

**ADOPTION OF CLIMATE-SMART TECHNOLOGIES AND THEIR EFFECT  
ON INCOME AMONG AGRO-PASTORALISTS IN MARSABIT COUNTY,  
KENYA**

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## DECLARATION

This thesis is my original work and has not been presented in any other university for any award.

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We confirm that the work reported in this thesis was carried out by the student under our supervision.

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## **DEDICATION**

I dedicate this work to my beloved husband, Steve Timbor, for his unwavering support as he went against the society's cultural beliefs to allow me to leave our homestead to pursue further studies, my dear children, Jeto Ejere, Jonathan Sugo, Miriam Kerraya and Emmanuel Yogle, who, despite their tender age, tolerated my long absence from home at a time when they needed me most. I also dedicate it to all agro-pastoralists and pastoralists in Marsabit including my mother, Ntumalo Gudere, who taught me the value of integrity.

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## ACRONYMS AND ABBREVIATION

<b>ASALs</b>	Arid & Semi-Arid Lands
<b>ASDSP</b>	Agriculture Sector Development Support Programme
<b>CIFA</b>	Community Initiative Facilitation and Assistance
<b>CSA</b>	Climate Smart Agriculture
<b>CST &amp; Ps</b>	Climate Smart Technologies and Practices
<b>CF</b>	Conceptual Framework
<b>FAO</b>	Food and Agriculture Organization
<b>IPCC</b>	Intergovernmental Panel on Climate Change
<b>KALRO</b>	Kenya Agricultural & Livestock Research Organization
<b>KCSAP</b>	Kenya Climate Smart Agriculture Project
<b>KNBS</b>	Kenya National Bureau of Standards
<b>KMD</b>	Kenya Meteorological Department
<b>MoALF</b>	Ministry of Agriculture, Livestock and Fisheries of Kenya
<b>MF</b>	Marsabit Forest
<b>MK</b>	Mann Kendall
<b>MVP</b>	Multivariate Probit
<b>NGOs</b>	Non-governmental organizations
<b>PACIDA</b>	Pastoralists Community Initiative Development
<b>PSM</b>	Propensity Score Matching
<b>UNSDG</b>	United Nations sustainable development
<b>VIF</b>	Variance Inflation Factors
<b>WB</b>	World Bank
<b>WFP</b>	World Food Programme
<b>WMO</b>	World Meteorological Organization

## ABSTRACT

The world is facing variable weather events and gradual climatic change and Kenya's arid lands where pastoralism is a viable livelihood option are not exceptional. Marsabit County, inhabited by diverse pastoral and agro-pastoral groups, faces extreme climatic events that affect local livelihoods. Despite the government and development organizations disseminating climate smart technologies and practices, the communities still rely on emergency food aid which is unsustainable. Given climate-induced uncertainties, climate-smart technologies may offer viable adaptation options for agro-pastoralism based economies that enhances resilience, increases productivity and reduces greenhouse gases. This study was conceptualized in line with the action theory of adaptation to climate change leading to four objectives; analyze temperature and rainfall trends in Saku Sub-County (1980-2020), identify livestock-crop smart technologies adapted, analyze determinants of climate-smart technologies adoption and assess the impact of adoption of smart technologies on household income. The research design was a survey with a sample size of 373 households in Karare, Marsabit Central (Dakabaricha) and Sagante/Jaldesa wards. Stratified sampling was used in selecting the study sites while systematic random sampling was applied in selecting the households of the agro-pastoralists. The data was collected using questionnaires installed in Kobocollect that were administered through face-to-face interviews with agro-pastoralists, interview schedules administered to 10 key informants and focus group discussions held with 6 groups. Climate data on temperature and rainfall trends were analyzed with Mann Kendall and Sen's slopes, descriptive statistics were generated for the socio-demographic characteristics of the sampled households while determinants were assessed through multivariate probit regression and propensity matching score on the impact of climate smart technologies adoption on income. Decreasing rainfall and increasing maximum temperature trends were significantly in August and September while the minimum temperature trend was significantly increasing in all the months. Agro-pastoralists practiced crop and livestock climate smart technologies and the most adopted categories were improved and traditional crop varieties and soil fertility management (92%), followed by water and water use management (85%) while the least used was livestock management (15%). Agro-pastoralists age, household size, gender, education status, marital status, average income per month, access to credit, training, extension services and weather information influenced the adoption, with agro-pastoralists who adopted multiple climate smart technologies showing significantly higher income. The study recommends that agro-pastoralists should have timely access to weather information in order to make important decisions for adoption of climate smart technologies. Governments, research institutions and non-governmental institutions should closely work together in training and providing extension services to agro-pastoralists on livestock and crop husbandry best practices. The governments and development partners to consider socioeconomic and institutional factors when disseminating multiple crop-livestock climate-smart technologies and practices for enhanced income and more resilient communities.

## CHAPTER ONE: INTRODUCTION

### 1.1 Background of the Study

Climate variability and change is a serious concern in our planet Earth that calls for interventions to reduce its impact (Intergovernmental Panel on Climate Change, 2007). The National Geographic report (National Geographic, 2019), indicated that climate variation is worsening and will continue aggravating and this has serious implication on biodiversity (Muluneh, 2021; Shivanna, 2022). Achieving the United Nations Sustainable Development Goal (UNSDG) number one on eradicating poverty and number two on food security has been a big challenge in Sub-Saharan African developing countries (Biswas *et al.*, 2021; Citaristi, 2022). It has been predicted that Africa is the hardest hit continent by climate change related catastrophic phenomena due to its low adaptation capacity and dependency on natural resources (Adepoju, 2021). This is particularly true for desert and semi-desert where incidences of increased frequencies of dry spells, aridity, water shortages, and low productivity in the farms, livestock deaths, increased food insecurity, malnutrition and pandemics are more prevalent (Thornton & Lipper, 2014; FAO, 2021; Ayugi *et al.*, 2022).

The World Bank (2021), defines climate-smart agricultural practice, technologies and services as sustainable interventions that enhance adaptability of climatic stresses, productivity and reduce greenhouse gases. They are solutions to the current challenges of climate variations and changes facing humanity. Agricultural climate-smart (CSA) aims at developing resilient food production systems that will lead to food and income security in advanced climate variability and change as seen for adoption of conservation agriculture by Indo-Gangetic Plains of India (Lipper, *et al.*, 2014; Bedmar, 2016) in a study on CSA observed that crop and livestock practices and technologies such water harvesting, supplementary feeding, improved livestock practices, conservation of communal grazing fields, conservation of soils and water, among others, help to increase crop yields and improve water and nutrient efficiency as well as reduce greenhouse gases emissions. Nonetheless, factors such as age, gender, marital status, access to extension service, training among others which determine the adoption of CSA have diverse influential effects on the various adaptations of crop-livestock-based strategies thus the need for the current study (Aryal, *et al.*, 2018; Kurgat, *et al.*, 2020). Negera, (2022) in Ethiopia used

multivariate probit model, found that improved agronomy, soil and water conservation, drought tolerant high yielding crop variety, small-scale irrigation, integrated disease, pest, and weed management, and integrated soil fertility management were significantly influenced by the age of the household head, education, land size, household total asset value, frequency of extension contacts, farmer awareness of climate change, farmer experience with climatic shocks, parcel fertility, slope, and severity of soil erosion.

Climate-smart technologies and practices (CST&Ps) are gaining attention as key responses to improving food productivity and enhancing a food secure environment (Palombi, & Sessa, 2013). Khanal (2021) in a study on the impact of adaptations on food production by smallholder farmers in Nepal found that adaptations had the possible contribution to the UN's sustainable development goals of zero hunger (SDG 2) and no poverty (SDG 1). Further, the study established that farmers who adopted CST&Ps had technical efficiency in food production and higher levels of productivity thus contributing to the eradication of hunger and poverty. Moreover, Zakaria *et al.*, (2020) posit that capacity building promotes the uptake of various CST&Ps among farmers in Ghana. Although the study showed a positive relationship with the uptake of smart practices among farmers in Ghana, there is still limited information about interventions that can be put in place to promote multiple climate-smart technologies adaptations. In a related study in Kenya, it was revealed that extreme recurrence of climatic events negatively impacted livestock and crop production systems (Kogo *et al.*, 2020).

Counties in the northern part of Kenya that fall under agro-ecological zones V, VI and VII had faced frequent and intensive droughts since 1960s (Recha, 2019). The Ministry of Agriculture, Livestock and Fisheries (MoALF, 2017) indicated that the above-mentioned regions are the most vulnerable and drought-prone. However, there is little information about rainfall and temperature trends in agro-ecological zones V, VI and VII where food aid has been prevalent (Rono *et al.*, 2023).

Agro-pastoralists are in critical need of climate-smart technologies and practices since they face challenges such as frequent and prolonged drought, intensive floods, and heavy dust, strong winds and locust invasions (Djido, *et al.*, 2021). This has made

them vulnerable and food insecure due to inefficient and ineffective adaptation options. This study filled the gap by documenting the presence of climate-smart livestock and crop technologies that are being practiced by agro-pastoralists to increase food production and thus enhance climate change resilience in ASALs of Marsabit (World Bank, 2021; Radeny, *et al.*, 2022).

Marsabit County has experienced many droughts that are a threat to livestock and crop production which are the main livelihoods and socio-economic (FAO, 2018). This is exemplified in livestock deaths due to scarcity of pasture and crop failures or reduced yields in the arable pockets (MoALF, 2017). Marsabit County is among the highly vulnerable counties to weather and climatic conditions (FAO, 2018). The County is characterized by poor rainfall distribution and reliability which is manifested through prolonged and frequent dry spells and flash floods (Cuni-Sanchez, *et al.*, 2019; Wato *et al.* 2022). The magnitude, prevalence and severity of these catastrophes have increased over the past decades, and this has eroded the production assets and traditional coping capabilities that support livelihoods (Chufe *et al.* 2019; Marsabit County Integrated Development Plan 2018-2022). Climate variability and change has further contributed to ecosystem degradation and livelihood threats thus forcing the communities to adopt maladaptation practices that include overstocking beyond resource capacity limits, charcoal burning and Khat planting (Boru & Koske 2014; MoALF., 2017). Muhati *et al.*, (2018), further cited that the destruction of forests had a significant influence on rainfall patterns which affect water availability, agricultural productivity and availability of quality pasture.

Climate-smart livestock and crop technologies are therefore a necessity in increasing food production and resilience to climate-induced uncertainties in ASALs of Marsabit. The study investigated the factors affecting adoption of climate-smart technologies to changing climate among Mt. Marsabit agro-pastoralists in Saku Sub-County with a view to recommend intervention measures that could enhance adoption.

## **1.2 Statement of the Problem**

Agro-pastoralists in Saku Sub-County who occupy arable land practice mixed farming to diversification. However, there is still over-reliance on food aid with about 90

percent of people living at the mercy of government and non-governmental organizations for emergency food aid which is unsustainable (MoALF, 2017). Despite the efforts of development partners and government institutions to disseminate CST&Ps, food aid is still the norm in Marsabit County. It is not clear what could be causing the low adoption even with the dissemination of knowledge on CSA and integration of crop and livestock production (Kirina, *et al.*, 2022). Adoption of these technologies and practices by agro-pastoralists will make them food secure and more resilient during the dry seasons as seen in studies done worldwide (Lipper *et al.*, 2014; FAO, 2015; Radeny *et al.*, 2018; Ghosh, 2019). Although studies have been conducted on the level and factors that influence adoption of CSA and their impacts in Kenya, little information on the same is known among agro-pastoralist communities of Marsabit (Wekesa *et al.*, 2018; Maina *et al.*, 2020; Muriithi *et al.*, 2021; Mwaura *et al.*, 2021; Emongor *et al.*, 2022 ; Gikonyo *et al.*, 2022; Musafiri *et al.*, 2022). These among others form key knowledge gaps that this study was conceptualized to fill. The findings of the study will be integral in enabling the adaptation of crop and livestock practices to improve production and inform government and development partners about the best intervention mechanisms that promote uptake of CST&Ps.

### **1.3 Research questions**

- 1) What are the trends in rainfall and temperature from 1980 to 2020 in Saku sub-County, Marsabit County, Kenya?
- 2) What are the climate-smart technologies practiced by agro-pastoral communities in Saku sub-County, Marsabit County, Kenya?
- 3) Which factors influence the adoption of climate-smart technologies among agro-pastoral communities of Saku sub-County, Marsabit County, Kenya?
- 4) How does the adoption of climate-smart technologies affect the income of agro-pastoralists of Saku sub-County, Marsabit County, Kenya?

### **1.4 Research objectives**

#### **1.4.1 General objective**

To investigate the adoption of climate-smart technologies and their effect on income among agro-pastoralists in Marsabit County, Kenya.

### **1.4.2 Specific Objectives**

- 1) To analyze temperature and rainfall trends from 1980 to 2020, in Saku Sub-County, Marsabit County, Kenya.
- 2) To identify climate-smart technologies practised by agro-pastoral communities of Saku Sub-County, Marsabit County, Kenya.
- 3) To assess the determinants of adoption of climate-smart technologies by agro-pastoral communities of Saku Sub-County, Marsabit County, Kenya.
- 4) To evaluate the impact of adopting climate-smart technologies on income of agro-pastoralists of Saku Sub-County, Marsabit County, Northern Kenya.

### **1.5 Significance of Research**

The study findings documented existing climate-smart practices and technologies, factors affecting the adaptation and the effect of these practices on the income of agro-pastoralists. The research findings may be beneficial to agro-pastoralists in identification of crop and livestock-smart strategies that the non-governmental organizations, national government, community based organizations and county governments and community-based organizations in the area can promote. In addition, the findings may be useful to actors in designing interventions in dissemination of crop-livestock strategies. Moreover, the findings may be significant in other parts of the County for upscaling and strengthening identified climate-smart practices and technologies. Further, the findings may contribute to the knowledge of science and policy on agricultural resilience among the agro-pastoralists in similar ecological conditions worldwide.

### **1.6 Justification of the Study**

Drought is the most frequent climatic parameter affecting Northern Kenya, Sustainable measures to cope with climate variations and changes are critical for pastoralists and agro pastoralists of Marsabit County. Declining productivity of livestock and crops in the study area is alarming (FAO, 2017). However, there is greater potential to redress this through investing in CST&Ps interventions that would increase productivity and mitigate climate change risks, such as water harvesting technologies, soil fertility management, pasture management and conservation,

integration of crops and livestock coupled with small-scale irrigation among others (World Bank, 2021).

Agro pastoralists are finding ways to cope with drought impacts for their livelihoods. There is need to develop appropriate technologies in response to agro-pastoralists needs and challenges in the wake of climate change. Climate smart livestock and crop technologies and practices play an important role in improving food productivity and livelihoods of communities. Past research on adoption of climate smart technologies exists a gap where most studies over the past years have deliberately on pastoralism systems and farming with little studies being conducted on agro-pastoralism. Therefore, the study is justified since it will highlight the adoption of CST&Ps categories among the agro-pastoralists and their effect on income in Marsabit County.

### **1.7 Scope and Limitations of the Study**

The study covered Saku Sub-County in Marsabit County of Northern Kenya and targeted small scale agro-pastoralists. The study analyzed temperature and rainfall trends from 1980 to 2020, identified CST&Ps, examined social, economic and institutional factors influencing the adoption of CST&Ps and their effects on income among agro-pastoralists. The study did not cover the whole County since agro-pastoralism is practised in a few arable pockets such Moyale and Sololo. There was limitation of funds to cover all the arable pockets due to the vastness of the County. Marsabit County was chosen because of it experiences climatic changes such as drought and flash floods.

### **1.8 Theoretical Framework**

The researcher in this section discusses the theory underpinning and guiding the application on assessing adoption of crop-livestock smart technologies in Saku Sub-County of Marsabit County Kenya. The theory of Action theory of adaptation to climate change informed the theoretical foundation of the study.

#### **1.8.1 Action Theory of Adaptation to Climate Change**

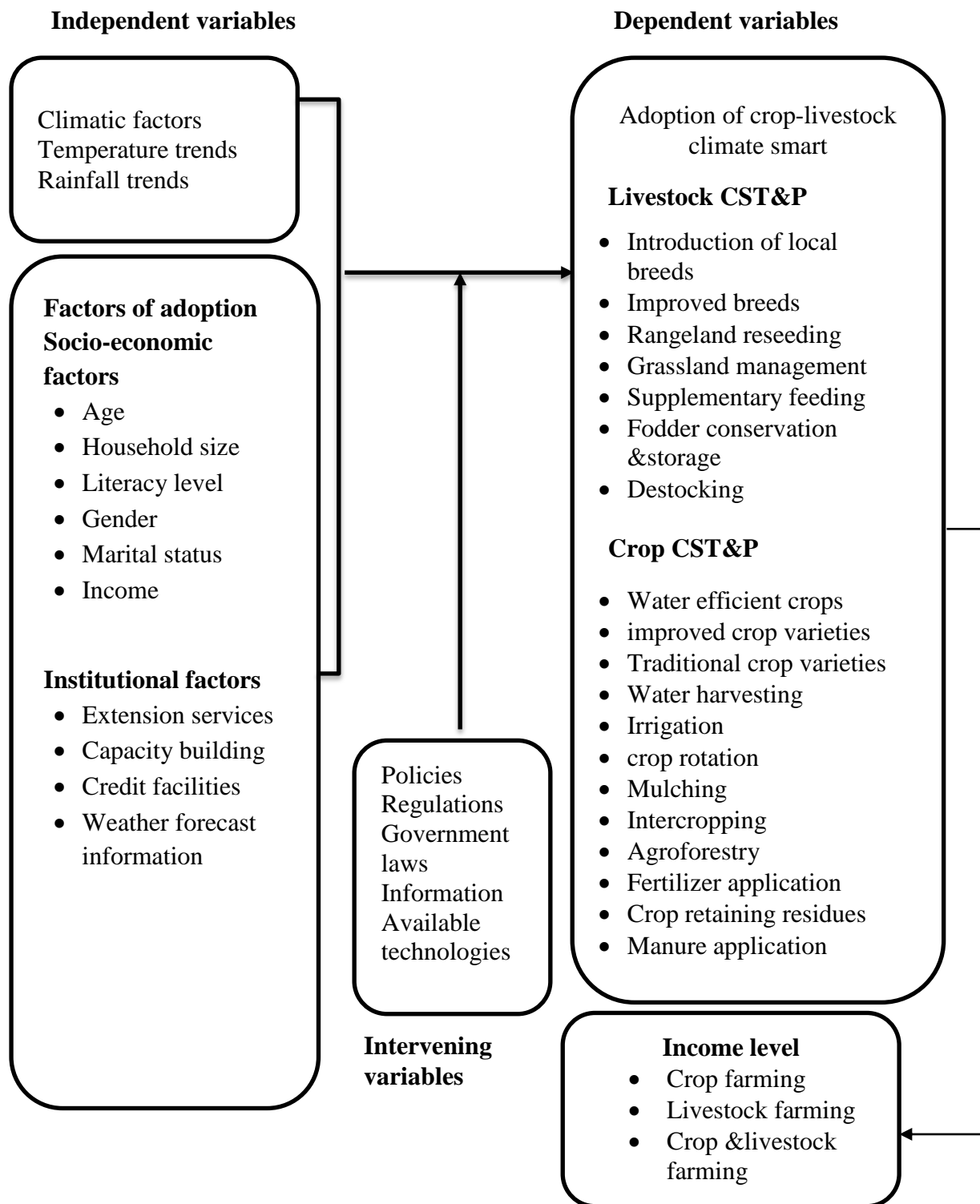
The Action Theory of Adaptation to Climate Change was advanced by Eisenack and Stecker (2010), the theory has four main components; actual or potential stimuli, exposure unit, operator and receptor in terms of resources. Knowledge and power

enable the operator to take up adaptations (actions) as response to the stimuli. The Systems theory is important and relevant in this study since it allows for an in-depth understanding of the interactions, inter-dependability and interconnections among the different parts of the systems. This contributes to the adaptation of CST&Ps which enhance resilience to climate change and increase productivity in Saku Sub County, Marsabit.

### **1.9 Conceptual Framework**

In the context of the study and as illustrated in Figure 1.1, the stimulus is the statistical changes in temperature and precipitation which affect an exposure unit who are the agro-pastoralists. The effects on the exposure unit, which include food security, makes the operator or actor who in this case is an individual household to adapt climate-smart technologies making him or her to adapt to climate perturbations (Tangui, 2014). The adaptation, however, will be affected by the institutional and socio-economic factors of the households and intervening variables.

The study conceptualizes that the trends in temperature and rainfall patterns and the affected system which in this case are the socioeconomic background of the actors (agro-pastoralists) are important components in understanding the response (actions) which will be adaptation of climate-smart technologies (Macharia *et al.*, 2017; Eve, 2021). The actors, who are the agro-pastoralists, are perceived to be the exposure unit and will respond to the stimuli based on the policies, processes, and procedures available. These form the intervening variables of the study. The response (actions to adapt) which are the dependent variables of the study, however, will be determined by the socio-economic variables of the individual actors (operators). The meteorological variables and the socio-economic variables will form the independent variables.



**Figure 1.1: Conceptual Framework**

Source: Adapted from Eisenack and Stecker, (2010)

The study envisages a resilient agro-pastoral production system that seeks to establish assisted adaptation through scalable technological interventions. The study identified smart technologies available to the households, analyzed factors that determine adaptation of the technologies and assessed how adaptation of technologies impact livelihoods to enhance adaptive capacity. Adaptation is conceptualized as a viable response to climate change in form of human action. The adaptations purposefully remit to actions that foster sustainable livelihood within uncertainty. Here adaptations are concerned with actors, actions, and agency (Eisenack & Stecker, 2010).

### **1.10 Definition of operational terms**

- Adaptation:** It refers to adjustments in social, ecological, or economic systems in response to actual or expected climatic stimuli and their effects or impacts (IPCC, 2012).
- Adoption:** Decision of an individual to make use of an innovation as the best course of action available. Process of accepting a new innovation based on the demographic and psychological characteristics of a defined adopter group or individual (IPCC, 2014).
- Agro-pastoralism:** This is the production of crops and livestock, and is practised amongst sedentarized communities living in arable areas (Faso, (2016).
- Agro-pastoralists:** These are farmers who keep livestock and grow crops in their fields (Faso, (2016).
- Formal Education:** This is a system where the respondents/agro-pastoralists have gained skills and knowledge from attending school (Melnic, & Botez, 2014).
- Informal Education:** This means a system where agro-pastoralists have not attended school (Melnic, & Botez, 2014).

## CHAPTER TWO: LITERATURE REVIEW

### 2.1 Introduction

The world is facing variable weather events and gradual climatic changes (IPCC, 2007; WMO, 2021). United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as the change of climate that is directly or indirectly attributed to human activity that alters the composition of the global atmosphere (Bodansky, 1993). It also defines it as natural climatic variations observed over comparable time periods or as variability in the mean state and other statistics. These phenomena are important in agricultural productivity. Adaptation to climate-induced vulnerability through CSA is key for the survival of communities (Hennessy *et al.*, 2022). This chapter reviewed literature on temperature and rainfall trend, climate-smart technologies and practices, factors affecting the adoption of CST&Ps and their effect on the income of household heads. It concludes with the research gaps identified in the literature reviewed.

### 2.2 Rainfall and Temperature trends

Global climatic changes and variations are worsening, and these are a major concern because they have varied indicators and their impacts are not uniform from one region to another. Progress indicates escalating trends in the frequency and magnitude of climatic related hazards (Forzieri *et al.*, 2018). Climate extremes such as high temperature and unreliable and inadequate rainfall have a major impact on food security (FAO, 2015; Affoh *et al.* 2022). Studies (Abbass *et al.*, 2022; NOAA, 2023; Raihan, 2023) have been done worldwide on the temperature and precipitation trends that inform possible ways to cope with these challenges. National Geographic recorded that temperatures have been rising and indicated 2019 as the second hottest year after 2016. The World Meteorological Organization (WMO, 2021) indicated that there was reduced rainfall and increase in temperature in most areas of the world. Increased rainfall and annual temperature trends, but also decrease in monsoon temperatures in India have recently been reported (Panda & Sahu, 2019).

Variations in climatic parameters have been studied in Africa and it is evident that the continent is warming (IPCC, 2013; Li *et al.*, 2022). Temperatures are rising and rainfall is decreasing in most parts. The impact of decreasing rainfall has led to

recurrent droughts in East African countries such as Ethiopia, Tanzania, and Kenya (Gebrechorkos *et al.*, 2019; Haile, *et al.*, 2019; Ayugi *et al.*, 2022).

The impact of climate change is high in Kenya and as one of the developing countries, it mainly depends on crop and livestock production, which are climate driven economy (Pörtner *et al.*, 2022). Kenya Meteorological Department (KMD, 2020) on the state of climate reported that weather patterns are changing through increase in their frequency and intensity in most parts of the county which agreed with a study by (Yvonne *et al.*, 2020) which showed that there was a rise in temperature.

Marsabit County is amongst the counties that are highly affected by the extreme recurrence of climatic events in northern Kenya. The climate is characterized by poor rainfall distribution and reliability which is manifested through prolonged and frequent dry spells and flash floods. The magnitude, frequency and severity have increased over the past decades which has seriously eroded the production assets and traditional coping capabilities that support livelihoods (Boru & Koske, 2014; Dabasso & Okomoli, 2015). Studies on temperature and precipitation in Marsabit County indicated a declining amount precipitations received and increasing temperatures (Boru & Koske, 2014; Dabasso & Okomoli, 2015; Muhati *et al.*, 2018; Cuni-Sanchez *et al.*, 2019). The study conceptualizes that the trends in temperature and rainfall patterns and the affected system which in this case are the socioeconomic background of the actors (people) are important components in understanding the response (actions) which will be adaptation of climate-smart technologies as fronted by (Eisenack & Stecker, 2010).

### **2.3 Crop and Livestock Climate-Smart Technologies and Practices**

The problems imposed by climate change makes CSA packages and services crucial in managing cropland, landscapes, livestock, fisheries, and forests (FAO, 2018; Fusco *et al.*, 2020). Climate-smart agriculture aims at achieving three outcomes as stated by World Bank to; increase productivity through improving food and nutrition security, and boost incomes by producing sufficient food for people living in rural areas (World Bank, 2021) and whose livelihood is mainly dependent on agriculture , enhance resilience by reduction of exposure to climatic related hazards such as drought, flash floods, disease geography, wild fires and other shocks; and enhance

capacity to adapt and grow in the face of longer-term stresses like shortened seasons and erratic weather patterns, and reduction of emissions by pursuing lower emissions for each calorie or kilo of food produced, avoid deforestation from agriculture and identify ways to suck carbon out of the atmosphere (FAO, 2018; World Bank, 2021; United Nation, 2023). There are various practices and technologies which are said to be climate-smart in crop and livestock production, for example; integrated pest management, improved water use and management, conservation agriculture, improved animal husbandry and health, sustainable pasture management, manure management, among others (FAO, 2018).

Climate-smart technologies and practices (Thornton, *et al.*, 2019; Ayayia, 2023; Belay *et al.*, 2023) are important contributors to food security and alleviate livelihood for the poor who mainly depend on climate-based livelihoods and they are context specific (Negesse, *et al.*, 2020). The knowledge on climate extremities help to determine the choice of adopting CSA as seen in the study carried out by (Bedmar, 2016; Shikuku *et al.*, 2017; Wekesa *et al.*, 2018) who found that adopters of larger packages with variety of practices were more food secure among the smallholder farmers in Kenya.

Climate is changing and communities have to bear the consequences hence the need for agro-pastoral communities in Marsabit County to employ a number of adaptation and coping strategies to combat the impact of the frequent droughts on their livelihoods (Lekapana, 2013; Boru & Koske 2014). While these studies gave general adaptation strategies, this study addressed the CST&Ps in the study area. Little is known about the knowledge, practices and coverage of livestock crop climate-smart technologies which have been done in study wards as well as in Marsabit County.

#### **2.4 Factors Influencing Climate-Smart Technologies and Practices**

Adoption is an adaptation strategy thus promoting interventions to reduce vulnerability to climate extremities. Several factors determine the adoption of CST&Ps by farmers, agro-pastoralists, and pastoralists whether to adopt or not. The literature reviewed indicates that several factors affect adoption of climate-smart technologies and practices, and these vary from one context to another although there are some common factors. Saha *et al.*, (2019) in Bangladesh indicated that farmers'

demographic characteristics, farming experience, size of the farm, access to farm information, cattle ownership, annual income, market difficulty, learning, organization affiliation and the perception of climate change, affect their selection of adaptation strategies for climate change.

Farmers get information on climate-smart technologies and practices through different channels such as colleagues, government officers, development partners, such as NGOs, local radios channels and mobile phones. Institutions have greater capacities in disseminating technologies whereby training and knowledge have been major hindrances to CSA adoption (World Bank, 2018).

The level of adoption was affected by plot and household characteristics, market access and major climate risks (Aryal *et al.*, 2018). Kurgat *et al.*, (2020) found that in Tanzania; household resources, farm location, female control of farm resources and farm location were major determinants of adoption. A study in Kenya by (Musafiri *et al.*, 2022; Maina *et al.*; Okoth, 2019) found that socio-economic and institutional characteristic influence adoption of CSA. The household characteristics are common in the reviewed literature as one of determinants of adoption of CSA. There were various means and barriers that structure desired climate-smart technologies adoption; thus, it is not uniform, but it is context specific (Aryal *et al.*, 2018; Saha *et al.*, 2019; Okoth, 2019; Kurgat *et al.*, 2020; Maina *et al.*, 2020; Musafiri *et al.*, 2022). As such, the study establishes the factors hindering the uptake of disseminated livestock and crop-smart technologies that are being undertaken by the agro-pastoralists of Marsabit County.

The preceding texts appropriately emphasized that adoption determinants are context-specific and vary across regions and contexts. This is an important insight, as it underscores the need for tailored interventions and policies that consider local conditions when promoting CST&Ps adoption. The studies were elected to situate and apply the nexus of crop and livestock climate-smart technologies-practices-adoption among various livelihoods in the areas of interest. The study sought to assess instances of confluence and divergence as regards spatial reference and geographical focus (Bangladesh, Tanzania, and Kenya); where the investigation thus suggests that adoption determinants might be influenced by local contexts, economies, and

institutions. In essence, the factors influencing adoption are multifaceted and not uniform across all studies. While some factors like household characteristics and socio-economic variables appear in multiple studies, other factors such as market access, climate risks, and female control of resources are unique to specific studies. The researcher suppose from the cross synthesis adoption is underscored by diversity of adoption factors, the importance of context, and the role of information dissemination and institutions in shaping adoption behaviors. To enhance its critical evaluation, addressing potential limitations of the studies reviewed would further strengthen this possibility.

## **2.5 Impact of Agricultural Smart Technologies and Practices on Income**

The adoption of crop and livestock climate-smart technologies and practices are sustainable adaptation strategy for food security and climate variability and change. Different organizations internationally, regionally and locally make remarkable efforts in promoting CST&Ps due to their benefits in increasing productivity, enhancing resilience and reducing the emission of greenhouse gases (World Bank, 2021) Successful stories from America, Asia and Sub-Saharan Africa by FAO and World Bank Group revealed that CSA adaptation enhances food security and sustains (FAO, 2014; Neate, 2015; World Bank, 2021).

Also in Pakistan, cotton growers had realized the benefit of water-smart, knowledge-smart and energy-smart technologies as they led to an increase in yields, efficiency in resource use, good germination rates and high financial returns (Imran *et al.*, 2018). There was an increase in maize production when using climate smart technologies as observed by Mango *et al.*, (2020). Issahaku and Abdulai (2020), in Ghana, showed that soil and water conservation and the farmers' crop choice contributed to reduced risk of crop loss and promoted crop production and higher crop revenues.

Improved household income and assets were seen among the smallholder farmers in Nyando, Kenya when drought tolerant crops were planted (Ogada *et al.*, 2020). This study also agrees with Wekesa *et al.*, (2018) and Musafiri *et al.*, (2022) in Kenya. It is evident from reviewed literatures that there are benefits of CSA for the adopters. However, knowledge gaps on the factors influencing adoption of smart technologies and practices among communities in Marsabit exist.

## **2.6 Research gaps in the reviewed literature**

From the literature reviewed, it is evident that temperature and precipitation is changing (Boru & Koske, 2014; Dabasso & Okomoli, 2015; Muhati *et al.*, 2018; Cuni-Sanchez *et al.*, 2019; WMO, 2021). The intensity of these climatic parameters differs from one region to another and the adaptations to reduce the shocks also differ from one area to another (McKinley, *et al.* 2021). Studies have revealed that agro-pastoral and pastoral communities in Marsabit County have been employing a number of coping and adaptation strategies to combat the effects of recent droughts on their livelihoods. There are however gaps in adaptation of CST&Ps by agro-pastoral communities (Sanga *et al.*, 2014; Watson *et al.*, 2016; Okoth, 2019; Pörtner *et al.*, 2022).

Although various research was carried out on adaptation of climate-smart technologies, it is appreciated that adaptation is context specific (Palombi & Sessa, 2013). Little is however known as to which climate-smart technologies are applicable to agro-pastoralists. Agro-pastoralists have unique socio-economic backgrounds that need to be understood before designing an adaptation model that will seek to yield appreciable positive outcomes. Although studies have been undertaken to identify how socio-economic variables influence adoption, little is known about the factors that determine the adaptation of climate-smart technologies (Agbenyo *et al.*, 2022; Belay, 2023) which exist among the agro-pastoralists in Marsabit County (Watson *et al.*, 2016).

## **CHAPTER THREE: RESEARCH METHODOLOGY**

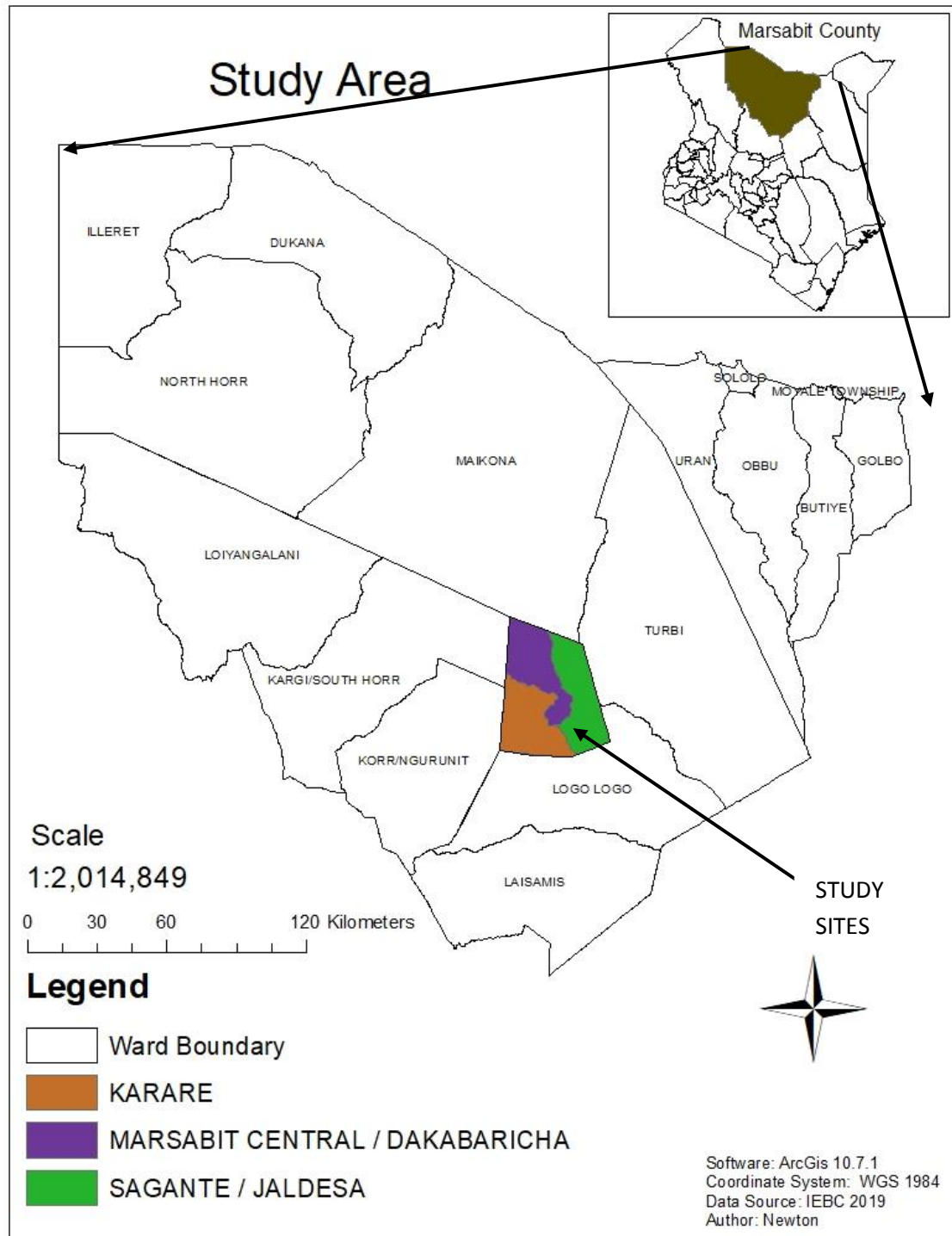
### **3.1 Introduction**

This chapter outlines the study area, the climate of the study area, economic activities, research design, target population, the sample size and sampling procedure, data collection, validity and reliability, data analysis and ethical considerations.

### **3.2 Study Area**

#### **3.2.1 Study location**

The study was conducted in Sagante /Jaldesa, Marsabit central (Dakabaricha) and Karare wards in Saku Sub-County of Marsabit County. Marsabit lies on latitude of N 2° 19 and longitude of E 37° 58. The study areas are adjacent to Marsabit Forest and Marsabit town (Fig.3.1). The study areas were selected based on their potential in supporting crop and livestock production and many organizations had been working in the study areas through supporting agro-pastoralists on CSA (MoALF, 2017).



**Figure 3.1: Map of the study areas in Saku Sub-County, Marsabit**

### 3.2.2 Target Population

The target population for the study was all household heads from 5557 households in Karare, Sagante/Jaldesa and Marsabit Central (Dakabaricha) Wards KNBS (2019).

### **3.2.3 Climate**

The study area is semi-arid and lies on the foot slopes of Marsabit Mountain with most of the communities living adjacent to Marsabit Forest. It falls under agro-ecological zones V and VI, and experience semi-arid climatic conditions with an average temperature range of 15 °C – 26 °C with annual rainfall ranging between 200 mm and 1,000 mm per annum (Gowing *et al.*,2020). The area experiences two rainy seasons; long rains (April to May) and short rains (October to December) which are inconsistent. The soils are clay loamy which are fertile and support crop and pasture production (Muya *et al.*, 2011).

### **3.2.4 Economic activities**

The communities in the study area derive their livelihood from subsistence rainy-fed mixed crop farming which involves production of maize, beans, cowpeas, vegetation, and green grams, although the production has diminished in the recent years due to erratic rainfall (WFP, 2018). Agro-pastoralists keep livestock such as cattle, goats, and sheep. The production of crop and livestock is integrated in the sense that animals migrate to the lowlands during wet seasons to avoid destruction of crops but migrate back to the highlands when crops are harvested to consume the crop residues. Other livelihoods activities in the study area include selling milk and vegetables.

### **3.3 Research Design**

The study employed descriptive research design which describes a population, situation, or phenomenon that is being studied. This design allowed the researcher an opportunity to collect data across the three Wards; Marsabit Central (Dakabaricha), Sagante/Jaldesa, and Karare and empirically test the relationship of the study variables (Mugenda &Mugenda, 2008). Descriptive research design was suitable for this study because the research questions answered were what? which? and how?

### 3.4 Sample size and sampling procedure

#### 3.4.1 Sample size

The study area has 5557 households in three Wards cohort. Respective cohort stratified sample was calculated using Yamane, (1967) to obtain a sample frame of 373 allocated proportionately to the relative population within each of the three wards. The sampling frameworks anticipate and provide for a 5% margin of error.

Yamane sample size is as given below:

$$n = \frac{N}{1+N(e^2)} \quad (3.1)$$

Where:  $n$  is the sample size;  $N$  is the total population of study and  $e$  is the allowable error (%).

$$n = \frac{5557}{1+5557(0.05)^2} = 373 \text{ households}$$

The respondents were from three Wards (Sagante/Jaldesa, Marsabit Township (Dakabaricha) and Karare) which are occupied by Borana, Burji and Rendille tribes respectively. The total number of respondents was 373 household heads with Karare having 162, Marsabit Central (Dakabaricha) 119, and Sagante/Jaldesa 92 as presented in (Table 3.1).

**Table 3.1: Sampled Study Wards, Locations and Sub-Locations**

Ward	Location	Sub-Location	Frequency (n)	Percentage (%)
		HulaHula	21	5.6
		Karare	56	15.0
		Kituruni	23	6.2
Karare Ward		Leiyai	14	3.8
		Ogicho	21	5.6
		Songa	56	15.0
Sagante/Jaldesa		Dakabaricha	119	31.9
Ward		DubGobba	32	8.3
		Gororukesa	60	16.1
Total			373	100.0

### 3.4.2 Sampling Procedure

The sampling framework was agro-pastoralists households in Saku Sub-County who have practiced agro-pastoralism for the last five years because some agro-pastoralists might have started engaging in the economic activity within a period of less than five years and hence might not have enough information on the existence of smart practices. Randomized households in these sub -locations were selected for the study (Njiru *et al.*, 2021). Development partners who have not worked in the area for the last 10 years were not involved in the study because most of them come to the study area only during emergency periods and disappear when the situation stabilizes and hence might not have given accurate information regarding the practices adapted by agro-pastoralists. A stratified sampling according to Cramer & Howitt, 2004) which constituted cohort samples of key informant interview was conducted with livestock, agricultural officers, and development partners. A proportionate number of key

informants residing within permanent settlements was designated for a semi-structured interview according to Sperenza, 2008).

### 3.4.3 Model specification

#### Mann-Kendal Test

This is a non-parametric approach that is less sensitive to outliers and it's valuable to test for a trend of climatic variables which is widely used in trend detection studies (Teshome *et al.*, 2021). Mann–Kendall's test statistic is given as;

$$S = \sum_{i=1}^{N-1} \sum_{j=i+1}^N \text{sgn}(x_j - x_i) \quad (3.2)$$

The sign function is given as

$$\text{sgn} = \begin{cases} +1 & \text{if } (x_j - x_i) > 0 \\ 0 & \text{if } (x_j - x_i) = 0 \\ -1 & \text{if } (x_j - x_i) < 0 \end{cases} \quad (3.3)$$

Where  $S$  is the Mann–Kendal's test statistics;  $x_i$  and  $x_j$  are the sequential data values of the time series in the years  $i$  and  $j$  ( $j > i$ ) and  $N$  is the length of the time series.

#### Sen Slopes test

The study employed the non-parametric approach to estimate the magnitude of trend in the rainfall and temperature data. The following formula was used to estimate the slope of “n” pairs of data.

$$\beta = \text{median}\left(\frac{x_j - x_i}{j - i}\right) \quad j > i \quad (3.4)$$

**Where**  $\beta$  is the Sen's slope estimator,  $x_j$  and  $x_i$  data value at the time  $j$  and  $i$ , ( $j > i$ ) respectively. The ‘n’ values of  $\beta$  are ranked from the smallest to the largest and the median on ‘n’ values of  $\beta$  is the Sen's slope given as;

$$\beta = \begin{cases} \beta_{\lfloor \frac{(n+1)}{2} \rfloor}, & \text{If } n \text{ is odd} \\ \frac{1}{2} \left\{ \beta_{\lfloor \frac{n}{2} \rfloor} + \beta_{\lfloor \frac{(n+2)}{2} \rfloor} \right\}, & \text{If } n \text{ is even} \end{cases} \quad (3.5)$$

A negative  $\beta$  value represents a decreasing trend; a positive  $\beta$  value represents an increasing trend over time.

Multivariate probit regression model was used for objective 3. The study was based in how a number of binary variables of CST&Ps where each category was assigned a unique index taking (1, 2, 3, 4, 5 and 6) for a positive integer variables relate to the independent variables. In this study, the multivariate probit regression was of the form: It was assumed that each agro-pastoralist may consider a combination of technologies, which were further assumed to depend on a set of the socio-anomic and institutional factors.

$$Y_{ij} = X'_{ij}\beta_j + \varepsilon_{ij} \quad (3.6)$$

where  $Y_{ij}$  ( $j = 1, 2, 3, 4, 5 \& 6$ ) represents the different adaptation practices by the  $i$ th agro-pastoralist ( $I = 1, \dots, 302$ ),  $X'_{ij}$  is a  $1 \times k$  vector of observed variables that affect the adaptation practices,  $\beta_j$  is a  $k \times 1$  vector of unknown parameters (to be estimated), and  $\varepsilon_{ij}$  is the unobserved error term. The vectors were variables including age, marital and education status, size of the household, income, credit, extension, training, and weather information. Multivariate probit estimation has already been used in a number of studies that evaluated factors that affect adoption of agricultural technologies (Kangogo *et al.*, 2021; Musafiri, *et al.*, 2022).

Propensity score matching

$$\tau_i = Y_i (D_i = 1) - Y_i (D_i = 0) \quad (3.7)$$

Where  $\tau_i$  is the treatment effect due to adopting CST&Ps,  $Y_i$  is the outcome variable (income) observed on household of agro-pastoralist, and  $D_i$  indicates whether agro-pastoralists  $i$  adopted CST&Ps or not.

### 3.4.4 Study variables

The study variables as presented in Table 3.2 consist of explanatory (independent) variables which are the socio-economic characteristics (Aidoo *et al.*, 2021) of respondents and included age, gender, marital status, education status, household size and income, and institutional factors which consisted of credit access, weather information, training, and extension service. Explanatory variables influence the decision of agro-pastoralists to use a certain CST&Ps.

The dependent variables were the crop and livestock climate-smart technologies selected and grouped into six categories as follows: improved and traditional crop varieties, managing diversity on farm, water-harvesting and water use management, soil fertility management, livestock management, and pasture conservation and management. CST&Ps influences income and remains a constant variable.

**Table 3.2: Study variables**

<b>Independent Variables</b>	<b>Dependent variables</b>		
Socio-economic factors	Adaptation	of	Crop-livestock-smart technologies
Institutional factors	Adaptation	of	Crop-livestock-smart technologies

## 3.5 Data Collection Methods

### 3.5.1 Document analysis guide

The data to ascertain trends in temperature and rainfall (Ilori & Ajayi, 2020) which was secondary data, was sourced from KMD headquarters in Nairobi. The sourced secondary data grounded the inquiry on key variables, which transcended discourses pertaining to aspects of climate change. Trend analysis intends to inference vulnerability exit points and ascertain probable climate induced livelihood end points of no or delayed adaptation.

### 3.5.2 Questionnaires

Questionnaires were used to collect data for objectives 2, 3 and 4. Semi-structured questionnaires were administered through face-face. The questions were entered on Kobocollect software in mobile phones and administered through face-face. Any aspects that were not captured in Kobocollect were written in notebooks. A semi-structured questionnaire was deployed and accessed from a cloud storage to mobile handsets.

### 3.5.3 Interview Schedule

The data was collected using a qualitative interview schedule (Table 3.3).

**Table 3.3: Organizations interviewed as key informants**

<b>Name of Organizations</b>	<b>Persons interviewed</b>
Ministry of Agriculture, Livestock & Fisheries	Director of Agriculture Director of Livestock, ASDSP coordinator
Pastoralists Community Initiative Development (PACIDA)	Program officer
CARITAS	Program officer
CIFA	Program officer
Kenya Forest Service	Director
KALRO	Institute director
Wilt-hunger	Program officer
Ministry of Water & Environment	Director

Table 3.3 shows that the researcher interviewed directors of agriculture, livestock environment, Sheep, Goat & Camel Research Institute and Kenya Forest Service, program officers of CARITAS, PACIDA, Wilt-hunger and CIFA. These respondents were selected because of their experience in the study area.

### 3.5.4 Focused Group Discussion

Group discussions were used to ground focus on value-laded issues that were used as proxy indicators in the semi-structured questionnaire interviews. Additional follow up

group discussions, as appropriate were undertaken to understand the nuances of the conflict perceptions. Six focused group discussions were done where each group had eight participants including each set of gender, one with male only and one with female only. This was done to allow free participation and avoid cultural biasness.

### 3.6 Validity and Reliability

During the initial interface, the effectiveness of research tools and methods were tested for reliability and validity before the actual data collection. The data collection tool used basic language that was free from jargon making it easy to be understood by the respondents. Cronbach’s Alpha ( $\alpha$ ) was used in testing for the reliability of the questionnaire. It indicates the extent to which a set of test items can be treated as measuring a single latent variable (Cronbach, 1951). Cronbach’s Alpha was 0.969 which means that the constituency was good (Table 3.4).

**Table 3.4: Cronbach Alpha Reliability Test**

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
0.969	1.000	6

### 3.7 Data Analysis

Mann-Kendall test and Sen’s slopes were used to analyze the rainfall and temperature trends (Huang *et al.*, 2017; Praveen *et al.*, 2020; Gikonyo *et al.*, 2022) for the last forty years in Saku Sub-County using XLSTAT software. Assumptions of the significance of data were inferenced through Mann- Kendall (MK) test to determine whether a time series has a monotonic upward or downward trend. The test does not require data to be normally distributed or be linear, and it is a dominant method in the literatures reviewed. Mann-Kendall test analysed differences in signs between earlier and later data points. The idea is that if a trend exists, the sign value will tend increase/decrease consistently. Every value is compared to every preceding value in the time series. The P value  $< 0.05$  means that there is trend and if positive, then increasing trend is, and if tau is negative, there is decreasing trend. The Sen’s slope is the median of all slopes passing between pairs of distinct  $x$  and  $y$ .

In addition, descriptive statistics such as percentages, frequencies and mean using Statistical Package for the Social Sciences (SPSS) version 22 were applied to analyze identified crop and livestock climate-smart technologies adopted by agro-pastoralists and the results were presented in graphs and tables.

Similarly, multivariate probit regression analysis (Yu *et al.*, 2008) was used to analyze the factors for the adoption of climate-smart technologies. The Multivariate regression analysis aim at identifying key determinants of adaptation choices (Atube, 2021). This empirical approach was successfully used by several previous studies to assess factors affecting the choices farmers make in the context of climate change adaptation strategies in the agricultural sector (Aryal *et al.*, 2018; Kurgat *et al.*, 2020; Muriithi *et al.*, 2021; Musafiri *et al.*, 2022).

The MVP simultaneously models the influence of a set of explanatory variables on adaptation strategies used by agro-pastoralists; it also allows to understand the potential correlation between unobserved disturbances, as well as the relationship between the different practices (Karen, 2023). Based on our previous investigation in the study area, the study considered that since agro-pastoralists used a mix of CST&Ps strategies simultaneously, the appropriate modelling procedure should not be univariate, but needs to consider the interactions and possible simultaneity CST&Ps adopted. It is also appreciated that the agro-pastoralists households were more likely to adopt more than one adaptive strategy to deal with agricultural production challenges than adopting only one CST&Ps coping or adaptation strategy. STATA 15.1 software was used for the analysis. Probit analysis was the best model to avoid heteroscedasticity since it outperforms most of the competing approaches in terms of efficiency and effectiveness in minimizing heteroscedasticity and error term have standard normal distribution (Adekoya *et al.*, 2002). The existence of multicollinearity between the explanatory variables was checked using the variance inflation factor (Dougherty, 2021).

Finally, propensity matching score method was used to analyze the adoption of climate smart technologies (Oduniyi & Tekana, 2019; Nkuba *et al.*, 2020; Negera, 2022) and their effect on the income of agro-pastoralists. PSM is non-experimental method for comparison that minimize selection bias which estimate the impact of the

intervention (Austin, 2011; Li, 2013)). The variable understudy is the average monthly income of agro-pastoralists who adopt the six categories of CST&Ps. The PSM estimator investigated the income of the adopters of climate smart technologies and practices and non- adopters and caliper (0.3) and nearest neighbor were used to confirm the results. No normality, autocorrelation, heteroscedasticity, endogeneity, multicollinearity problems were detected.

### **3.8 Ethical considerations**

The researcher abided with research protocols as stipulated on various statutes that govern such works in relation to caveats, confidentiality and conduct (Mugenda & Mugenda, 2008). During the study, the utmost level of confidentiality and anonymity was observed to protect the information given by the respondents and this was done in way that there was no a question asking the name of respondent in Kobocollect.

## CHAPTER FOUR: RESULTS AND DISCUSSION

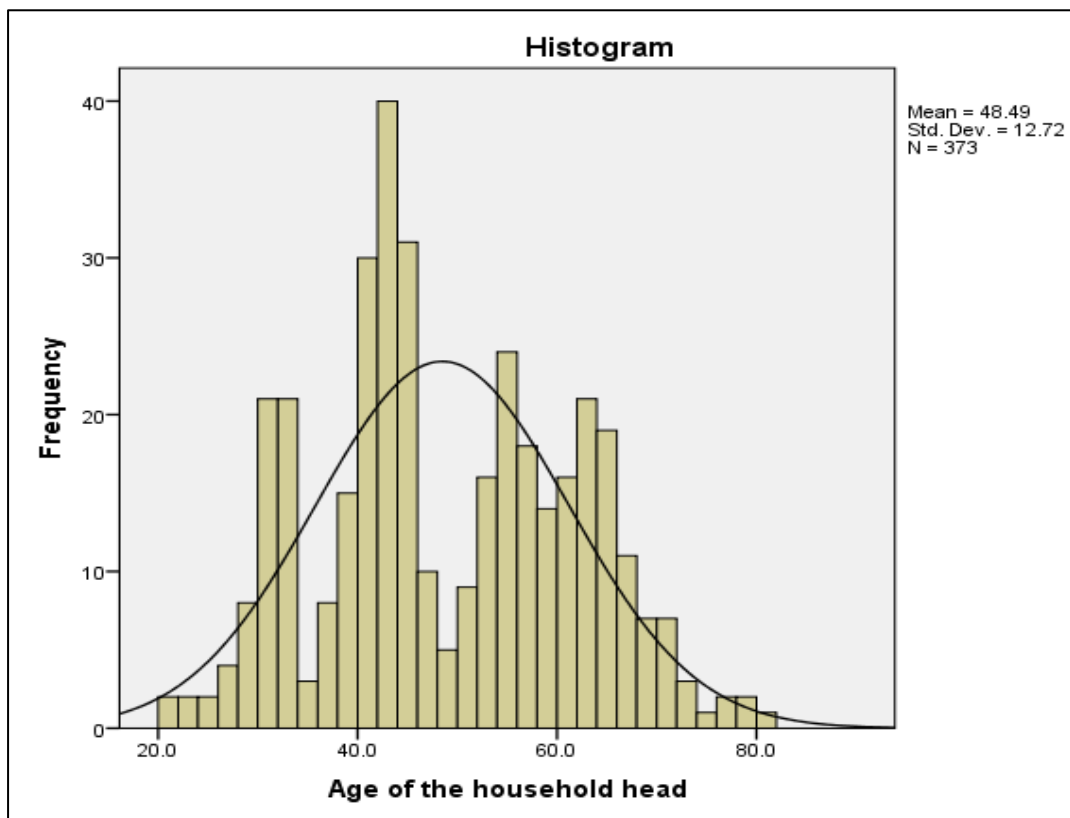
### 4.1 Introduction

This chapter presents results of secondary data from KMD Nairobi and primary data collected from respondents. The study was guided by four objectives; to analyze temperature and rainfall trends in Saku Sub-County (1980-2020), to identify livestock-crop climate-smart technologies adopted by agro-pastoralists, to analyze the factors that determine adoption of CST&Ps and evaluate the adaptation of CST&Ps impacts on household income. The results obtained are presented according to the objectives.

### 4.2 Demographic Information of the Respondents

#### 4.2.1 Age of respondents

Figure 4.1 shows that the average age of the respondents was 48.5 years which means that most of the respondents were in their active age bracket.



### Figure 4.1: Age of respondents in years

The study is in agreement with Musafiri *et al.*, (2022) who found that the average age of people involved in agriculture in Western Kenya was 51.9 years. This shows that the younger generation was not actively involved in agro-pastoralism since the average age of the respondents was beyond the youth age bracket of 18 to 35 years.

#### 4.2.2 Gender, Marital status and education

The researcher also sought to establish the gender, marital status and education of the head of household. Results are presented in Table 4.1. According to the findings presented the total number of males were 218 while females were 155 which implied that both male and female engage in crop farming and livestock keeping (agro-pastoralism).

**Table 4.1: Gender, Marital and Education Status of the Household Head**

Variable	Description	Frequency(n)	Percentage (%)
<b>Gender</b>	Female	155	41.6
	Male	218	58.4
<b>Marital status</b>	Single	73	19.6
	Married	300	80.4
<b>Level of education</b>	Non-formal	243	65.1
	Education		
	Formal Education	130	34.9

More households were headed by men than by women. This finding agrees with a study that was conducted in Ghana whose findings indicated females were less undertaking smart practices than male counterparts (Aryal *et al.*, 2020). Further studies have shown that agriculture is affected by gender gap as observed by (Paudyal *et al.*, 2019; Huyer & Chanana, 2021).

The majority of the agro-pastoralists were married (80.4%). This can be explained by the fact that married household heads have more chances of adaptation because of

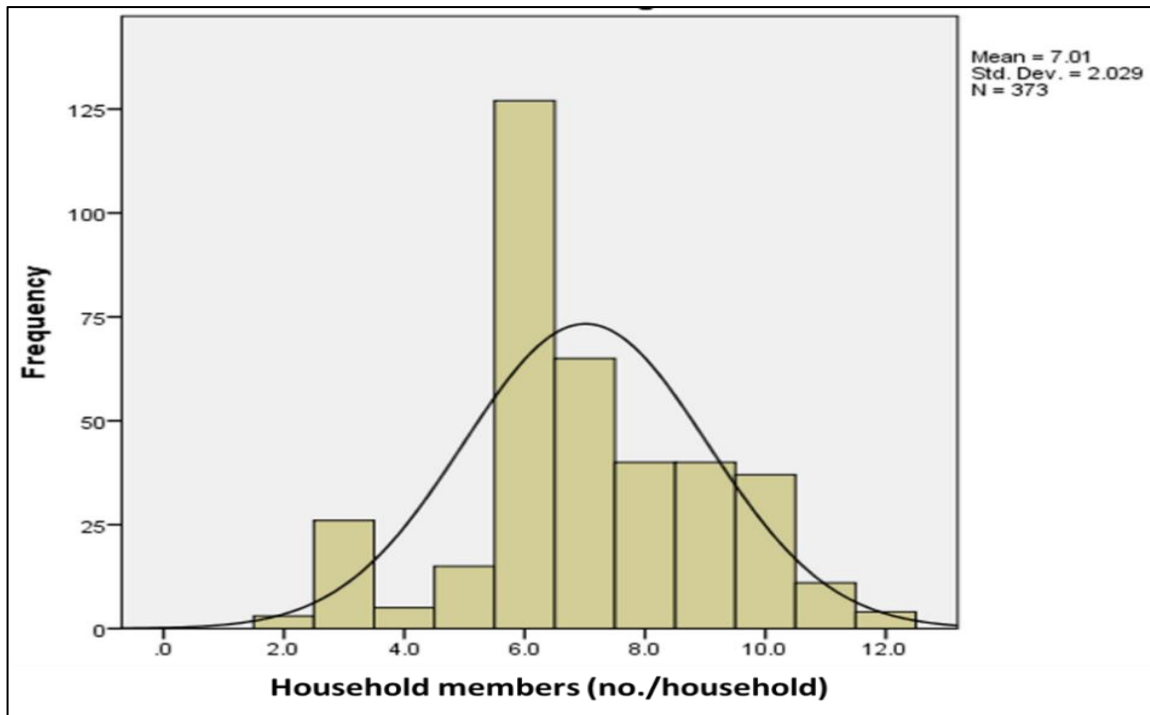
joint decision making and division of roles which agrees with a study by (Musafiri et al., 2022) in Kenya.

Additionally, findings in Table 4.1 indicate that agro-pastoralists without formal education constitute 65.1% (n=243) while those with formal education constitute 34.9% (n=130). This shows that the rate of illiteracy is high, and this finding agrees with the 2019 census results which concluded that the illiteracy level is high in the County (KNBS, 2019). However, although majority of the respondents are illiterate, they do practise agro-pastoralism and hence the government and development partners should find the best interventions to reach them when upscaling climate-smart technologies.

Level of education has an impact on mitigation and adaptation of climate-smart technologies with more educated farmers showing willingness compared to the less educated farmers (Agbenyo *et al.*, 2022). This indicates that formal knowledge is important in understanding and implementing climate-smart agricultural technologies.

#### **4.2.3 Household size**

The results in Figure 4.2 show that most of the households have an average of 7 members. The KNBS (2019) report indicated that the average number of persons in the household was 6 which is slightly low compared to this finding. The size of the household has an effect on adoption of practices. The higher members in a household the more the chances of adaptation since there is family labour which is cheap and readily available (Musafiri *et al.*, 2022).



**Figure 4.2: Size of the households in Karare, Dakabaricha and Sagante/Jaldesa wards**

#### 4.2.4: Household income

Table 4.2 shows the average income from crop growing and livestock rearing by adopting practices was Ksh. 5562.07. The income for those who adopted livestock CST&P and crops CST&P only was Ksh. 2177.78 and Ksh.5023.23 respectively.

**Table 4.2: Average monthly income of Household head**

Average income per month (Ksh)	Mean	Std. Err.	min	max
both crop & livestock farming	5562.069	4028.253	1000	30000
livestock farming	2177.778	900.1424	1000	4000
crop farming	5023.232	2008.9	1000	13000

This shows that the income was highest for those agro-pastoralists who rely on both crops and livestock smart practices followed by those who adopted crop smart practices and agro-pastoralists who had only livestock CST&P earned the least income. This finding confirms the need to integrate crop and livestock production by agro-pastoralists for increased income and resilience.

#### **4.2.5 Access to credit, Extension services Training and Weather information**

The results shown in Table 4.3 indicates 56% (n=209) of the respondents were able to get weather information through various means, focus groups and key informants affirm the same. Weather information accessibility was highest received service among the services provided by institutions working in Saku-Sub County. The more weather information the agro-pastoralists get in time the higher the preparedness in anticipation of climate change and variability thus leading to adoption of CST&Ps. A study by (Djido, *et al.*, 2021) indicated that weather and climate information significantly increased the adoption of water management and multiple cropping practices in the Upper West Region of Ghana.

**Table 4.3: Credit, extension service, training and weather information**

Services	Frequency(n)	Percentage (%)
Credit facilities	40	10.6
Weather information	208	55.5
Extension services	104	27.7
Training	64	17.0

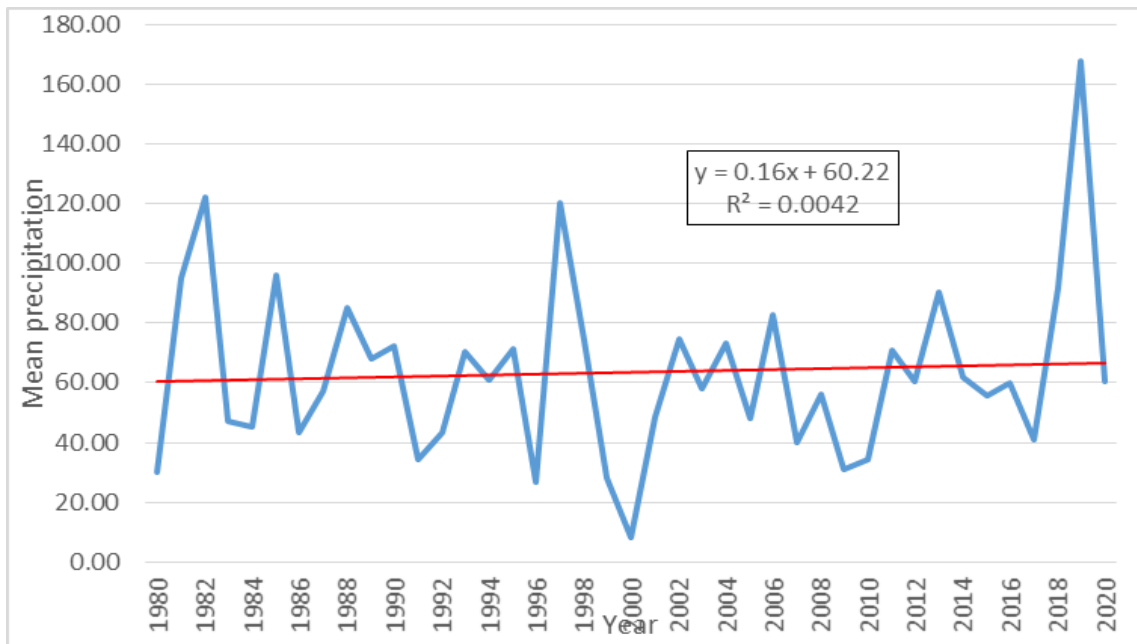
The study findings indicated that few agro-pastoralists received extension services 28% (n=104) and training on CST&Ps 17 % (n=63). The visit by extension officers to agro-pastoralists helps to improve the knowledge and an acceptance of practices (Danso-Abbeam, *et al.*, 2018). Accessibility to credit facilitates greatly improves adoption of various technologies. (Emongor *et al.*, 2022; Masca *et al.*, 2022). The results illustrate that 89.4% of agro-pastoralists had no access to credit facilities while 10.6 % of the respondent's accessed credit facilities. Credit provision has the advantage to ease financial constraints to meet their needs of adopting practices that

suit the forecasted climate change. Lack of credit facilities and extension services were cited as the main challenges facing agro-pastoralists as per group discussions and demonstrated the need for field demonstrations, trainings at village levels which will increase knowledge for sustainability of CST&Ps and help communities to be more resilient.

### **4.3 Rainfall and Temperature trends for the 40-year period from 1980 to 2020**

#### **4.3.1 Rainfall trends**

The average annual rainfall for the forty years under study (1980-2020) shows that the major drought periods were experienced in the years 1984, 1991, 1995-1996, 2000-2001, 2007, 2010 and 2017 (Figure 4.3). The approximate average amount of rainfall received was 120 mm, 120 mm and 170 mm, rainfall in 1981, 1997, and 2019 respectively, which agrees with Mulinya (2017) who reported that the said years received the highest average rainfall. The drought years are more than wet seasons thus leading to deficiency of precipitation over an extended period of time thus leading water shortages and agro-pastoralists are forced to find ways to cope with it. Gebrechorkos *et al.*,(2020) observed that the 1980s 1990s, and 2000s were decades of drought in East Africa which most region received less than average rainfall that threatened the livelihoods.



**Figure 4.3: Mean Annual Precipitation for Saku Sub-County (1980-2020)**

Results from both Man-Kendall ( $Z_s$ ) and Sen's slopes ( $Q_{med}$ ) presented in Table 4.4 show negative precipitation in the months of January, March April, May, June, July August, September and December meaning that the rainfall is decreasing in most of the months in 1980-2020 while increasing in February, October, and November. A significant negative trend exists in the months of August, September and December which means that these months are becoming drier. The observed rainfall showing both downward and upward trends suggests variable precipitation over time and may be attributed to the wetting and drying trends in the study area. Ongoma and Chen (2017) also observed that droughts have become more common, especially in the tropics and sub-tropics since 1970, with significant socioeconomic and environmental consequences. The negative rainfall anomalies observed in MFR from the early 1990s to today support earlier observations made by Cuni-Sanchez *et al.*, (2018), who established a statistically insignificant decrease in annual rainfall in the past three decades in Marsabit County which corroborate with our findings though significantly decreasing in the months of August, September and December which are the normally fall in dry season (Dabasso & Okomoli, 2015). The trends suggest that rainfall patterns in the study area were shifting, with reduced rainfall over time, a feature associated with climate change.

**Table 4.4: Rainfall Trends using Mann Kendall and Sen's slopes**

Period	Test	Trends	P-Value
JANUARY	<i>Zs</i>	-0.086	0.532
	<i>Qmed</i>	-0.020	-
FEBRUARY	<i>Zs</i>	0.124	0.271
	<i>Qmed</i>	0.036	
MARCH	<i>Zs</i>	-0.004	0.533
	<i>Qmed</i>	-0.015	-
APRIL	<i>Zs</i>	-0.199	0.432
	<i>Qmed</i>	-3.581	-
MAY	<i>Zs</i>	-0.134	0.154
	<i>Qmed</i>	-0.753	-
JUNE	<i>Zs</i>	0.071	0.397
	<i>Qmed</i>	0.063	-
JULY	<i>Zs</i>	-0.134	0.216
	<i>Qmed</i>	0.100	-
AUGUST	<i>Zs</i>	-0.020	0.010***
	<i>Qmed</i>	-0.014	-
SEPTEMBER	<i>Zs</i>	-0.061	0.000***
	<i>Qmed</i>	-0.015	-
OCTOBER	<i>Zs</i>	0.183	0.575
	<i>Qmed</i>	1.964	-
NOVEMBER	<i>Zs</i>	0.200	0.670
	<i>Qmed</i>	1.973	-
DECEMBER	<i>Zs</i>	-0.048	0.069*
	<i>Qmed</i>	-0.245	

*Zs*: Mann-Kendall Test, *Qmed*: Sen's slope estimator

\* Note: \* and \*\*\* represents 10%, and 1% significance levels

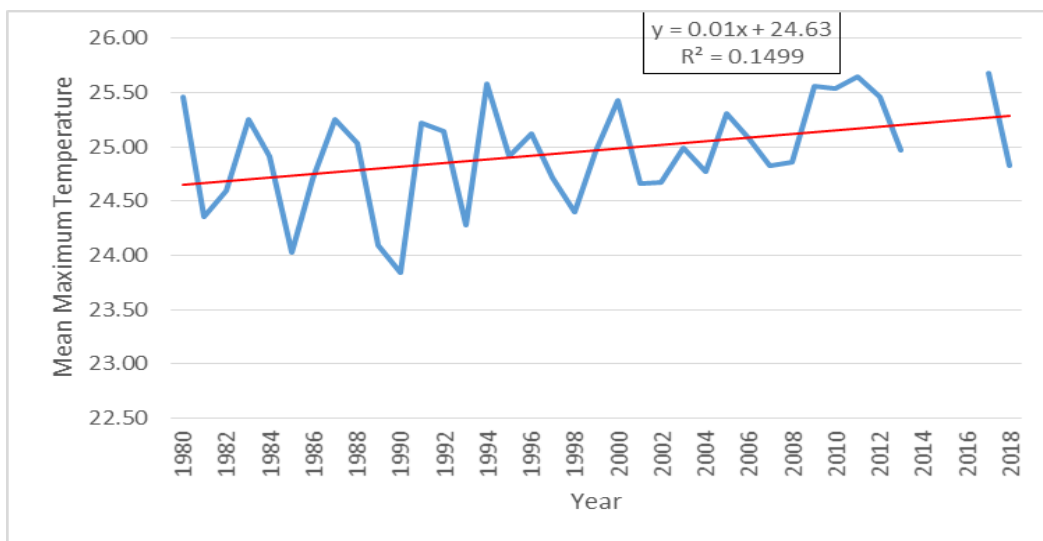
Various authors have interpreted the cause of the depressed rainfall in the last three decades in East Africa differently. Malhi, et al., (2021) and Zappa, et.al. (2020) in a global study, argued that increased greenhouse gases concentration increased average global surface temperatures, which weakens the sea surface temperature gradient,

producing less rainfall, especially over the tropics. Yang *et al.*, (2014) argued that the drying trend was because of decadal rainfall variability and not anthropogenic forcing.

### 4.3.2 Temperature trends

#### Maximum Temperature in Saku Sub-County in 1980-2020

The average annual maximum temperature as presented in Figure 4.4, indicates that 1983, 1995, 2010, 2011 and 2012 had approximately 25.30°C, 25.8°C, 25.5°C, 25.4°C and 25.6°C respectively, this shows that the maximum temperature is rising.



**Figure 4.4: Mean Annual Maximum Temperature for Saku Sub- County (1980-2018)**

Table 4.5 presents result for maximum temperature trends and shows that All months have positive trends for Mann Kendall( $Z_s$ ) and Sen's slopes( $Q_{med}$ ) thus indicating that the temperature had risen in 1980-2018. High temperature has been experienced in the study area. The maximum temperature trends in August and September are statistically significant.

**Table 4.5 Maximum Temperature trend using Mann-Kendall and Sen's slopes**

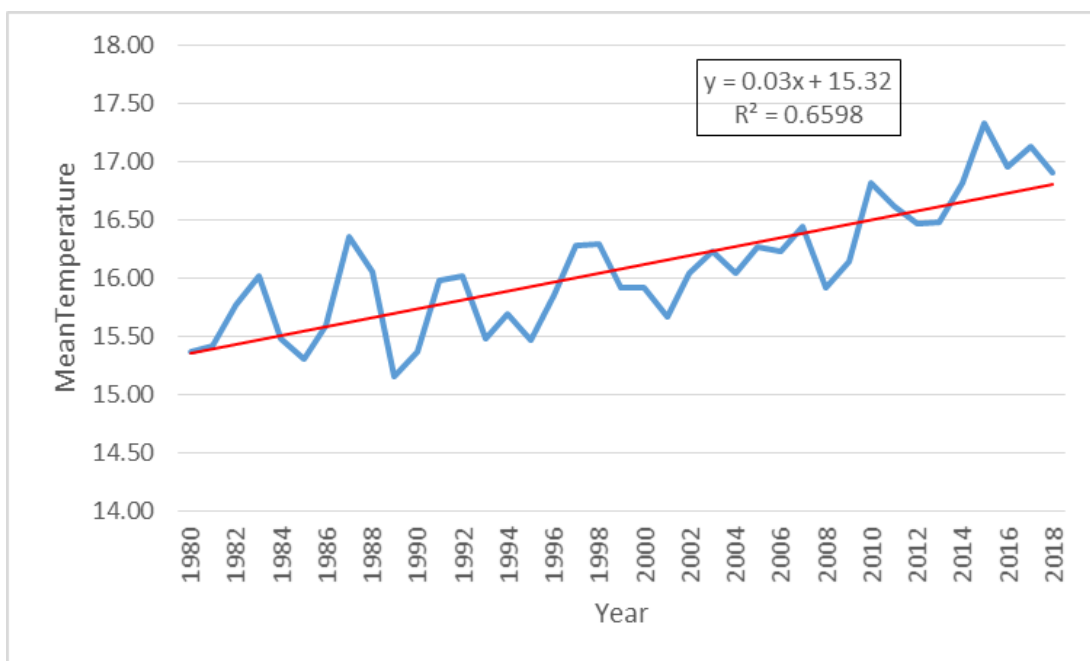
Period	Test	Trends	P-Value
JANUARY	<i>Zs</i>	0.076	0.532
	<i>Qmed</i>	0.015	-
FEBRUARY	<i>Zs</i>	0.137	0.271
	<i>Qmed</i>	0.017	
MARCH	<i>Zs</i>	0.077	0.533
	<i>Qmed</i>	0.015	-
APRIL	<i>Zs</i>	0.097	0.432
	<i>Qmed</i>	0.020	-
MAY	<i>Zs</i>	0.174	0.154
	<i>Qmed</i>	0.030	-
JUNE	<i>Zs</i>	0.104	0.397
	<i>Qmed</i>	0.011	-
JULY	<i>Zs</i>	0.150	0.216
	<i>Qmed</i>	0.012	-
AUGUST	<i>Zs</i>	0.313	0.010***
	<i>Qmed</i>	0.021	-
SEPTEMBER	<i>Zs</i>	0.421	0.000***
	<i>Qmed</i>	0.025	-
OCTOBER	<i>Zs</i>	0.068	0.575
	<i>Qmed</i>	0.003	-
NOVEMBER	<i>Zs</i>	0.052	0.670
	<i>Qmed</i>	0.006	-
DECEMBER	<i>Zs</i>	0.215	0.069*
	<i>Qmed</i>	0.032	

*Zs*: Mann-Kendall Test, *Qmed*: Sen's slope estimator

\* Note: \* and \*\*\* represents 10%, and 1% significance levels

### Minimum temperature in Saku Sub-County in 1980-2018

The study findings on the mean minimum annual temperature from 1980 to 2018 in Figure 4.5, show that temperature is increasing with 1987, 2011 and 2016 recording approximately 16.48 °C, 16.80°C and 17. 40°C respectively. This shows that the average minimum temperature is rising. A study by Gebrechorkos et al.,(2019) in East Africa indicated that trends for minimum temperatures were regionally more diverse, significantly increasing trend (up to +1.2 °C) in Southern Ethiopia and large parts of Kenya and Tanzania and decreasing trend (up to -1.5 °C) in limited areas in the eastern and western parts of Ethiopia which corroborate with our findings.



**Figure 4.5: Mean Annual Minimum Temperature for Saku Sub- County (1980-2018)**

Mann-Kendall and Sen's slopes in all months in 1980-2020 showed a positive trend meaning that the minimum temperature has increased from 1980-2020 in Marsabit (Table 4.6). The Minimum temperature trends in all months were statistically significant thus indicating that the likelihood for minimum temperature rising is high and it is moving towards the maximum temperature.

**Table 4.6 Minimum Temperature trend using Mann Kendall and Sen's slopes**

Period	Test	Trends	P-Value
JANUARY	<i>Zs</i>	0.399	0.001 ***
	<i>Qmed</i>	0.039	-
FEBRUARY	<i>Zs</i>	0.375	0.001***
	<i>Qmed</i>	0.035	
MARCH	<i>Zs</i>	0.516	0.0001***
	<i>Qmed</i>	0.033	-
APRIL	<i>Zs</i>	0.363	0.001***
	<i>Qmed</i>	0.034	-
MAY	<i>Zs</i>	0.458	0.0001***
	<i>Qmed</i>	0.034	-
JUNE	<i>Zs</i>	0.480	0.0001***
	<i>Qmed</i>	0.041	-
JULY	<i>Zs</i>	0.490	0.0001***
	<i>Qmed</i>	0.035	-
AUGUST	<i>Zs</i>	0.570	0.0001***
	<i>Qmed</i>	0.046	-
SEPTEMBER	<i>Zs</i>	0.508	0.000 ***
	<i>Qmed</i>	0.044	-
OCTOBER	<i>Zs</i>	0.550	0.0001 ***
	<i>Qmed</i>	0.039	-
NOVEMBER	<i>Zs</i>	0.536	0.0001 ***
	<i>Qmed</i>	0.037	-
DECEMBER	<i>Zs</i>	0.622	0.000***
	<i>Qmed</i>	0.050	

*Zs*: Mann-Kendall, *Qmed*: Sen's slope

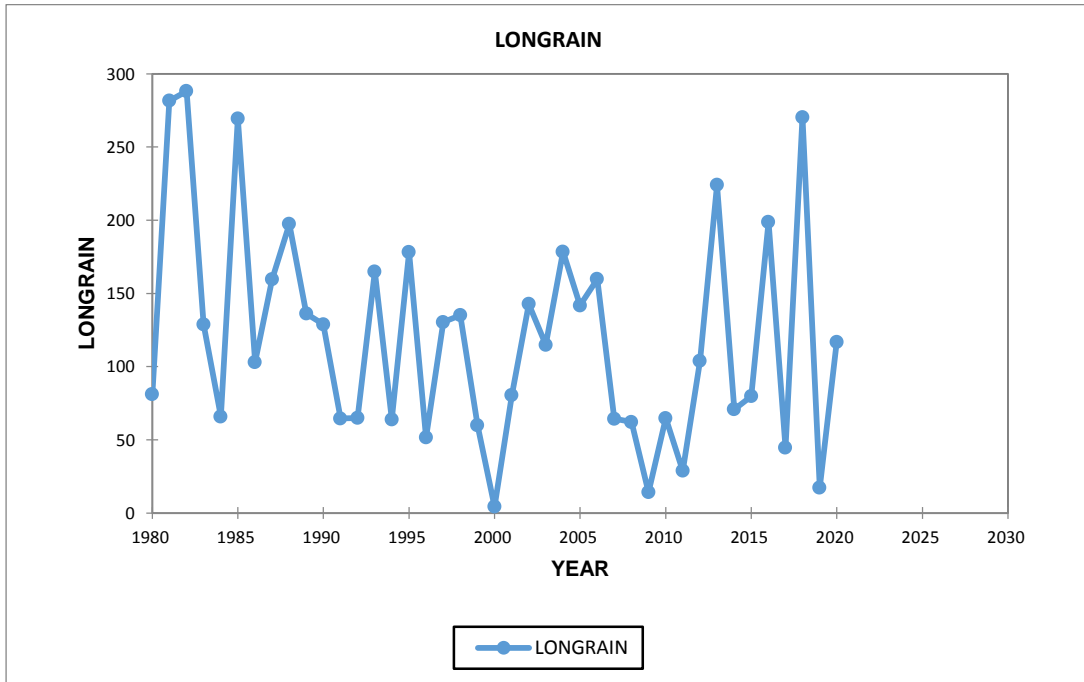
\* Note: \*\*\* represents 1% significance levels

### 4.3.3 Long and short rains trends in Marsabit County from 1980 to 2020

Marsabit has bimodal seasons with the long rains being experienced in March, April and May while the short rains come in the months of October, November and December. The results of the study show that rainfall is decreasing in both seasons (Figure 4.5). Ouma *et al.*, (2018) indicated that long rains experienced in March, April

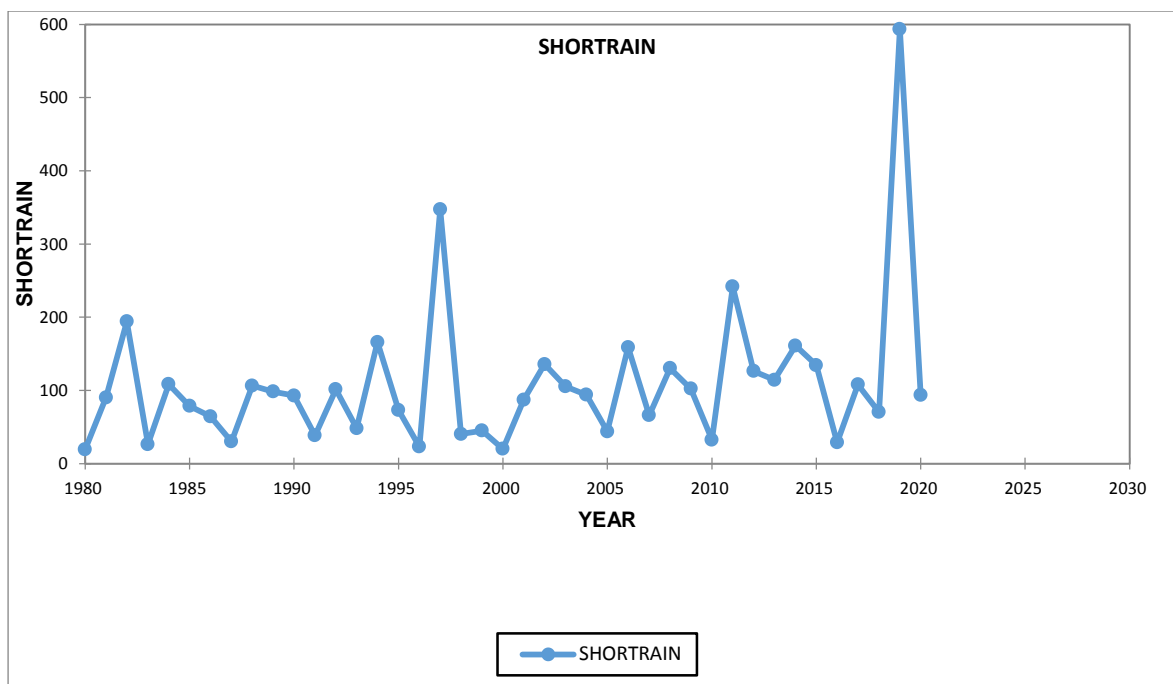
and May are the highest decreasing seasonal rainfall amounts. This declining seasonal rainfall will affect livelihoods. A study by Palmer *et al.*, (2023) projected that rainfall changes differ, but that the short rains in East Africa will deliver more rainfall than the long rains by 2030–2040.

Figure 4.6 shows the years with high precipitation in 2019, 1981-1983 and 1985 having approximately 283mm, 280mm and 282mm respectively.



**Figure 4.6: Long rains trend from 1980 to 2020**

Results in Figure 4.7 presented the highest precipitation received in 2019 and 1997 with 600mm and 350mm respectively and indication that rainfall in short rains is high in amounts.



**Figure 4.7: Short rains trend from 1980 to 2020**

#### Rainfall trends for long and short rains

Rainfall in long rains shows negative trends while in short rains showed positive trend in Mann-Kendall and Sen's slopes an indication that the precipitation for long rains is decreasing and short rains increasing in 1980-2020 and trends are significant which is inconsistent with observation made by Muhati *et al.* (2018) in MF.

**Table 4.7: Rainfall trends for long and short rains using Mann-Kendall and Sen's slopes in 1980-2020 in Saku Sub-County**

Rainfall	Period	Test	Trends	P-Value
Long Rains		Zs	-0.180	0.099*
		<i>Qmed</i>	-1.661	-
Short Rains		Zs	0.190	0.08*
		<i>Qmed</i>	1.244	

Zs: Mann-Kendall, *Qmed*: Sen's slope

\* Note: \* represents 10% significance levels

#### Maximum temperature trend for long and short rains

Maximum temperature in 1980-2018 shows that long and short rains are positive which indicates that maximum temperature is rising and significant at  $P < 0.5$

**Table 4.8 Maximum Temperature trend using Mann Kendall and Sen's slopes**

Period	Test	Trends	P-Value
long rains	<i>Zs</i>	0.132	0.279
	<i>Qmed</i>	0.017	-
short rains	<i>Zs</i>	0.188	0.111
	<i>Qmed</i>	1.244	

*Zs*: Mann-Kendall, *Qmed*: Sen's slope

### Minimum temperature trend for long and short rains

The minimum temperature trend is positive in long and short rains and significant at  $p < 0.000$ . This shows that temperature is increasing and a similar observation was made by Muhati *et al.*, (2018).

**Table 4.9 Minimum Temperature trend using Mann Kendall and Sen's slopes**

Period	Test	Trends	P-Value
long rains	<i>Zs</i>	0.532	0.000***
	<i>Qmed</i>	0.035	-
short rains	<i>Zs</i>	0.642	0.0001***
	<i>Qmed</i>	0.043	

*Zs*: Mann-Kendall, *Qmed*: Sen's slope

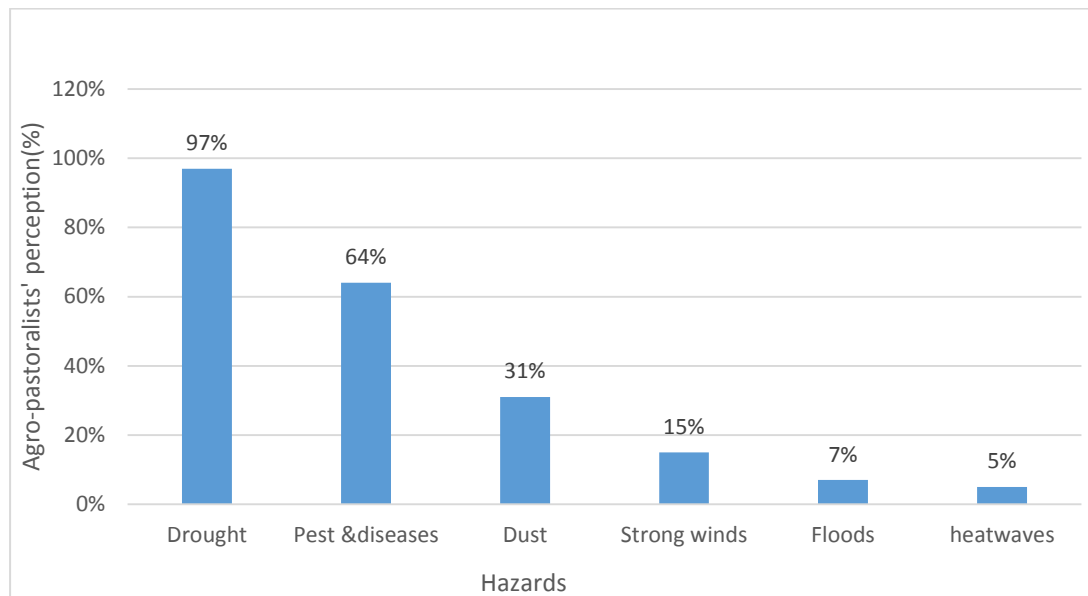
\* *Note*: \*\*\* represents 1% significance levels

The results on trends of rainfall which is decreasing (negative) and temperature increasing (positive) indicate that the changing climatic parameters has led to climatic challenges which affect the humanity. This is ascribed to the long periods of drought experienced in the area. This therefore affect both crop and livestock production in the region. The escalating trends in the frequency and magnitude of climatic related hazards such as drought, flash floods, pests and diseases, and resultant resource

conflicts will invariably hasten the incidence and spread of vulnerability of communities. (Adelaja and George, 2021; FAO, 2021).

#### 4.4 Agro-pastoralists' perception on hazards experienced

The research study collected data on frequently experienced hazards as perceived by agro-pastoralists which informs the possible interventions and backs the rainfall and temperature trend as presented in Figure 4.8. The main hazard cited by the respondents was drought (93.7%). This study agrees with studies done by Muhati *et al.* (2018); Cuni-Sanchez *et al.* (2019) which indicated that rainfall in Marsabit County is decreasing. Other hazards reported included pests and diseases (64.3%), dust (31.4%), strong winds (15.3%), and heat-waves (4.8%).



**Figure 4.8: Agro-pastoralists perception on hazards**

Adaptive capacity constitutes planning for strategies, which anticipate and minimize exposure (Mimura *et al.*, 2015). It involves risk assessment through comprehensive risk mapping as well as propping up innovative livelihoods programs, which insure against future vulnerability.

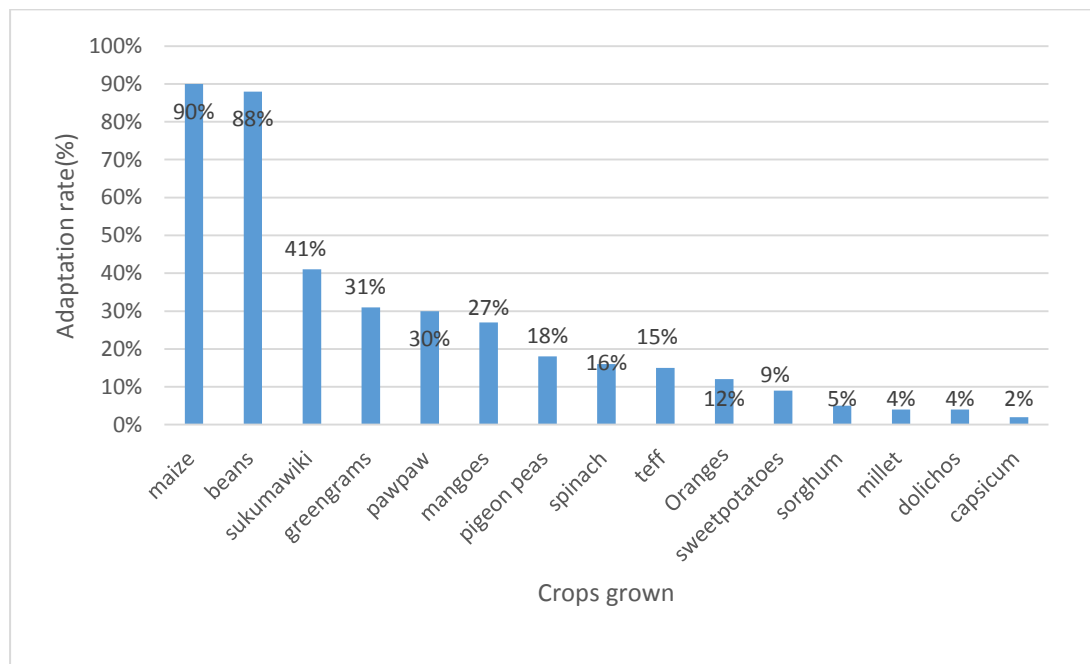
Knowledge on perception are drivers to possible intervention measures that can be initiated by affected communities. González-Hernández, *et al.*, (2022) concluded that climate perceived knowledge climate drives a household's efforts for adaptation and

mitigation measures. The life time experience contributes to knowledge of risk analysis and adaptive actions. People’s beliefs and perception of climate change shape the adaptive capacity through planning for anticipated exposures and varies from individual to individual and geographical locations (Liu, *et al* 2022).

#### 4.5 Crop and livestock climate-smart technologies adapted by agro-pastoral communities in Saku Sub-County

##### 4.5.1 Crops grown by agro-pastoralists

The researcher collected data on crops grown by agro-pastoral communities in Saku Sub-County. The findings are shown in Figure 4.9.



**Figure 4.9: Crops grown**

The study established that beans and maize were the most grown crops in the study area (Figure 4.9). The least grown crops being; sorghum, dolichos, millet, sweet potatoes, teff, capsicum and pigeon peas. The findings from the result show that the respondents mainly grow maize 90% (n=336) and beans 88% (n=328) under rain-fed production. Interestingly, a very low percentage of respondents cultivated crops that are known to be drought tolerant such as sorghum and millet (MoALF, 2017). This implies that the respondents had not shifted to drought tolerant crops which require minimal rainfall. Sanga *et al.* (2014) agrees that maize and beans are less adaptable to

climate change compared to other crops like millet, sorghum, and dolichos. Despite sorghum having been promoted in many parts of arid and semi-arid areas, is yet to be embraced by the agro-pastoralists. During the fieldwork period in November 2021, it was evident that agro-pastoralists use sorghum donated by the World Food Programme (WFP) as a feed supplement for cattle.

#### 4.5.2 Livestock reared by agro-pastoralists

The researcher further established livestock kept by agro-pastoralists in Saku Sub-County and presented the data in Table 4.10.

**Table 4.10: Categories of Livestock Reared**

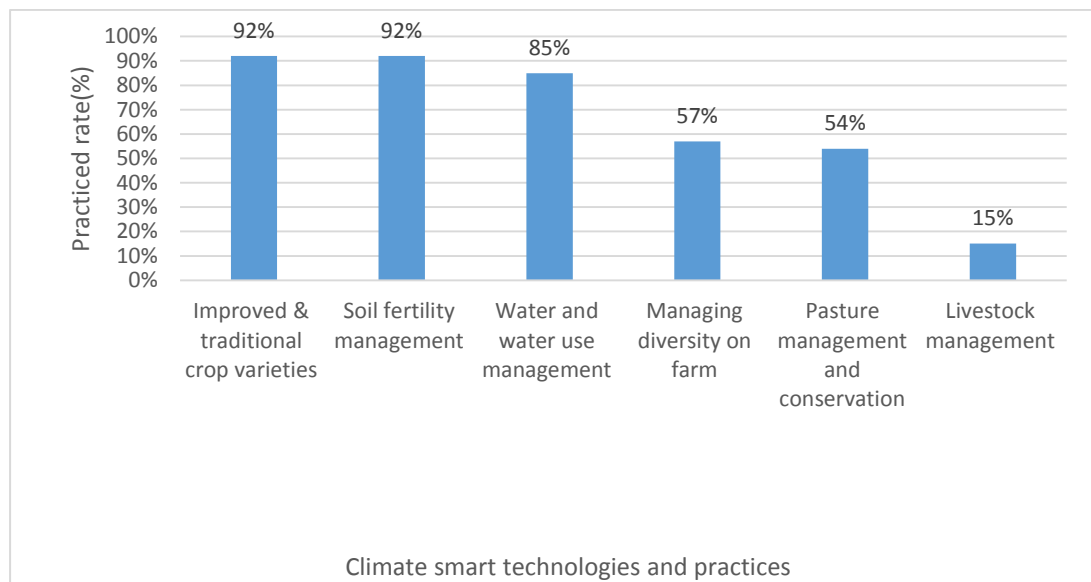
<b>Livestock Category</b>	<b>Frequency(n)</b>	<b>Percentage (%)</b>
Cattle	329	87.5
Goats	289	76.9
Sheep	150	39.9
Donkey	111	29.5
Camel	35	9.3

The study showed that cattle 87.5% (n=329) and goats 76.9% (n=289) were the most reared animals. This was followed by sheep 39.9% (n=150), donkeys 29.5% (n=111) and, the least reared animals were camels 9.3% (n=35). Donkeys were mainly used as a means of transport and for ploughing as per group discussion done with Karare women. Although camels are said to be the hope of climate change challenge (Watson *et al.*, (2016), only 9.3% of respondents reared them. Camels can tolerate harsh climatic conditions hence a climate-smart livestock but adoption of this strategy was found to be quite low with only 9.3 % of respondents affirming ownership.

### 4.5.3 Crop and livestock technologies & Practices in Six Categories

Climate-smart agricultural technologies were categorized into six groups and analyzed as shown in (Figure 4.10). Specific crop and livestock CST&Ps in each category were analyzed and their percentages are presented in Table 4.11.

The findings of the research (Figure 4.10) indicated that agro-pastoralists perceived to be using CST&Ps in the study area to help in adapting and mitigating the advancing effect of climate change. This shows that almost all respondents have adopted one or more technologies and practices in each category.



**Figure 4.10: Crop and Livestock Technologies & Practices in Six Categories**

The most commonly practised perceived categories were improved and traditional crop varieties and soil fertility management with 92 % which means that agro-pastoralists were using at least a practice of these categories. Improved and traditional crop varieties comprised of practices such as growing of improved crop varieties such as maize and beans and growing of traditional crops such as teff, sorghum and millet while soil fertility management comprises of fertilizer application, agroforestry crop retaining residues and manure application. The third most practised category was of water use and management by 85% which entailed water tank rainwater harvesting, water pan rainwater harvesting irrigation water efficient crops and mulching. The

least used category was livestock management by 15% of agro-pastoralists which comprised of improved livestock breed and introduction of local breeds.

**Table 4.11: Summary crop-livestock smart technologies adopted by agro-pastoralists**

<b>Climate smart Technologies &amp; Practices</b>	<b>Frequency (n)</b>	<b>Percentage (%)</b>
<b>1. Improved &amp; Traditional crop varieties</b>		
Traditional crop varieties	58	15.5
Improved crop varieties	344	92.2
<b>2. Managing diversity on farm</b>		
crop rotation	209	56
intercropping	136	36.5
<b>3. Water and water use management</b>		
water tank rainwater harvesting	111	29.8
water pan rainwater harvesting	43	11.5
irrigation	63	16.9
water efficient crops	137	36.7
mulching	50	13.4
<b>4. Soil fertility management</b>		
fertilizer application	34	9.1
agroforestry	81	21.7
crop retaining residues	117	31.4
manure application	255	68.4
<b>5. Livestock management</b>		
Improved livestock breed	74	19.8
introduction of local breeds	27	7.2
<b>6. Livestock pasture management</b>		
rangeland reseeding	7	1.9
grassland management	70	18.8
supplementary feeding	166	44.5
fodder conservation & storage	185	49.6
destocking	90	24.1

#### **4.5.3.1 Improved and traditional crop varieties**

In this study, improved crop varieties and traditional crop varieties were grouped under improved & traditional crop varieties which was perceived to be practised at 92.2 %. The respondents who grew maize and beans were grouped as practicing improved crop varieties while those growing teff, sorghum and millet as practicing

traditional crop varieties. The number of agro-pastoralists growing traditional crops was low at 15.5%. Teff, which is an indigenous crop from Ethiopia is one of the traditional crop varieties grown in Marsabit. It is drought tolerant and hence a climate-smart crop mainly grown in Dakabaricha. It is a multipurpose crop used as food for human beings and fodder for livestock (Tadele & Hibistu, 2021). It also requires minimal water and is less damaged by pests and diseases compared to maize and beans. Participants of the group discussion in Dakabaricha agreed that promotion of teff growing is ongoing in the area by KCSAP through community registered groups although they said that its production is labour intensive.

#### **4.5.3.2 Managing diversity on farm**

The findings in Table 4.11 indicates that crop rotation and intercropping were the two strategies of managing diversity on farm identified among the agro-pastoralists of Saku sub county with crop rotation at 56% (n=209), and intercropping at 36.5% (n=136). Crop rotation is an old crop husbandry practice and agro pastoralists agreed to have been practising crop rotation involving beans and maize to improve soil fertility according to the focus discussions conducted. Findings in China by YYu *et al.*, (2022) explored the benefits of crop rotation in farming while Kifle *et al.*, (2022) found that crop rotation was among the most adopted practice in Siyadebrina Wayu district in Ethiopia which corroborates with these findings.

#### **4.5.3.3 Water use and management**

The efficient use of water is a climate-smart practice that enhances food security by extending production periods during drought, especially in ASALs. Water harvesting technologies help to fight water scarcity as seen in studies done by Snelder, *et al.*, (2018), Gebru, *et al.*, (2021) & Wekesa *et al.*, (2021).

Four technologies were identified by the respondents and they included rainwater harvesting by use of tanks and small water pans, irrigation and growing of water efficient crops. Results presented in Table 4.11, shows that 36.7% (n=137) of the respondents grew water efficient crops. Majority of the key informants confirmed that kitchen gardening involving growing of sukumawiki is being practised in the study area. Rainwater harvesting by use of storage tanks was at 29.5% (n=111) while use of water catchment pans was at 11.5 % (n=43). This implied that 70.5% (n=262) of the

respondents were not using storage tanks which increase water for domestic use or water crops and livestock during dry seasons.

The capacity of water tanks used ranged between 1000 and 5000 litres while most water pans had a capacity of 10,000-30,000 litres. These capacities are too small to sustain livelihoods considering that Marsabit County lacks permanent water sources thus depends on springs and seasonal rivers. Some agro-pastoralists also practised small scale irrigation at 16.9% (n=63) using boreholes to grow vegetables such as kales and spinach during dry seasons. They also practised mulching at 13.4% (n=50) to reduce high evapotranspiration from the vegetable gardens and improve soil fertility according to the focus group discussion.

#### **4.5.3.4 Soil fertility management**

According to Gowing *et al.*, (2020) agro-pastoralists have been growing crops in the same farm fields for many decades since 1970 and therefore soil fertility has deteriorated over the years thus soil fertility improvement is crucial for high crop yields. Table 4.11 shows manure application was practised by 68 % (n=255) of the households because farm yard manure was readily available. This study results agreed with the results of a study that was done in Mali where organic manure was the most used fertilizer at 89 % (Ouédraogo, *et. al.*, 2019). A study which was done in Kenya by Mwaura *et al.*, (2021) shown that manure application on farms is a practice that helps boost crop production. There is need to train agro-pastoralists about the appropriate time to apply manure, the right amount to apply, and the types of manure that can help to improve soil fertility. Artificial fertilizer application was practised by a few households (9.1 %) and this was attributed to its high cost and the level of education whereby majority of the respondents are illiterate. Agroforestry was practised at 21.7% (n=81) and one of the participants' in a focus group asserted that,

“People are always cutting down trees for construction and firewood, the population is increasing and new settlements are coming up but no efforts are being made by community members in planting trees in their homesteads.”

From this discussion, it is evident that very little has been done to promote agroforestry hence the low adaptation rate. As it has been observed that windstorm is being experienced, a hazard whose effects can be reduced by promoting agroforestry.

There is need for sensitization on the use of this strategy to help adapt to climate change and variability.

#### **4.5.3.5 Livestock management**

Livestock management was adopted by very few households (15 %.). The results of this study show that agro-pastoralists have adapted to climate change by keeping improved livestock breeds 19.8% and local breeds 7.2% (Table 4.10). Few agro-pastoralists have embraced improved breeds since they believe that these breeds cannot tolerate harsh conditions although their milk production is higher than that of the indigenous breeds as per group discussions. The agro-pastoralists of Saku Sub-County used to rear cattle in large herds when Marsabit was semi-humid. They also believe that pastoralists who keep camel will never lack milk even in the driest of periods according to focus group discussions. Rearing of livestock breeds which can tolerate harsh climatic conditions such as camel (Watson *et al.*, 2016) will improve their adaptability capacity from anticipated climatic impacts. It is interesting that although the respondents perceive camels as an assured source of milk even in drought conditions, the percentage of those with camels was quite low at 7.2%.

#### **4.5.3.6 Pasture management and conservation**

Pasture is not only vital in agro-pastoralism and pastoralist systems, but also for biodiversity. Human conflicts mostly occur when this resource becomes scarce. Table 4.11 shows pasture management and conservation practices among agro-pastoralists in the study area. Fodder conservation and storage was the highest practised 49.6% (n=185) as indicated from this research. Supplementary feeding is important for livestock during dry seasons (Mudzengi *et al.*, 2020). The focus group discussions confirmed that poor quality pasture and insufficient pasture from grazing fields were supplemented with acacia tortillas, root tubers and forest leaves to improve livestock health and body condition of home-based herds (Lengarite *et al.*, 2014). Grassland management at 18.8% (n=70) and rangeland reseeding at 1.9% (n=7) were least practised and this has led to severe degradation and desertification of grazing zones as well as fueling conflicts as explained by one of the key informants.

## **4.6 Factors influencing adoption of crop-livestock CST&Ps**

### **4.6.1 Variables used in the Model**

Table 4.12 shows a descriptive summary of the variables. The study used data from 373 agro-pastoralists. The dependent variables are the six categories of technologies; improved and traditional crop varieties, managing diversity on farm, water and water use management, soil fertility management, livestock management, livestock pasture management. They are binary where the respondents choose to practice the CST&P or otherwise.

**Table 4.12: Summary statistics of variables used in the multivariate model**

Variable	Description of variables	Mean	Frequency (%)	SD
<b>Dependent variables</b>				
Decision to adopt	1=adopter,0=non-adopter			
Improved & Traditional crop varieties	1 if HH head choose Improved & Traditional crop varieties,0 if otherwise	-	92	0.26
Managing diversity on farm	1 if HH head choose Managing diversity on farm,0 if otherwise	-	57	0.50
Water and water use management	1 if HH head choose Crop water and water management,0 if otherwise	-	85	0.36
Soil fertility management	1 if HH head choose soil fertility management,0 if otherwise	-	92	0.26
Livestock management	1 if HH head choose Livestock management,0 if otherwise	-	15	0.36
Pasture management	1 if HH head choose Livestock pasture management,0 if otherwise	-	54	0.50
<b>Exploratory variables</b>		48.49		
Age of the household head (Years)	Number			12.72
Members in the household (number)	Number	7.01		2.03
Level of education	1 if HH has formal education,0 if otherwise	-	65	0.48
Gender of the household head	1 if HH head is male if 0 female	-	58.4	0.49
Marital status	1 if HH head is married,0 if single	-	80.4	0.40
Average household income per month (Ksh)	Ksh per month	5204.56		3633.09
Access credit facilities	1 if HH access credit,0 if otherwise	-	11	0.31
Available channels for Weather information	1 if HH get weather information,0 if otherwise	-	56	0.50
Access to extension services			28	0.45
Training of CSP&T	1 if HH undergone training for 2 weeks,0 if otherwise	-	17	0.38

The factors influencing adoption were selected based on the literature reviewed. The socio-economic factors under study were the six socio-economic factors: age, marital status, household size, education level, gender and average monthly income and four institutional factors which included credit facilities access, access to extension service, training on CST&Ps and access to weather information.

Multivariate probit regression analysis was suitable for analysis for this study since there were various dependent variables and various independent variables, thus giving us reliable results. The results have shown that there is a correlation of six categories of CST&Ps practised by the agro-pastoralists as contained in Table 4.13, hence justifying the use of multivariate regression. The likelihood test is Breusch-Pagan test of independence:  $\chi^2 (15) = 469.302$ ,  $p > 0.0000$ .

**Table 4.13: Multivariate Probit model correlation for adaptation strategies**

	Improved & traditional crop varieties	Managing diversity on farm	Water use & management	Soil fertility management	Livestock management	Pasture conservation & management
Improved & traditional crop varieties	1.0000					
Managing diversity on farm	0.0334	1.0000				
Water use & management	0.3146	0.1706	1.0000			
Soil fertility management	0.8379	0.0814	0.3152	1.0000		
Livestock management	0.0109	-0.0655	-0.4110	-0.0010	1.0000	
Pasture conservation & management	-0.0660	0.2813	0.2370	-0.0511	-0.0731	1.0000

Breusch-Pagan test of independence: Chi-Square (15) = 469.302,  $p = 0.000$

### Variance inflation factors (VIF)

Prior to the estimation of the model parameters, it is crucial to look into the problem of multicollinearity among the explanatory variables. The results from the variance inflation factor (Table 4.14) shows that multicollinearity does not affect the outcome of the findings and we can trust this coefficient and P-Value with no further action since the values are near to 1. This confirmed that there was no serious linear relationship among the explanatory continuous variables tested since VIF values were less than 10 (Kim, 2019)

**Table 4.14: VIF**

Variable	VIF	1/VIF
Education Status	1.55	0.646005
Access to credit	1.42	0.704379
Gender	1.39	0.721378
Average income per month	1.35	0.739722
Marital status	1.27	0.788933
Access to weather information	1.22	0.817843
Access to extension	1.18	0.848908
Training	1.10	0.907839
size of the household	1.10	0.907839
<b>Mean VIF</b>	<b>1.28</b>	

The previous objective identified climate-smart technologies practised by agro-pastoralists and the study findings showed that some practices were highest adopted while others were least adapted, and thus there was need to establish which factors influence adoption. Several factors necessitate livestock keepers and crop growers to adopt or not adopt the climate-smart technologies and practices as observed by Shikuku *et al.*, (2017), Wekesa *et al.*, (2018), Aryal *et al.*, (2018), Kurgat *et al.*, (2020), Saha *et al.*, (2019), Maina *et al.*, (2020), Sardar *et al.*, (2021) and Musafiri *et al.*, (2022).

## **4.6.2 Socio-economic factors**

### **4.6.2.1 Age of household head**

Multivariate probit result (Table 4.15) shows that the age of the household head of agro-pastoralist influences the adoption of CST&Ps where it indicated that there were positive coefficients in all CST&Ps adopted. The age was significantly positive on improved and traditional crop varieties and soil fertility management. This implies that the older the age of the household head, the more the chances for adoption of these climate-smart practices and this might be attributed to long time experiences. Gauchan *et al.*, (2020) in the mountains of Nepal found that age was significant for rice and finger millet. Additionally, Mogaka *et al.*, (2021) observed similar results when using smart soil practices. Musafiri *et al.*, (2022) further found that the use of animal manure had a positive association. More over the results concurred with findings from Addis and Abirdew (2021). The study, however, disagree with a study by Issahaku & Abdulai, (2020), who found a negative coefficient in all practices studied which implies that an increase in the age of the farmer leads to a decrease in the likelihood of adoption of climate-smart practices.

### **4.6.2.2 Household Size**

The study indicated that the members of the household had a negative coefficient for four categories of crop-livestock practices; managing diversity on farm, soil fertility management, water and water use management and improved and traditional crop varieties ( Table 4.15). This means that the smaller the size of the household, the greater the chances for adoption hence agrees with study by Darkwah et al., (2019), who found a positive effect on sustainable soil and water conservation practices adoption using the Poisson model. Managing diversity on farm was negatively and statistically significant, this result is contrary to an observation made by Mebrate *et al.*, (2022) on soil fertility management.

Pasture conservation and management and livestock management have a positive coefficient which implies that the larger the family size the higher the likelihood of

adoption, this is because large family provides labour and requires more food than a small family. Livestock management was significantly positive which means that agro-pastoralists who keep large herds of livestock require many people for provision of labour. The result is consistent with findings by Kemal *et al.*, (2022).

#### **4.6.2.3 Education Level**

The level of education in this study was binary which means that the head of the household has formal education or non-formal education. Table 4.15, shows that the coefficient for water and water use management and managing diversity on farm; this means that, the more literate the household head is, the higher the likelihood for adoption as aligned with an observation by Muriithi *et al.*, (2021). In addition, the agro-pastoralists who went to school have knowledge on various ways of conserving water and might not have time to search water as compared to those who have not gone to school. Livestock management and pasture conservation & management had negative coefficients. The negative association for livestock management and pasture conservation and management implies that illiterate heads of households have higher likelihood for adoption since they own large number of livestock that they migrate with. In addition, it could be due to indigenous knowledge of conserving and storing fodder for later use during time of shortages. Radeny *et al.*, (2022) found that the lower the education level of the farmer the higher the likelihood of adopting improved crop varieties and livestock breeds varieties which is aligned with our findings.

#### **4.6.2.4 Gender of Household Head**

The gender of households has both negative and positive influences of the adoption of technologies (Table 4.15). Soil fertility management, improved and traditional crop varieties, pasture conservation & management, water use & water management and livestock management were found to have negative coefficients. Improved & traditional crop varieties, soil fertility management and pasture conservation were statistically significant. The negative association means that more agro-pastoralists women were adopting these CST&Ps. Men are less likely to adopt these practices

while women have higher likelihood to adopt to these practices. This finding disagree with findings by Kurgat *et al.*, (2020) and Musafiri *et al.*, (2022). Managing diversity on farm (crop rotation and intercropping) had positive coefficient, which implies that men were likely to undertake this technology that female counterparts.

#### **4.6.2.5 Marital Status**

The marital status of the household heads in Table 4.15, shows a negative association in improved and traditional crop varieties, soil fertility management, livestock management and livestock management meaning those single agro-pastoralists were undertaking these CST&Ps, while pasture conservation and management, and managing diversity on farm had positive coefficients revealing that those who are married were taking up these categories. The managing diversity on farm was significantly negative which indicates that the likelihood of adoption is high for agro-pastoralists who are single or not married. Our result corresponds to findings by Mthethwa, *et al.*, (2022) that a farmer's marital status had a negative relationship with the intensity of CSA adoption.

#### **4.6.2.6 Average Monthly Income**

Results (Table 4.15) show positive coefficient influence of income of the head of the household on the adoption of all the six categories of the CST&Ps, which means that the higher the income from the practices the greater the likelihood of adoption of CST &Ps. This study agrees with studies done by Imran *et al.*, (2018) and Issahaku and Abdulai (2020). This is important to agro-pastoralists as it makes them realize that CST&Ps are beneficial in improving their income. Improved and traditional crop varieties, managing diversity on farm, water use and water management, and pasture conservation & management were statistically significant.

### **4.6.3 Institutional Factors**

#### **4.6.3.1 Credit facilities**

The study finding (Table 4.15) has shown that access to credit facilities had negative coefficient on improved and traditional crop varieties, soil fertility management, livestock management and pasture conservation & management. Pasture management & conservation was negatively significant. This implies that, when credit facilities are availed, the likelihood of adoption of these practices is low. The negative effect might be due to few credit facilities available for agro-pastoralists which this study affirms that only 11% of agro-pastoralists received this service. The agro-pastoralists who received credit might divert the funds to other needs instead of agricultural activities that the loans were intended for. The findings corroborated with Okoth (2019) who observed low influence of financial services. In our study, the impact of access to credit on managing diversity on farm and water use and water management had positive coefficient but not significant. Tanti *et al.*, (2022) and Aryal *et al.*, (2020) found similar results where credit was not significant on CSA technologies adopted by farmers.

#### **4.6.3.2 Extension services**

The extension services help in increasing the adoption of CSA. Multivariate probit model (Table 4.15) shows that improved and traditional crop varieties, water use and water management, soil fertility management and livestock management were significantly positive. This implies that extension services play a great role in the promotion of climate change strategies (Maka *et al.*, 2019; Kamruzzaman, *et al.*, 2021). This study agrees with Mwaura *et al.*, (2021) Musafiri *et al.*, (2022) on soil water conservation and crop managing diversity who found a positive coefficient.

#### **4.6.3.3 Training Received on CST&Ps**

Training of agro-pastoralists on CST&Ps is very crucial as seen in this study where training was found to have a positive coefficient in all CST&Ps adopted. Improved and traditional crop varieties, water use and water management, soil fertility

management and livestock management were statistically significant (Table 4.15). Intensity and continuous adoption of CST&Ps is influenced by the knowledge acquired from institutions. Studies have indicated that attendance to any climate CSA through capacity building was significantly positive as observed by Zakaria *et al.*, (2020), Ferrer & Le, (2021) and Mapanje *et al.*, (2021).

#### **4.6.3.4 Weather information**

Access to weather information on different channels by agro-pastoralists has a positive effect in improved and traditional crop varieties, soil fertility management, livestock management and pasture conservation and management, managing diversity on farm and water use management (Table 4.15). Availability of weather information improves the adaptation of practice which agrees with observations made by Belay *et al.*, (2022) and Mujeyi *et al.*, (2022). The six categories are more climate-sensitive where early weather information prepares the agro-pastoralists from impacts of anticipated outcomes. The research hypothesized that there was no effect of socio-economic and institutional factors on the adoption of CST&P hence the null hypothesis was rejected.

**Table 4.15: Results of multivariate probit model estimates of determinants of CST&Ps**

variable	Improved & traditional crop varieties		managing diversity on farm		water use and water management		soil fertility management		livestock management		pasture conservation & management	
	Coef. (S.E.)	p-value	Coef. (S.E.)	p-value	Coef. (S.E.)	p-value	Coef. (S.E.)	p-value	Coef. (S.E.)	p-value	Coef. (S.E.)	p-value
Age of head of household	0.003 (0.001)	0.014**	0.001 (0.002)	0.918	0.001 (0.001)	0.527	0.002 (0.001)	0.062*	0.001 (0.001)	0.740	0.003 (0.002)	0.141
Household size	-0.003 (0.006)	0.654	-0.042 (0.012)	0.00***	-0.002 (0.009)	0.28	-0.002 (0.007)	0.45	0.020 (0.009)	0.04**	0.010 (0.012)	0.680
Education status of Household head	0.005 (0.042)	0.901	0.111 (0.077)	0.15	0.819 (0.055)	0.14	-0.017 (0.042)	0.69	-0.101 (0.043)	0.002**	-0.117 (0.082)	0.152
Gender of household head	-0.002 (0.001)	0.014**	0.031 (0.055)	0.57	-0.027 (0.039)	0.49	-0.064 (0.029)	0.03**	-0.049 (0.051)	0.27	-0.134 (0.058)	0.022**
Marital status	-0.007 (0.029)	0.825	-0.012 (0.064)	0.063*	-0.023 (0.046)	0.610	0.001 (0.035)	0.960	-0.050 (0.052)	0.34	0.026 (0.069)	0.703
Average monthly income	0.231 (0.026)	0.000***	0.421 (0.049)	0.000**	0.329 (0.036)	0.000**	0.236 (0.027)	0.000**	0.082 (0.039)	0.055*	0.462 (0.053)	0.000***
Access to credit facilities	-0.026 (0.043)	0.545	0.004 (0.079)	0.955	0.014 (0.057)	0.795	-0.027 (0.043)	0.523	-0.059 (0.063)	0.35	-0.186 (0.084)	0.03**
Weather information	0.025 (0.042)	0.550	0.167 (0.077)	0.031*	0.112 (0.056)	0.05**	0.032 (0.042)	0.44	0.149 (0.062)	0.02**	0.035 (0.082)	0.669
Extension services	0.078 (0.026)	0.003***	0.054 (0.048)	0.26	-0.090 (0.035)	0.083*	0.094 (0.026)	0.00***	0.181 (0.038)	0.00***	0.023 (0.051)	0.651
Training	0.078 (0.026)	0.003***	0.054 (0.048)	0.262	0.106 (0.043)	0.015*	0.094 (0.026)	0.000**	0.181 (0.038)	0.023*	0.023 (0.051)	0.860

\* Note: \*, \*\* and \*\*\* represents 10%, 5% and 1% significance levels

#### 4.7 Impact of climate-smart technologies and practices on income of the agro-pastoralists

The study investigated the effect of practised technologies and practices on income of the agro-pastoralists. This study's outcome variable was average monthly income. The outcomes of individual agro-pastoralists who were practising CST&Ps (y1) are compared with that of similar agro-pastoralists who did not participate in CST&Ps adoptions (y0), which serves as the basis for the ATE.

**Table 4.16: Summary of CST&Ps**

Variable	Obs	Mean	Std. Dev.	Min	Max
Improved & traditional crop varieties	373	0.925	0.264	0	1
Managing diversity on farm	373	0.568	0.496	0	1
Water use and water management	373	0.852	0.355	0	1
Soil fertility management	373	0.924	0.263	0	1
Livestock management	373	0.152	0.360	0	1
Pasture management & conservation	373	0.536	0.499	0	1

The causal effect of adoption of CST&Ps on household income was estimated using the Propensity Score Matching (PSM) procedure. The analysis employed the Nearest Neighbor Matching (with 3-Neighbors and One-to-One matching algorithms) using the `psmatch2` command with STATA 15.1 software. In what follows, the results pertaining to estimation of propensity scores, Average Treatment Effect on the Treated (ATT), and post-matching quality analyses are presented.

The PSM approach is used for estimation of causal effects in a binary treatment framework (Rosenbaum & Rubin, 1985). The challenge with evaluating the climate smart technologies, is that all the agro-pastoralists in the sample have at least implemented one climate smart technology. This makes it challenging because the

treatment indicator is a binary variable taking the value 1 or 0, but not both (Rubin 1976; Holland 1986). For this study the agro-pastoralists were classified as lead agro-pastoralists who had adopted four practices and above out of the six (>70%) identified for this study (Mkwambisi, *et al.*, 2016). The follower agro-pastoralists were those that practiced two and below of the six (<30%) identified climate smart technologies (Mkwambisi, *et al.*, 2016). The adopters were regarded as the lead agro-pastoralists of different CST&Ps, while follower agro-pastoralists and any other agro-pastoralists were classified as non-adopters. This resulted to 240 adopters against 133 non-adopters. Adoption of CST&Ps (1 for adopter and 0 for non-adopter) was investigated as treatment variable while the outcome variable was the average monthly household income from the agro-pastoralism. The treatment variable was the adoption or non-adoption of CSA and the covariates were variables identified to have logical and reasonable rational in determining household adoption to CST&Ps were identified as follows.; Age of head of household, Household size, Education status of Household head, Gender of household head, Marital status, Access to credit facilities, Weather information, Extension services and Training.

**Table 4.17: Propensity matching score estimate on adoption of CST&Ps**

Outcome variable	Coefficient	S.E	P- value
Average Monthly income for agro-agro-pastoralists	0.65	0.05	0.000

(ATE adopt vs non-adopt)

From the Table 4.17, the coefficient of the average household income for the adopters is positive and significant at 5%. This means that the average monthly income of all households who adopt the CST&Ps would be higher by about 65% compared to non-adopters. This supports the study by Mkwambisi, *et al.*, (2016) who reported that CSA technologies has resulted in higher crop yields and increased incomes among smallholder farming households. Another study by Lipper *et al.*, (2014) observed that adopting CSA practices boosts agricultural productivity, raises household income,

strengthens farmer resilience, and slows climate change. A study in Punjab province, Pakistan, Sardar et al., (2021), reported that farmers who adopted a full set of CSA practices gain higher yield 32% and 44% kg/ha, and higher farm income 45% and 48% US\$ per ha than non-adopted farmers for cotton–wheat and rice–wheat crops, respectively. While in Evidence from Southern Ethiopia, the study concluded that households that adopted CSA practices had a 20.30% higher average annual farm income per hectare than non-adopters (Belay *et al.*, 2023).

## **CHAPTER FIVE: SUMMARY, CONCLUSION AND RECOMMENDATIONS**

### **5.1 Summary**

The purpose of the study was to investigate on adoption of climate-smart technologies and their effect on income among agro-pastoralists in Marsabit County, Kenya. The study was guided by four objectives.

The first objective was to analyze temperature and rainfall trends period from 1980 to 2020 in Saku Sub-County, Marsabit County. Mann Kendall and Sen's slopes indicated that the annual rainfall trend was decreasing while maximum temperature was increasing and the trends were significant in August, September and December while minimum temperature trend was significantly decreasing in all the months. The respondents perceived that drought was a major hazard experienced. The research sheds light on the demographic characteristics of the respondents, revealing that a majority were beyond the youth age bracket, signifying limited engagement of the younger generation in agro-pastoralism. The gender distribution showcased the prevalence of male-headed households, resonating with findings from other 'regions. Married households showed higher adaptation capacity, attributed to joint decision-making and shared responsibilities.

The second objective was to identify crop and livestock climate-smart technologies practiced by agro-pastoral communities in Saku Sub-County, Marsabit County. The respondents mainly grow maize and beans while cattle and goats were the most reared animals. The climate-smart technologies in practice were improved crop varieties, manure application, crop rotation, fodder conservation and storage, supplementary feeding, intercropping, growing water efficient crop, crop retaining residues, harvesting of rainwater using water tanks, destocking, agroforestry, improved livestock breed, grassland management, irrigation, growing traditional crop varieties, mulching, harvesting rainwater in water pans, fertilizer application, introduction of local breeds of animals and rangeland reseeding.

Manure application have emerged as the most practised crop CST&P while fodder conservation and storage coupled with supplementary feeding have emerged as the most practised livestock strategies among the agro-pastoralists of Saku Sub-County.

On the other hand, fertilizer application and rangeland reseeding have emerged as the least practised crop and livestock-smart strategies respectively.

The third objective was to determine factors for adoption of crop and livestock climate-smart technologies by agro-pastoral communities. The coefficient from multivariate probit regression showed that age was significantly positive on improved and traditional crop varieties and soil fertility management. Household size was negatively significant in managing diversity on farm, and positively significant in livestock management. The status of education of agro-pastoralists had significantly negative influence on livestock management. The gender of the household head was significantly negative on improved and traditional crop varieties, soil fertility management and pasture conservation and management. The marital status of the household head was found to have significant negative effect on managing diversity on farm.

Credit facilities was statistically negative on pasture conservation and management. Additionally, income of head of the household was positively significant on soil fertility management, livestock management, improved & traditional crop varieties managing diversity on farm, water use and water management, and pasture conservation & management.

Availability of weather information was significantly positive on managing diversity on farm water use and water management and livestock management. Extension services among agro-pastoralists showed significantly positive coefficient on water use and water management, improved and traditional crop varieties, soil fertility management and livestock management. Training was found to be statistically positive on improved and traditional crop varieties, water use and water management, soil fertility management and livestock management.

Finally, establishment of the effect of adaptation of crop and livestock climate smart technologies on income of agro-pastoralists in Saku Sub-County, Marsabit County, Kenya. Propensity matching score indicated that, agro-pastoralists who adopted CST&Ps had significantly high incomes with positive coefficients. The study also revealed that the agro-pastoralists whose main sources of income was from both crops

and livestock recorded a positive coefficient while those who relied on either crop farming or livestock farming as their main source of income had a negative coefficient income.

## **5.2 Conclusion**

The study unveiled changing climatic trends with declining rainfall, increasing temperatures, and shifting precipitation patterns. These changes, coupled with the dominant hazard of drought, accentuate the urgency for CST&Ps adoption. Despite challenges, agro-pastoralists showed notable adoption of technologies, particularly improved crop varieties and soil fertility management. Water management practices were also embraced, while livestock-related practices witnessed lower adoption rates.

The conclusion drawn from the study's results highlights the intricate interplay between various factors influencing the adoption of climate-smart technologies and practices (CST&Ps) among agro-pastoralists in Saku Sub-County, Marsabit County. Further, the study underscores the significance of socio-economic and institutional factors in shaping CST&Ps adoption. By emphasizing education, access to weather information, and targeted interventions to overcome challenges, the findings provide valuable insights for policymakers, government bodies, and development organizations. Ultimately, fostering climate-smart practices can enhance community resilience, mitigate vulnerabilities, and contribute to sustainable livelihoods in Marsabit County as evident for increased incomes for adopters of all CST&Ps.

## **5.3 Recommendation**

Agro-pastoralists in Marsabit County should have a timely access to weather information in order to make important decisions for adoption of climate smart technologies. Since agriculture is devolved, the county government should map agropastoralists for bulk messages on weather alerts. Agro-pastoralists can be introduced to simple weather forecasting platforms in order to increase information access. The adoption of climate smart technologies is promoted by increased access to extension services. Therefore, the county government, research institutions and non-governmental organizations should endeavour to promote dissemination of climate smart technologies that enhance crop and livestock production.

Training of agropastoralists on crop and livestock production significantly increases the adoption of climate smart technologies. Therefore, county government, research

institutions and non-governmental institutions should closely work together in training agro-pastoralists on livestock and crop husbandry best practices.

The adoption of climate-smart practices has a positive coefficient on income and those who adopted majority of these practices, their income increased significantly. Championing multiple integration of climate-smart practices, can engender heightened community resilience, mitigate vulnerabilities, and foster sustainable livelihoods within Marsabit County and beyond. The policy makers can use the research findings as guided for information dissemination and formulation of policy on crop-livestock smart technologies that agro-pastoralists can embrace. Further research endeavors should consider delving deeper into the nuanced interplay of these determinants and exploring strategies for effectively bridging the identified gaps to realize meaningful impact.

## REFERENCES

- Abbass, K., Qasim, M. Z., Song, H., Murshed, M., Mahmood, H., & Younis, I. (2022). A review of the global climate change impacts, adaptation, and sustainable mitigation measures. *Environmental Science and Pollution Research*, 29(28), 42539-42559.
- Addis, Y., and Abirdew, S. (2021). Smallholder farmers' perception of climate change and adaptation strategy choices in Central Ethiopia. *International Journal of Climate Change Strategies and Management*.
- Adekoya, A. A., Quaye, A. K., & Eyob, E. (2002). A multivariate probit analysis of selected factors influencing electronic commerce adoption in organizations. *Journal of International Information Management*, 11(2), 9.
- Adelaja, A., & George, J. (2021). Food and Agricultural Security: An Introduction to the Special Issue. *Sustainability*, 13(21), 12129.
- Adepoju, P. (2021). Africa worst hit by climate change impacts, COP26 told. *Nature Africa*, 11.)
- Affoh, R., Zheng, H., Dangui, K., & Dissani, B. M. (2022). The impact of climate variability and change on food security in sub-Saharan Africa: Perspective from panel data analysis. *Sustainability*, 14(2), 759.
- Agbenyo, W., Jiang, Y., Jia, X., Wang, J., Ntim-Amo, G., Dunya, R., Siaw, A., Asare, I. and Twumasi, M.A. (2022). Does the Adoption of Climate-Smart Agricultural Practices Impact Farmers' Income? Evidence from Ghana. *International Journal of Environmental Research and Public Health*, 19, 3804. <https://doi.org/10.3390/ijerph19073804>
- Aidoo, C., Danley, Boateng, S., Freeman, C and Anaglo, J. (2021). The effect of smallholder maize farmers' perceptions of climate change on their adaptation strategies: the case of two agro-ecological zones in Ghana. *Heliyon*. 7.
- Aryal, J. P., Rahut, D. B., Maharjan, S., & Erenstein, O. (2018). Factors affecting the adoption of multiple climate-smart agricultural practices in the Indo-Gangetic Plains of India. In *Natural Resources Forum* (Vol. 42, No. 3, pp. 141-158). Oxford, UK: Blackwell Publishing Ltd.
- Aryal, J. P., Farnworth, C. R., Khurana, R., Ray, S., Sapkota, T. B and Rahut, D. B. (2020). Does women's participation in agricultural technology adoption decisions affect the adoption of climate-smart agriculture? Insights from Indo-Gangetic Plains of India. *Review of Development Economics*, 24(3), 973-990.
- Atube, F. G. (2021). Determinants of smallholder farmers' adaptation strategies to the effects of climate change: Evidence from northern Uganda. *Agric & Food Security*, 10(6). <https://doi.org/https://doi.org/10.1186/s40066-020-00279-1>

- Austin, P. C. (2011). An introduction to propensity score methods for reducing the effects of confounding in observational studies. *Multivariate behavioral research*, 46(3), 399-424.
- Ayayia, G. (2023). Climate-Smart Agriculture as an adaptative tool for reducing food Insecurity in Sub- Saharan-Africa: A Case Study of Kenya.
- Ayugi, B., Shilenje, Z. W., Babaousmail, H., Lim Kam Sian, K. T., Mumo, R., Dike, V. N and Ongoma, V. (2022). Projected changes in meteorological drought over East Africa inferred from bias-adjusted CMIP6 models. . *Natural Hazards*, 1-26.
- Bedmar Villanueva, A., Jha, Y., Ogwal-Omara, R., Welch, E., Wedajoo, S., & Halewood, M. (2016). Adoption of climate smart technologies in East Africa: Findings from two surveys and participatory exercises with farmers and local experts. *CCAFS Info Note*.
- Belay, A., Oludhe, C., Mirzabaev, A., Recha, J. W., Berhane, Z., Osano, P. M., & Solomon, D. (2022). Knowledge of climate change and adaptation by smallholder farmers: evidence from southern Ethiopia. *Heliyon*, 8(12).
- Belay, A. M. (2023). Does climate-smart agriculture improve household income and food security? Evidence from Southern Ethiopia. *Environment, Development and Sustainability*.
- Belay, A., Mirzabaev, A., Recha, J. W., Oludhe, C., Osano, P. M., Berhane, Z., ... & Solomon, D. (2023). Does climate-smart agriculture improve household income and food security? Evidence from Southern Ethiopia. *Environment, Development and Sustainability*, 1-28.
- Biswas, S. S., Ahad, M. A., Nafis, M. T., Alam, M. A., and Biswas, R. (2021). Introducing “ $\alpha$ -Sustainable Development” for transforming our world: A proposal for the 2030 agenda. *Journal of Cleaner Production*, 321, 129030.
- Bodansky, D. (1993). The United Nations framework convention on climate change: a commentary. *Yale J. Int'l l.*, 18, 451.
- Boru, H. J., & Koske, J. K. (2014). Climate Variability and Response Strategies among the Gadamoji Agro-Pastoralists of Marsabit County, Kenya. *International journal of humanities and social science*, 4(11), 69-78.
- Chufe, J. C., Oindo, B. O., and Abuom, P. O. (2019). Assessment of Magnitudes of Vulnerabilities to Drought in Pastoral Production System in Marsabit, Northern Kenya. *The International Journal of Science and Technoledge*, 7(10).
- Citaristi, I. (2022). United Nations Development Programme—UNDP. In *The Europa Directory of International Organizations 2022* (pp. 183-188). Routledge.

- County Government of Marsabit (2018). Second County integrated plan 2018-2022. Nairobi: Government Press; 2018.
- Cramer, D., & Howitt, D. (2004). A practical resource for students in the social sciences. Sage Pub.
- Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika*, 16(3), 297-334.
- Cuni-Sanchez, A., Omeny, P., Pfeifer, M., Olaka, L., Mamo, M. B., Marchant, R., & Burgess, N. D. (2019). Climate change and pastoralists: perceptions and adaptation in montane Kenya. *Climate and Development*, 11(6), 513-524.
- Dabasso, B. H., & Okomoli, M. O. (2015). Changing pattern of local rainfall: analysis of a 50-year record in central Marsabit, northern Kenya. *Weather*, 70(10), 285-289.
- Danso-Abbeam, G., Ehiakpor, D. S., & Aidoo, R. (2018). Agricultural extension and its effects on farm productivity and income: insight from Northern Ghana. *Agriculture & Food Security*, 7(1), 1-10.
- Darkwah, K. A., Kwawu, J. D., Agyire-Tettey, F., & Sarpong, D. B. (2019). Assessment of the determinants that influence the adoption of sustainable soil and water conservation practices in Techiman Municipality of Ghana. *International soil and water conservation research*, 7(3), 248-257.
- Djido, A., Zougmore, R. B., Houessionon, P., Ouédraogo, M., Ouédraogo, I., & Diouf, N. S. (2021). To what extent do weather and climate information services drive the adoption of climate-smart agriculture practices in Ghana? *Climate Risk Management*, 32.
- Dougherty, M. V. (2021). The use of confidentiality and anonymity protections as a cover for fraudulent fieldwork data. *Research Ethics*, 17(4), 480–500. <https://doi.org/10.1177/17470161211018257>
- Eisenack, K., & Stecker, R. (2010). An action theory of adaptation to climate change. *Climate and Development*. 11(6), 513-524.
- Emongor, R. A., Matiri, F. M., Magana, A., Wamaitha, J., Daniel, A. M., & Mulindo, J. (2022). Factors Influencing Adoption of Pigeon Pea and its Impact on Household Food Security in Machakos County, Kenya.
- Eve, A. (2021). *Humans are adaptable. But can we handle the climate crisis?*. Retrieved from <https://grist.org/ask-umbra-series/humans-are-adaptable-but-can-we-handle-the-climate-crisis/>
- Faso, B. (2016). Analyses of determinants of Pastoralist and Agro-pastoralist households' Adaptation to climate change in the Sudano-Sahelian zone.

- Ferrer, A. J. G., & Le, H. T. (2021). Factors Affecting Farmer's Decision to Adopt Climate-Smart Agriculture Technologies and Practices in a Climate Smart Village: The Case of My Loi Village, Ha Tinh Province, Vietnam.
- Food Agriculture Organization. (2014). FAO success stories on climate-smart agriculture.
- Food Agriculture Organization of the United Nations (2015). Climate change and food security: risks and responses <http://www.fao.org/publications>
- Food Agriculture Organization (2018) Climate-smart agriculture training manual – A reference manual for agricultural extension agents. Rome. 106 pp. Licence: CC BY-NC-SA 3.0 IGO
- Food Agriculture Organization (2021). The impact of disasters and crises on agriculture and food security: 2021. Rome. <https://doi.org/10.4060/cb3673en>
- Forzieri, G., Bianchi, A., e Silva, F. B., Herrera, M. A., Leblois, A., Lavalle, C., & Feyen, L. (2018). Escalating impacts of climate extremes on critical infrastructures in Europe. *Global environmental change*, 48, 97-107.
- Fusco, G., Melgiovanni, M., Porrini, D., & Ricciardo, T. M. (2020). How to improve the diffusion of climate-smart agriculture: What the literature tells us. *Sustainability*, 12(12), 5168. How to improve the diffusion of climate-smart agriculture: What the literature tells us. *Sustainability*, 12 (12), 5168.
- Gauchan, D., Joshi, B. K., Sthapit, S., & Jarvis, D. I. (2020). Traditional crops for household food security and factors associated with on-farm diversity in the mountains of Nepal. *Journal of Agriculture and Environment*.
- Gebrechorkos, S. H., Hülsmann, S., & Bernhofer, C. (2019). Changes in temperature and precipitation extremes in Ethiopia, Kenya, and Tanzania. *International Journal of Climatology*, 39(1), 18-30.
- Gebrechorkos, S. H., Hülsmann, S., & Bernhofer, C. (2020). Analysis of climate variability and droughts in East Africa using high-resolution climate data products. *Global and Planetary Change*, 186, 103130.
- Gebru, T. A., Brhane, G. K., & Gebremedhin, Y. G. (2021). Contributions of water harvesting technologies intervention in arid and semi-arid regions of Ethiopia, in ensuring households' food security, Tigray in focus. *Journal of Arid Environments*, 185(1).
- Gikonyo, N., Busienei, J., Gathiaka, J., & Karuku, G. (2022). Analysis of household savings and adoption of climate smart agricultural technologies. Evidence from smallholder farmers in Nyando Basin, Kenya. *Heliyon*. <https://doi.org/10.1016/j>

- González-Hernández, D. L., Aguirre-Gamboa, R. A., & Meijles, E. W. (2022). The role of climate change perceptions and sociodemographic on reported mitigation efforts and performance among households in northeastern Mexico. *Environment, Development and Sustainability*, 1-23.
- Ghosh, M. (2019). Climate-smart agriculture, productivity and food security in India. *Journal of Development Policy and Practice*, 4(2), 166-187.
- Gowing, J. W., Golicha, D. D., & Sanderson, R. A. (2020). Integrated crop-livestock farming offers a solution to soil fertility mining in semi-arid Kenya: evidence from Marsabit County. *International Journal of Agricultural Sustainability*, 18(6), 492-50.
- Haile, G. G., Tang, Q., Sun, S., Huang, Z., Z. X., & Liu, X. (2019). Droughts in East Africa: Causes, impacts and resilience. *Earth-science reviews*, 193, 146-161.
- Hennessy, K., Lawrence, J., & Mackey, B. (2022). IPCC sixth assessment report (AR6): climate change 2022-impacts, adaptation and vulnerability: regional factsheet Australasia.
- Holland, P. W. (1986). Statistics and causal inference. *Journal of the American statistical Association*, 81(396), 945-960.
- Huang, H., Xu, Z., Shao, X., Wismeijer, D., Sun, P., Wang, J., & Wu, G. (2017). Multivariate linear regression analysis to identify general factors for quantitative predictions of implant stability quotient values. *PloS one*, 12(10). <https://doi.org/e0187010>
- Huyer, S., & Chanana, N. (2021). Gender-smart agriculture: An agenda for gender and socially inclusive climate-resilient agriculture.
- Ilori, O. W., & Ajayi, V. O. (2020). Change Detection and Trend Analysis of Future Temperature and Rainfall over West Africa. *Earth Systems and Environment*, 4(3), 493-512.
- Imran, M. A., Ali, A., Ashfaq, M., Hassan, S., Culas, R., & Ma, C. (2018). Impact of Climate Smart Agriculture (CSA) practices on cotton production and livelihood of farmers in Punjab, Pakistan. *I Sustainability*, 10(6), 2101.
- Intergovernmental Panel on Climate Change (2007). Impacts, Adaptation, and Vulnerability: Contribution of Working Group II to the Third Assessment Report of the Inter. (O. C. M.L. Parry, Ed.)
- Intergovernmental Panel on Climate Change (2012): Glossary of terms. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and

P.M. Midgley (eds.)). *A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change*

- Intergovernmental Panel on Climate Change (2013). *Change Summary for policymakers*. T. Stocker, D. Qin, G. Plattner, M. Tignor, S. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex, P. Midgley (Eds.), *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press (2013)
- Intergovernmental Panel on Climate Change (2014). *Climate change 2014: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK: Cambridge University press.
- Issahaku, G., & Abdulai, A. (2020). Adoption of climate-smart practices and its impact on farm performance and risk exposure among smallholder farmers in Ghana. *Australian Journal of Agricultural and Resource Economics*, 64(2), 396-420.
- Jiddah, C. (2022). *Assessment of vulnerabilities to drought, impact and adaptation options in pastoral production systems in Laisamis, Marsabit County, Kenya* (Doctoral dissertation, Maseno University).
- Kangogo, D., Dentoni, D., & Bijman, J. (2021). Adoption of climate-smart agriculture among smallholder farmers: Does farmer entrepreneurship matter? *Land Use Policy*, 109, 105666.
- Karen, G. M. (2023). *The steps for running any statistical model. Steps-regression-nova*: <https://www.theanalysisfactor.com/>
- Kemal, A. W., Mohammed, A. A., & Lelamo, L. L. (2022). Pastoralists' Adaptation Strategies to Climate Change and Determinant Factors in Korahey Zone, Ethiopia. *American Journal of Climate Change*, 11(2), 79-102.
- Kenya Meteorological Department. (2020). *State of the Climate in Kenya 2020*. [https://meteo.go.ke/sites/default/files/downloads/STATE%20OF%20THE%20%20CLIMATE%202020\\_14042021.pdf](https://meteo.go.ke/sites/default/files/downloads/STATE%20OF%20THE%20%20CLIMATE%202020_14042021.pdf)
- Kenya National Bureau of Statistics (2019), *Kenya Population and Housing Census: Vol 1 Population by County and Sub-county*. Government printers, Nairobi, Kenya.
- Kamruzzaman, M., Daniell, K. A., Chowdhury, A., & Crimp, S. (2021). The role of extension and advisory services in strengthening farmers' innovation networks to adapt to climate extremes. *Sustainability*, 13(4), 1941.

Khanal, U. W. (2021). Smallholder farmers' adaptation to climate change and its potential contribution to UN's sustainable development goals of zero hunger and no poverty. *Journal of Cleaner Production*, 281.

- Kifle, T., Ayal, D. Y., & Mulugeta, M. (2022). Factors influencing farmers adoption of climate smart agriculture to respond climate variability in Siyadebrina Wayu District, Central highland of Ethiopia. *Climate Services*, 26. <https://doi.org/100290>.
- Kim, J. H. (2019). Multicollinearity and misleading statistical results. *Korean journal of anesthesiology*, 72(6), 558-569.
- Kirina, T., Groot, A., Shilomboleni, H., Ludwig, F., & Demissie, T. (2022). Scaling climate smart agriculture in East Africa: experiences and lessons. *Agronomy*, 12(4), 820.
- Kogo, B. K., Kumar, L., & Koech, R. (2020). Climate change and variability in Kenya: a review of impacts on agriculture and food security. *Environment, Development and Sustainability*, 1-21.
- Kurgat, B. K., Lamanna, C., Kimaro, A., Namoi, N., Manda, L., & Rosenstock, T. S. (2020). Adoption of climate-smart agriculture technologies in Tanzania. *Frontiers in Sustainable Food Systems*, 4(55).
- Lekapana, P. L. (2013). Socioeconomic impacts of drought on pastoralists, their coping strategies, and government interventions in Marsabit County, Kenya. *Doctoral dissertation, University of Nairobi*.
- Lengarite, M. I., Getachew, G., Akudabweni, L., & Hoag, D. (2014). Supplementary feeding of lactating goats with processed and unprocessed *Acacia tortilis* pods and local grass in the dry season in northern Kenya. *Agricultural Science Research Journal*, 4(3), 63-71.
- Li, M. (2013). Using the propensity score method to estimate causal effects: A review and practical guide. *Organizational Research Methods*, 16(2), 188-226.
- Li, Q., Sheng, B., Huang, J., Li, C., Song, Z., Chao, L., & Jones, P. (2022). Different climate response persistence causes warming trend unevenness at continental scales. *Nature Climate Change*, 12(4), 343-349.
- Lipper, L., Thornton, P., Campbell, B. M., Baedeker, T., Braimoh, A., Bwalya, M., & Hottle, R. (2014). Climate-smart agriculture for food security. *Nature climate change*, 4(12), 1068-1072.
- Liu, T., Shryane, N., & Elliot, M. (2022). Attitudes to climate change risk: classification of and transitions in the UK population between 2012 and 2020. *Humanities and Social Sciences Communications*, 9(1), 1-15.
- Maina, K. W., Ritho, C. N., Lukuyu, B. A., & Rao, E. J. O. (2020). Socio-economic determinants and impact of adopting climate-smart *Brachiaria* grass among dairy farmers in Eastern and Western regions of Kenya. *Heliyon*, 6(6).

- Maka, L., Ighodaro, I. D., & Ngcobo-Ngotho, G. P. T. (2019). Capacity development for scaling up Climate-Smart Agriculture (CSA) innovations: Agricultural Extension's role in mitigating climate change effects in Gqumashe Community, Eastern Cape, South Africa. *South African Journal of Agricultural Extension*, 47(1), 45-53.
- Malhi, G. S., Kaur, M., & Kaushik, P. (2021). Impact of climate change on agriculture and its mitigation strategies: A review. *Sustainability*, 13(3), 1318.
- Malpeli, K. C., Weiskopf, S. R., Thompson, L., & Hardy, A. R. (2020). What are the effects of climate variability and change on ungulate life-histories, population dynamics, and migration in North America? A systematic map protocols. *Environmental Evidence*, 9(1), 1-9.
- Mango, N., Makate, C., Tamene, L., Mponela, P., & Ndengu, G. (2020). Impact of the adoption of conservation practices on cereal consumption in a maize-based farming system in the Chinyanja Triangle, Southern Africa. *Sustainable Futures*, 2.
- Marin, A. (2010). Riders under storms: contributions of nomadic herders' observations to analysing climate change in Mongolia. *Global Environmental Change*, 20(1), 162-176.
- Masca, U., Mirriam, K. N., & Bor, E. K. (2022). Does access to credit influence the adoption of good agricultural practices? The case of smallholder potato farmers in Molo Sub-County, Kenya. *Journal of Agricultural Extension and Rural Development*, 14(1), 24-32.
- Mebrate, A., Zeray, N., Kippie, T., & Haile, G. (2022). Determinants of soil fertility management practices in Gedeo Zone, Southern Ethiopia: logistic regression approach. *Heliyon*, 8(1).
- Melnic, A. S., & Botez, N. (2014). Formal, non-formal and informal interdependence in education. *Economy Transdisciplinarity Cognition*, 17(1), 113-118.
- Macharia, M. M., & Raude, J. M. (2017). Analysis of the Trends in Temperature and Rainfall in Thika River. *International Journal of Climate Research*, 2(1), 26-35. <https://doi.org/10.18488/journal.112.2017.21.26.35>
- McKinley, J. D., LaFrance, J. T., and Pede, V. O. (2021). Climate change adaptation strategies vary with climatic stress: Evidence from three regions of Vietnam. *Frontiers in Sustainable Food Systems*, 5, 762650
- Mimura, N., Pulwarty, R. S., Elshinnawy, I., Redsteer, M. H., Huang, H. Q., Nkem, J. N., ... & Kato, S. (2015). Adaptation planning and implementation. In *Climate change 2014 impacts, adaptation and vulnerability: Part A: Global and sectoral aspects* (pp. 869-898). Cambridge University Press.

- Mkwambisi, D., Maguza-Tembo, F., Abdi-Khalil, E., & Mangisoni, J. (2016). Does adoption of climate smart agriculture (CSA) technologies reduce household vulnerability to poverty?.
- MoALF. (2017). *Climate Risk Profile for Marsabit County. Kenya County Climate Risk Profile Series. The Ministry of Agriculture, Livestock and Fisheries (MoALF)*. Nairobi, Kenya.
- Mogaka, O., B., Bett, H. K., & Karanja Ng'ang'a, S. (2021). Socioeconomic factors influencing the choice of climate-smart soil practices among farmers in western Kenya. *Journal of Agriculture and Food Research*, 5. <https://doi.org/100168>
- Mthethwa, K. N., Ngidi, M. S. C., Ojo, T. O., & Hlatshwayo, S. I. (2022). The determinants of adoption and intensity of climate-smart agricultural practices among smallholder maize farmers. *Sustainability*, 14(24), 16926.
- Mudzengi, C. P., Dahwa, E., and Kapembeza, C. S. (2020). Livestock Feeds and Feeding in Semi-Arid Areas of Southern Africa. In *Livestock Health and Farming*. IntechOpen.
- Mugenda, A. G. (2008). *Social Science Research: Theory and principles*. Nairobi, Kenya.
- Muhati, G. L., Olago, D., & Olaka, L. (2018). Past and projected rainfall and temperature trends in a sub-humid Montane Forest in Northern Kenya based on the CMIP5 model ensemble. *Global Ecology and Conservation*, 16, e00469.
- Mujeyi, A., Mudhara, M., & Mutenje, M. J. (2022). Adoption patterns of Climate-Smart Agriculture in integrated crop-livestock smallholder farming systems of Zimbabwe. *Climate and Development*, 14(5), 399-408.
- Mulinya, C. (2017). Factors affecting small scale farmers coping strategies to climate change in Kakamega County in Kenya. *IOSR Journal of Humanities and Social Science*, 22(2), 100-109.
- Muluneh, M. G. (2021). Impact of climate change on biodiversity and food security: a global perspective—a review article. *Agriculture & Food Security*, 10(1), 1-25.
- Muriithi, L. N., Onyari, C. N., Mogaka, H. R., Gichimu, B. M., Gatumo, G. N., & Kwena, K. (2021). Adoption determinants of adapted climate smart agriculture technologies among smallholder farmers in Machakos, Makueni, and Kitui Counties of Kenya. *Journal of Agricultural Extension*, 25(2), 75-85.

- Musafiri, C. M., Kiboi, M., Macharia, J., Ng'etich, O. K., Kosgei, D. K., Mulianga, B., & Ngetich, F. K. (2022). Adoption of climate-smart agricultural practices among smallholder farmers in Western Kenya: do socioeconomic, institutional, and biophysical factors matter? *Heliyon*, 8(1).
- Muya, E. M., Obanyi, S., Ngutu, M., Sijali, I. V., Okoti, M., Maingi, P. M., & Bulle, H. (2011). The physical and chemical characteristics of soils of Northern Kenya Arid lands: Opportunity for sustainable agricultural production. *Journal of Soil Science and Environmental Management*, 2(1), 1-8.
- Mwaura, G. G., Kiboi, M. N., Bett, E. K., Mugwe, J. N., Muriuki, A., Nicolay, G., & Ngetich, F. K. (2021). Adoption intensity of selected organic-based soil fertility management technologies in the Central Highlands of Kenya. *Frontiers in Sustainable Food Systems*, 295.
- National Geographic (2019). <https://www.nationalgeographic.com/environment/article/global-warming-overview>
- Neate, P. (2015). Climate-smart agriculture success stories from farming communities around the world. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS); Technical Centre for Agricultural and Rural Cooperation (CTA), Wageningen, Netherlands.
- Negera, M. A. (2022). Determinants of adoption of climate smart agricultural practices among farmers in Bale-Eco region, Ethiopia. *Heliyon*. 8(7).
- Negesse, A., Dube, Habtamu, T., Mulugeta, H., Abebaw, Z., & Taddege, T. (2020). The impact of being of the female gender for household head on the prevalence of food insecurity in Ethiopia: a systematic-review and meta-analysis. *Public Health Reviews*. <https://doi.org/10.1186/s40985-020-00131-8>
- Njiru, M. M., Mogaka, H. R., Ndirangu, S. N., & Gichimu, B. M. (2021). Factors influencing adoption of improved cultivars of macadamia (*Macadamia* spp.) among small-scale farmers in Embu County, Kenya. *Journal of Agricultural Extension*, 25(4).
- Nkuba, M. R., Chanda, R., Mmopelwa, G., Kato, E., Mangheni, M. N., & Lesolle, D. (2020). Influence of indigenous knowledge and scientific climate forecasts on arable farmers' climate adaptation methods in the Rwenzori region, Western Uganda. *Environmental management*, 65, 500-516.
- NOAA. (2023). *U.S. Climate Normals*. Retrieved from <https://www.ncei.noaa.gov/products/land-based-station/us-climate-normals>
- Oduniyi, O. S., & Tekana, S. S. (2019). Adoption of agroforestry practices and climate change mitigation strategies in North West province of South Africa. *International Journal of Climate Change Strategies and Management*, 11(5), 716-729. <https://doi.org/https://doi.org/10.1108/IJCCSM-02-2019-0009>

- Ogada, M. J., Rao, E. J., Radeny, M., Recha, J. W., & Solomon, D. (2020). Climate-smart agriculture, household income and asset accumulation among smallholder farmers in the Nyando basin of Kenya. *World Development Perspectives*, 18, 100203.
- Okoth, N. W. (2019). *Factors Influencing Adoption of Climate-smart Agriculture as a Climate Change Adaptation in Tigania West-Meru County Kenya* (Doctoral dissertation, University of Nairobi).
- Ongoma, V., & Chen, H. (2017). Temporal and spatial variability of temperature and precipitation over East Africa from 1951 to 2010. *Meteorology and Atmospheric Physics*, 129, 131-144.
- Ouma, J. O., Olang, L. O., Ouma, G. O., Oludhe, C., Ogallo, L., & Artan, G. (2018). Magnitudes of climate variability and changes over the arid and semi-arid lands of Kenya between 1961 and 2013 period. *American Journal of Climate Change*, 7(01), 27.
- Ouédraogo, M., Houessionon, P., Zougmoré, R. B., & Partey, S. T. (2019). Uptake of climate-smart agricultural technologies and practices: Actual and potential adoption rates in the climate-smart village site of Mali. *Sustainability*, 11(17), 4710.
- Palmer, P. I., Wainwright, C. M., Dong, B., Maidment, R. I., Wheeler, K. G., Gedney, N., & Turner, A. G. (2023). Drivers and impacts of Eastern African rainfall variability. *Nature Reviews Earth & Environment*, 4(4), 254-270.
- Palombi, L., & Sessa, R. (2013). *Climate-smart Agriculture: Sourcebook*. Food and Agriculture Organization of the United Nations.
- Panda, A., & Sahu, N. (2019). Trend analysis of seasonal rainfall and temperature pattern in Kalahandi, Bolangir and Koraput districts of Odisha, India. *Atmospheric Science Letters*, 20(10), e932.
- Paudyal, B., Chanana, N., Khatri-Chhetri, A., Sherpa, L., Kadariya, I., & Aggarwal, P. (2019). Gender Integration in Climate Change and Agricultural Policies: The Case of Nepal. *Frontiers in Sustainable Food Systems*, 3(66). <https://doi.org/10.3389/fsufs.2019.0006>
- Pörtner, H. O., Roberts, D. C., Adams, H. A., Aldunce, P., Ali, E., & Fischlin, A. (2022). *Climate change 2022: Impacts, adaptation and vulnerability*. IPCC Sixth Assessment Report.
- Raihan, A. (2023). A review of the global climate change impacts, adaptation strategies, and mitigation options in the socio-economic and environmental sectors. *Journal of Environmental Science and Economics*, 2(3), 36-58.
- Radeny, M. A., Ogada, M. J., Recha, J. W., Kimeli, P., Rao, E. J., & Solomon, D. (2018). Uptake and impact of climate-smart agriculture on food security, incomes and assets in East Africa. *CCAFS Working Paper*.

- Radeny, M., Rao, E. J., Ogada, M. J., Recha, J. W., & Solomon, D. (2022). Impacts of climate-smart crop varieties and livestock breeds on the food security of smallholder farmers in Kenya. . *Food Security*, 1-25.
- Recha, C. W. (2019). Regional variations and conditions for agriculture in Kenya. *Current Politics and Economics of Africa*, 12(1), 87-130.
- Rono, P. K., Rahman, S. M., Amin, M. D., & Badruddoza, S. (2023). Unraveling the Channels of Food Security of the Households in Northern Kenya: Evidence from an Exclusive Dataset. *Current developments in nutrition*, 7(2), 100005.
- Rosenbaum, P. R., & Rubin, D. B. (1985). Constructing a control group using multivariate matched sampling methods that incorporate the propensity score. *The American Statistician*, 39(1), 33-38.
- Rubin, D. B. (1976). Inference and missing data. *Biometrika*, 63(3), 581-592.
- Saha, M. K., Biswas, A. A., Faisal, M., M. J., Ahmed, R., Prokash, J., & Sakib, F. M. (2019). Factors Affecting to Adoption of Climate-smart Agriculture Practices by Coastal Farmers' in Bangladesh. *American Journal of Environment and Sustainable*, 4(4), 113-121.
- Sanga, G., Hella, J., Mzirai, N., & Senga, H. (2014). Impacts of Climate Change on Maize and Beans Production and Compatibility of Adaptation Strategies in Pangani River Basin, Tanzania. *International Journal of Sciences: Basic and Applied Research*.
- Sardar, A., K., K. A., & Kuslu, Y. (2021). Does adoption of climate-smart agriculture (CSA) practices improve farmers' crop income? Assessing the determinants and its impacts in Punjab province, Pakistan. *Environment, Development and Sustainability*, 23(7), 10119-10140.
- Shikuku, K. M., Winowiecki, L., Twyman, J., Eitzinger, A., Perez, J. G., Mwongera, C., & Läderach, P. (2017). Smallholder farmers' attitudes and determinants of adaptation to climate risks in East Africa. . *Climate Risk Management*, 16, 234-245.
- Shivanna, K. R. (2022). Climate change and its impact on biodiversity and human welfare. *Proceedings of the Indian National Science Academy*, 88(2), 160-171.
- Snelder, D., Kahimba, F., Korodjouma, O., Abebe, A., Oughton, E., Bunclark, L., & Lasage, R. (2018). Adaptations in water harvesting technologies for enhancing food security and livelihood: A multi-country study in Sub-Saharan Africa. In *Rainwater-Smart Agriculture in Arid and Semi-Arid Areas*. Springer, Cham. 95-119 .
- Speranza, C. I., Kiteme, B., & Wiesmann, U. (2008). Droughts and famines: the underlying factors and the causal links among agro-pastoral households in semi-arid Makueni district, Kenya. *Global Environmental Change*, 18(1), 220-233.

- Tadele, E., & Hibistu, T. (2021). Empirical review on the use dynamics and economics of teff in Ethiopia. *Agriculture and Food Security*, 10(1), 1-13.
- Tangui, J. K. (2014). The role of community based organizations in the conservation of the environment in Kenya. A case of Kapcherop division, Elgeyo Marakwet County (Doctoral dissertation, University of Nairobi).
- Teshome, H., Tesfaye, K., Dechassa, N., Tana, T., & Huber, M. (2021). Analysis of past and projected trends of rainfall and temperature parameters in Eastern and Western Hararghe zones, Ethiopia. *Atmosphere*, 13(1), 67.
- Thornton, P. K., Loboguerrero Rodriguez, A. M., Campbell, B. M., Mercado, L., Shackleton, S., & Kavikumar, K. S. (2019). Rural livelihoods, food security and rural transformation under climate change.
- United Nation. (2023). *Water – at the center of the climate crisis*. Retrieved from <https://www.un.org/en/climatechange/science/climate-issues/water>.
- The World Bank. (2021). *Climate Smart Agriculture*. Retrieved April 11, 2021, from [www.worldbank.org/en/topic/climate-smart-agriculture](http://www.worldbank.org/en/topic/climate-smart-agriculture)
- Thornton, P. K., & Lipper, L. (2014). How does climate change alter agricultural strategies to support food security? (Vol. 1340). Intl Food Policy Res Inst.
- Wato, M., Koech, M. K., & Maraga, J. N. (2022). Effects of climate-change variability on livestock production and coping strategies in Maikona, Marsabit County, Kenya. *International Journal of Tropical Drylands*, 6(2).
- Watson, E. E., Kochore, H. H., & Dabasso, B. H. (2016). Camels and climate resilience: adaptation in northern Kenya. *Human Ecology*, 44(6), 701- 713.
- Wekesa, B. M., Ayuya, O. I., & Lagat, J. K. (2018). Effect of climate-smart agricultural practices on household food security in smallholder production systems: micro-level evidence from Kenya. *Agriculture & Food Security*, 1(80).
- World Food Programme Climate impacts on food security and nutrition A review of existing knowledge <https://documents.wfp.org/stellent/groups/public/documents/communications/wfp258981.pdf>
- World Meteorological Organization (2021). State of Global Climate <https://public.wmo.int/en/our-mandate/climate/wmo-statement-state-of-global>
- Yamane, T. (1967). *Statistics: An Introductory Analysis. 2nd Edition*, Harper and Row, New York.
- Yang, W., Seager, R., Cane, M. A., & Lyon, B. (2014). The East African long rains in observations and models. *Journal of Climate*, 27(19), 7185-7202.

- Yu, L., Hurley, T., Kliebenstein, J., & Orazem, P. (2008). *Testing for Complementarity and Substitutability among Multiple Technologies: The Case of U.S. Hog Farms*.
- Yvonne, M., Ouma, G., Olago, D., & Opondo, M. (2020). Trends in climate variables (Temperature and rainfall) and local perceptions of climate change in Lamu, Kenya. *Geography, Environment, Sustainability*, 13(3), 102-109.
- YYu, T., Mahe, L., Li, Y., Wei, X., Deng, X., & Zhang, D. (2022). Benefits of crop rotation on climate resilience and its prospects in China. *Agronomy*, 12(2).
- Zakaria, A., Azumah, S. B., Appiah-Twumasi, M., & and Dagunga, G. (2020). Adoption of climate-smart agricultural practices among farm households in Ghana: The role of farmer participation in training Programmes. *Technology in Society*, 63.
- Zappa, G., Ceppi, P., & Shepherd, T. G. (2020). Time-evolving sea-surface warming patterns modulate the climate change response of subtropical precipitation over land. *Proceedings of the National Academy of Sciences*, 117(9), 4539-4545.

## APPENDICES

### Appendix I: Questionnaire

Dear farmer/livestock keeper,

I am undertaking a Master's degree in Environmental Studies (Climate Change and Sustainability) in the School of Agriculture and Environmental Sciences at Kenyatta University. I'm conducting research on "Adoption of climate-smart technologies and their effect on income among agro-pastoralists in Marsabit County, Kenya"

Please do not write your name on this document for the sake of anonymity and confidentiality. Any information obtained is for academic and high degree of confidentiality will be observed.

Thank you for your time and the helpful information.

Anne Gudere.

### SECTION I: Demographic Information of the Respondent

Questionnaire No: #.....Date of questionnaire administration.....

Sub-County	Ward	Location	Sub- Location	Village

1. Please tick as appropriate.

i. Farmer  ii Herder  iii Farmer/Herder  Other(s).... (Specify

3. Gender Male  female

4. Age in years.....

5. Marital status

a. Single  b. Married  c. Widower/Widower  d. Separated/Divorced

6. Educational status

a. Primary  b. Secondary  c. Tertiary (College/University)

d. No formal education

7. Members in the household.

8. Select the sources of income of the household head.

Crop farming	Livestock farming	Crop and Livestock farming	Formal employment	Informal employment	Business/Trade	Other(s).... .( Specify
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

9. What is the average household income (Ksh) per month? -----

**Section 11:**

**Perception on Climate variability**

1. Do you know that there is climate variability? Yes No.
2. What is the frequently experienced climatic hazard? Floods b. drought c. Strong winds d. Heatwaves e. Pest and diseases f. storms
3. How have rainfall patterns been like from 1980 to 2020?
4. How is the temperature trend from 1980 to 2020?

**Section III: Crop-livestock climate-smart technologies adopted by agro pastoralists**

1. Which crop do you grow in your farm?
  - a. Maize  b. Sorghum  c. Millet  d. Teff
  - e. Beans  f. Greengrams  g. Dolichols
  - h. Pigeon peas  i. Sukumawiki  j. Spinach
  - k. Pawpaw

1. Sweetpotatoes  m. Capsicum  n. Mangoes  o. Oranges

2. Which of the following livestock are 'improved' breeds due to climate variability?

- a. Cattle      b. Camel      c. Goat      d. Sheep  
e. Donkey

3. Which climate-smart technologies and practices on improved and traditional crop varieties do you practise?

- a. Traditional crop varieties      b. Improved crop varieties

4. Which strategy of managing diversity in the farm do you practise?

- a. Intercropping      b. Crop rotation

5. Which climate-smart technologies and practices on water use and water management do you practise?

- a. Irrigation      b. Water harvesting by use of tanks      d. Rainwater harvesting by use of water pans  
c. Mulching  
e. Growing water efficient crops

6. Which climate-smart technologies and practices on soil fertility management do you practise?

- a. fertilizer application      b. Agroforestry      c. Manure application      d. Crop retaining residues

7. Which climate-smart technologies and practices on livestock management do you practise?

- a. Keeping improved livestock breeds      b. Introduction of local breeds

8. Which climate-smart technologies and practices on pasture conservation and management do you practise?

- a. Rangeland reseeding      b. Supplementary feeding      c. Fodder conservation & storage  
e. destocking      f. grassland management

9. Which organizations have been working with you?

Have you received the following from any organization? a. Extension services b. training

10. Are credit facilities available during extreme climates?

11. Do you receive weather information on different channels such as radio, word of mouth, television, extension workers?

**Section V: Adoption of livestock-crop climate-smart technologies and practices impacts on livelihood**

1. Which activities contributes to your household incomes? 1= Livestock keeping 2= Crop farming 3=Both crop farming and livestock keeping

2. What is your average household income (Ksh) per month?

**Guideline for Key informant interview**

Name of Organization/Institution

.....

Date.....

Wards of Operation, Please tick, Sagante      Dakabaricha      Songa

Locations-----Sub-Location-----

Villages-----

1. (a) Have you been operating in Saku sub -County for the last 10 years?

Yes.... No...

b) If yes, please indicate the number of years .....

2. What are your main activities in Saku-sub-County (in the wards you selected)?

-----

Which ones are related to crop and livestock?

-----

5. Do you agree that climate is changing? Yes.....No..... What are the indicators of climate change?

-----

Livestock-Crop CST&P

Which climate-smart technologies/practices are your organizations promoting?

Which one/ones have the communities adopted?

Which one/ones were not adopted?

Which one/ones have been mostly adopted?

How are you promoting these climate-smart technologies/practices?

Please explain

**Guideline for focus group discussions-agro-pastoralists**

Livestock-Crop CST&P

- 1) Have CST&P been tried in this area? If yes, what climate-smart practices? List
- 2) For how long have these practices been tried?

Factors influencing livestock-crop CSP&T

- 3) What are the challenges facing agro-pastoralists in food productivity?
- 4) What benefits do smart practices have on the livelihoods of agropastoralists?

## Appendix II: Research Approval Letter



### KENYATTA UNIVERSITY GRADUATE SCHOOL

E-mail: [dean-graduate@ku.ac.ke](mailto:dean-graduate@ku.ac.ke)

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P.O. Box 43844, 00100  
NAIROBI, KENYA  
Tel. 020-8704150

#### Internal Memo

**FROM:** Dean, Graduate School

**DATE:** 7<sup>th</sup> July, 2021

**TO:** Ms. Gudere Anne Ngauri  
C/o Department of Environmental  
Science & Education

**REF:** N50/26327/2018

**SUBJECT:** APPROVAL OF RESEARCH PROPOSAL

=====

This is to inform you that Graduate School Board, at its meeting on 25<sup>th</sup> June, 2021, approved your Research Proposal for the M.Env. Studies Degree entitled, "Adoption of Climate-Smart Technologies and their Effect on Farm Income among Agro-Pastoralists in Marsabit County, Kenya."

You may now proceed with your Data collection, subject to clearance with the Director General, National Commission for Science, Technology & Innovation and Kenyatta University Management.

As you embark on your data collection, please note that you will be required to submit to Graduate School completed Supervision Tracking and Progress Report Forms per semester. The forms are available at the University's Website under Graduate School webpage downloads.

Thank you.

**EDWIN OBUNGU**  
**FOR: DEAN, GRADUATE SCHOOL**

CC. Chairman, Environmental Science & Education Department

**Supervisors:**

1. Dr. Evelyn Wemali  
C/o Environmental Science & Education Dept.  
**Kenyatta University**
2. Dr. Ezekiel Ndunda  
C/o Environmental Science & Education Dept.  
**Kenyatta University**

Appendix II: Nacosti License

Republic of Kenya  
NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION

Ref No: 662986

**RESEARCH LICENSE**




This is to Certify that **Ms. Anne Ngari Gaderi** of **Kenyatta University**, has been licensed to conduct research in **Marsabit** on the topic: **ADOPTION OF CLIMATE-SMART TECHNOLOGIES AND THEIR EFFECT ON FARM INCOME AMONG AGRO-PASTORALISTS IN MARSABIT COUNTY, KENYA** for the period ending: **15/August/2021**

License No: **NACOSTUP21/02122**

Applicant Identification Number: **662986**

Director General  
NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION

Verification QR Code



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