figures

List of Tables

ACRONYMS AND ABBREVIATIONS

ASAL	Arid and Semi-Arid Lands
CBO	Community Based Organization
CC	Climate Change
CCD	Climate Change Directorate
CV	Climate Variability
CIDP	County Integrated Development Plan
FAO	Food and Agricultural Organization
FBO	Faith Based Organization
GDP	Gross Domestic Product
GoK	Government of Kenya
IPPC	Intergovernmental Panel on Climate Change
KNBS	Kenya National Bureau of Statistics
MoALF	Ministry of Agriculture Livestock and Fisheries
MoEF	Ministry of Environment and Forestry
NGO	Non-Governmental Organization
SDG	Sustainable Development Goals
SPSS	Statistical Package for Social Scientists
SSA	Sub-Saharan Africa
UN	United Nations
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
WMO	World Metrological Department

ABSTRACT

One of the key sectors in sub-Saharan Africa affected by climate variability is agriculture. The effects of climate variability results in low agricultural output and smallholder farmers are the most affected. This research aimed to interrogate how smallholder farmers from South Sakwa Ward of Siaya County, Kenya, perceive and respond to climate variability. The specific objectives were to 1) examine smallholder farmers' knowledge on climate variability; 2) determine the effect of climate variability on smallholder farming; 3) assess adaptation measures to climate variability of smallholder farmers; and 4) examine the role of community organizations and government agencies in enhancing climate adaptation measures. A multi-stage random sampling procedure was used in order to select the participating villages and smallholder crop farmers in South Sakwa Ward for the study. The first stage was to select one out of the forty-seven counties in Kenya, Siaya county was selected due to its unique agro ecological zones. Thereafter out of the six administrative wards in Bondo sub-County. South Sakwa Ward was selected purposively due to its fragile environment, frequency of drought, and familiarity of the researcher with the area. The second stage involved the selection of study villages in South Sakwa Ward. Three villages in South Sakwa Ward, namely, Wichlum, Wagusu and Gombe were selected for the study based on the consideration of similarity in frequent food shortage, as well as representation of similar agro-ecological profiles and livelihood systems (i.e. crop farming). Lastly, smallholder crop farmers in each of the villages were selected systematically using a sample population of smallholder crop farmers obtained from the Ward Administrator. The sample size was 130 smallholder farmers, as well as 7 key informants. The study has four major findings and conclusions. First, age of farmer, education level of farmer, and duration of farming experience influence the knowledge of a smallholder farmer about climate variability. However, no significant difference in knowledge was observed based on gender. Second, climatic variability directly affects farming activity and productivity. In conclusion smallholder farmers depend on onset of rainfall to start planting their crop and in the event that the rains are delayed or are lower than average, the crop productivity is affected negatively. Similarly, prolonged high temperatures lead to drying of crops in the field before they mature leading to low productivity in a season. Low rainfall combined with high temperature is a critical challenge that smallholder farmers face. Third, smallholder farmers require multiple adaptation measures in order to cope with climate variability. A farmer's economic status will determine his/her ability to choose one or more adaptation mechanisms and thus economic status of a smallholder farmer determines the extent to which he/she can adapt to climate variability. Lastly, smallholder farmers are receiving assistance in the form of trainings, farm input such as improved seedling and fertilize, as well as weather information services. However, this assistance is mainly being offered by Non-Governmental Organizations that operate within close proximity to the villages. The study recommends that the national and county government must be at the forefront in addressing climate threats to the agricultural sector by putting smallholder farmers at the center of climate resilience actions. Smallholder farmers need regular and accurate climate information in order to make correct judgement concerning adaptation to climate variability. In conclusion, future researches on climate adaptation need to focus on the gender varied impacts of climate. This study has showed that female farmers are disproportionately impacted and subsequently participate actively in climate variability adaptation.

CHAPTER ONE
INTRODUCTION

1.1 Background of the Study

Variable climatic conditions affect physical, human and biological systems in several ways. The international scientific body dealing with matters climate change also known as the lead scientific body on climate matters – Intergovernmental Panel on Climate Change (IPCC) – has defined climate variability as the deviations of weather elements from their long-term averages (IPCC, 2012). The climate body further defines variability in climate as "the difference in the average atmospheric state, including characteristic of climatic, geographical and sequential scales in comparison to a single weather event". The World Metrological Organization data trends since 1950 have shown an increase in climate extremes (WMO, 2019). It is clear that human systems and physical systems interact differently to climate variability. Scientifically, climate variability is described as continuous observed change in weather characteristics over a long period of time. Climate variability exhibits through rising temperatures leading to heat waves and wild fires. It can also manifest as declining rainfall, resulting to droughts and famines, and lastly it also manifests as high rainfall, leading to floods. The data has confirmed that indeed climate extremes occurred as a product of anthropogenic causes such as increase in the percentage of atmospheric greenhouse gases. These human induced factors have resulted to warming and extreme daily mean temperatures at global scale. Moreover, these factors have added to increased severity of rainfall at the global level. As indicated by IPCC (2012), there has been a steady surge in high water along the coastlines due to a rise in average sea level characterized by human induced influence.

Scientists have found that global warming is evident mostly due to anthropogenic activities (Gezie, 2019; IPCC, 2012). Weather and climate elements are likely to be at the extremes. This may result in significant negative consequences to human and natural systems due to variations in the cycles and the impact of these extreme climatic incidents and the unpredictability of weather patterns. Increasing incidences of heat waves, flooding and famine are projected to have numerous adverse effects over and above the effects (IPCC, 2012). For example, the magnitude of the effects of climatic changes relies majorly on the exposure level and vulnerability to these extremes. Within agriculture systems, climate variability in weather will impact majorly on number and quality of livestock, forest, crops and forage through alterations in the amount and quality of soil, water sources, land, increase pest, disease and weed outbreaks (Mutekwa, 2009).

Climate variability is manifested in various ways, including increasing temperatures, declining rainfall and increasing precipitation averages which results in reduced crop and livestock yield thus impedes food productivity in agriculture-reliant economies across sub-Sahara Africa (Gezie, 2019). Effects of climate variability are especially strong throughout countries situated along the tropics in Africa and who rely on agriculture as their major economic driver (Thornton *et al.,* 2014). Climate is an important factor in the agricultural and related sectors across Africa and as a result the sector remains very sensitive to climate variations. It is the driving force of the annual change in farm productivity in many countries across Africa as well as continuous basis for interference to environmental services (Recha *et al*., 2017). Populations that prominently rely on agricultural activity for livelihood and sustenance, are frequently more directly impacted by server weather and climate variations. The smallholder farming systems characterized by low-input and unpredictable rainfall combined with pastoral systems in the semi-arid and arid lands are frequently susceptible to negative consequences of climatic variability due to an over reliance on climate-sensitive natural resource-based economic activities (Gezie, 2019).

Research findings by Gioto *et al*. (2016) point out that smallholder farmers experience and have comprehension of climate variability. Similarly, smallholder farmers recognize signs of climate variability as consisting of declining rainfall patterns, increasing and prolonged occurrence of famine, erratic rainfall amounts, and inability to accurately predict annual seasons using traditional knowledge. The research outcomes further state that smallholder farmers mainly blamed low crop production to variances in rainfall distribution and cumulative occurrence of drought and dry spells thus causing soil moisture stress. As a result, agriculture dependent populations have slowly become food insecure. Similarly, research findings by Nyang'au *et al*. (2021) show that household biophysical, social, economic, demographic and functional characteristics define the perception of climate variability. In contrast, the level of knowledge, access to climate information and access to extension services significantly and positively affect response and knowledge to climate variability.

Smallholder farmers have to urgently adapt to the climatic and non-climatic effects in order to sustain their farming practices. Non-climatic effects include disease epidemics, research and knowledge, technology, government laws and policies, and market forces, among others (Morton, 2007). Climatic effects are varied depending on geographical location. Mutekwa (2009) noted that Zimbabwe and other Southern African countries experienced prolonged dry spells leading to droughts which then alternated with seasons of extremely heavy rainfall which resulted in floods that alternated with prolonged dry spells experienced during the same period. This contrasts with Eastern Africa where Arendse and Todd (2010) observed an increase in rainfall amount and frequency over time and that there was evidence of intensification of rainfall in the North-Eastern region (Northern Kenya, Southern Ethiopia, Northern Uganda and Southern Somalia) in comparison to conditions within the Southern Uganda region. Similar studies in Tharaka Nithi County of Kenya indicate that temperatures are consistently increasing and that night time temperatures are becoming warmer (Gioto *et al*., 2016). The study observed that March-May and September-November rainfall had a decreasing trend. Extended climate variability also affects groundwater resources and hydrological system while further reducing over dependence on rain-fed agriculture.

1.2 Statement of the Research Problem

Agriculture is a major economic activity in Kenya. It accounts for the largest share (27%) of Kenya's GDP (GOK, 2018). Additionally, agriculture sector gives critical supportive linkages to other economic sectors in Kenya. For example, the sector contributes to more than 55 percent of the entire national employment, more than 60 percent of export earnings, in addition to 75 percent of industrial raw materials (GOK, 2018). Climate variability is a significant challenge facing smallholder farmers whose daily source of sustenance is dependent on the function, existence and structure of the current environmental and business models. This means that changes in soil moisture, humidity, temperature and rainfall pattern have several biological and physical effects on farming systems (Pant, 2011). For example, in Zimbabwe and Zambia it was observed that due to frequent droughts, most crops dry up, which leads to reduced crop yield (Chipo *et al*., 2010). In both countries, food insecurity has been a major outcome of decrease in crop yield and drought. Similarly, in Kenya, climate variability has resulted in frequent droughts and floods which has caused adverse impacts on agricultural productivity. This has led to food insecurity and a dip in the country's economic activity (Agesa *et al*., 2019).

Familiarity and understanding of farmers on climatic variability is key to integrating adaption to climate variability in agriculture-related legislation, plans and strategies (Benoit *et al*., 2014). Farmer knowledge and understanding is viewed in most cases in relation to their cognizance of variations in rainfall and temperature. Studies on farmers' knowledge of climate variability, including available choices for coping, have produced varied evidence about whether farmers are cognizant that climate is changing in their geographical regions (Komba and Muchapondwa, 2012). The effective way that smallholder farmers would employ to significantly minimize the negative effects of climatic variability includes adaptation to specific climate changes. Measures in agriculture sector that are most widely used for adaptation include irrigation, changing planting dates, adapting improved crop varieties in the farm, soil management and conservation, and afforestation (Menike and Arachchi, 2016). These researchers have addressed to a limited extent the tactics that farmers employ to adapt to climate variability include crop diversification within the farm, on-farm forestry practices, planting variety of trees, off-farm income earning work, and for extreme cases, food aid, sale of personal assets, and long-term or short-term migration in search of employment.

There are both long-term and short-term adaptation measures. By definition, a long-term strategy is an action that takes effect after two or more planting seasons. For example, agro-forestry practices, tree planting, permanent migration, and abandoning of a crop in exchange for another. Short-term strategy is defined as an action whose effects are felt within one planting season. For example, terracing, water harvesting, early planting, planting drought resistant varieties, and non-farm activity to complement household income (Tessema *et al*., 2013). In addition, a number of direct and indirect factors informs the smallholder farmer's choice of adaptation measures. For example, direct factors include farmers' understanding on climate risk and availability of adaptation measures. The indirect factors include age, gender, income, and ability of the farmer to access extension services and credit facilities (Etana *et al*., 2020). Furthermore, local based community organizations have a vital role in addressing indirect factors such as gender barriers to adaptation. There are research gaps on why smallholder farmers who in most cases have a low adaptive capacity can benefit from support and trainings through community-based organizations and local non-governmental organization (NGOs). The gaps in research have not addressed the link between knowledge gained from extension services provided by NGOs and government agencies to enable smallholder farmers overcome low capacity to adaptation (Abdul-Razak and Kruse, 2017). This study sought to address the research gap on how knowledge of smallholder farmers can influence their choice of adaptation.

This study's focus is the assessment of climatic adaptation by smallholder farmers in South Sakwa Ward of Siaya County in Kenya. Siaya County is vulnerable to the effects of climatic variability. This risk or vulnerability can be attributed to the heavy reliance on nature-dependent agricultural activities in a fragile environment and decreasing capacity to adjust to climate change related effects. This study investigates how smallholder farmers in South Sakwa Ward perceive climate variability, including how existing knowledge informs their choice of adaptation measures. In addition, the study will assess how formal and informal institutions have supported smallholder farmers to translate knowledge into practical actions to adapt to climate change.

1.3 Research Questions

1. What is smallholder farmers' knowledge on climatic variability in South Sakwa Ward of Siaya County?
2. To what extent has climate variability affected smallholder farming in South Sakwa Ward of Siaya County?
3. What adaptation measures are smallholder farmers' using to overcome climate variability in South Sakwa Ward of Siaya County?
4. What is the role of community organizations and government agencies in enhancing climate variability adaptation measures in South Sakwa Ward of Siaya County?

1.4 Specific Objectives

1. To examine smallholder farmers' knowledge on climate variability in South Sakwa Ward of Siaya County.
2. To determine the effect of climate variability on smallholder farming in South Sakwa Ward of Siaya County.

3. To assess adaptation measures to climate variability of smallholder farmers in South Sakwa Ward of Siaya County.
4. To examine the role of community organizations and government agencies in enhancing climate adaptation measures in South Sakwa Ward of Siaya County.

1.5 Research Hypotheses

1. H_0: The choice of adaptation measure is not informed by smallholder farmers' knowledge on climate variability.

   H_1: The choice of adaptation measure is informed smallholder farmers' knowledge on climate variability.
2. H_0: Community organizations and government agencies do not influence smallholder farmers' adaptation to climate variability.

   H_1: Community organizations and government agencies influence smallholder farmers' adaptation to climate variability.

1.6 Significance and Justification of the Study

At international level, the study will contribute to Sustainable Development Goal (SDG) 13 that aims to address climate variability and the resultant effects through ensuring that urgent action is taken. One of the targets in this goal is to ensure relevant and timely development and execution of climatic variability related actions in developing countries through capacity building mechanisms, while focusing on local and marginalized communities, youth and women (UNSDG, 2015). At the national level, suggestions emanating out of this study will focus on contributing to the 2023-2027 Kenya National Climate Change Action Plan which prioritizes food security. The five-year action plan aims to significantly reduce emissions of greenhouse gas from the agriculture sector and at the same time improve the adaptation capabilities of farmer groups, pastoralists' communities and fishing communities (GoK, 2018).

At the county level, the County Government of Siaya identified that climate variability affects food production, processing and distribution more than on other development activities (County Government of Siaya, 2013). The County Development Plan emphasizes formulation of laws that address the existing climate variability effects. Additionally, the plan outlines a number of appropriate measures that can be undertaken to prevent and adapt to changes in climate. For instance, blending both local and scientific knowledge on adaptation, formation of multi-sector partnerships, afforestation and re-afforestation, sensitization of communities and capacity building of stakeholders, land use planning, and pans and dam construction, among other water harvesting measures.

This research will showcase the views of smallholder farmers who are caught up by the consequences of the negative effects of climatic variability by assessing their capacities about climate variability and how it leads to their adaptation actions. The research will also interrogate the adaptation measures so as to understand complexities of climate variability in smallholder agrarian systems. As such, the study findings will inform county, national and global level planning on adaptation measures to climate variability.

1.7 Scope and Limitations of the Study

The study's geographical coverage was South Sakwa Ward of Siaya County where the dominant means of livelihood is crop farming. This ward was selected due to the frequent food shortages characterized by frequent drought despite having a diverse number of smallholder crop farmers. The study will focus on 3 villages in South Sakwa Ward, namely, Wichlum, Wagusu and Gombe. The villages are selected based on the consideration of similarity in frequent food shortage as well as representation of similar agro-ecological profiles and livelihood systems (i.e. crop farming). The thematic scope will interrogate the farmer's capacities to cope and adjust to climate variability within rural farming set ups. The arguments will be premised on smallholder farmers' knowledge and how it informs uptake of adaptation measures. The research will also detail government's roles in comparison to roles of agencies and community organizations in supporting farmers to cope with climatic related events. The methodological scope will involve collection of relevant information and data through literature review, semi structured interviews and household surveys. The temporal scope of the study is one year, which comprises of two planting seasons. This was decided based on time and financial constrain by the researcher.

In addition, this study is limited to the following parameters of climate variability: precipitation, temperature, drought and floods that occur within two planting seasons. Based on similar studies on climate variability, two planting seasons occurring within 12 consecutive months is sufficient to measure these parameters. In addition, this study is limited to climate adaption measures that are confined to actions taken by smallholder farmers within two planting seasons occurring within 12 consecutive months in order to safeguard farm productivity. They include planting drought resistant crops, selling assets, irrigation, employment, borrowing money, and food aid.

1.8 Operational Definitions and Concepts

Climate change: An alteration in transboundary weather patterns, in particular, a gradual change that has been evident from the mid to late 20th century and credited mainly to the increased amounts of atmospheric carbon dioxide produced by extensive reliance by industries on fossil fuels for production (IPCC, 2007).

Climate variability: The short-term weather parameters of a geographical area that fluctuates from its long-term mean (IPCC, 2007).

Smallholder farmer: A category of farmers whose land area cover less than 2 hectares and whose farm products are mainly for domestic consumption and only surplus is sold (FAO, 2015).

Adaptation: Modification of natural or artificial structures so as to prevent actual or perceived climatic stimuli (UNFCCC, 2018).

Vulnerability: The extent to which human and their surroundings are impacted to, or are unable to cope with, the adverse and severe effects of climatic variability (UNFCCC, 2018).

Subsistence farming: Agriculture activities which comprise of a survival strategy where the main output is consumed directly by the household (FAO, 215).

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

This chapter summarized related studies through a specific emphasis on research done on smallholder farmers' knowledge of climate variability and how it determines their choices of adaptation measures. The first section is an overview of climate variability, including the regulatory and policy frameworks on climatic changes in Kenya. The successive two sections review relevant empirical studies done on farmers' knowledge on climate variability; its effects of on farming systems; how farmers are coping/adapting to climate variability; and the responsibility of community organizations and government agencies in climate variability adaptation measures. The concluding section summarizes the research gaps that emanate from the literature review. The chapter ends by presenting the theoretical and conceptual frameworks of the study, respectively.

2.2 Climate Variability and Change: An Overview

According to WMO (2019), air temperatures in Africa have been rising at a rate that is faster than global average surface temperature, which includes a large ocean component. In 2019, the annual mean rainfall showed distinct geographical variation and was amid the third hottest years on record for the continent of Africa. The same year was depicted by high winds in the westward side and above-average rainfall recorded in eastward side. In particular, in East and Central Africa there was remarkably low long-term rainfall averages compared to Southern Africa (WMO, 2019). Throughout the world, the prevailing and accelerated trends have increased some major climate indicators such as a continuous and rapid decline in the Arctic sea-ice extent, resulting in accelerated rise in sea levels. Other indicators include continued loss in ice mass in the glaciers, a sudden and significant decline in Antarctic sea ice and the Greenland and Antarctic ice sheets, and the pronounced rapid decline in the northern hemisphere spring snow cover (UNFCCC, 2019).

The United Nations Framework Convention on Climate Change (UNFCCC) is climate body focused on achieving an international accord convened by the 1992 Conference on Environment and Development of the United Nations. The aim of the treaty is to bring down atmospheric gas concentrations to levels that lead to prevention of harmful changes with the climatic system

(UNFCCC, 2018). The treaty sets legally un-enforceable confines on emission of Greenhouse Gases (GHG) for individual countries and is therefore not enforceable unless ratified by a member state. In that sense, the treaty is based on the goodwill of member states.

The UNFCCC Paris Agreement, a key instrument in implementing the convention entered into force internationally in 2016. As of May 2018, 178 countries had adapted the convention into their country policy context, this number surpassed the expected limit for entry of at least 55 parties. The Paris Agreement seeks to consolidate global actions that will wholly address climate change, through restraining the intensification in worldwide temperature to below 2°C over and above the preindustrial levels. Moreover, the treaty focuses on enhancing countries ability to effectively address effects of climatic changes. In order to attain these ambitious targets there is need for the Paris Agreement to put in place the following: an improved training framework, innovative expertise framework, linking with local actions and suitable monetary flows to support developing countries (UNFCCC, 2018).

2.3 Regulatory and Policy Framework on Climate Change in Kenya

2.3.1 The Constitution of Kenya

The 2010 Constitution of Kenya has put in place a legal obligation to achieve ecologically sound sustainable development; therefore, giving a foundation for solving climate change, while aiming to meet the development objectives set in Kenya's development strategy called Vision 2030 (GoK, 2010a). The key values and guiding philosophies of national governance are clarified in Article 10 of the Constitution. These include public participation, devolution of power and sustainable development. These values are required on all persons and the State, when implementing the Constitution, developing and implementing any public policy or law. Additionally, Article 69(2) provides that every person (individual and companies) has an obligation to work together with government organs to sustain the environment, and enhance the realization of environmental and sustainable development in Kenya.

2.3.2 The National Climate Change Response Strategy

The 2010 National Climate Change Response Strategy (NCCRS) was Kenya's foremost step to embracing a development pathway that adapts carbon reduction and enhances climate resilience development (GoK, 2010b). Among its attributes were a comprehensive documentation of climate change causes and effects across multiple sectors of the economy, including respective or proposed measures to address those effects. The strategy also projected the cost of climate change across the different sectors and made recommendations on the necessary legal and institutional structures that would ensure effective tackling of climate variability and change. The strategy facilitated the formation of the Directorate of Climate Change within the Ministry of Environment and Forestry, thus legally anchoring the directorate within the Climate Change Act of 2016. The Directorate's mandate is to guide and coordinate the NCCRS implementation process and related initiatives.

2.3.3 The National Climate Change Action Plan

The first National Climate Change Action Plan (NCCAP) 2013-2017 was formulated as an implementation instrument for the 2010 National Climate Change Response Strategy (NCCRS) (GoK, 2013). This followed a review of the Action Plan which showed that it was non-implementable in its present state for a number of flaws that included a lack of complete prioritisation of actions leading to unrealistic cost estimates. The Plan of Action thus prioritised and concretised sectorial climate change actions as well as strengthened the institutional, legal and policy recommendations made by the NCCRS. The updated Action Plan of 2018-2022 contains comprehensive steps that Kenya must implement in order to address climate change (GoK, 2018b). Specifically, the Action Plan seeks to provide guidelines and principles to attain low carbon technology and resilient development as a means to further Kenya's development goals, in order to give priority to suitable actions on adaptation, and acknowledges the importance of increasing resilience to climate for the disadvantaged groups, including kids, youth, women, elderly, disabled persons, and minority and marginalized groups.

2.3.4 The National Adaptation Plan

The National Adaptation Plan 2015-2030 responds to Kenya's recognition and appreciation of effects of climate variability on its people and economy, given the country's over-reliance on natural resource sectors that are sensitive to climate for its social and economic wellbeing and growth, and therefore the need to adapt (GoK, 2016a). It also responds to Paris Accord Article 7.9 which explains that every country will, as much as possible, participate in adaptation preparation exercises and the execution of activities. This may include establishment and improvement of country specific plans, laws and/or regulations (UNFCCC, 2018).

2.3.5 The 2016 Climate Change Act

The 2016 Climate Change Act was passed by Parliament in order to provide Kenya with a legal framework that will support and accelerate coordinated actions in response to climate change (GoK, 2016a; GoK, 2016b). The Act provides the overall structure of prevention and management of climate change in Kenya to support development and implementation of procedures and mechanisms that will improve climate resilience (through adaptation) and low-carbon technologies (through mitigation) for national development. The main objectives of the Act are 1) including climate change in every development-related decision making, planning and implementation; 2) putting in place adaptation plans and programmes that will enhancement and support actions that address climate vulnerability and strengthen capacity of ecological and human systems; 3) including climate change disaster risk reduction in public policy decisions; 4) facilitation and supporting the development of capacity for climate change relevant public participation through public consultation, public representation, awareness creation and access to information; and 5) taking into account sustainable development needs when making plans and decisions in response to climate change.

2.4 Farmers' Knowledge on Climate Variability

In developing countries, securing the livelihoods of poor community groups requires adaptation of agricultural practices to climate effects (Belay *et al*., 2017). Farmers' knowledge determines their adaptive capacity since climate variability is location specific. In Sri Lanka, Menike and Arachchi (2016) examined how rural smallholder farmers perceives on climate variability based on their different agro-ecological zones. One of their key findings showed that in the last 20 years of the survey, extreme climatic events were accounted to have increased. These events included winds, floods and drought or prolonged dry seasons.

A study in Ethiopia by Aemro *et al*. (2012) deciphered that the household head's education level determines his/her selection of an adaption to climate variability. The findings continue to explain that literate farmers have a higher chance of making the best adaptation measure or preference and may likely influence individual farmer's decision making in respond to climate variability and therefore increase farmers' ability to avoid climate risk. These finding are in line with the investigation of Komba and Muchapondwa (2012) who state that a farmer who is literate has a higher chance of making positive adaptation decisions.

However, Mutekwa (2009) disputes these findings explains that local farmers' climate variability knowledge is pinned on long term assessments of mainly temperature and precipitation events as per their occurrence within their locality. These findings summarize that age and experience of individual farmers, and not literacy level, determines the chances of making positive adaptation choices. Mutekwa (2009) further observed that limited knowledge on the type and level of climate variability begins with academics, including researchers. In addition, he expounded that there are climate variability issues in Southern Africa that have not yet been clearly established that are important for agriculture. He gives an example of start of periodic summer rains together with the persistent drought season in between the rainy seasons. Such issues interfere with the information flow that farmers need and the subsequent specific actions that are planned, supported, and executed.

Smallholder farmers' knowledge and awareness of climate variability can be determined by institutional and farmer specific characteristics. According to Mabe *et al*. (2021) these factors may include characteristics that include access to knowledge and information proxies like owning a mobile phone, a TV or radio, internet availability and use, proximity to district and regional centers, subscription to a farmer-based group, and visits by an extension service. A study done by Rapholo (2020) on smallholder farmer's perception towards climate variability shows that education level, years of experience in farming, access to relevant information, and age affected the likelihood of farmer's knowledge on climate variability and thereafter the choice of their adaptation strategies. The research also concluded that there is no major difference in knowledge based on gender and that coping and adaptation strategies is influenced by their knowledge of climate variability.

2.5 The Effects of Climate Variability on Farming Systems

For smallholder farming practices in Africa, change in climate alongside its unpredictability are highlighted as the main limitations to the already stressed farming system (Rurinda, 2014). Smallholder farmers are susceptible to exposure, sensitivity and adaptive capacity because of their susceptibility to climatic effects. Likewise, the assessment of aftermath of climate variability occurs in terms of system vulnerability. According to the IPCC (2007), vulnerability is determined by assessing the rate, scale and character of changing climate, thereafter calculating the differences to which an ecosystem is predisposed, its sensitivity and its adaptive capacity. Thus, agricultural risk to climate variability can, as an example, be defined in terms of exposure to higher mean temperatures, the susceptibility of crop yields to the raised temperatures, and the capability of farmers to cope and adjust to effects of these exposures and sensitivities. In Uganda, research findings by Nsubuya *et al*. (2017) shows that climatic effects over the last 20 to 30 years indicate a rapid drop in rainfall and a rise in daily mean temperatures and, as a result, climatic variability trends have impacted on key sectors such as agriculture.

Negative and positive effects of climatic variability are being experienced at varying levels. However, the effects are more likely to be different because certain social groups, sectors or ecosystems have higher vulnerability to climate than others (Mubaya *et al*., 2010). A survey in Sri Lanka by Menike and Arachchi (2016) found that severe atmospheric occurrences such as strong winds, floods and extreme drought seasons were documented to have occurred more frequently in the last 20 years of the survey. Likewise, a study in Ethiopia's Central Rift Valley conducted by Belay *et al*. (2017) found that climate variability had occasioned high rates of pest and diseases occurrence and persistent drought that adversely affected crop production and livestock.

Morton (2007) recognized that the most unfavorably impacted group by climatic change are the smallholder farmers. His study findings elaborate that increased vulnerable state of smallholder farmer groups to climatic variability emanates both through primarily being originally from the tropics and from a number of demographics, socioeconomic and legislative actions. A comparative study done by Halvard *et al*. (2015) which gives fifty years of data on climatic variability, farming and conflict across sub-Saharan Africa reveals an interlinkage between farming and weather patterns where more rainfall is largely associated with higher farm output. Conversely, further findings show that low agriculture output as a result of drought is weakly linked to conflict.

In Kenya, Agesa *et al*. (2019) undertook a study to understand climate variability effects to smallholder farmers. Their findings showed that reduction in soil water content and alteration in planting time reduced farm yield and resulted into crop failure. The findings further explained that due to variability in climate, agriculture production and failure were significantly felt by smallholder farmers. Other effects that a small section of the sampled farmers mentioned included reduced soil moisture, increased pest and disease invasion, and flooding of agricultural fields due to heavy rains. Research done by Ochieng *et al*. (2016) concluded that climate variability disrupts farm production, but with varied effect across different crops. For example, high temperature leads to adverse effects on farm yield revenues of crops such as maize. Conversely, the same condition has a positive effect on crops such as tea, while high precipitation results in damaging effects on crops such as tea. Furthermore, tea depends on steady temperature and reliable rainfall amounts and, therefore, any excess of temperature or rainfall would affect production negatively.

It has become more evident that climate variability manifests differently depending on geographical location and, specifically, based on agro-ecological zones. A study conducted in Tharaka sub-County in Kenya showed that statistics on climate variability trends include sharp rise in number and magnitude of extreme weather conditions such as extended drought, modification in rainfall quantity, change in onset dates, and shortened planting season (Recha *et al*., 2017). Majority of the respondents in this study especially from different climatic zones, considered extreme events such as flood and drought as proof that climate variability is real.

2.6 Farmers’ Adaptation Measures to Climate Variability

Rural farmers engage multiple approaches to adapt to climatic variability. These approaches may vary depending on the smallholder farmer’s geographical location and vulnerability. Arendse and Todd (2010) defines adaptation as modification in the environmental, social and economic systems due to actual or predicted variability in climatic stimuli and other effects so as to minimize or completely remove negative effects of change.

According to Etana *et al*. (2020), farmers experience multiple threats to their livelihoods and these threats plays key roles in shaping decision structures that necessitate adaptation. These threats include wind storms, rainfall variability, extreme events (floods and droughts), in addition to non-climate risk aspects which may include youth unemployment, price volatility of consumption goods and farm products, inter-communal conflict, and landlessness or owning small plot of land. As such, adaptation requires adjustment in economic, social and ecological pillars. These findings are supported by Abdul-Razak and Kruze (2017) in their study of smallholder farmers in Ghana's northern region. Their study assessed smallholder farmer's adaptive capacity using an indicator-based framework. Their findings show that knowledge and training, financial resources, and information technology were key for smallholder farmers' adaptation.

According to Menike and Arachchi (2016), farmers may use short term or long-term measures to adapt to climate variability. Their findings explained that in the lowland regions, the most important actions farmers undertake to help reduce climate variability effects is to alter their short-term measures such as using different variance of crops and changing their planting date. By using these short-term measures, farmers are able to obtain high yields in spite of climatic changes. However, in cases of extreme drought, the farmers adapt long term measures such as migrating to the high potential areas for a number of seasons. Other short-term measures that they use include maintenance of grain reserves, drying and packing of crop residues for storage to be used for relief feed during dry spells, using early maturing crop types, and using different crop varieties. The same study found that in the high potential areas, smallholder farmers applied long term actions to adaptation to changes in climate. For example, crops such as maize, peas, beans and barley were having low yields and, therefore, some farmers allocated less land for the cultivation of these crops. In other instances, farmers decided to completely halt cultivation.

In Sri Lanka, farmers adapted through planting trees, planting drought resistant crops, planting short season crops, change planting dates, as well as agroforestry (Menike and Arachchi, 2016). However, studies done in the semi-arid regions of Niger, Chad and Burkina Faso indicated that priorities for adaptation focused on relying more on heat stress tolerant crops and shifting the dates of planting (Sarr *et al*., 2014). Other measures include the use of forage production crops, agroforestry and wind breaking crops to lessen the effects of high temperatures. In high rainfall systems, adaptation measures target agroforestry, soil fertility management, rapidly maturing crops and supplemental irrigation. Similarly, research done in Tanzania by Komba and Muchapondwa (2012) noted how farmers experienced variance in mean precipitation and temperature and responded to changes by using tree planting, fast growing crops, irrigation, drought-tolerant crops, and shifting dates for planting crops to adjust to the potential and actual harmful effects of climate change on their farm produce.

A number of issues affect a smallholder farmer's choice of adaptation strategy. Research done in Laikipia West sub-County in Kenya demonstrated how these factors vary depending on climatic zones (Atsiaya *et al*., 2019). The results showed that ability to obtain weather and climate information had a great effect on how one can apply risk management actions and intensification approaches. Increase in education level, combined with sole reliance on farm activity, improved likelihood of establishing fresh breeds by 30-53%. Additionally, ability to get extension advise enhanced the uptake and use of terraces in farms. Finally, institutions that avail data and financing are prone to create changes in certain household features, which positively affect response to effects of climate variability.

Further research evidence by Wood *et al*. (2014) showed that proximity to climate information services, access to agriculture inputs, and active engagement in social institutions are the main reasons impacting a smallholder farmer's adaptive capacity. The research further opines that three factors (availability of climate information services, availability of agriculture inputs, and engagement in formal institutions) can lead to smallholder farmers' adaptation actions such as increasing fertilizer use, improved crop varieties, capitalizing on improved farm management activities, and variation of agriculture calendar. When these actions are adapted, then there is the overall achievement of climate adaptation. Similar studies by Asfaw *et al*. (2014) have shown that smallholder farmer's affluence is a key factor in household adaptive capacity. This is because an affluent household is more capable of adapting both modern and sustainable land management practices to address the effects of climate variability. These findings further show that security of land tenure ensures that a household can take part in more long-term adaptation measures.

2.7 The Role of Community Organizations and Government Agencies in Climate Variability Adaptation Measures

Observed climatic and environmental conditions are causing smallholder farmers to change their agricultural practices. The key factors that define a farmers' decision to adaptation include regular contact with extension workers, education, and access to information on climate, among others (Belay *et al*., 2017). This, therefore, means that the role of formal and informal institutions remains significant as they determine the type of information a smallholder farmer receives. Etana *et al*. (2020) and Benoit *et al*. (2014) opines that adaptation is facilitated by informal institutions through enabling of access to livelihood assets such as labor and oxen. However, the support is mainly based on tradeoff, which not only excludes poor people, but also limits their social support proximity to close relatives.

Aemro *et al*. (2012) findings explains the role of community centered groups and organizations in helping to create awareness on climatic change through using diverse means such as broadcast media, agriculture extension workers, indigenous knowledge and social groups, formal education and training meetings, and enhancing knowledge through exchange visits based on conditions of various agro-ecological zones. In contrast, Komba and Muchapondwa (2012) recognizes the government as a key stakeholder in this process. The two explain that the government has the capacity to support smallholder farmers overcome challenges they experience, while incorporating adaption to climatic variability. Furthermore, the institutions within government can engage at a strategic level by enhancing implementation of adaptation methods appropriate for particular regions, such as particular agro-ecological zones or crops growing zones.

2.8 Research Gaps from Literature Review

While it is widely recognized that there exist clear linkages between the effects of climatic changes, adaptive capacity and the measures for adaptation, there is limited understanding on the current interaction of these factors in Siaya County and their resultant effect on smallholder farmers' adaptation to climatic changes. Siaya County is one of the counties that is at risk to the effects of climatic variability. The county's vulnerability arises mainly from high dependence on nature-based agricultural activities in a fragile environment and lower adaptation capacity to effects of climatic changes and variability. Additionally, there is a need for localized evaluation of climate risks and context specific adaptation designs that respond to the unique characteristics of different areas, coupled with recording and incorporation of local adaptation knowledge for a sustainable response. A study done by Simotwo (2014) identified a knowledge gap on the role that private and public institutions play in helping farmers to adapt to climate variability. Similarly, Ogallo (2014) identified a knowledge gap on research on the role of government and non-governmental institutions in climate adaptation. This research is addressing knowledge gap on county level understanding of climate variability knowledge by smallholder farmers and their response to its effect. The research also seeks to inform action by government and non-governmental agencies by looking at the existing actions they undertake.

2.9 Theoretical Framework

This study adapts two theoretical frameworks. These are Drivers Pressure State Impact Response (DPSIR) and environmental possibilism frameworks.

2.9.1 The Drivers, Pressure, State, Impact, Response (DPSIR) Framework

The DPSIR framework intends to link causal factors (drivers and pressures) to ecological results (state and impacts), including effects of changing climate, and to events that determine the external outcomes (regulations, actions and decisions), such as adaptation and mitigation responses to climatic change (Bizikov *et al*., 2009). This study addresses the drivers, pressure and state of climatic changes in South Sakwa Ward of Siaya County. The study focuses on the environmental changes overtime, the causes of these changes, and the trends linked with such changes. In addition, the study focuses on actions that should be undertaken to in order to tackle these impacts and ensure that these responses are guided in a manner that reduces the impacts of the drivers and causes on environment and enhances the well-being of people (Gupta, 2019).

2.9.2 Environmental Possibilism

Environmental possibilism theory is premised on the fact that the environment does not prescribe what human beings would become, but rather that the environment gives chances for human beings to become what they choose. For example, people adapt to varied conditions that the earth has to offer at different places and that is how a variety of living conditions and habits emerge (Fekadu, 2014). Environment-human connection is the interaction between people and their environment, including the arrangements and elements by which people use the environment and the limitations the environment sets upon human behavior and vice versa (Relph, 1987).

Based on this theory, the external surrounding offers the opportunity for varied human responses and reactions and that human beings have significant option to select from. Therefore, environmental possibilism separates the current absolute causal approach that exists in determinism and focuses on human agency. Furthermore, in relation to climate change adaptation, this theory holds that people take into consideration their adjacent environment, including the changing weather patterns, to determine how they respond to it. This theory relates to the study since it explains the how human beings in this case smallholder farmers will modify their behavior by selecting a variety of adaptation measures to climate variability phenomenon such as prolonged drought, floods, high temperatures in order to cope. Therefore, the changing environment (climate variability) has given humans (smallholder farmers) a chance to become what they want (adapting to climate variability). Furthermore, the reasons for adapting to change in climate as well as climatic variability based on their environment, and why farmers choose specific and planned short and long-term adaptation actions to shield them against adverse effects of climatic variability.

These two theories complement each other in that DPSIR framework looks at the causal factors and the resulting effect that produces outcomes that we see as changes in the physical environment i.e., climate variability results in droughts and floods which impacts of land productivity. On the other hand, environmental possibilism interrogates how humans respond to the physical changes in the environment i.e., adaptation measures from climate variability. These two frameworks show the inter-connected nature of the physical environment and human behavior.

2.10 Conceptual Framework

Figure 2.1 presents the study's conceptual framework. Climate change and variability is a major hazard to agrarian and other natural resource dependent sectors. The effects of climate variability due to changes in CO_2 in the atmosphere include erratic rainfall patterns, rise in sea water level, and increase in temperature, which are causing the most devastating effects on agricultural production. Low yield in agriculture is a key outcome of changes in climate that has necessitated application of smallholder farmers' adaptation.

However, farmers' knowledge on climatic variability is one of the key prerequisites for adaptation. While risk information and knowledge are obtained in multiple ways and from diverse sources, understanding and application of this information is strengthened and meaning of the information is determined by social interactions, which, in turn, influences action. Farmers' knowledge can be acquired through formal education, through experience and age and also through media of information dissemination. For example, specific cultivators can identify climatic elements that have altered their past farming experiences and opinions, and as a result of long periods of variations, the farmers are individually capable, of protecting themselves from the repeated climatic shocks. Up to this point, the DPSIR framework enables the study to assess the cause-and-effect relationship between environmental system and human activities.

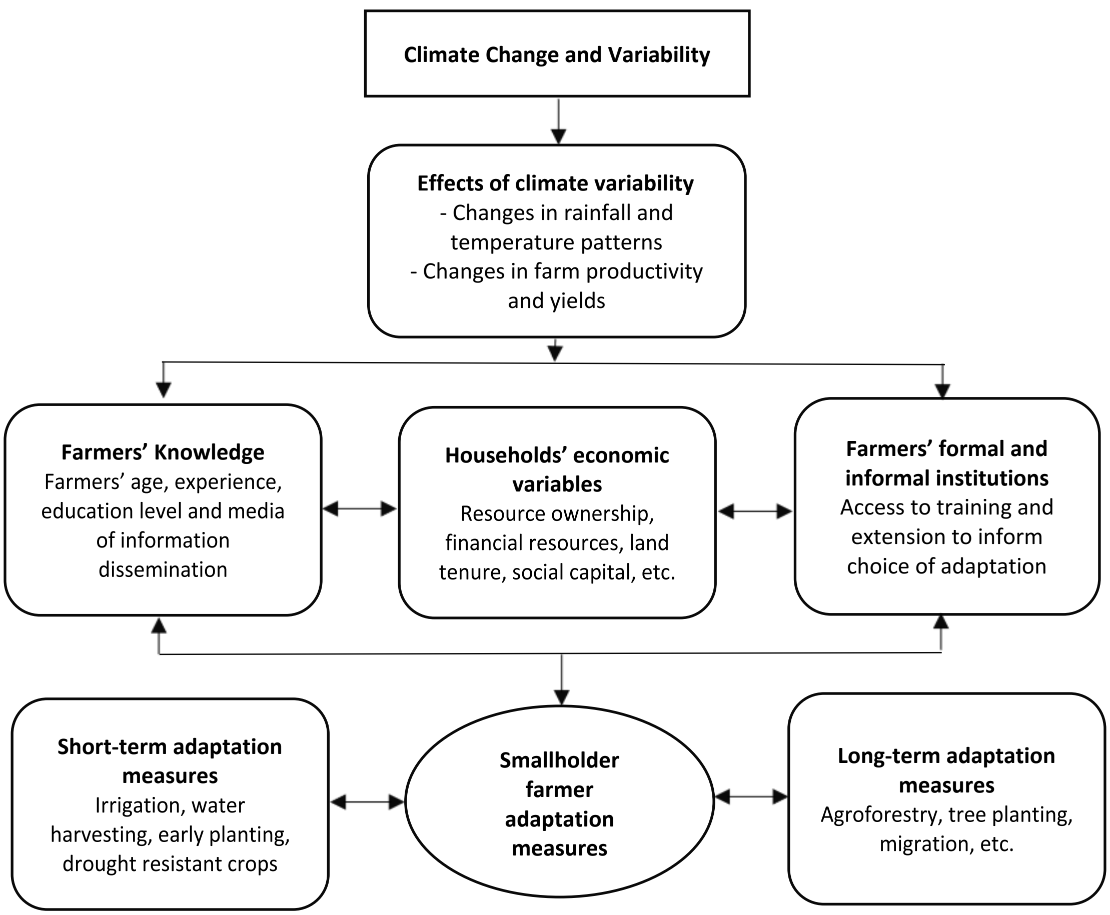

Figure 2.1: Conceptual framework
Source: Researcher

Households' economic variables are also vital in making adaptation decisions. Farmers' adaptation choices aimed at capitalizing economic benefits are the functions of their financial resources, resource ownership, land tenure system, and social capital, among others. Social capital is considered an enabler for adaptation, since it helps to overcome limitations of adaptation activities. Social capital is not only limited to resources required for adaptation but also factors that influence risk knowledge, experience, norm and value orientations.

Institutional support mechanisms are also among the enablers or barriers of adaptation. Farmers' formal and informal institutions enables their access to climate and weather information services and this interface with extension services and other farmer training that enables their decision making. This leads to amplified opportunity for a farming household to implement adaptation actions which enhances the farmer's capability and reduces their vulnerability through the application of learnt adaptation measures.

Adaptation to climatic variability is a reaction to the real or potential effects of climatic change and variability. Adaptation approaches can be short term or long term. Long term adaptation may involve policy decisions while short term adaptation involves autonomous decisions such as substituting old crop breeds with new ones, among others. No adaptation could result to inaction taken to mitigate the aftermath of climatic change. In summary, adaptation decisions at household level are made through dynamic interaction that include knowledge, formal and informal institutions, and climate variability effects on the smallholder farmer's livelihood. The framework confirms this when farmer households choose what is offered by their environment to adapt to climate effects.

CHAPTER THREE
THE STUDY AREA AND METHODOLOGY

3.1 Introduction

This chapter presents the study area and research methodology that guided the study. The aspects of the study area described in this chapter include geographical location; population characteristics; economic activities and livelihood strategies; soils, climate and hydrology; and land use and farming systems. The aspects of the study methodology presented in this chapter include the target population, the sampling design, as well as sources and methods of gathering data.

3.2 The Study Area

3.2.1 Geographical Location

The area of study covered South Sakwa Ward in the county of Siaya, Kenya (Figure 3.1). Siaya County comprises of six administrative sub-counties. These are Rarieda, Bondo, Siaya, Ugenya Gem, and Ugunja. The administrative sub-counties are further split into 30 administrative wards, one of them being South Sakwa. South Sakwa Ward has 8 villages, namely, Lela, Ndonyo, Wagusu, Ndati, Oganya, Arude, Gombe and Wichlum. This research focused on 3 villages for data collection: Wichlum, Wagusu and Gombe. Siaya County is bordered to the north-east by Vihiga and Kakamega counties, to the south-east by Kisumu County, to the south by Homabay County across the Winam Gulf, and to the north by Busia County (County Government of Siaya, 2013).

3.2.2 Population Characteristics

Siaya County's total population in 2019 was 993,183 persons, comprising 471,699 males, 521,496 females and 18 inter sex persons. The total population of South Sakwa Ward was 23,142, comprising of 11,095 males and 12,047 females, and 5,562 households. (GoK, 2019).

3.2.3 Economic Activities and Livelihood Measures

Wage employment in the County of Siaya is averagely 17 percent of the entire employment prospects spread across a number of sectors, including the transport industry, the government, agriculture sector and Non-Governmental Organizations. Agriculture alone offers averagely 61 percent of all the county's employment opportunities (County Government of Siaya, 2013). Majority of the residents of the rural areas are entrepreneurs and are involved in small and micro enterprises such as 'bodaboda' operator services, vending foodstuffs, kiosks selling grocery, undertaking small scale farming, and running small hotels. Those in urban areas and are self-employment are involved in businesses like hotels, shop keeping, hairdressing, chemists, cottage industry and foodstuff trade, among others (County Government of Siaya, 2013).

Figure 3.1: Administrative Map of Siaya County
Source: Siaya County Government CIDP (2013)

3.2.4 Soils, Climate and Hydrology

The County of Siaya receives rainfall twice in a year, with short rains starting in September and ending in December, while long rains start from March to June. The altitude and relief determine rainfall amount and distribution. For example, rainfall on the highlands varies from a low of 800mm and a high of 2000mm, while in lowland areas the rainfall received varies from a low of 800mm to a high of 1600mm. There is temperatures variation the higher you climb, with increasing temperature experienced at 21° C around the north-east to a further increase of 22.5°C along the Lake Victoria shoreline. This is contrary to the south where temperatures range from averages of below 16.3°C and mean highest temperature of 29.1°C. There is comparatively increased humidity with recorded average evaporation ranging between 1,800mm and 2,200mm in a year (County Government of Siaya, 2013). The county has three major geomorphologic regions. These are Yala swamp, temperate lowlands and dissected uplands. These have different land use patterns, relief and soils. The rise in altitude ranges start at 1,140m on Lake Victoria shores and progress to peak of 1,400m above sea level northwards. A number of hills fall within in the county borders, namely, Naya, Mbaga, Ragae, Akala, Odiado, Usenge, Nyambara, Rambugu, Raamogi, Abeiro, and Sirafungo. Rivers Yala and Nzoia flow and enter through Yala Swamp into Lake Victoria (County Government of Siaya, 2013).

3.2.5 Land Use and Farming Systems

There are three categories of land ownership in Siaya County, namely, public land, private land, and community land. Averagely, arable land is estimated at 2,059 kilometers square and smallholder farming is the chief type of land use. A small percentage of Siaya town has been demarcated for industrial use. The standard size of farm in Siaya County varies with each sub-County. For example, in South Sakwa the standard farm size for a smallholder farmer is approximately 3.0 Ha while for a commercial scale farmer the standard farm size is approximately 7.0 Ha (County Government of Siaya, 2013). The majority of the farmers plant potatoes, cowpeas, millet, beans sorghum, sorghum, cassava, ground nuts and finger millets, while the main commercial crops are sugarcane, rice, cotton and groundnuts. Some crops that are gaining popularity in the county include chili, palm oil, irrigated rice, grain amaranth and passion fruits. The county also produces vegetables such as kale, onions and tomatoes, while the seasonal fruits that grow in the county are watermelon, oranges, pawpaw, banana and mangoes (County

Government of Siaya, 2013). The county sustains several breeds of livestock. These include improved breed and pure dairy cows, zebu cows, local beef goats, dairy goats, sheep, pigs, rabbits, poultry, and bees. Among these, poultry, local goat and sheep as well as zebu cattle, are kept by a majority of livestock keeping households in the county (County Government of Siaya, 2013).

3.3 The Study Methodology

3.3.1 Study Design

The study used cross-sectional design because it examines a specific occurrence (or phenomena) at a certain point in time. The goal of a cross-sectional study is to characterize the probability of a phenomena at a certain point in time.

3.3.2 Study Population and Sampling Procedure

The study's target population was smallholder crop farmers in South Sakwa Ward, Bondo sub-County in Siaya County. As such, the unit of analysis in this study is smallholder crop farmers. A multi-stage random sampling procedure was used in order to select the participating villages and smallholder crop farmers for the study. Siaya County was selected because of the frequent occurrence of climate events in the area. The County Integrated Development Plan of Siaya County lists climate change as one of the key threats to its development. Since Siaya County is too big for the study's resources and time, the first stage of sampling involved determining the sub-County of focus. Siaya County has six sub-Counties, namely, Alego Usonga, Bondo, Ugenya, Ugunja, Gem and Rarieda. Bondo sub-County was selected for the study because of its agro-ecological zones and also as a sub-County that borders Lake Victoria, it receives good rainfall throughout the year.

The second step was to determine the administrative ward of study. Bondo sub-County has six administrative wards. South Sakwa Ward was selected for the study due to its fragile environment, frequency of drought, and familiarity of the researcher with the area. The third stage involved determining study villages in South Sakwa Ward. There are eight villages in South Sakwa Ward. The study selected three villages namely, Wichlum, Wagusu and Gombe. The criteria of selection were based on the consideration of similarity in frequent food shortage based on county data, as well as representation of similar agro-ecological profiles and livelihood systems i.e. crop farming.

Lastly, smallholder crop farmers in each of the villages were selected systematically using a list of smallholder crop farmers obtained from the Ward Administrator. The list (sampling frame) consisted of 450 smallholder crop farmers from Wichlum, 391 smallholder crop farmers from Gombe, and 479 smallholder crop farmers from Wagusu. Overall, 130 smallholder crop farmers were selected for the interviews, distributed proportionately between the three selected villages, as illustrated in Table 3.1. The formula for arriving at sample size is elaborated in detail in section 3.3.3.

Additionally, 7 respondents were purposively selected for key informant interviews based on their relevance to the study. The key informants were an official from the Metrological Department, County Agriculture Officer, County Agriculture Extension Officer, South Sakwa Ward Administrator, and one official each from an NGO, CBO and Faith Based Organization.

Table 3.1: Sampling Population and Sample Size

Name of village	Number of smallholder farmers per village	Selected sample for study
Wichlum	450	53
Gombe	491	29
Wagusu	479	48
Total	**1420**	**130**

Source: Bondo sub-County Agriculture Office

Subsequently, questionnaires were administered to the sampled smallholder crop farmers in each village by trained field assistants. The field assistants, as much as possible, targeted to reach the smallholder crop farmers in the morning hours when they were in their farms. Where it was not possible to reach the smallholder crop farmers in their farms, the head of the household was interviewed instead. Previous studies have shown that the household head is more likely the decision maker for farming activities, and as such the information given was still relevant (Mutekwa, 2009). Before administering the questionnaire, it was pre-tested with 10 farming households to ascertain that the tools were relevant and adequate to obtain the information needed.

3.3.3 Determination of the Sample Size

Based on data in Table 3.1, the study's sample size of 130 smallholder crop farmers was obtained by using below formula as applied in similar study by Brymann (2016) model. The model obtains a sample size using the equation:

$$\mathbf{n=} \quad \frac{\boldsymbol{N\ (CV)2}}{\boldsymbol{(CV)2\ +\ (N-1)e2}}$$

Where n = sample population; CV= the coefficient of variation; and e = desired margin of error. For this study, N = 1420; CV= 0.6; and e = 0.05. Therefore,

$$\frac{1420(0.6)^2}{(0.6)^2 + (1420\text{-}1)0.05^2}$$

$$= 130.8$$

A coefficient of variation of 0.6 was used because agriculture is the county's primary source of income, accounting for almost 60% of all household income and nearly 61% of all employment opportunities (MoALF, 2016).

3.3.4 Methods of Data Collection

The study obtained information from primary and secondary sources. The primary data was gathered through the use of questionnaires administered to smallholder crop farmers, key informant interviews, and field observations. The questionnaire covered a diverse set of information that included farmers' profile, farmers' awareness and climate change awareness and access to data through formal and informal institutions. As such, the survey generated data on the characteristics of smallholder crop farmers and information on their farming activities; their awareness and knowledge on climatic changes; the effect of climatic changes on their farming; farmers' adaptation choices; and lastly the function of government agencies and community organizations in enhancing adaptation measures in South Sakwa Ward.

On the other hand, a semi-structured questionnaire guided the key informant interviews and provided more details, while field observation entailed taking note of any important variables observed during the interviews and data collection process. Informal but relevant information with the respondents was also recorded. Secondary data was gathered from county climate data, articles in scientific journals, manuscripts, government periodic reports, Intergovernmental Panel on Climate Change (IPCC) reports, and other related resources.

3.3.5 Measurement of Key Study Variables

Table 3.2 presents the key variables factored during the study and assessed for effects on smallholder farmers adapting measures for climate variability.

Table 3.2: Measurement of Study Variables

Objective	Key variables	Measurement of the variable
SHF knowledge on climate variability	Observation of climatic variables	Compared with metrological data
	Understanding of cause of climate variability	Compared with IPCC report
	Source of information on climate variability	0=no 1=yes, if at least one measure is applied
Effects of climate variability on SHF	Effect of temperature and rainfall on crop productivity	0=no 1=yes
adapting to climate variability	Adaptation measures chosen by farmer	0=no 1=yes, if at least one measure is applied
Role of institutions	Access to extension services	0=no 1=yes
	Access to trainings	0=no 1=yes

3.3.6 Data Analysis

Data obtained was coded and analyzed using Statistical Package for Social Scientists (SPSS) software Version 28 and MS Excel Tool Pak. Descriptive statistics of the key variables were computed and expressed using univariate analyses. The suitable univariate statistic at the descriptive level depended on the level of measurement. Frequency tables were used for nominal variables. Additionally, for other nominal variables, a one-way chi-square (goodness of fit) test was applied at the inferential level. A one-sample t-test allowed the researcher to determine whether the mean in the study sample matched the proposed value for interval level data. The results from univariate analysis were presented using frequency distribution tables and figures. Bivariate analysis was used to find out if there were a relationship between different variables.

Both parametric and non-parametric coefficients were computed depending various variable measurements, for example, ordinal and nominal. The p-values for testing group differences were computed using one sample t-Tests. Group inequality measures were computed using chi-square and visualized by means of the tables and bars. Composite variables were computed, for example, the knowledge score that was an amalgamation of multiple construct measures.

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{s^2 (\frac{1}{n_1} + \frac{1}{n_2})}}$$

Where:

t is the t-value

$\bar{x}_1$ $\bar{x}_2$ are the means of the two groups being compared (male and female)

s^2 is the pooled standard error of the two groups

n_1 and n_2 are the number of observations in each of the groups.

All the key informant interview audio files were transcribed and verification was done by comparing interview notes to the transcribed scripts. Data entry, cleaning, and coding was done using emergent themes and analysis done using qualitative content analysis. The major themes in all transcripts were further coded into sub-themes, which were then clustered together using comparable topics. This was followed by a tally of the groups that had similar themes/sub-themes. Lastly, the information was illustrated by direct quotations, while recounting the relevant experiences and views of the discussants.

3.3.7 Hypothesis testing

The study hypotheses were tested using Kendall's Tau-b correlation coefficient (r_s), a nonparametric measure of the strength and direction of association that exists between two variables measured on at least an ordinal scale. This test is denoted and constrained as follows: $-1 \leq r_s \leq 1$. The threshold for accepting or rejecting the null hypothesis was an alpha of 0.05 ($\alpha = 0.05$, $p < 0.05$ or $p > 0.05$). The results were visualized using various inequality measures, namely Hoover, Coulter, Atkinson, Theil-T and Theil-L.

Smallholder farmers' knowledge of climate variables within the study area was a construct of multiple measures captured through questionnaires and the key informants. Similarly, the role of institutions in enabling smallholder farmers to adapt to climate change was identified based on information and services obtained from these institutions and captured by the questionnaire and the key informants. The knowledge construct measurement was then scored on the basis of their ability to improve farmer's adaptive capacity to climatic shocks.

3.4 Ethical Considerations

The team comprising of the researcher and three assistants used caution when obtaining information from the respondents by ensuring privacy, among other measures. Before any interview started, the researcher and assistants ensured that an introduction was done explaining the purpose of the study, expected duration, procedure to be followed and assurance of confidentiality.

CHAPTER 4
RESULTS AND DISCUSSION

4.1 Introduction

This chapter summarizes the findings, data analysis as well as discussion with a focus on the research problem, objectives and hypothesis as stated in chapter one. Further, the chapter gives an outline of the results from interviews with varied respondents. The specific findings per objective are discussed chronologically. Even then, the chapter starts by describing the characteristics of the sampled smallholder farmers in South Sakwa Ward. The response rate for the sample size was 98% with 127 respondents filling in the questionnaire.

4.2 Characteristics of the Sampled Smallholder Farmers

4.2.1 Gender and Age Distribution

Gender is a significant factor when assessing vulnerability and the choice of coping mechanism. Males and females experience climate variability in different ways and their response is also different. The study sample constituted of 57% male and 43% female respondents. The male headed household were the majority, because they are mainly the people responsible for managing farm activities. According to Bhatasara (2018), smallholder farmers' adaptive capabilities are underpinned by demographic factors including gender. Bhatasara further explains that addressing gender inequalities unlocks adaptive constrains to smallholder farmers. The average age of the smallholder farmers was 40 years old. This data is compatible with data from KNBS 2019 census. Furthermore, smallholder farmers' ages were fairly distributed (Skewness < 1).

4.2.2 Education Level

Education determines a smallholder farmers' ability to obtain, interpret and apply information to their day to day farming activities. Wood *et al*. (2014) study findings argued that farmers' education level is directly related to their economic development and directly determines a farming household's access to weather information services and corresponding responds to that information. Results show that 51% of the smallholder farmers have attained primary school as the highest education level, while 38% attained secondary school as the highest education level and 2% have attained university education as the highest level of education (Figure 4.1).

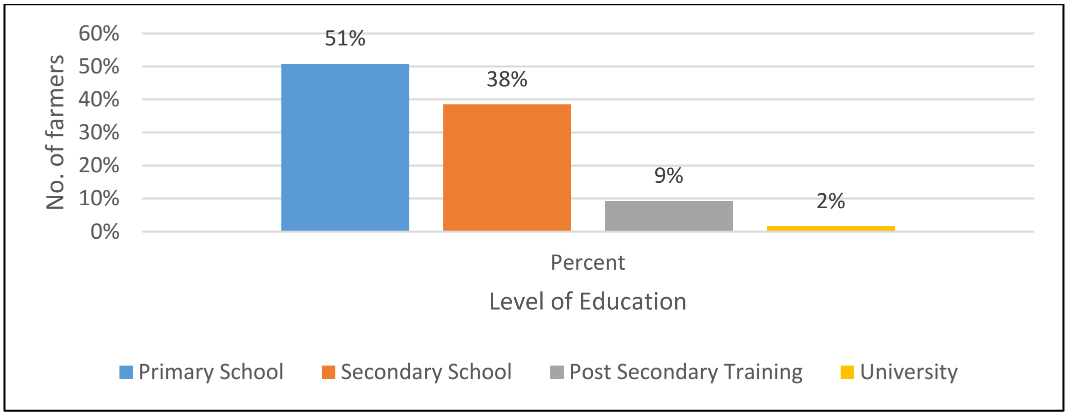

Figure 4.1: Education Level
Source: Fieldwork, 2022

4.2.3 Number of Years in Farming

On farming experience (Figure 4.2), it was evident that 60% of the smallholder farmers have between 1-5 years of experience, 15% have 6-10 years of experience, and 12% have more than 20 years of experience in farming. A small percentage of 5% have less than a year of experience in farming.

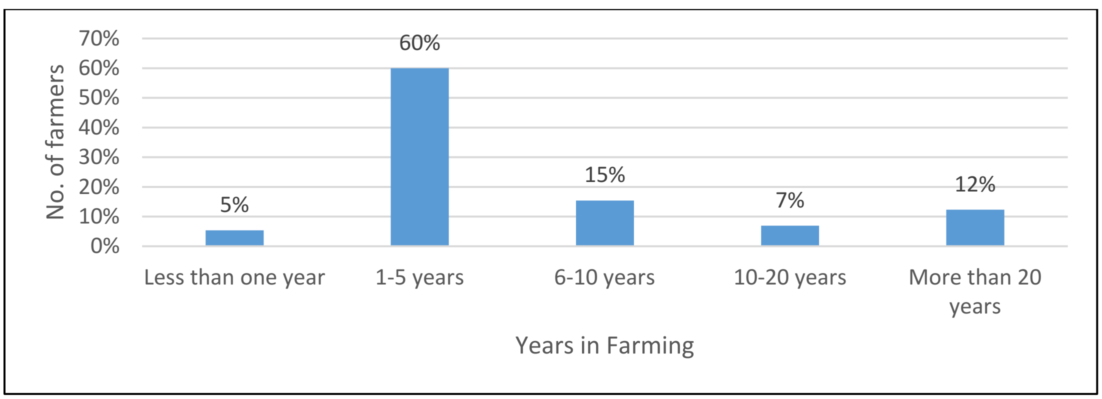

Figure 4.2: Years of Experience in Farming
Source: Fieldwork, 2022

4.2.4 Other Sources of Income and Livelihoods

Smallholder farmers often depend on other sources of income to cushion from climate variability effects. Studies by Mtintsilana *et al*. (2020) have shown that smallholder farmers often rely on alternative sources of income such as small-scale business, artisanal mining, fisheries and formal employment to cope with on-farm losses due to extreme weather events. The results in Figure 4.3

show that smallholder farmers in South Sakwa Ward have diverse sources of income with 35% of the them being small scale business owners, 20% practicing fish trading, 10% being artisanal miners, 5% in formal employment, and 1% practicing other activities. Conversely, 30% of the farmers indicated that they do not have any other source of livelihood apart from farming (Fig 4.3).

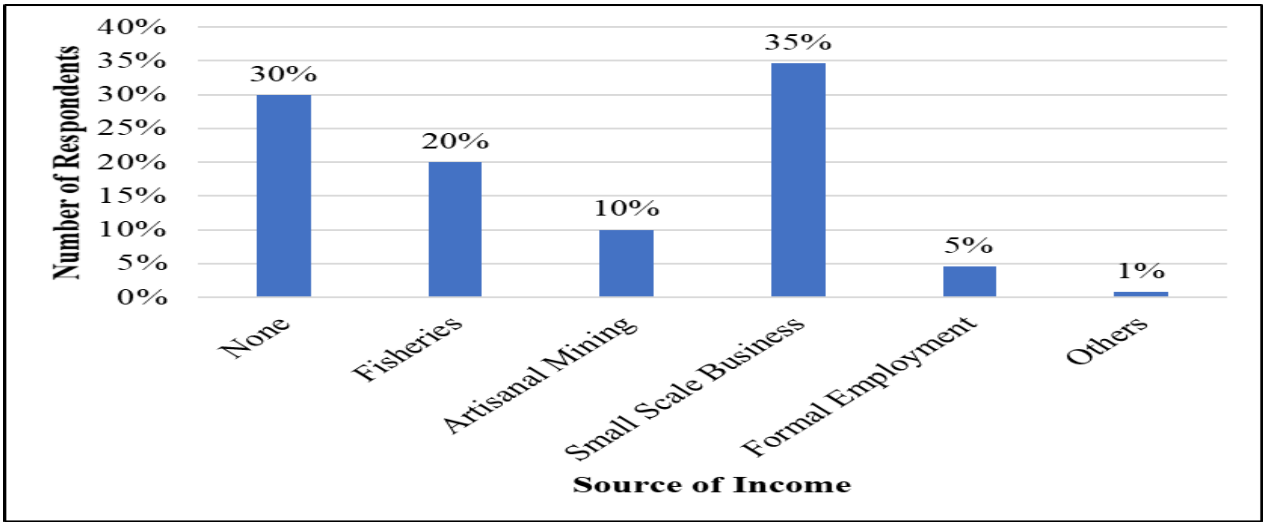

Figure 4.3: Other Sources of Income
Source: Fieldwork, 2022

4.2.5 Income from Farming

Income from farming determines how well a farmer can withstand and adapt to climate variability. Findings in Table 4.1 give the average income from farming per farmer per month as 12,093 Kenya Shillings. However, there is a large disparity between the lowest income (1,667) and the maximum income (75,000).

Table 4.1: Income per Month

Income Category	Frequency	Percent
<= 3500	34	26.2
3501 - 8833	31	23.8
8834 - 15000	33	25.4
15001+	32	24.6
Total	**130**	**100**

Source: Fieldwork, 2022

4.3 Knowledge of Smallholder Farmers on Climate Variability

4.3.1 Determination of Overall Knowledge

Knowledge of climate variability is important to smallholder farmers because it enables them to cushion themselves and employ coping mechanisms in order to maintain productivity of their farms. The responses on knowledge were compared against the county weather information for the same period. The findings in Table 4.2 indicate that smallholder farmers have knowledge on variations in rainfall seasons and variations of temperature, and over time this has enhance their knowledge on the climatic weather patterns in South Sakwa Ward. Based on the responses, 56.9% of the farmers answered that they noticed changes in the end of the rainfall season and 57.7% noticed changes in temperatures. Similarly, 50.8% noticed changes on the weather-related effects which was mainly prolonged drought.

4.3.2 Overall Knowledge Score

This research sought to examine smallholder farmers' knowledge on climate variability. This was done using climate variability data for two planting seasons occurring within 12 consecutive months. The smallholder farmers' responses were correlated with the climate variability data to generate the knowledge score. The knowledge score was cross tabulated with other factors such as gender, education level of the smallholder farmer and the number of year of experience of the smallholder farmer. The average score on knowledge is 47.86%. This score was arrived at by generating the mean of the "yes" responses (Table 4.2) and it represents the percentage of respondents who have provided accurate knowledge of the changes in weather pattern as compared to climate variability data during the same period.

Table 4.2: Knowledge of Farmers on Climate Variability

Question	Yes		No	
	f	%	*f*	%
Over the last one year, has the respondent noticed any changes in the weather patterns?	128	98.5%	2	1.5%
Over the last one year, has the respondent noticed any changes in the start of rainfall?	10	7.7%	120	92.3%
Over the last one year, has the respondent noticed any changes in the amount of rainfall?	24	18.5%	106	81.5%
Over the last one year, has the respondent noticed any changes in the end of the rainfall season?	74	56.9%	56	43.1%

Over the last one year, has the respondent noticed any changes in temperature?	75	57.7%	55	42.3%

Source: Fieldwork, 2022

4.3.3 Overall Knowledge Score by Gender

Cross tabulation of knowledge score by gender postulates a slightly higher knowledge score for women than men. The results show that male farmers had a mean knowledge score of 47%, while the female farmers had a mean knowledge score of 50%. The overall distribution is illustrated in Figure 4.4. The slightly higher knowledge by women can be attributed to the gender roles where women are mainly responsible for domestic work, including farming activities, while men seek formal jobs outside the homestead (Asare-Nuamah *et al*., 2019).

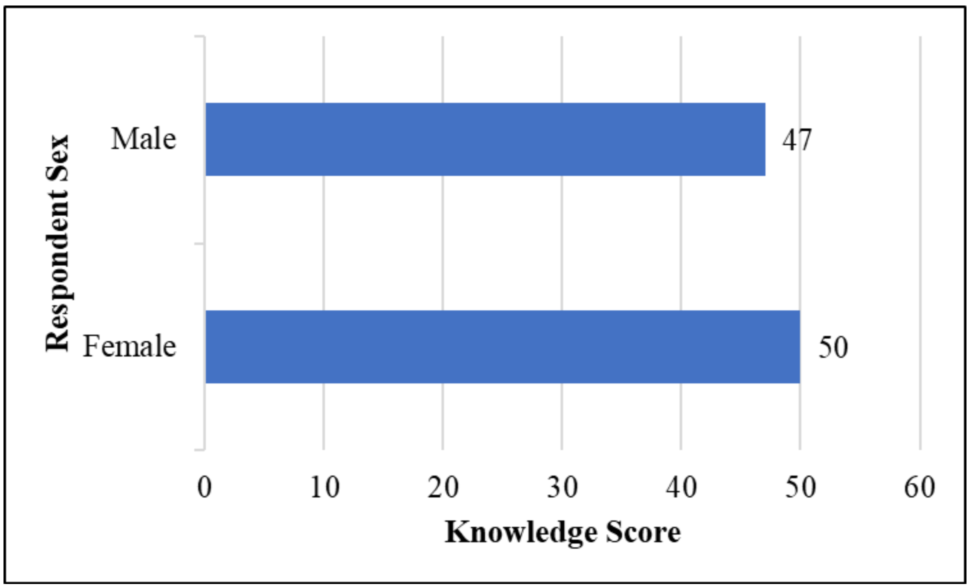

Figure 4.4: Knowledge Score by Gender
Source: Fieldwork, 2022

4.3.4 Overall Knowledge Score by Education Level

Knowledge score was cross tabulated with education and it was found that those who had attained university education had the highest mean knowledge score of 58%, followed by those with secondary school education at 52%, and lastly those who had attained primary school education had the least mean score of 46% (Figure 4.5).

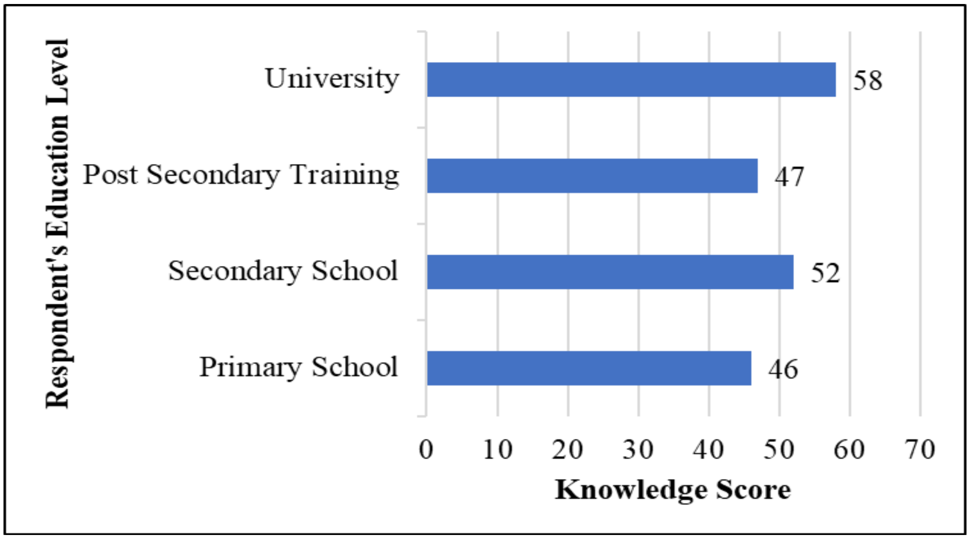

Figure 4.5: Knowledge Score by Education Level
Source: Fieldwork, 2022

4.3.5 Overall Knowledge Score by Years in Farming

The results of knowledge score analysis against years of farming experience shows that the more a person had practiced farming, the more knowledge they had on changing weather patterns. As shown in Figure 4.6, smallholder farmers with greater than 20 years' experience in farming had the highest mean knowledge score of 54%, followed by those with 10-20 years' experience at 50%. The lowest mean score was 45% and this was from those farmers with less than one-year experience.

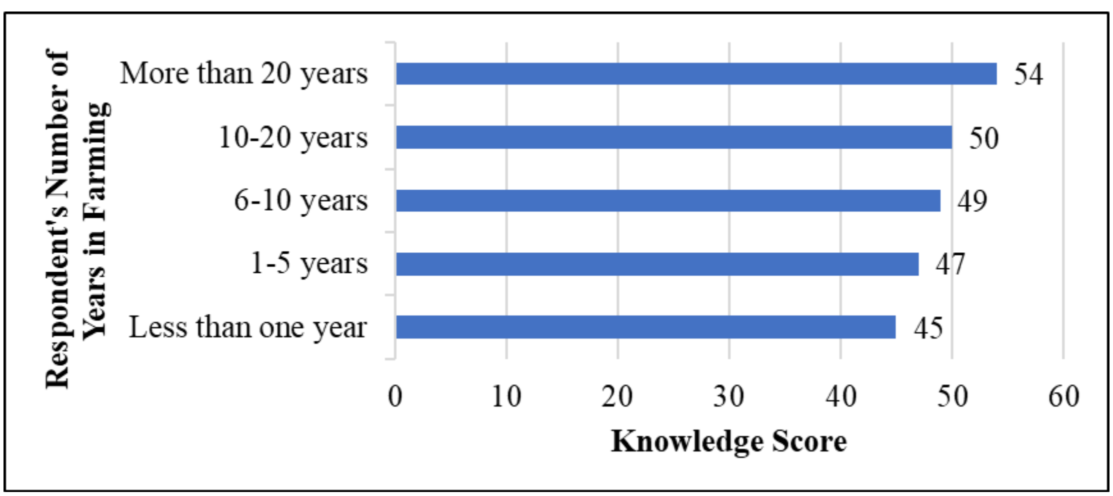

Figure 4.6: Knowledge Score by Years of Farming Experience
Source: Fieldwork, 2022

4.4 The Effect of Climate Variability on Smallholder Farming

4.4.1 Rainfall Variability and Crop Productivity

The climate variability trends based on rainfall show that 90% of the farmers experienced low rainfall and this affected their crop productivity, leading to low yields (Table 4.3). Another 2% reported late start date of planting due to low rainfall and subsequently their crop productivity was low leading to low yields. The effects are measured over a period of 12 months.

Table 4.3: Effect of Rainfall Variability on Crop Productivity

How rainfall variability affected crop productivity	Frequency	Percent
The rains were low so the respondent planted on time but harvest was little	117	90%
The rains were low so the respondent planted late and the crop did not germinate	3	2%
The rains were adequate so the respondent planted and got a good harvest	9	7%
Other	1	1%
Total	**130**	**100%**

Source: Fieldwork, 2022

The effect of rainfall on crop productivity were cross tabulated against the three villages and the results show that 46% of respondents from Wichlum experienced low rainfall and subsequently low crop yield (Table 4.4). This is compared against 42% in Wagusu and 29% in Gombe.

Table 4.4: Effect of Rainfall Variability on Crop Productivity by Village

Village		Frequency	Percent
Wichlum	The rains were low so I planted on time and harvest was little	46	87%
	The rains were low so I planted late and my crop did not germinate	3	6%
	The rains were adequate so I planted and got a good harvest	3	6%
	Others (Specify)	1	2%
	Total	**53**	**100%**
Wagusu	The rains were low so I planted on time and harvest was little	42	88%
	The rains were adequate so I planted and got a good harvest	6	13%
	Total	**48**	**100%**
Gombe	The rains were low so I planted on time and harvest was little	29	100%

Source: Fieldwork, 2022

4.4.2 Temperature Variability and Crop Productivity

The results of temperature effect on crop productivity shows that 76% of the farmers experienced normal temperature and this in turn enabled them to obtain good harvest (Table 4.5). Further 14% of the farmers planted late because of prolonged high temperatures and this led to low crop productivity.

Table 4.5: Effect of Temperature Variability on Crop Productivity

How temperature variability affected crop productivity	Frequency	Percent
The respondent did not harvest because the temperatures were too cold	2	2%
The respondent did not harvest because the temperatures were too hot and the land too dry	1	1%
The respondent harvested little because of prolonged high temperature and crops dried in the field	18	14%
The respondent harvested on time and got a good harvest because the temperatures were normal	99	76%
Other	10	8%
Total	**130**	**100%**

Source: Fieldwork, 2022

4.4.3 Farmers' Perceptions on Causes of Climate Variability

Analysis of the results of the smallholder farmers' perceptions on the causes of climate variability patterns shows that 99% agree that cutting down trees in forest without replacement is a leading trigger of variability to climate and thereafter intensification of farming practices at 80% and the release of greenhouse gases from industries at 54% and finally 19% agree that there is no change in weather pattern (Table 4.6). These responses were compared to the IPCC 6th Assessment Report (2022) that outline the top five leading causes of climate variability to be carbon and methane emissions from industrial activity, destruction of natural forests that act as carbon sinks, and intensification of farming activities such as commercial livestock keeping. The concepts were explained to the respondents in a simplified way and through illustrations. For example, the concept of release of greenhouse gases was explained using photos from a climate change booklet (UNFCCC, 2016). The concept of intensification of farming was illustrated using examples such as nearby large scale farming known as Dominion Farm in Siaya county.

Table 4.6: Perceptions on Causes of Changing Weather Patterns

Cause	Frequency	Percent
Cutting down trees in forests without replacement	129	99%
Release of greenhouse gases that are released from industries leading to warming in the earth	70	54%
Intensification of farming practices	104	80%
There is no change in weather pattern	25	19%

Source: Fieldwork, 2022

4.5 Adaptation to Climate Variability of Smallholder Farmers

Climate adaptation measures are confined to actions taken by smallholder farmers to safeguard their agriculture produce against climate variability. In this research they include planting drought resistant crop varieties, selling assets, irrigation, seeking employment, borrowing money and food aid. The results on climate variability adaptation actions show that the smallholder farmers in South Sakwa Ward applied multiple adaptation actions to changing weather patterns (Figure 4.7). As such, 58.5% of them agreed that they planted drought resistant crop, 57.7% used irrigation, 50% sold assets, while a few borrowed money and sought employment at 20% and 16.2%, respectively. A further analysis shows that the farmers adapted multiple measures to enable them adapt to variability in climate as illustrated in Figure 4.8.

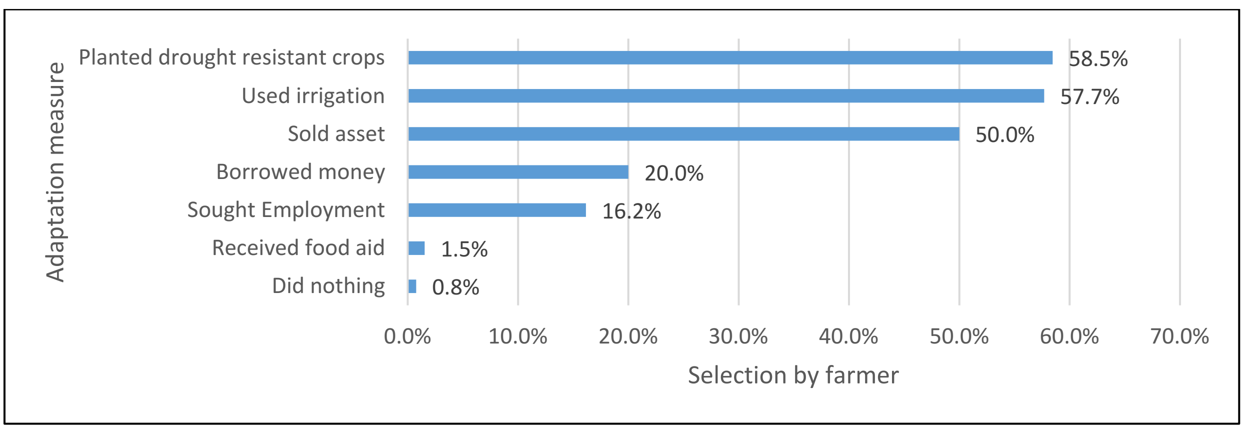

Figure 4.7: Adaptation Measures Selected by Smallholder Farmers
Source: Fieldwork, 2022

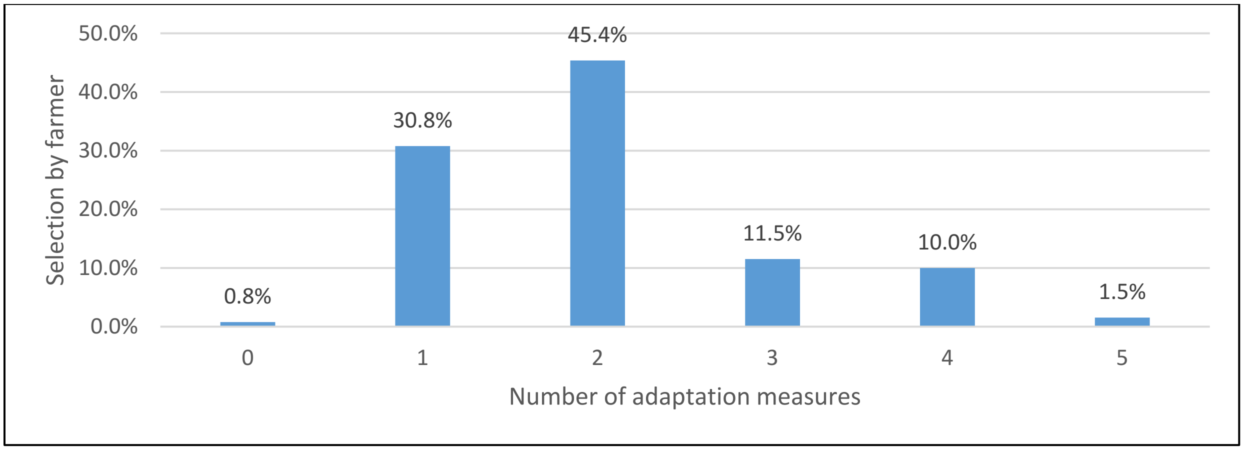

Figure 4.8: Number of Adaptation Measures per Farmer
Source: Fieldwork, 2022

A comparative analysis of adaptation actions per village (Table 4.7) shows that in Gombe, planting of drought resistant crops was the most practiced coping mechanism (82.8%) followed by Wichlum (62.3%) and Wagusu (39.6%). A comparative analysis of adaptation actions by gender (Table 4.8) shows that more female farmers (21.4%) than males (12.2%) sought employment as an adaptation to climate variability. Lastly, when adaptation actions were compared with income (Table 4.9), it shows that farmers with higher income of Ksh. 15,000 and above relied on irrigation, while those with low income of Kshs. 3,500 and below relied on selling assets as adaptation to climate variability.

Table 4.7: Adaptation to Climate Variability by Village

	Village		
Adaptation measures	**Wichlum**	**Wagusu**	**Gombe**
Planted drought resistant crops	33	19	24
	62.3%	39.6%	82.8%
Sold asset	20	29	16
	37.7%	60.4%	55.2%
Used irrigation	25	36	14
	47.2%	75.0%	48.3%
Sought employment	11	6	4
	20.8%	12.5%	13.8%
Borrowed money	13	9	4
	24.5%	18.8%	13.8%
Received food aid	2	0	0
	3.8%	0.0%	0.0%

Did nothing	1	0	0
	1.9%	0.0%	0.0%
Total	**53**	**48**	**29**

Source: Fieldwork, 2022

Table 4.8: Adaptation by Gender of Farmer

	Gender	
Adaptation measures	**Male**	**Female**
Planted drought resistant crops	43	33
	58.1%	58.9%
Sold asset	38	27
	51.4%	48.2%
Used irrigation	49	26
	66.2%	46.4%
Sought employment	9	12
	12.2%	21.4%
Borrowed money	17	9
	23.0%	16.1%
Received food aid	1	1
	1.4%	1.8%
Did nothing	0	1
	0.0%	1.8%
Total	**74**	**56**

Source: Fieldwork, 2022

Table 4.9: Adaptation by Monthly Income

	Monthly Income			
Adaptation measures	**<= 3500**	**3501 - 8833**	**8834 - 15000**	**15001+**
Planted drought resistant crops	13	12	30	21
	38.2%	38.7%	90.9%	65.6%
Sold asset	24	17	10	14
	70.6%	54.8%	30.3%	43.8%
Used irrigation	14	19	20	22
	41.2%	61.3%	60.6%	68.8%
Sought employment	0	5	10	6
	0.0%	16.1%	30.3%	18.8%
Borrowed money	0	9	10	7
	0.0%	29.0%	30.3%	21.9%
Received food aid	0	0	2	0
	0.0%	0.0%	6.1%	0.0%

Did nothing	0	1	0	0
	0.0%	3.2%	0.0%	0.0%
Total	**34**	**31**	**33**	**32**

Source: Fieldwork, 2022

4.6 The Role of Community Organizations and Government Agencies in Enhancing Climate Variability Measures

Smallholder farmers rely on assistance in the form of extension services in order to improve their farming productivity. This study focused on those who received assistance from various governmental and non-governmental agencies. Less focus was given on those who did not receive assistance. Atsiaya *et al*. (2019) study findings show that farmers that receive extension services in form of information and farm inputs have a greater chance of adapting to climate variability compared to farmers that do not. The results show that 59% of the smallholder farmers in South Sakwa Ward did not receive assistance, compared to 41% who said that they received assistance. For those who received assistance, 89% of them received training, while 79% received improved seedlings, and a further 28% received fertilizer only (Table 4.10). In addition, 15% of them received weather information services. Majority of the respondents reported that the assistance came from NGOs. While Faith Based Organizations (FBOs) did not give any form of assistance.

Table 4.10: Type and Source of Assistance

Type and source of assistance	Frequency	Percentage
Training		
NGO	43	81%
CBO	2	4%
Government	2	4%
Total	**47**	**89%**
Improved Seedling		
NGO	34	64%
CBO	2	4%
Government	1	2%
Total	**37**	**70%**
Fertilizer		
NGO	12	23%
CBO	1	2%
Government	2	4%
Total	**15**	**28%**
Weather Information		

NGO	6	11%
CBO	2	4%
Total	**8**	**15%**

Source: Fieldwork, 2022

The distribution of assistance per village indicated that farmers from Wagusu received the highest assistance at 45.3%, followed by Wichlum at 28.3% and then Gombe village at 26.4% (Table 4.12).

4.7 Hypothesis Testing

4.7.1 Choice of Adaptation Measure and Farmers' Knowledge

H_0: The choice of adaptation measure is not informed by smallholder farmers' knowledge on climate variability

H_1: The choice of adaptation measure is informed smallholder farmers' knowledge on climate variability

A chi-square test was run to assess the differences between choice of adaptation measure and smallholder farmer's knowledge on climate variability using a sample of 130 participants aged between 20 and 71 years. There was an inverse association between choice of adaptation measure and smallholder farmer's knowledge on climate variability, which was statistically significant (p =. 020) (Table 4.11). The higher number of coping mechanisms adapted the lower the knowledge level. Farmers with higher knowledge on climate variability adapted fewer number of adaptation mechanisms. We therefore reject the null hypothesis that "the choice of adaptation measure is not informed by a smallholder farmers' knowledge on climate variability". As such, "the choice of adaptation measure is informed by smallholder farmer's knowledge on climate variability" on an inverse trajectory. The higher the levels of knowledge, the more focused the farmer is on a specified adaptation measure. This is further demonstrated in the Ordinal-by-Ordinal Kendall's Tau-b in Table 4.12.

Table 4.11: Chi-Square Tests

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	5.352[a]	1	.021		
Continuity Correction[b]	4.376	1	.036		
Likelihood Ratio	5.120	1	.024		
Fisher's Exact Test				.027	.020
Linear-by-Linear Association	5.311	1	.021		
N of Valid Cases	130				

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 9.78.

b. Computed only for a 2x2 table

Source: Fieldwork, 2022

Table 4.12: Ordinal by Ordinal Kendall's Tau-b.

Symmetric Measures

		Value	Asymptotic Standard Error[a]	Approximate T[b]	Approximate Significance
Ordinal by Ordinal	Kendall's tau-b	-.203	.092	-2.151	.031
N of Valid Cases		130			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Source: Fieldwork, 2022

4.7.2 The Role of Community Organizations and Government Agencies

H_0: Community organizations and government agencies do not influence choice in smallholder farmers' adaptation to climate variability

H_1: Community organizations and government agencies influence choice in smallholder farmers' adaptation to climate variability

Kendall's Tau-b was run to assess the relationship between choice of adaptation measure and whether a smallholder farmer received support from the government/CBO using a sample of 130 participants aged between 20 and 71 years. There was a weak association between choice of adaptation measure and whether a smallholder farmer received support from the government/CBO, which was statistically insignificant (r_s=.0465, p=.5996) (Table 4.13). We therefore fail to reject the null hypothesis that "community organizations and government agencies do not play a role in smallholder farmers' adaptation to climate variability".

Table 4.13: Kendall's Tau-b

Symmetric Measures

		Value	Asymptotic Standard Error[a]	Approximate T[b]	Approximate Significance
Ordinal by Ordinal	Kendall's tau-b	.010	.087	.110	.912
N of Valid Cases		130			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Source: Fieldwork, 2022

CHAPTER 5

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter presents an overview of the summary of findings, conclusions and recommendations based on the results from the study's four specific objectives, namely, 1) to examine smallholder farmers' knowledge on climate variability; 2) to determine the effect of climate variability on smallholder farming; 3) to assess adaptation measures to climate variability of smallholder farmers; and 4) to examine the role of community organizations and government agencies in enhancing climate adaptation measures in South Sakwa Ward of Siaya County.

5.2 Summary of Findings

5.2.1 Knowledge of Smallholder Farmers on Climate Variability

This objective was aimed at determining to what extent smallholder farmers have climate variability knowledge and the effects that it has on farm productivity. In order to understand how smallholder farmers' knowledge of climate variability and subsequent reaction, the responses were measured against the linear trends and changes in rainfall and temperature. The results showed that farmers have been observing climate variability because more than half of the respondents responded accurately regarding changes in the end of the rainfall season, and also on the changes in temperatures. Similarly, half of the respondents accurately answered on the weather-related effects, which was mainly prolonged drought. When analyzing the overall knowledge score the Kernel Density Estimate shows that the average score on knowledge was above average based on the percentage of farmers who provided accurate knowledge on changes in weather pattern as compared to county weather information during the same period. Analysis of knowledge level by gender deciphers a slightly higher knowledge level in females than male farmers. The findings showed that male farmers have a mean knowledge score while the female farmers have a slightly above mean score. Knowledge level was measured against education level and it was found that those who had attained university education had the highest mean knowledge score compared to those with secondary school education and primary school education The results of knowledge level analysis against years of farming experience showed that the more a farmer had practiced farming, the more knowledge they had on changing weather patterns. The smallholder farmers with more than 20 years of farming exposure had a higher mean knowledge score of compared to those with 10-20 years' experience and much less for those with less than one-year experience.

5.2.2 The Effects of Climate Variability on Smallholder Farmers

This objective was aimed at determining the effects of climate variability on smallholder farmers. Periodic temperature and rainfall changes were the key variables being analyzed. From the analysis, majority of the farmers experienced low rainfall and this affected their crop productivity leading to low yields. A small percentage of respondents reported late start date of planting due to low rainfall and subsequently their crop productivity was low leading to low yields. When analyzed across the three villages, the results show that farmers from Wichlum experience low rainfall and subsequently low crop yield. This is compared against farmers in Wagusu and in Gombe. Further analysis of the effects of temperature variability showed that a high percentage of the farmers experienced normal temperature and this in turn enabled them to obtain good harvest. Further some of the farmers planted late because of prolonged high temperatures and this led to low crop productivity.

5.2.3 Smallholder Farmers' Adaptation to Climate Variability

A closer analysis of the actions that farmers were undertaking to cope with climate variability showed that smallholder farmers applied a number of comping mechanisms to changing weather patterns. The analysis showed that most of the farmers agreed that they planted drought resistant crops, more than half used irrigation, while others sold their assets, only a few borrowed money and sought employment. Further analysis showed that smallholder farmers rely on multiple adaptation measures to cope with climate variability. A comparative analysis of coping mechanisms per village shows that in Gombe, planting of drought resistant crops was the most practiced coping mechanism compared to Wichlum and Wagusu. A smallholder's level of income determines a farmers' choice of adaptation mechanism. The study infered that respondents with higher income relied on irrigation, while those with low income relied on selling assets as a coping mechanism.

5.2.4 The Role of Community Organizations and Government Agencies in Smallholder Farmers' Climate Variability Adaptation

This objective aimed to understand how government agencies and community organizations can engage with and enable farmers manage climate variability. Based on results, most of the farmers did not receive assistance, compared to a smaller number who received assistance. Further analysis showed that out of those who received assistance, included assistance such as training, received improved seedlings, received fertilizer and a small percentage received weather information services. Majority of the farmers reported that the assistance came from NGOs rather than from the government. Proximity to government offices was analyzed and this showed that villages that were close to government and community organizations offices obtained assistance more. For example, Wagusu farmers received the highest assistance followed by Wichlum and Gombe.

5.3 Conclusion

First, education level, age and duration of farming experience can influence the knowledge of a smallholder farmer about climate variability. However, no significant difference in knowledge was observed based on gender. Second, climatic variability directly affects farming activity and productivity. Smallholder farmers depend on onset of rainfall to start planting their crop and in the event that the rains are delayed or are lower than average, the crop productivity is affected negatively. Similarly, prolonged high temperatures lead to drying of crops in the field before they mature leading to low productivity in a season. When these climatic variables become erratic and unpredictable, farmers are unable to plan for planting season. Likewise, this unpredictable patters cause farmers to harvest low yields. Farmers require adequate support in order to be able to overcome these challenges. Third, smallholder farmers require multiple adaptation measures in order to cope with climate variability. Relying on one adaptation measure may not adequately address the effects of climate variability. Likewise, a farmer's economic status will determine his/her ability to choose one or more adaptation mechanisms and thus economic status of a smallholder farmer determine the extent to which he/she can adapt to climate variability. Farmers with a limited social and financial capability need support in order to achieve the adaptation measures they require. Fourth, smallholder farmers are receiving assistance in the form of trainings, farm input such as improved seedling and fertilize, as well as weather information services. For smallholder farmers to effectively adapt to climate change there is need for collaboration by different agencies. However, these agencies need to be actively engaged with farmers to respond to the urgent needs as opposed to generalized need. For example, tranings need to be preceded by capacity assessment and vulnerability assessment.

5.4 Recommendations

5.4.1 Recommendations to Policy Makers

The national and county government must be at the forefront in addressing climate threats to the agricultural sector by putting smallholder farmers at the center of climate resilience actions. Smallholder farmers need regular and accurate climate information in order to make correct judgement concerning adaptation to climate variability. Generation and transmission of climate information should include partnership at national and county level and collaborations among stakeholders in agriculture, ICT and metrological department. The partners include climate change experts drawn from meteorological services departments, agronomists from government agencies in agriculture, private companies in agriculture and information technology, academia in research and the smallholder farmers themselves. The partners should work towards the efficient and effective production, dissemination, and delivery of actionable climate information services. In addition, the ministry of agriculture should invest in recruitment and training of more extension agents to support smallholder farmers in translating climate information into meaningful actions that will enhance farm level resilience.

Smallholder farmers use multiple approaches to adaptation to climate variability. Farmers' capability to select applicable adaptation measures is impacted on by household factors including socio-economic factors, household composition, annual revenue, and access to information. This suggests that it is important for state and non-state actors to support and focus on the smallholder farmers’ wellbeing with a wide range of capacity, policy, and technology support. Government policy should additionally prioritize regular sensitization and support to non-classroom education on climate through knowledge cafes and farmer field schools as knowledge sharing forums. Focus of policy should be an enabler to market access and credit access, in order to economically empower the smallholder farmer to be able to have access to technologies that increase smallholder farmers' likelihood to enhance their adaptation action on a variety of adaptation portfolios.

The government of Kenya has adapted progressing laws and policies that address climate variability, these include, Climate Change Act 2016. Despite having robust laws in place, climate change still continues to ravage Kenya and especially smallholder farmers. Similarly, the County Government of Siaya has adapted climate change laws that has provisions that can tackle the current impacts being faced by smallholder farmers. This research recommends that both national and county government use a bottom-up approach in addressing climate change. This means that at county level, there will be establishment of ward project committees that prioritize activities that will then be financed by the county government to address climate change. Furthermore, at national level, bottom-up planning and prioritization will ensure that climate change actions are prioritized and funded by the national government. This bottom-up approach can begin at constituency level where the constituency development committees identify projects which are then prioritized for funding. As the national government develop the 4th Medium Term Plans and as county governments develop the 3rd County Integrated Development Plans, they should prioritize the integration climate adaptation actions into these plans and ensure that finance is allocated for action.

5.4.2 Recommendations for Further Research

Future researches on climate adaptation need to focus on the gender varied impacts of climate. This study has showed that female farmers are disproportionately impacted and subsequently participate actively in climate variability adaptation. Although traditionally women have the understanding and know-how on the requirements to adapt and utilize available solutions. However, there are not enough studies that shows this inter-relationship. Researchers need to unlock how barriers, including deferred land tenure rights, limited access to credit, lack of training, limited access to technology, and limited decision-making powers act as barriers to women's ability to tackle changing climate.

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HOUSEHOLD QUESTIONNAIRE

SECTION A: General Information

1. Which village in South Sakwa Ward do you reside?
   [1] Gombe [2] Wichlum [3] Wagusu

2. Name …………………………… Age ………. Sex: [1] Female [2] Male

3. How many members are in your household?

4. How many years have you practiced farming?
   [1] Less than one year [2] 1 -5 years [3] 6 – 10 years
   [4] 10 – 20 years [5] More than 20 years

5. What is your education level?
   [1] Never went to school [2] Primary school [3] Secondary school
   [4] Post-secondary training [5] University

6. What type of farming system do you practice?
   [1] Crop only [2] Livestock only [3] Both crop and livestock

7. Is farming your primary source of income? [1] Yes [2] No

8. Do you have other sources of income/livelihoods? ………………………………

9. Approximately, how much income (Kshs) per month do you get from farming? ………

10. What size of your farm is under crop cultivation?
    [1] Less than one acre [2] between 1-5 acres [3] between 5-10 acres [4] more than 10

11. What crops do you grow? ………………………………………………………

12. Why do you grow each one of these crops?
    ………………………………………………………………………………

13. Are there any crops you were growing before but you have nowadays stopped growing?
    [1] Yes [2] No

14. **If YES**, which crops and why?……………………………………………………

15. Are there new crops that you have introduced in your farm? [1] Yes [2] No

16. **If YES**, which crops and why? ………………………………………………

17. Which of the following farming practiced have you used to improve your crop production?
    [1] Use of Fertilizers [2] Use of manure [3] Minimum tillage [4] Crop varieties
    [5] Others (specify)

18. Where do you primarily obtain information of best practices in crop cultivation?
    [1] None [2] Radio [3] Newspaper [4] Television [5] Internet [6] Friends/Relatives
    [7] Extension Officers [8] NGO/CBO/FBO [8] Others (Specify) …………………..

19. Which methods do you use in weather forecasting?
    [1] Indigenous/traditional knowledge [2] Scientific knowledge [3] Both

20. Briefly explain how you do it
    [1] Indigenous/traditional knowledge …………………………………………………

    [2] Scientific knowledge ………………………………………………………………

21. What challenges do you experience in your crop cultivation?
    [1] Crop pests and diseases [2] Unpredictable/inadequate rainfall [3] Lack of rain
    [4] Labour scarcity [5] Low soil fertility [6] Lack of inputs [7] Low quality seeds/seedlings
    [8] Others (specify) …………………………

SECTION B: Knowledge on Changing Weather Patterns

22. Have the following weather conditions affected your crop productivity?
    [1] Increasing temperatures [2] Prolonged droughts [3] Flooding due to heavy rains [4] Low rainfall [5] Others (specify) …………………

23. **IF YES**, where do you primarily obtain information on the changes in weather pattern?
    [1] Radio [2] Newspaper [3] Television [4] Internet [5] Friends/Relatives
    [6] Agricuture Officers [7] Others (Specify) …………………..

24. Please indicate if **TRUE or FALSE.**
    [1] County agriculture office gives information on when the rain season will begin
    [2] County agriculture office gives information on how long the dry spell will last
    [3] County agriculture office gives information on how long the high temperatures will last
    [4] County agriculture office gives information which crops to plant in a season

25. What additional information did you obtain from county agriculture office?**…………**

26. Write TRUE or FALSE. Changing weather patterns is caused by?
    [1] Cutting down trees in forests
    [2] Gases that are release from industries leading to warming in the earth
    [3] Changing farming practices

[4] Increase in population that causes increased waste production

SECTION C: The Effects of Weather Changes

27. Fill in the table below

Indicate (1) Yes or (2) No for each weather condition that farmer has experienced in the last two years	Indicate how frequent the farmer has experienced the weather condition in the last two years
Drought …..	
Increased Temperature …..	
Floods ……	
Low rainfall ……	

28. Briefly explain how the weather condition has affected crop productivity
    [1] Drought…………………………………………………………………

    [2] Increase temperature…………………………………………………………

    [3] Floods……………………………………………………………………

    [4] Low rainfall……………………………………………………………

SECTION D: Adaptation to changing weather conditions

29. How do you cope with changing weather condition? Please write your answer against each weather condition below.
    Flooding ………………………………………………………………
    Drought ………………………………………………………………
    Increase in temperature ……………………………………………
    Low rainfall ……………………………………………………….

SECTION E: The Role of Community Organizations and Government Agencies

30. Have you ever received agricultural assistance from the government or any other organization? [1] Yes [2] No

31. **IF YES**, from whom organization did you receive assistance?
    [1] NGO (give name) …………………………………………………..
    [2] CBO (give name) …………………………………………………..
    [3] FBO (give name) …………………………………………………..
    [4] Government (give name) ……………………………………………

32. Explain the type of assistance you get from them
    [1] NGO (give name) …………………………………………………..
    [2] CBO (give name) …………………………………………………..
    [3] FBO (give name) …………………………………………………..

[4] Government (give name) ………………………………………………

KEY INFORMANT INTERVIEW GUIDE

1. For how long have you interacted with farmers in South Sakwa? What climate change trends have you observed?
2. In your expert opinion, what is the level of knowledge on climate change among farmers in South Sakwa?
3. How does farmers’ knowledge effect of their adaptation measures?
4. Is there a coordinate forum that you meet with other actors on regular basis?
5. What factors contribute to a farmers’ choice of adaptation measures?
6. How does your institution support farmers to adapt to the effects of climate change?
7. Any existing opportunities that farmers’ can use to maximize on their adaptation measures.