CLIMATE-SMART AGRICULTURE AND ITS IMPLICATIONS ON FOOD SECURITY AMONG SMALL-SCALE FARMERS IN NYAMIRA COUNTY, KENYA

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DECLARATION AND CERTIFICATION

Declaration

This thesis is my original work prepared with no other than the indicated sources' support and has not been presented elsewhere for a degree or any other award.

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Certification

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DEDICATION

In profound gratitude, this thesis is dedicated posthumously to my late father, Mr. Daniel Omboga Otwori and my loving mother, Mrs. Catherine Wanja Njagi, who inspired and supported me while developing this thesis. Secondly, I wish to dedicate this thesis to my siblings: Brother Otwori Erick Otwori, and Sisters Damacline Kwamboka Otwori, Purity Mong'ina Otwori, and Lydiah Mong'ina Otwori for their unwavering encouragement and unwavering belief in me has been instrumental in achieving this milestone.

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ABSTRACT

Climate change and climate variability threaten global food security, especially in sub-Saharan Africa, where agriculture is central to income generation and the economy. Nyamira County in Kenya, despite its high agricultural potential, experiences challenges arising from climate change and climate variability. The overall objective was to examine climate-smart agriculture and its implications on food security among small-scale farmers in Nyamira County, Kenya. The specific objectives were to determine rainfall and temperature trends and patterns on food security among small-scale farmers in Nyamira County, determine the existing Climate Smart Agriculture practices among small-scale farmers in Nyamira County, examine the influence of climate-smart agriculture practices on food security among small-scale farmers in Nyamira County and evaluate the effectiveness of climate-smart agriculture practices in enhancing food security among small-scale farmers in Nyamira County. The study adopted descriptive, correlation, and evaluation research designs, with a sample size of 384 households selected through a multistage sampling approach. Data collection methods included questionnaires, Focus Group Discussions (FGDs), observation checklists, and structured interview schedules. Secondary data was gathered from various sources such as the internet, journals, publications, and document analyses. Climate data for Nyamira station was obtained from the Kenya Meteorological Department (KMD). These data were analyzed using the Mann-Kendall test analysis for the various seasons (MAM, JJA, SON, and DJF). Quantitative data was analyzed using the Statistical Package for Social Scientists version 25, while qualitative data was summarized through narrative analysis. Inferential statistics involved Pearson Chi-Square tests, correlation, and logistic regression model analyses. The study findings revealed that the rainfall trends for Nyamira station covering the seasons MAM ($y = 0.2769x + 177.3$), SON ($y = 2.2095x + 104.43$), and JJA ($y = 0.109x + 131.63$) were increasing. The station exhibited statistically significant trends in maximum and minimum temperatures (p-value < 0.05). The second objective revealed that mixed cropping at 20.50% (230), crop rotation at 15.15% (170), organic farming at 10.52% (118), and cover cropping at 7.93% (89) had a significant influence on the food security of the small-scale farmers ($p<0.05$). Conversely, agroforestry 14.53% (163), drought-resistant crops 7.49% (84), water harvesting 13.10% (147), and integrated soil fertility management 7.31% (82) did not exhibit a significant influence (p-value > 0.05). The logistic regression model showed a statistically significant $\chi^2 = 20.267, p < 0.05$, between CSA practices and food security. On effectiveness, over 50% of respondents perceived mixed cropping, crop rotation, agroforestry, traditional crop varieties, organic farming, and cover cropping as either effective or highly effective strategies. However, traditional weather forecasting and pest control methods were perceived as ineffective. The study revealed that different CSA practices have varying effectiveness in enhancing household food security. The study recommends that the two levels of government strengthen the extension services to improve upscaling of CSA practices in Nyamira County. This will help small-scale farmers to adapt to changing climatic conditions and ensure long-term food security.

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LIST OF ABBREVIATIONS AND ACRONYMS

ACT-N	African Conservation Tillage Network
AEZ	Agro Ecological Zone
ASALs	Arid and Semi- arid Lands
ASDS	Agriculture Sector Development Strategy
AUC	Africa Union Commission
CA	Conservation Agriculture
CAADP	Comprehensive African Agricultural Development Programme
CCAFS	Climate Change, Agriculture and Food Security
CCKP	Climate Change Knowledge Portal
CGIAR	Consultative Group for International Agricultural Research
CIDP	County Integrated Development Plan
CO_2	Carbon Dioxide
CSA	Climate Smart Agriculture
CSAPs	Climate Smart Agriculture Practices
CT	Conventional Tillage
CVI	Content Validity Index
DJF	December, January, February
EAC	East African Community
FAO	Food and Agriculture Organization
FGDs	Focus Group Discussions
GDP	Gross Domestic Product
GHGs	Green House Gases
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GoK	Government of Kenya

HDDS	Household Dietary Diversity Score
HFCS	Household Food Consumption Score
HH	Household
ICRAF	International Centre for Research in Agroforestry
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IFAD	International Fund for Agricultural Development
IITA	International Institute for Tropical Agriculture
IPCC	Intergovernmental Panel on Climate Change
ISFM	Integrated Soil Fertility Management
JJA	June, July, August
KARLO	Kenya Agricultural and Livestock Research Organization
KFS	Kenya Forest Service
KIIs	Key Informant Interviews
KMD	Kenya Meteorological Department
KNBS	Kenya National Bureau of Statistics
LH	Low Highlands
LMZ	Low Midland Zone
MALF	Ministry of Agriculture, Livestock & Fisheries
MAM	March, April, May
MFIs	Microfinance Institutions
MK	Mann- Kendall
MMUST	Masinde Muliro University of Science and Technology
MoA	Ministry of Agriculture
NACOSTI	National Commission for Science, Technology and Innovation
NARIGP	National Agricultural and Rural Inclusive Growth Project

NCCAP	National Climate Change Action Plan
NCCRS	National Climate Change Response Strategy
NGOs	Governmental Organizations
SAGCOT	Southern Agricultural Growth Corridor
SDGs	Sustainable Development Goals
SDMHA	School of Disaster Management and Humanitarian Assistance
SID	Society for International Development
SLF	Sustainable Livelihood Framework
SON	September, October, November
SPSS	Statistical Package for Social Sciences
$\mathbf{T_{MAX}}$	Maximum Temperature
$\mathbf{T_{MIN}}$	Minimum Temperature
UM	Upper Midland zone
UN	United Nations
UNEP	United Nations Environmental Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations International Children's Emergency Fund
USAID	United States Agency for International Development
WFP	World Food Programme
WHO	World Health Organization

DEFINITION OF OPERATIONAL TERMS

Adaptation: A process of undertaking necessary measures to cope with the uncertainty of risks associated with unpredictable, erratic and extreme weather events such as drought and floods on agriculture. It also means taking necessary measures to take advantage of opportunities that arise from these weather phenomena.

Adaptive Strategies: The specific measures (or actions) that small-scale farmers might take to minimize the consequences and impacts of climate change.

Adoption: It refers to the acceptance of a new product or innovation. According to this study, it is the process of implementing CSA practices after being aware of the presence of technologies in one's environment that is heavily affected by climate variability.

Agriculture: It is used to refer to both crop and animal husbandry in general. In the study, it will be used to refer to crop cultivation.

Climate change: This is a change in the climate system caused by significant changes in the concentration of greenhouse gases due to human activities, in addition to natural climate change observed during a considerable period. The period under consideration for this study is 30 years (1990-2019).

Climate-smart agriculture: Agriculture that sustainably increases productivity and resilience (adaptation), reduces/removes greenhouse gases (mitigation), and enhances the achievement of national food security and development goals.

Conservation Agriculture: An approach to managing agroecosystems for improved and sustained productivity, increased profits, and food security while preserving and enhancing the resource base and the environment. Three linked principles characterize it: continuous minimum mechanical soil disturbance, permanent organic soil cover, and diversification of crop species grown in sequences or associations.

Food insecurity: A situation where some people do not have access to sufficient quantities of safe and nutritious food and hence do not consume the food that they need to grow normally and conduct an active and healthy life

Food security: A situation that exists when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life

Greenhouse gases: The atmospheric gases responsible for causing global warming and climate change. The significant GHGs focused on this study are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O).

Household head: This is the eldest person above 18 years present in the household at the time of questionnaire administration.

Household: People who live within the same compound and have the same cooking arrangement

Mitigation: Measures undertaken to reduce or remove (carbon sequestration) greenhouse gas emissions from the atmosphere

Small-scale farmers: include pastoralists, forest keepers, and fishers who manage areas varying from less than one hectare to 10 hectares. Small-scale farmers are characterized by family-focused motives such as favoring the stability of the farm household system, using mainly family labour for production and using part of the produce for family consumption.

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Global food security faces grave and escalating peril due to the risks associated with climate change, stagnant agricultural productivity, a growing population, and deteriorating soil quality (Bjornlund *et al.*, 2020; Giller, 2020). Projections suggest that the number of people suffering from hunger could surge to 840 million by 2030 (FAO et al., 2020). This impending situation poses severe challenges to achieving the United Nations Sustainable Development Goal 2 (SDG 2), which aims to eliminate hunger and enhance nutrition by 2030. Additionally, it challenges the achievement of the African Union's Agenda 2063 (72(e)), which strives to eradicate hunger and food insecurity (AUC, 2015; UN General Assembly, 2015).

The demand for food and other agricultural products has reached unprecedented levels due to population growth, rising incomes, and various global factors (Lipper et al., 2017). According to FAO (2019a), the world's population is expected to reach approximately 9 billion by 2050, necessitating a 60% increase in agricultural production. The IPCC's fifth assessment report, published in 2014, highlights that the impacts of climate change are already being observed in agriculture and food security. These adverse effects are likely most pronounced in tropical regions, where most impoverished, agriculture-dependent populations reside (IPCC, 2014).

Climate Smart Agriculture (CSA) practices are defined as enhancing the delivery of production inputs, information, germplasm, finance, markets, and other resources observed by smallholder farmers. Additionally, it aims to increase and optimize the combination of yields/ productivity and adaptation to climate conditions concerning the sound and efficient management of natural resources and support climate change interventions. (FAO, 2013a: Lipper & Zilverman, 2018). The strategy makes use of tried-and-true technologies as well as other cutting-edge techniques like agroforestry, crop rotation, conservation agriculture, water harvesting, efficient use, cover cropping, intercropping with legumes, irrigation and integrated soil fertility management (ISFM) (Mutengwa *et al*., 2023). Climate change adaptation is achievable through cultivating varieties and breeds that can better withstand these stresses or through the farmer's ability to access timely weather information. (FAO, 2010; FAO, 2013b).

CSA practices are essential for achieving the Sustainable Development Goals (SDGs) of the United Nations (UN) in low- and middle-income countries, which include eradicating hunger and combating climate change (FAO, 2018; IPCC, 2018). Climate-smart agricultural (CSA) practices have triple bottom-line opportunities to reverse this trend since they equally enhance produce productivity and income, reduce greenhouse gas emissions or remove them, and improve household food security. (Wekesa *et al*., 2018).

Mutengwa *et al*., (2023) state that Southern Africa is experiencing persistent food insecurity primarily due to the numerous stressors affecting its agricultural practices. Weather-related issues are worsening food scarcity, particularly deep into rural districts, previously home to marginalized communities. Climate-smart agriculture has, therefore, been realized as a crucial way of offsetting the effects of climate change. Southern Africa is particularly vulnerable to these effects due to its low adaptive capacity and heavy dependence on agriculture. The demand for food in this region is increasing because of rapid population growth and urbanization (Msangi, 2014). The current population of Southern Africa is approximately 224 million and is projected to reach 241 million by 2050. Like other developing regions, Southern Africa needs to double its food production to meet the increasing demands for both quality and quantity of food (SADC, 2020).

As Nyasimi *et al*. (2017) opined, east African farmers are called upon to update themselves and develop skills in understanding CSA practices, technologies, and institutional innovations that could enhance their adaptation to climate change and manage the variability being experienced. According to GoK (2014), at least 55 percent of male-headed households, 59 percent of female-headed households, and 55 percent of youth-headed households do not have adequate food to sustain them for the year.

Agriculture is a primary income source and a vital economic contributor for most sub-Saharan countries. For instance, in Kenya, agriculture accounts for 70% of rural informal employment and contributes to 65% of the nation's exports (Recha, 2018). Most of the smallholder farmers in the country rely on agriculture as the main source of their income (Ochieng *et al*., 2017). Sadly, this region has, for instance, been affected by and faced detrimental impacts of climate change, which exposes people to heightened food insecurity and reduced agricultural productivity.

According to the Ministry of Agriculture, Livestock, and Fisheries (MALF), agriculture is the country's largest economic sector, contributing more than 25% of the GDP, more than 60% of all exports from Kenya, and more than 18% of all formal jobs (Recha, 2018: GoK, 2020). Production is made mainly for sale on commercial farms whose sizes are relatively small, with an average of 0.2 to 3 hectares. Small-scale farming provides over seventy-five percent of the total agricultural produce and nearly seventy percent of marketed agrarian output. As a result, the development and growth of agriculture are closely tied to the growth of the national economy. Nevertheless, most of Kenya's agricultural land is rain-fed, with 98% mainly smallholders in the medium to high potential lands representing 15% of the total area. Thus, it can be posited that climatic conditions precipitate productivity determinants in the sector (Njeru *et al*., 2016).

About 83-89% of the country's area is either arid or semi-arid with an annual average rainfall of 400mm, and more recently, there is evidence that land degradation has escalated while access to land and support services, credit and markets, attractive incentives for investment in agriculture; functional producer organizations; and supportive institutions have either been reduced or remained ineffective. This has resulted in the deterioration of productive assets and the empowerment of poor households with weak capacity to boost food security and reduce their poverty level (GoK, 2018a).

According to GoK (2018a), agricultural production and marketing in Nyamira County are the critical economic pillars, and 90% of the population draws their livelihood directly or indirectly from the sector. Currently, it supports 80% of total employment opportunities from the total available employment requirement in the County. Human beings have contributed to environmental issues through pollution, cutting down trees, emitting greenhouse gases, and eventually depleting the ozone layer, which causes climate change. Climate change thus poses a significant threat to agriculture universally, with the County affected (GoK, 2021).

Therefore, climate change's impact on agricultural and livestock production can be severe or general without any exhaustive elaboration. In the County, some of the observed effects are delayed onset and early cessation of rains, anomalous distribution of rainfall and rainfall magnitudes, occasional hail storms, and manifestation of new plant diseases and pests such as Maize Lethal Necrosis Disease and FAW in maize, and *tuta absoluta* in tomato (GoK, 2018c). These, among others, call for Mitigation and coping measures that would help reduce the impacts of Climate change on farmers. Safety nets, as a possibility of intervention by the government, NGOs, and private sector players, could be an aspect of protection. Climate-smart agriculture technologies for crops, fisheries, and livestock production extension should be popularized equally (GoK, 2018c).

1.2 Statement of the Problem

Nyamira County possesses substantial agricultural potential, with the capacity to cultivate a diverse range of food crops and dairy products for local consumption and a high potential to export to neighbouring counties (GoK, 2021: GoK, 2023). The agricultural landscape in the region encompasses prominent cash crops like tea, coffee, pyrethrum, bananas, and horticultural products. In addition, staple food crops such as maize, sweet potatoes, beans, millet, cassava, vegetables, and sorghum contribute significantly to the agricultural diversity. However, erratic weather conditions, characterized by unpredictable rainfall patterns, have disrupted the traditional bimodal rainfall cycle, challenging farmers' ability to prepare the land promptly and ultimately resulting in suboptimal harvests. Small-scale farmers in Nyamira County are particularly vulnerable to weather-dependent farming practices (World Bank; CIAT, 2015); World Bank, 2021; Musafiri *et al*., 2022).

Recognizing the multifaceted challenges posed by climate change, there is a growing imperative to integrate CSA practices into the agricultural policies of Nyamira County. This integration could be a vital step toward promoting the widespread adoption of CSA practices. CSA encompasses a spectrum of strategies, including the scaling of organic farming, carbon sequestration, soil structure enhancement, fertility improvement, and the implementation of water harvesting and conservation facilities (GoK, 2023).

Despite Nyamira County's location within the middle to high agricultural potential zones, the full agricultural capacity still needs to be tapped due to the pervasive impacts of climate change (GoK, 2021). This study seeks to leverage climate-smart agriculture practices to address agricultural production challenges and bolster food security in Nyamira County. This endeavour aligns with the perspective of Collins-Sowah (2018), who emphasizes the transformative potential of CSA in aligning agriculture, development, and climate resilience while concurrently promoting economic, environmental, and social integration.

Prior research has made significant contributions to the agricultural transformation landscape in Kenya, as evidenced by the works of Auya *et al*., (2022) and Kurgat *et al*., (2020). Nevertheless, more comprehensive empirical investigations remain focusing on the tangible impact of these practices on enhancing food security among small-scale farmers. This study aims to address this research gap by conducting a comprehensive and in-depth analysis to assess the direct implications of climate-smart agriculture interventions on food security indicators, including crop yields, income levels, and dietary diversity, among small-scale farming households in Nyamira County. In doing so, it seeks to facilitate the integration of CSA practices into food production systems, thereby advancing food security in the region.

1.3 Research Objectives

1.3.1 Overall Objective

The overall objective was to examine the impact of climate-smart agriculture on food security among small-scale farmers in Nyamira County, Kenya.

1.3.1.1 Specific Objectives

The specific objectives of the study included the following to:

i. Determine the rainfall and temperature trends and patterns on food security among small-scale farmers in Nyamira County, Kenya.
ii. Establish the existing Climate Smart Agriculture practices among small-scale farmers in Nyamira County, Kenya.
iii. Examine the influence of Climate Smart Agriculture practices on food security among small-scale farmers in Nyamira County, Kenya.
iv. Evaluate the effectiveness of climate-smart agriculture practices in strengthening food security among small-scale farmers in Nyamira County, Kenya.

1.4 Research Questions

The following questions guided the study;

i. What are the rainfall and temperature trends and patterns on food security among small-scale farmers in Nyamira County, Kenya?
ii. What are the existing Climate Smart Agriculture practices among small-scale farmers in Nyamira County, Kenya?

iii. How do climate-smart agriculture practices influence food security among small-scale farmers in Nyamira County, Kenya?

iv. What is the effectiveness of climate-smart agriculture practices in strengthening food security among small-scale farmers in Nyamira County, Kenya?

1.5. Justification of the Study

1.5.1: Academic Justification

Kenya's agricultural sector's vulnerability to extreme weather conditions, climate change, and variability is high. These climate changes have emerged in various ways and have caused a reduction in crop production due to changes in rainfall characteristics such as onset, amounts, distribution across the country, and cessation (GoK, 2021; Mugalavai & Kipkorir, 2013). Climate-Smart Agriculture (CSA) provides an ideal approach to addressing some of these challenges.

The research outcomes contribute to the existing body of knowledge by generating specific CSA data for Nyamira County, which currently has limited data on climatic changes and their effects on agricultural practices. Most Nyamira County farmers still practice traditional practices, and unfortunately, they lack adequate information on climate-smart practices to increase resilience. Thus, emphasizing the collection and analysis of CSA data, this research meets an essential need in the local and international literature and contributes evidence to the agricultural decision-making processes. The information collected in this study helps to understand how the microclimate in Nyamira influences crop production and which CSA measures can help make agriculture more sustainable.

1.5.2: Policy Justification

The findings from this study support the development of essential interventions to improve the understanding and adoption of selected climate-smart agricultural practices among small-scale farmers in Nyamira County and other regions. The study addressed the following SDGs: Goals 1, 2, 3, 13, 15. The goals include Goal 1: eliminate poverty; goal 2: eliminate hunger; goal 3: good health and well-being; goal 13: climate action; Goal 15: life on land. The findings from this study support and strengthen the existing policies on CSA practices and food security in the country and how these can be used to meet sustainable development goals. This will go a long way in ensuring that agriculture is sustainable and, at the same time, address the challenges of climate change.

It also furnishes vital data to inform ongoing policy development efforts about mainstreaming climate-smart practices within Kenya's agricultural sector. Ultimately, this empowers small-scale farmers to adapt and build resilience in the face of climate change risks. Additionally, this study’s output of policy briefs on CSA will offer an explicit roadmap for enactment by county, regional, or national policymakers, given the unique challenges and productive possibilities of small-scale farmers in Nyamira County. These policy briefs will be valuable tools in policy analysis for organizational decision-making and positively contribute to Kenya’s capacities towards addressing food security and climate resilience.

1.5.3: Philosophical Justification

The positivism philosophy underpinned this study. The philosophy emphasizes factual knowledge gained through observation and measurement. Researchers act as objective observers, distancing themselves from personal biases. Studies typically involve quantifiable data and statistical analysis. This approach aligns with empiricism, where knowledge comes from experience (Collins, 2010). Positivism views the world as made up of separate, observable elements interacting in predictable ways. Researchers are considered independent of the study, and human interests are not explicitly considered. Compared to phenomenology, which focuses on meaning and human experience, positivism prioritizes facts and avoids subjective interpretations.

Based on the understanding that CSA practices are innovative solutions to climate change issues, the researcher collected data from the respondents through observation and measurements of the different CSA practices. Nyamira County, being a county that is dependent on rain-fed agriculture, is prone to issues of climate change and food insecurity. This, therefore, calls for adopting CSA practices to help reverse the adverse effects of climate change. Hence, this study examined the two variables: climate-smart agriculture and food security. It established the implication of the CSA practices adopted by the small-scale farmers on the food security of the small-scale farmers.

1.6. Scope of the Study

The study focused on five sub-counties within Nyamira County: Nyamira South, Nyamira North, Borabu, Manga, and Masaba North. Nyamira County was selected since it is one among the 21 counties that benefitted from the National Agricultural and Rural Inclusive Growth Project (NARIGP) (2017-2022). Additionally, small-scale farmers' households within the five sub-counties were targeted. The study only targeted crop production-related practices. Under Climate Smart Agriculture (CSA) practices, the study focused on conventional and indigenous knowledge practices. Conventional practices include mixed cropping, crop rotation, agroforestry, water harvesting, conservation agriculture, organic farming, cover cropping, drought-resistant crops, and integrated soil fertility management (ISFM). The unit of analysis for this study was the household heads, who were small-scale farmers in Nyamira County, Kenya.

The study focused on how CSA practices help to mitigate carbon dioxide, methane, and nitrous oxide gases from the atmosphere. The key stakeholders for this study included extension officers, the Kenya Meteorological Department (KMD), the National Agricultural and Rural Inclusive Growth Project (NARIGP), county agriculture officials, and One Acre Fund officials. The daily rainfall and temperature datasets for Nyamira station were obtained from the Kenya Meteorological Department (KMD). The period for this study was from 1990 to 2019. Primary and secondary data were collected between November 2023 and January 2024, and the study covered 30 years. The reason for choosing a 30-year duration is that it exceeds the minimum requirement for observing the average weather conditions for climate change studies (WMO, 2017).

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

The chapter examines previous research related to this study and is structured according to the specific objectives. The sections cover various aspects, including practices of CSA (Climate-Smart Agriculture), pillars of CSA, the current state of food security, the rate of adoption of CSA practices, food security pillars, food security measurement, legal and policy frameworks in Kenya, the impact of CSA practices on food security, models reviewed, and lastly the conceptual framework. These models ultimately contributed to the development of the study's conceptual framework.

2.2 Climate Trends and Patterns

Climate patterns and trends refer to the long-term variations and changes in the Earth's climate system. Studying climate patterns and trends is essential for understanding the effects of human activities on the environment and developing strategies for mitigating climate change. Kenya has recently experienced extreme weather events, including severe droughts, floods, and landslides. For example, the drought of 2016–2017 was one of the worst in Kenya's history, affecting over 3 million people and leading to crop failures and livestock deaths (Opiyo *et al*., 2018).

The floods of 2019 affected over 100,000 people and caused significant damage to infrastructure and crops (UNOCHA, 2019). Climate change is expected to increase the frequency and intensity of extreme weather events in Kenya, further exacerbating the country's vulnerability (Opiyo *et al*., 2018). Several studies have examined adaptation strategies to address the impacts of climate change in Kenya. These strategies include rainwater harvesting, soil conservation, drought-resistant crops, and improved livestock management practices (Muthama *et al*., 2020). However, these strategies face several challenges, including inadequate funding, awareness, and insufficient policy support (Olang *et al*., 2020). This study looks at the rainfall and temperature elements of climate.

Global warming is due to the more frequent and severe adverse weather conditions, among them heat, drought, floods, and hurricanes (IPCC, 2014). For example, the European heatwave of 2003, which resulted in 70,000 deaths, was found to be four times more likely due to climate change (Stott *et al*., 2004). Similarly, the 2010 Pakistan floods, which affected over 20 million people, were found to be more likely due to anthropogenic climate change (Herring *et al*., 2014). Therefore, it is clear that climatic conditions and their fluctuations are the most essential factors that reveal the consequences of human interventions on the natural environment. As highlighted in this review, climate change is one of our generation's most pressing global issues that demands nations' attention to prevent and mitigate.

Climate change significantly impacts agriculture, including reduced crop yields, increased pests and diseases, and reduced water availability. Studies show that the decline in rainfall has affected the production of tea and bananas, leading to reduced incomes for farmers (Muthama *et al*., 2020). The county government has implemented several adaptation strategies, such as water harvesting and irrigation, to address the impacts of climate change on agriculture (Opiyo *et al*., 2018). In conclusion, climate change significantly impacts Nyamira County's economy, especially agriculture, the primary livelihood source for most of the population. The county government and other stakeholders need to implement adaptation strategies to address the impacts of climate change on the agricultural sector.

2.2.1 Temperature Trends and Patterns

The Intergovernmental Panel on Climate Change (IPCC) has reported that the global average temperature has increased by 0.85 °C from 1880 to 2012 (IPCC, 2014). The warming trend has been more pronounced in the last few decades, with 1981–2010 being the warmest three-decade period in the Northern Hemisphere in the past 1400 years. Despite human activities such as burning fossil fuels and cutting down trees, gases such as carbon dioxide have steadily risen in the atmosphere, causing an increase in the average temperature globally (IPCC, 2014).

Temperature records from meteorological stations in Kenya show an overall warming trend over the past few decades, with 1990–2016 being the warmest (Omondi *et al*., 2019). The average temperature in Kenya has increased by about 0.3 °C per decade since the 1960s (Omondi *et al*., 2019). The warming trend is attributed to increased greenhouse gas emissions, land-use change, and urbanization (Muthama *et al*., 2020). According to the Government of Kenya (GoK, 2016b), temperatures in Kenya are forecasted to experience a continued increase, with a projected rise of 1.7°C by the 2050s and approximately 3.5°C by the end of the century. There is also expected to be an increase in extreme temperatures, including hot days and nights, where 'hot days' are projected to range between 19% and 45% of days mid-century. Similarly, hot nights are expected to rise rapidly, with projections indicating they will transpire on 45%–75% of nights by mid-century and 64%–93% of nights by the end of the century. Conversely, cold days and nights are predicted to become increasingly rare. Across all emissions scenarios, temperatures in Kenya are anticipated to persist upward (GoK, 2015).

Nyamira County is one of Kenya's counties. It is situated in the country's western region and is mainly an agricultural-based economy. The county is vulnerable to the impacts of climate change, including changing temperature and precipitation patterns, which affect the agricultural sector. Temperature records from meteorological stations in Nyamira County show an overall warming trend over the past few decades, with 1990–2016 being the warmest on record (Muthama *et al*., 2020). The average temperature in the county has increased by about 0.2 °C per decade since the 1960s (Opiyo *et al*., 2018). The warming trend is attributed to increased greenhouse gas emissions, land-use change, and urbanization.

2.2.2 Rainfall Trends and Patterns

Climate models predict global precipitation will increase by 1–2% per degree of warming. Still, the distribution and intensity of rainfall will be unevenly distributed, resulting in more frequent and intense droughts and floods in certain regions (IPCC, 2014). For example, the African Sahel region has experienced a 30% decline in rainfall since the 1950s, leading to severe droughts and food insecurity (Nicholson, 2013). In contrast, some regions, such as Southeast Asia, have experienced increased rainfall intensity and frequency, leading to more frequent flooding (Hirabayashi *et al*., 2013).

Global climate change is one of the biggest concerns in the world today, and one of its impacts is the sea level rise, which mainly arises from the melting of the ice caps, glaciers, and ice shelves, as well as the thermal expansion of seawater (IPCC, 2014). The global sea level has risen by 0.19 meters from 1901 to 2010, and the rate of rise has accelerated from 1.7 mm/year in the early 20th century to 3.2 mm/year from 1993 to 2010 (IPCC, 2014). Rising sea levels significantly threaten low-lying coastal regions, increasing the risk of flooding and erosion and threatening infrastructure and human settlements (IPCC, 2014).

The rainfall pattern in Kenya is highly variable, with most of the country receiving bimodal rainfall, which occurs in March-May and October–December. Studies show that the total annual rainfall in Kenya has decreased in recent years, with some regions experiencing significant declines (Olang *et al*., 2020). For example, Kenya's coastal region has experienced a decrease in rainfall of up to 30% over the past few decades (Muthama *et al*., 2020). In contrast, some areas in western Kenya have experienced increased rainfall intensity and frequency, leading to more frequent flooding events (Olang *et al*., 2020).

According to the Climate Change Knowledge Portal (CCKP, 2020), precipitation patterns in Kenya are anticipated to persist in their highly variable and uncertain nature. However, there is a projection of an increase in average rainfall by mid-century, especially during the 'short rains' period, which typically falls between October and December. Furthermore, extreme rainfall events are expected to become more frequent, prolonged, and intense, with a higher proportion of heavy rainfall occurring within these events. Nevertheless, the intervals between heavy rainfall occurrences may also extend. Notably, rainfall in Kenya's arid zones is generally forecasted to decrease.

Nyamira County experiences two major rainfall seasons: the long rainfall season stretching from March to May and the short rainfall season stretching from October to December (GoK, 2023). Studies show that the total annual rainfall in the county has decreased in recent years, with some areas experiencing significant declines (Olang *et* *al*., 2020). For example 2016, Nyamira County experienced a severe drought that affected agricultural production and led to water scarcity (Muthama *et al*., 2020). The decline in rainfall is attributed to climate change, deforestation, and land-use change. Nyamira County's economy is primarily agricultural, with tea and bananas being the main cash crops.

2.3 Climate Smart Agriculture

This study aims to explain the climate-smart agriculture (CSA) practices introduced by the FAO in 2010 and expanded in 2013. Many renowned institutions have endorsed it, including the World Food Program (WFP), the International Fund for Agricultural Development (IFAD), the World Bank, the United Nations Environment Agency (UNEP), the Consultative Group on International Agricultural Research/Climate Change, Agriculture and Food Security (CGIAR/CCAFS), and the Comprehensive African Agricultural Development Program (CAADP).

CSA practices aim to enhance small-scale farmers' access to essential services, information, genetic and financial resources, markets, and other necessary assets. These practices have a twofold objective: promoting sustainable intensification and effective management of natural resources while contributing to climate change mitigation efforts. To achieve these goals, CSA incorporates established agricultural techniques along with innovative methods, including agroforestry, crop rotation, conservation agriculture, water harvesting, cover cropping, intercropping with legumes, contour farming, integrated nutrient management, mixed farming, terracing, crop residue management, the use of crop varieties and breeds suited for various climatic challenges, and providing timely weather information to farmers. These strategies collectively enhance agriculture's resilience and productivity in changing environmental conditions (FAO, 2010; FAO, 2013; Lipper & Zilverman, 2018).

2.4 Pillars of Climate Smart Agriculture Practices

The foundation of the CSA concept is built upon three fundamental pillars: productivity, adaptation, and mitigation, as opined by Fusco *et al*., (2020).

2.4.1 Productivity

CSA practices aim to refine agricultural methods to boost crop, livestock, and fisheries productivity and income while safeguarding the environment. They also enhance food and nutritional security, as emphasized by Branca *et al*., (2011). One key aspect of CSA practices is the concept of sustainable intensification, which involves making the most of natural resources without depleting them. Since crop cultivation is sensitive to the negative influences of climatic change, enhancing adaptive capacity is the key to fostering sustainable intensification and, therefore, productivity improvement (Yassin *et al*., 2008).

2.4.2 Adaptation

Climate-smart agriculture (CSA) approaches strive to reduce immediate risks for farmers while simultaneously building their ability to withstand long-term challenges. There is a specific emphasis on safeguarding the ecosystems that benefit farmers and the broader community (Zougmore' *et al*., 2016). Implementing these climate change practices is vital to improve the ability to adapt to climate change and improve the production of crops in farmland or agricultural fields. CSA enhances the system's flexibility; thus, resources, strengths, and attributes required by farmers or other actors are brought in to reduce the adverse impacts and enhance the opportunities for beneficial action when CSA actions are in place.

2.4.3 Mitigation

Climate-smart agriculture also aims to minimize or control the emissions of other greenhouse gases connected to food, fiber, and fuel production. These practices entail finding ways of harnessing the capacity of the soils and the trees to sequester CO_2 from the atmosphere. The Food and Agriculture Organization (FAO) defines mitigation as the capacity of systems, societies, groups, or individuals to avoid, minimize, lessen, palliate, or cope with risk and stress (FAO, 2013). In the case of climate change, the emphasis is placed on developing the ability to adapt to minimize future risks and negative impacts.

2.5 Climate Smart Agricultural Practices

2.5.1 Conservation Agriculture

It has been proposed that conservation agriculture is an effective approach to enhance soil productivity and the long-term health of cropping systems. This approach is grounded in three core principles: minimizing soil disturbance (restricting soil disturbance to the bare minimum required for seed sowing), maintaining continuous soil cover with crops, and diversifying crops spatially and temporally (FAO, 2021). In the context of CA, reducing soil disturbance conserves soil and lowers the expenditure on fuel and lubricants for tractors and other self-propelled machinery.

CA also has the following advantages: By minimizing soil disturbance and keeping crop residues on the surface, erosion is prevented, water runoff is reduced, evaporation is minimized, and structure and organic carbon content is improved in the soil. Effective weed management ensures productivity and profitability within the CA system. The crop rotation aspect of CA fosters biodiversity, contributes to soil nutrient balance, and influences the weed spectrum (Kumar *et al*., 2020).

Despite its numerous advantages, the adoption of CA has been limited in Kenya (Chepkemboi & Mulyungi, 2021). To promote CA among farmers, it is essential to raise awareness about CA, provide on-site training, develop and demonstrate simple and efficient CA machinery, and implement effective weed control strategies (Neeraj *et al*., 2020).

In the Midwest of Asia, soil erosion peaked in different areas, and other factors washed away the topsoil. (Hobbs, 2006; Berger *et al*., 2008). To overcome these limitations, farmers have opted to cover the soil by planting cover crops and changing the growing techniques using crop rotation methods. Information on these practices went around faster, and by the year 2000, Conservation Agriculture (CA) was practiced on nearly 60 million ha of land worldwide (FAO, 2006).

CA was introduced in Kenya in the 1950s with a primary focus on preserving water reservoirs and preventing soil erosion (Kassam *et al*., 2009). From a historical perspective and experience, it can be deduced that conservation agriculture has proved to be one of the most viable and effective methodologies for transforming sustainable agriculture in the country (Shetto *et al*., 2007).

Several organizations and institutions have always supported and promoted the concept of Conservation Agriculture in Africa. It has received support from major actors, notably the Food and Agriculture Organization of the United Nations (FAO), research organizations oriented on agriculture in Africa, such as the International Maize and Wheat Improvement Center (CIMMYT), the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and the International Institute for Tropical Agriculture (IITA among others. Other additional organizations that require attention include other conservation measures such as the African Conservation Tillage Network (ACT-N) and the International Centre for Research in Agroforestry (ICRAF) (Baudron *et al*., 2007; Kaumbutho & Kienzle, 2007).

Conservation agriculture practices used in sub-Saharan Africa are many and depend on the specific conditions of each farming region and environment, and this may differ considerably (Corbeels *et al*., 2015). Despite over two decades of investment in developing and promoting CA, its adoption could be higher. One major problem that needs to be mentioned is that yield anomalies to CA are not constant and can be positive, negative, or neutral. These fluctuations are a major challenge in adoption mainly because the CA technologies are developed to be used by smallholder farmers who cannot afford to wait long for returns on their investments to feed their families. This means that for smallholder farmers in sub-Saharan Africa or similar settings, there is variability in cost reductions with CA as opposed to the observed reductions in costs observed in commercial farms like those in Brazil.

Another critical problem concerning CA is mulching with crop residues. These residues serve as a valuable livestock feed source, especially within the semi-arid zone where biomass is scarce and livestock is highly valued in farming systems. Prior research indicates that all three CA strategies, including mulching, must increase crop productivity against traditional CT practices. Mulching has been the least applied of these principles in Africa's past and present cropping systems.

CA can potentially change the dynamics of the soil water regime and enhance soil fertility. However, the findings show that the improvement benefits only some African farmers. The main question, therefore, is where and under which circumstances it will be most beneficial to smallholder farmers in sub-Saharan Africa. It can be noted that CA would be more suited to farmers with an intensity strategy over and above coming up with techniques to feed the increasing population rather than an appropriate farming technique to sustain themselves through farming. The latter are usually put in a situation where they experience multiple constraints that would prevent their fuller interaction with technology change. Some farmers also might not be interested in new technologies because they invest in other income-generating activities.

This paper contends that while adopting CA or any other new agricultural technology for intensification requires effective markets for the supply of inputs and the sale of excess output, critical input and output markets are typically lacking in many smallholder-farming communities. As for CA, improved knowledge and awareness of CA among the target beneficiaries are required in sub-Saharan Africa, with CA practices being matched with local conditions and contexts as well as potential users of these practices at the farming systems level (Corbeels *et al*., 2015).

The tendency of the adoption of zero tillage in the production of wheat by farmers of the western Indo-Gangetic plains, for instance, saw a 20% discount on the overall cost per hectare and had a corresponding 28% increment in net income (FAO, 2016) even though conservation agriculture, which includes the system of zero tillage, is quite efficient and useful as it needs 20 to 50 percent less labour, thereby reducing the emission of greenhouse gases because less energy and nutrients are required. Besides, it significantly contributes to checking on the degradation of soils and carbon emission in the atmospheric other by providing protection and stability of the specific soils.

It has emerged from the Food and Agriculture Organization (FAO) that sub-Saharan Africa has, for the last thirty-five years, experienced zero food production, even with an average population growth rate of 2.3% annually. This has called for urgency on the need for a revolution in farming to tackle the population increases, high production costs on agricultural inputs, scarce water, and environmental issues that threaten most of Africa's set food security goals. Therefore, Conservation Agriculture, the subject of focus herein, is a significant resource in combating and mitigating food insecurity, especially amongst smallholders in Africa. In addition to being an eco-friendly technology, CA is easy to practice and inexpensive, and it offers accessible technology in the agricultural industry. CA, based on the three main principles of minimal tillage of the soil, the continuous use of some organic matter cover, and crop rotation or intercropping, is today implemented in more than 117 million hectares around the world (Saidi, 2011).

There is a conscious effort across the world to push for the adoption of conservation agriculture to boost crop yields while at the same time maintaining ecological standards. It is considered a remedy to the problems of low production and soil productivity, which are the characteristic features of many sub-Saharan African nations. For example, as one of the countries influenced by climate change, Tanzania advocates for conservation agriculture, one of the climate-smart practices one can take (Mkonda & He, 2017). This applies to organic soil management practices, including minimal soil turning over, use of much, and incorporation of legume plants. Furthermore, it contains agroecosystems that are agroforestry, organic fertilization of the soils, and improved crop cycling, among others.

While leveraging conservation agriculture practices is vital for sustainable agriculture, its focus varies over space and time. For example, while the farmers in the Arusha region prefer terrace practices, those in the Dodoma region prefer conservational tillage practices. In the Ruvuma Region, for instance, applying what is famously known as 'Matengo pits' and terraces has borne fruit with increased production of maize and coffee crops. In the Southern Agricultural Growth Corridor (SAGCOT), planting basins have recorded at least double the yields of Maize than those from conventional tillage. This has mainly been realized in regions with irrigation potential or in areas with water conservancy, whereby conservation agriculture has enhanced yields in areas facing difficulties in water availability or areas occasionally struggling with drought (Msaki *et al*., 2015).

In northern Tanzania, the implementation of conservation agriculture has greatly enhanced food crop production, raising yields from an average of 0.5 tons per hectare to 1.5 tons per hectare. As a result, maize yields have increased from 12,000 kg to 20,000 kg per 4.8 hectares and 3.75 tons per hectare when grown alongside lablab. The appeal of conservation agriculture lies in its ability to produce some yield even under low rainfall conditions. The review highlighted current farming management practices, the principles and advantages of conservation agriculture for farmers, society, and the environment, and the challenges this system faces (Mkonda & He, 2017).

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Agriculture is the primary source of income for residents in many sub-Saharan countries and is essential to their economies. In Kenya, for instance, agriculture makes up 70% of informal employment in rural areas and contributes 65% of the country's total exports (Recha, 2018). The National Climate Change Action Plan 2013–2017 highlights conservation agriculture as a critical priority for adaptation and mitigation. It is viewed as a way to shift agriculture towards a low-carbon, climate-resilient development path (GoK, 2017).

Conservation agriculture is currently being implemented as part of a project by the FAO of the United Nations. The project aims to help small-scale farmers transition to commercially oriented, climate-resilient agriculture in semi-arid areas. This transformation will be achieved by improving productivity, adopting post-harvest production practices, and establishing market linkages for specific value chains like pulses, sorghum, and sunflower. The project is active in eight counties: Kitui, Makueni, Machakos, Tharaka Nithi, Meru, Laikipia, Kwale, and Kilifi (Waswa & Mulyungi, 2021).

2.5.2 Agroforestry

Agroforestry, according to FAO, refers to "land-use systems and technologies in which woody perennials, such as trees, shrubs, palms, and bamboos, are deliberately integrated within the same land-management units as crops and animals, either through specific spatial arrangements or temporal sequences" (FAO, 2017). According to the International Center for Research on Agroforestry (ICRAF), agroforestry is described as a farming system that combines crops and livestock with trees and shrubs. The interactions within this integrated system yield various benefits, including increased biological production, enhanced water quality, and improved habitat for humans and wildlife.

A study conducted in Bangladesh by Riyadh *et al*. (2021), titled "Adaptation of Agroforestry as a Climate-Smart Agriculture Practice in Bangladesh," demonstrated that agroforestry contributes to climate resilience by integrating trees and crops into various land-use practices. Agroforestry systems enhance resilience to climate change through several mechanisms, including increasing tree cover, sequestering carbon, boosting production, reducing threats to associated crops, creating a favourable microclimate for these crops, decreasing pressure on natural forests, preserving biodiversity, and cycling nutrients. Globally, 23 countries recognize agroforestry as a priority for mitigating climate change, while 29 countries prioritize it for climate change adaptation (Riyadh *et al*., 2021).

Agroforestry is often hailed as a practical strategy for African smallholder farmers to adapt to climate change and variability (Quandt, 2020). The advantages of agroforestry for the environment, economy, and society can significantly support efforts to adapt to climate change. The research highlights two key aspects: (1) how agroforestry trees reduce vulnerability to droughts and floods and enhance adaptability, and (2) the essential qualities of agroforestry trees that are crucial for both situations.

In drought and flood scenarios, agroforestry plays a substantial role in decreasing vulnerability. This is primarily achieved by improving environmental conditions through shade, erosion control, windbreaks, and microclimate regulation. Agroforestry also enhances adaptability by providing valuable tree products and financial benefits, such as fruits, food, firewood, construction materials, fodder, traditional medicines, and income from the sale of fruit products (Sahoo & Wani, 2019).

Climate change seriously threatens small farmers and the world's food supply. Farming is especially vulnerable to changing weather patterns (Quandt, 2020). Finding ways to adapt agriculture to these changes is crucial. Additionally, a study conducted by Reppin *et al*., (2020) in Western Kenya revealed that agroforestry systems offer multiple benefits, including providing firewood for household use, generating income through timber sales, and contributing to climate change mitigation by sequestering carbon (approximately 4.07 metric tons of carbon per hectare). This highlights the multifaceted advantages of agroforestry in supporting livelihoods and environmental sustainability.

Planting trees and shrubs alongside crops offers a powerful solution to three major challenges in agriculture. It helps secure food supplies, lessens the impact of climate change, and makes farms more resilient to future problems. Trees are a win-win for farms facing climate change. They boost farmers' income and diversify what they can grow, lessening the blow of bad harvests or market slumps. This is even more important as climate change gets worse. Trees and shrubs act as shields for crops, shielding them from harsh winds, droughts, and downpours. They also keep the land healthy by preventing soil erosion, helping water soak in better, and stopping it from washing away. Additionally, they contribute to ecosystem stability and biodiversity in the surrounding area.

Trees are nature's fertilizer factories and sponges for farmland. Their roots add organic matter to the soil, making it richer and better at holding moisture. This is especially helpful in areas with limited access to chemical fertilizers. Certain trees and shrubs, like legumes, can even capture nitrogen from the air, further boosting soil fertility. Improved soil fertility has the potential to increase agricultural productivity and expand the variety of crops that can be cultivated. For example, in Africa, agroforestry systems have led to annual maize yield increases of 1.3 to 1.6 tons per hectare (Sileshi *et al*., 2008).

Traditionally, farmers and pastoralists have used fodder trees in extensive agricultural systems. However, more recent utilization of fodder shrubs, such as calliandra and leucaena, in intensive systems has increased production and reduced reliance on external livestock feeds (Franzel *et al*., 2003). In developed countries, agroforestry fodder systems have also proven profitable. For instance, the use of tagasaste (Chamaecytisus proliferus) has improved returns for farmers in the northern agricultural region of Western Australia, where cattle previously grazed on annual grasses and legumes (Abadi *et al*., 2003). These examples highlight the valuable contributions of trees and shrubs in enhancing agricultural sustainability and livelihoods.

Across the globe, advanced and developing countries heavily depend on agroforestry systems for their supply of timber and fuel. For example, China dedicates 3 million hectares of land to cultivating trees alongside crops. In the United Kingdom, farmers have found success in various timber/cereal and timber/pasture systems (McAdam *et al*., 1999). In regions like East Africa, Southern Africa, and parts of Asia, trees cultivated on farms serve as the primary source of timber for construction purposes.

Expanding wood production on farms helps alleviate the stress on forests, which would otherwise suffer from degradation.

Nyamira County has significantly emphasised promoting farm forestry to boost the region's tree coverage, aiming to raise it from 15% to 35%. The county currently boasts 6,650 farm forests, employing about 48% of its population through various forest-related activities. It's important to highlight that farmers' incomes positively correlate with the extent of forested areas. Additionally, the county has initiated a campaign to raise awareness regarding the economic and environmental benefits of cultivating bamboo rather than eucalyptus in catchment areas (GoK, 2018a).

2.5.3 Crop Rotation

Crop rotation involves cultivating different crops in the exact location over multiple seasons (Mutua *et al*., 2014). Farmers can diminish their reliance on artificial fertilizers through specific crop rotation methods and maintain continuous field productivity, avoiding the costly practice of leaving fields fallow.

Crop rotation yields the beneficial outcome of interspersing various crops in a given area, which can help slow the spread of pests and diseases during the growing season. Furthermore, crop rotation provides several advantages for soil health. It includes replenishing nitrogen by using green manure with cereals and other crops as a standard practice in crop rotation. By alternating between crops with deep and shallow root systems, crop rotation can improve soil structure and fertility while reducing the buildup of pathogens and pests.-up when one species is continuously farmed. Crop rotation is a type of polyculture.

2.5.4 Crop Diversification

Crop diversification, characterized by planting various crops, is pivotal in mitigating risks linked to crop failures, such as pests, diseases, or climate-related events like droughts and floods. These practices are essential to Climate-Smart Agriculture (CSA) as they bolster resilience and diminish vulnerability to climate change impacts. Studies have shown crop diversification can result in higher yields, enhanced soil quality, and increased farmer income (Rusinamhodzi *et al*., 2011).

Sain *et al*., (2020) opine that crop diversification boosts agricultural productivity by augmenting soil nutrient availability, curbing soil erosion, and mitigating the risk of crop failure caused by pests and diseases. Other studies have shown crop diversification can boost yields by as much as 35% (Alam *et al*., 2018). Techniques such as crop rotation, intercropping, and mixed cropping are among the methods used for crop diversification that have been found to enhance agricultural productivity.

Crop diversification has been demonstrated to positively affect soil health by reducing soil erosion, augmenting organic matter content, and enhancing soil structure (Gathala *et al*., 2017). Moreover, research indicates that crop diversification can enhance the diversity of soil microorganisms, thereby improving nutrient cycling and soil fertility (Li *et al*., 2020). Techniques like crop rotation, cover cropping, and intercropping are examples of crop diversification practices that have been identified as beneficial for promoting soil health.

Crop diversification stands out as a crucial strategy for enhancing food security in developing nations, as Dawoe et al. highlighted (2019). Farmers can establish a consistent food supply year-round through the cultivation of various crops, diminish the vulnerability to crop failure resulting from adverse weather conditions, and enhance the nutritional quality of their diets. Research findings indicate crop diversification can boost food security by as much as 50% (FAO, 2019b).

2.5.5 Cover cropping

Recent research has indicated that cover cropping can enhance soil health through several mechanisms, including increased soil organic matter content, improved soil structure, and the promotion of beneficial microbial activity (Dumigan *et al*., 2018; Zhong *et al*., 2020). Cover crops have been shown to augment soil biodiversity and facilitate nutrient cycling, ultimately improving soil fertility (Zhong *et al*., 2020). Specific types of cover crops, such as legumes, can fix atmospheric nitrogen and enhance soil nitrogen availability (Chen *et al*., 2021).

The impact of cover cropping on crop yield varies. Some studies have demonstrated that cover cropping can enhance crop yields by improving soil health and nutrient availability (Dumigan *et al*., 2018; Zhong *et al*., 2020). However, in certain crops and regions, improper management of cover cropping may result in lower yields, as found in other studies (Chen *et al*., 2021).

Furthermore, cover cropping has been recognized as a sustainable agricultural practice with the potential to reduce environmental impacts, including soil erosion, water pollution, and greenhouse gas emissions (Dumigan *et al*., 2018; Chen *et al*., 2021). By reducing the reliance on synthetic inputs such as fertilizers and pesticides, cover cropping can decrease their use and mitigate the risk of runoff into waterways.

Additionally, cover cropping can serve as a habitat for beneficial insects and pollinators (Zhong *et al*., 2020).

2.5.6 Organic Farming

Organic farming has been demonstrated to positively impact soil health by increasing the content of soil organic matter, improving soil structure, and fostering beneficial microbial activity (Mäder *et al*., 2002). Research indicates that organic farming practices can enhance soil biodiversity and more efficient nutrient cycling, increasing soil fertility (Kabir *et al*., 2019). Organic farming techniques like cover cropping, crop rotation, and composting have proven effective in promoting soil health.

Moreover, organic farming has been shown to produce comparable or even higher crop yields in some instances than conventional agriculture (Seufert *et al*., 2012). Improved nutrient availability and water retention associated with organic farming practices supporting soil health can lead to better crop growth and yields, as Badgley et al., (2007) highlighted. However, it's worth noting that organic farming may result in lower yields in specific crops and regions, mainly when soil fertility management is inadequate.

Research conducted by Pimentel *et al*., (2005) has recognized organic farming as a potentially sustainable agricultural system capable of mitigating adverse environmental impacts, including soil erosion, water pollution, and greenhouse gas emissions. Organic farming techniques, which rely less on synthetic inputs, can help reduce pesticide and fertilizer runoff, thus safeguarding aquatic ecosystems and wildlife from harm. Nevertheless, it's crucial to acknowledge that the environmental benefits of organic farming can vary depending on the specific farming practices, the geographical location of the farm, and other contextual factors.

2.6 Climate Change and Agriculture

Research conducted on global climate change shows that climate change is partially caused by man's activities (IPCC, 2001), and it will cost society and the economy dearly to adapt and respond to the effects of climate change. The available information unambiguously shows that the climate of the entire planet is posing a challenge of climate change like never in recorded history due to human-caused emissions of heat-trapping gases such as GHG, especially carbon dioxide, which raises the global temperature, thus causing changes in weather on the Earth. Projections for the atmospheric concentration of CO_2 range from 278 ppm during pre-industrial level to 379 ppm in 2005. In this regard, Asfaw *et al*., (2018) posited that despite disagreement on their causes, there is no doubt that the planet is warming due to the emission of GHG.

There is ample evidence to attest that this climate change results from increasing levels of carbon dioxide, methane, nitrous oxide, and other gases that trap heat in the atmosphere (IPCC, 2001). Global warming is confirmed through analyses showing that average global temperatures have risen gradually through the years, with the earth becoming relatively warmer by 0.74°C over the past century. For instance, the 1990s were roughly 0.6°C higher than during the late 1890s. The warming trend that has characterized the end of the twentieth century makes the 1990s the warmest decade in the entire record keeping spanning from 1860 to the present. Moreover, the frequency of heatwaves has been observed to be on the rise, while the occurrence and duration of the frosts have been declining in most parts of the world.

Climate change also has benefits and costs to agriculture; generally, its costs are considered more significant in tropical climates than in temperates. The analysis reveals that developed countries will likely reap significant benefits since cereal productivity in regions such as Canada, North Europe, and the former Soviet Union, among others, will be enhanced. On the other hand, developing regions are expected to suffer from negative impacts of climate change: reduction in the size and coping rates of croplands over 50-100 years, specifically in Africa, Latin America, and European countries (IPCC, 2001; Parry *et al*., 1999).

The analyzed data imply that climate change is a significant challenge threatening global sustainable development and requiring immediate intervention. Understanding these effects, the United Nations Framework Convention on Climate Change (UNFCCC), as defined in Article 2, finds that the world's governments need to work towards limiting anthropogenic interference with climate systems by reducing and preventing atmospheric GHG emissions. According to the 2015 Paris Agreement with the UNFCCC, the global community can manage the impact of climate change while modelling world agriculture to feed the growing population without compromising the earth’s environment.

The SDGs relevant to agricultural development include ending poverty and hunger, ensuring healthy lives, achieving gender equality, ensuring availability and sustainable management of water, access to clean energy, ensuring sustainable economic growth, fostering industrialization and innovation, reducing inequalities, promoting responsible consumption and production, interventions on climate change, conservation of marine ecosystems, protection and restoration of terrestrial ecosystems, and promoting partnerships for goals.

The United Nations launched the 2030 Agenda for sustainable development in 2015. It consists of seventeen Sustainable Development Goals (SDGs). These SDs cover several concerns also recognized in the Kenya Vision 2030 (GoK, 2007). The SDGs relevant to agricultural development include hunger elimination, reducing maternal mortality, providing universal access to quality education, improving reproductive health, promoting gender equality, improving access to water, making clean energy affordable, stimulating innovations for sustainable consumption, achieving sustainable population growth, protecting lives on the sea, and ensuring sustainable resource use and management.

World agriculture, particularly in the African economy, depends more on the sector, while about 27.3% of the total geographical area in Africa is used for arable land and permanent pasture. Agriculture remains essential, with returns on Gross Domestic Product (GDP) averaging 30% in Africa. However, it is estimated that seventy-five percent of the African population lives in rural areas, and the primary source of employment in rural localities is connected with agriculture production, such as crop production farming, animal husbandry, fisheries, and forestry.

However, climate change remains a feature that is still very real and is already being felt to some extent in African agriculture. From 1886 to 2012, the global mean temperature has risen by around 0.85°C in sub-Saharan Africa. Further temperature increases of approximately 1.5°C by 2050 are almost inevitable. In 2013, Africa experienced a scorching year, ranking as the second warmest on record after 2010.

Changes in rainfall patterns are less specific, but there have been observed declines in precipitation in West Africa since the late 1960s, ranging from 20% to 40% between 1931-1960 and 1968-1990 (IPCC, 2007). A study by Fabusoro *et al*. (2014) revealed that over several sub-humid regions of Nigeria, mean monthly rainfall increased by 65mm/month/decade between 1982 and 2010. Scientists have noted that these climatic conditions resulted in more prolonged and more severe droughts in eastern Africa and repeated flooding in West Africa, decreased rain forests within equatorial Africa, and increased ocean acidity in the southern part of the African continent. That is why adaptation and advocacy for measures to tackle climate change effects on African agriculture remain an important issue.

Since the country is heavily dependent on rain-fed subsistence farming, these adverse effects of climate change are likely to have more profound repercussions, mainly changes in temperature, precipitation, and extreme weather conditions in the region. This vulnerability complements Nelson *et al*. (2010), who pointed out that climate change mitigation and adaptation, reduction of rural poverty, and global food and nutrition security are currently the most challenging and interconnected goals to achieve worldwide. As noted by Musafiri *et al*., (2022), one of the significant global challenges to the growth of agriculture is climate change, which is evident as having the most adverse effects in developing countries, especially those in sub-Saharan Africa (SSA), where most agriculture is rain-fed.

Climate change impacts present themselves in various forms, such as vaporization, meteorological dry periods, floods, irregular rainfall patterns, changes in cropping calendar, and temperature increases in the atmosphere (Seneviratne *et al*., 2021). Depending on weather changes such impacts, one can see crop failure and loss of livestock, eventually leading to food insecurity that is dangerous to society. Thus, a large population in developing countries is still involved in farming as most live in rural areas and are smallholders primarily practising rain agriculture. Hence, they remain gravely exposed to climate events, although rain-fed agriculture only puts developing nations through more changes.

According to the IPCC Fourth Assessment Report, climate change has been attributed to changes in rainfall patterns varying across the African regions. It implies that throughout most of the Mediterranean part of Africa, rainfall has decreased over the years, especially moving towards the North and the northern Saharan territories and along the Mediterranean coastal basin. However, the projection to southern Africa reveals that many parts of the Winter Rainfall region and Western margins will experience a reduction in rainfall. There is an anticipated increase in annual mean rainfall in East Africa, but the evolution of rainfall in the Sahel, Guinean Coast, and the Southern Sahara remains unpredictable. These changes in rainfall patterns significantly affect agricultural production and food security in Africa, affecting the continent's ability to grow and develop.

According to the GoK (2023), Nyamira County, like many other regions in the country, climate change has remained a thorn in the environment primarily driven by human activities. These activities have contributed to the depletion of the ozone layer, resulting in climate change. Climate change has adverse effects on Nyamira County, mainly affecting agricultural productivity. Some of the specific impacts in the county include variations in rainfall patterns, where there is increased variability in the distribution and intensity of rainfall, early failure of rains, late or early cessation of rains, hail storms, and appearances of new diseases and pests like MLND & FAW in Maize, tuta absoluta in tomatoes.

Among other aspects, these consequences make it vital to (i) carry out measures of prevention, (ii) use measures of adoption and adaptation, and (iii) put into practice measures to support farmers in facing the challenges that climate change poses. Providing safety nets is one option that the government, NGOs, and other private sector players may employ. Also, adequate emphasis must be placed on the commercialization of climate-compatible practices and technologies in agriculture, fisheries, and animal husbandry to improve their durability and efficiency (GoK, 2023).

2.7 Food Security

According to the World Food Summit in 1996, "food security exists when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life."

In recent years, several significant factors have impeded progress toward eradicating world hunger and malnutrition by 2030 (FAO *et al*., 2021). The report emphasizes the necessity of a more comprehensive approach to addressing global food security and nutrition. By analyzing data from the past four editions, the report provides a substantial evidence-based understanding of the primary drivers behind recent food security and nutrition changes.

Food insecurity is on the rise due to several worsening problems. These include armed conflicts, increasingly volatile weather patterns, and economic downturns. All of these factors are made even more severe by existing poverty and vast income inequality. Millions of people worldwide can't afford healthy foods, contributing to hunger and various nutritional deficiencies (FAO *et al.*, 2021).

The report adds the COVID-19 pandemic is a significant factor in worsening global food insecurity. It highlights a jump in the number of severely food insecure people: nearly 928 million, or 12% of the world's population in 2020, 148 million more than in 2019. UNICEF (2022) data shows a similar trend. The pandemic caused food prices to rise, making healthy diets unaffordable for an additional 112 million people, bringing the total to almost 3.1 billion globally. These numbers emphasize the pressing need to tackle the intricate issues surrounding worldwide food security and nutrition.

Furthermore, Eastern and Western Africa collectively contribute to a significant portion of the increase in food insecurity across the African continent, accounting for 83 percent of the total increase between 2014 and 2020 (as reported by FAO, ECA, and AUC in 2021). Severe food insecurity is most pronounced in Central Africa, affecting 35.8 percent of the population. In contrast, moderate food insecurity is more prevalent in Eastern and Western Africa, affecting 36.6 percent and 39.5 percent of the population. These two sub-regions, Eastern and Western Africa, account for 71 percent of moderate food insecurity on the continent.

Specifically, more than a quarter of Africa's population, equivalent to 346.6 million people, grapple with severe food insecurity, with Central, Eastern, and Western Africa experiencing the most severe impacts. Additionally, 33.7 percent of the African population, or approximately 452.2 million individuals, contend with moderate food insecurity. These statistics underscore the significant challenges facing large segments of the African population regarding food security and nutrition.

There are severe problems in Kenya, such as people not having enough food and proper nutrition. More than 10 million Kenyans experience this constantly, and millions more need immediate food aid at any time. This situation is tough on children, with nearly a third of them being chronically undernourished.

The national per capita energy consumption per day in Kenya falls below the recommended levels (Gitu, 2004). Even in years of good food production, chronic under-nutrition, represented by stunting, affects 30% of children. This condition indicates long-term insufficient dietary intake of food, including macronutrients such as carbohydrates, proteins, and fats, as well as micronutrients like vitamins and minerals. This situation contributes to insufficient food distribution, limited access to high-quality foods, inadequate knowledge about feeding and caregiving for young children, and repeated infections (GoK, 2009; GoK, 2011a).

The 2015/16 Kenya Household and Budget Survey revealed that a significant portion of the Kenyan population faces food insecurity. The report indicated that the national food poverty headcount rate for individuals is 32 percent, signifying that approximately 14.5 million individuals live below the poverty line. Food poverty is most prevalent in rural areas, where 35.8 percent of the population resides below the poverty line. These figures underscore the pressing need to address food security and nutrition challenges in

Kenya and develop strategies that can help alleviate these issues and improve the population's overall well-being (GoK, 2016).

Agriculture is vital to Nyamira County's economy, contributing to approximately 90% of its Gross Domestic Product (GDP). Within the agricultural sector, crop production accounts for 50% of the agricultural GDP and employs a substantial portion of the local labour force. This sector significantly influences the socio-economic development of the County by providing households with food, income, and nutritional security (GoK, 2016).

The agricultural sector in Nyamira County can produce enough goods and by-products to meet domestic and industrial market demands and generate surplus products for export. It consists of both large-scale and small-scale farmers. Small-scale farmers typically own land parcels of around 0.7 hectares, while large-scale farmers have more extensive holdings of approximately 4 hectares. These farm holdings are concentrated in high-potential areas (GoK, 2021).

It is worth noting that the division of land into smaller holdings has led to a significant increase in the number of farm holdings in the County. As a result, the agricultural sector has the potential to create a substantial number of jobs, reduce poverty, and alleviate pressure on capture fisheries. The success of this industry is central to Nyamira County's economic performance and overall development (GoK, 2015).

2.8 Food Security Pillars

This study reviewed the four pillars that constitute food security.

2.8.1 Food Availability

According to FAO (1983), "food availability" refers to an adequate quantity of food that meets the required quality standards, supplied through either domestic production or imports, which may include food aid. Food availability is influenced by the volume of food transported from the production site to distribution points (Chima & Rahman, 2019).

Food availability encompasses two primary aspects: food sufficiency and the capacity of the agricultural system to produce an adequate food supply. It is shaped by factors such as crop and grazing land suitability for agriculture, agro-climatic conditions, and various elements that influence farmers' responses to market dynamics (Zhou *et al*., 2017).

2.8.2 Food Accessibility

Food accessibility is closely tied to the resources necessary for acquiring food, and income plays a significant role in determining food access (Mbukwa, 2013). It is defined by one's capability to obtain the required resources, i.e., legal, political, economic, or social needs, to access food (FAO, 2015). This definition encompasses having access to the resources essential for acquiring food that contributes to a healthy diet.

It is worth noting that the concept of food security has evolved. Before the 1970s, it was primarily focused on national food production and international trade, whereas today, it extends to the level of individuals and households (FAO, 2015).

2.8.3 Food Utilization

The temporal or permanent nature of access to the resources required for sufficient food consumption is a critical factor that impacts food stability (FAO, 2015). Climate variability plays a significant role in determining the security of food access. The anticipated increase in weather variability will likely intensify food insecurity, potentially jeopardizing the reliability of food systems at both local and global levels (FAO, 2015).

Food utilization encompasses various aspects, including food safety, nutritional value, and the absorption of nutrients. It also considers factors like the social values associated with food and the quality and safety of food supplies, all of which influence the types of food consumed on different occasions and at different times (FAO, 2013; FAO, 2015).

2.8.4 Food Stability

The UN's Food and Agriculture Organization (FAO) says that proper food security means everyone always has enough nutritious food. This isn't just about having food available but also about reliable access to it without fear of disruptions like economic crashes, bad weather, or seasonal shortages. The World Food Summit highlights that all aspects (availability, access, and utilization) must be consistently stable for true food security.

Studies differentiate between two types of food insecurity: chronic and temporary. Chronic food insecurity refers to situations where people can't consistently meet their food needs for long (Maxwell & Frankenberger, 1992). Temporary food insecurity, on the other hand, is a short-term issue. Food stability, which reflects how reliably people have access to food, can be rated as "good" for consistent access, "fair" for occasional disruptions, and "poor" for frequent or constant lack of access.

2.9 Food Security Measurement

2.9.1 Household Dietary Diversity Score (HDDS)

The HDDS is a simple way to assess household diets by asking people what they ate on the last day. This short recall period makes it easier for people to remember accurately and reduces the burden on them. Similar to other dietary diversity studies, the HDDS focuses on the variety of food groups consumed within a day. The score is simply the number of food groups a household reports eating (FAO, 2010; Huluka *et al*., 2019).

Many studies have shown that HDDS is crucial for understanding food security (Mango *et al*., 2014; Sibhatu & Qaim, 2017; Wekesa *et al*., 2018). Goshu *et al*. (2013) found a strong link between HDDS and essential factors like calorie and protein intake, making it a valuable indirect measure of food security. In simpler terms, the variety of foods a household eats (as shown by HDDS) reflects their diet and their ability to afford different types of food (Mango *et al*., 2014).

The HDDS considers twelve food groups: (A) Cereals, (B) Root and tubers, (C) Vegetables, (D) Fruits, (E) Meat and poultry (F) Eggs, (G) Fish and seafood, (H) Pulses, legumes, and nuts, (I) Milk and milk products, (J) Oil and fats, (K) Sugar and honey, and (L) Spices, Condiments and Beverages. Each food group counts as one point if the household consumed it in the past 24 hours. The total score can range from zero (if no groups were consumed) to twelve (if all groups were consumed). Therefore, the HDDS is equal to the total number of food groups consumed by the household, and it is given by:

HDDS = Sum (A + B + C + D + E + F + G + H + I + J + K + L).

FAO (2022a) created a system to classify households as food secure or insecure using households' HDDS scores. The average score is then used to determine whether a household has enough variety in its diet (FAO, 2022a).

2.9.2 Household Food Consumption Score (HFCS)

The HFCS builds on the HDDS by considering how often a household eats certain foods (Mango *et al*., 2018). It considers what people ate last week and categorizes it into eight food groups: vegetables, fruits, and meat. Instead of counting the number of different food groups (like the HDDS), the HFCS assigns weights based on importance, with more nutritious groups like vegetables getting a higher weight. A final score is calculated by adding up these weighted scores. The overall HFCS score can then classify households into different consumption categories: poor, borderline, or acceptable (Mango *et al*., 2018). Therefore, a higher HFCS indicates a more diverse and nutritious diet.

2.10 Climate Change and Food Security

Studies by Kogo *et al*., (2021) warn that climate change is a significant threat to farming worldwide. Island nations in the Pacific, similar to those near Singapore, are especially at risk, according to Barnett (2020). Climate change disrupts food security in these areas in several ways. It can reduce food production on land and at sea, limit a country's ability to buy food from other countries and make it harder for people to afford food.

In Africa, climate change is already impacting food security, as noted by Alemu and Mentistu (2019). The changing climate is leading to concerns about achieving food security in the region, with environmental changes like shifts in rainfall patterns, drought, fluctuating temperatures affecting growing seasons, and alterations in land cover all playing a role. These climate-related factors can disrupt agriculture and livestock production, causing erratic rainfall, floods, and droughts that impact food security.

Research by Kabubo-Mariara & Mulwa (2019) shows that climate change is seriously disrupting weather patterns and seasons in Kenya, hurting how much food farmers can produce. To address this, they recommend several farm strategies, such as planting new types of crops, raising a wider variety of crops and animals, and using technologies to collect rainwater. These steps are expected to boost food production and improve food security, especially for small farms that grow food for their families.

Building on research by Kogo *et al*. (2021), climate change is a significant concern for global agriculture. The biggest threats come from changes in temperature, rainfall, sea levels, and carbon dioxide in the air. However, farmers can increase crop production and improve food security by adopting successful adaptation strategies. This emphasizes the importance of tackling climate challenges in agriculture.

The Kenyan Ministry of Environment and Natural Resources (2016) predicts climate change will bring more extreme weather. Floods are expected to become more frequent and intense, while average rainfall will increase overall. However, this won't be evenly distributed, and some areas will likely experience more frequent droughts. Heightened rainfall intensity and ensuing flooding could elevate the susceptibility to mudslides and landslides, particularly in mountainous terrain. The escalation in extreme rainfall events is expected to contribute to increased soil erosion and waterlogging of crops, thereby diminishing yields and exacerbating food insecurity.

Moreover, rising temperatures are projected to extend periods of aridity in northwest regions, potentially reducing water storage capacities as prolonged droughts become more prevalent. This scenario could lead to considerable economic losses, agricultural land, infrastructure damage, and human casualties. Furthermore, the compounding effects of recurrent floods, including land degradation and soil erosion, are poised to negatively impact agricultural productivity, disproportionately affecting the livelihoods of rural communities, particularly the economically disadvantaged (GoK, 2016a).

2.11 Adoption of CSA Practices among Households

The FAO (2013) defines climate-smart agriculture (CSA) as three guiding principles. These are: 1. Sustainably increasing agricultural productivity and income; 2. Adapting and building resilience to climate change (mitigation strategies refer to the potential for agriculture to mitigate emissions); and 3. GHG emissions can be reduced and removed relative to business-as-usual practices (FAO, 2013; McCarthy & Brubaker, 2014). A recent study by Lipper *et al*., (2014) highlights climate-smart agriculture (CSA) as a critical approach to ensure food security in the face of climate change. Unpredictable rainfall and temperature swings threaten food production, especially for those who rely on agriculture, including many of the world's poorest people. Climate change disrupts food markets, putting entire populations at risk of food shortages. CSA offers a solution by increasing farmers' ability to adapt, build resilience, and use resources more efficiently.

While CSA is seen as a critical solution to food security challenges in a changing climate, implementing these practices isn't straightforward. It's a complex process influenced by a range of factors and obstacles. CSA practices aim to integrate adaptation and mitigation measures into agricultural growth initiatives to make them more resilient and sustainable.

Even though research shows CSA practices can improve crop yields and make farming more sustainable, many small-scale farmers in sub-Saharan Africa aren't adopting them widely. There are several reasons for this, and a major one is uncertainty about land ownership and rights. Farmers are hesitant to invest in long-term improvements like CSA practices if they're not sure they'll be able to benefit from them in the future. This is supported by studies like Abegunde *et al*. (2020), which looked at factors affecting CSA adoption in South Africa.

The study by Abegunde *et al*., (2020) showed that most farmers in their sample were using some CSA practices, but not all. This suggests there's potential to get even more farmers on board. To achieve this, it's essential to understand what factors influence whether farmers adopt CSA. By identifying the challenges and obstacles farmers face, we can develop better strategies to promote the widespread use of these practices. Ultimately, helping farmers overcome these barriers will encourage more climate-smart agriculture and make farms more resilient to climate change.

The study found that while most farmers used some CSA practices, a smaller group (only 17.7%) were classified as high adopters. The most common practices were using organic manure, crop rotation, and planting various crops. The research also identified several factors linked to higher CSA adoption. Farmers with higher education, higher income, more farming experience, larger farms, and exposure to agricultural resources (extension services, media) were more likely to be high adopters. Additionally, being part of a farmer association and believing climate change is a real threat positively influenced CSA adoption (Abegunde *et al*., 2020).

Research by Zakaria *et al*. (2020) shows that even though there's a lot of promotion of CSA practices aimed at African farmers, they aren't continually adopting them as expected. This is surprising because African countries are particularly vulnerable to food insecurity and poverty, and CSA could be a significant help. There seems to be a gap between the efforts to promote CSA and what's happening with farmers.

Even with changing weather patterns, CSA is proving effective in boosting food production globally. It's a framework that aims to improve food security for everyone, especially in rural areas. It also helps farms adapt to climate change and offers other benefits (Scherr *et al*., 2012). However, CSA practices are still being developed and evolving. More research is needed to understand the connections between CSA and sustainable agriculture. Determining how to promote CSA practices best is crucial to achieving food security and development goals (Sarker *et al*., 2019).

A study by Okumu (2021) investigated the impact of a CCAFS program on promoting CSA practices in Kenya. The research found that CCAFS's efforts led to the development of various policies by Kenyan counties to support CSA. These policies include establishing dedicated climate change units and funds. However, there seems to be a lack of coordination between national and county levels in implementing these practices, except for multi-stakeholder platforms.

The study also found that over half (53.4%) of Kenyan farmers have adopted at least some CSA practices, with crop management being the most common (60.9%). Interestingly, the choice of specific CSA practices by individual households depended on various factors, including the age, gender, and education level of the household head, as well as smartphone ownership and prior experiences with extreme weather. Exposure to agricultural extension officers, knowledge about CSA, and whether the household is involved in crop farming were also found to influence which CSA practices were adopted.

2.12 Influence of CSA Practices on Food Security

A study in Bangladesh by Hasan *et al*., (2018) investigated how CSA practices affect food security for coastal farmers. They found a clear link: farmers who adopted more CSA practices tended to have more secure food supplies, as measured by how much they spent on food per person each year. The study also showed that several factors made it more likely for a household to be food secure: higher education levels, farming as the primary source of income, having larger ponds for fish farming, owning more cattle, higher overall household income, smaller families, and easier access to markets to sell crops and livestock.

The Bangladesh study by Hasan *et al*., (2018) reinforces the value of climate-smart agriculture (CSA) in improving food security for coastal farmers. However, their findings go beyond just adoption. While adopting CSA practices is crucial, it's not the only factor. The study identified several other important influences on a household's food security, such as the education level of the household head, the size of their ponds for fish farming, the number of cattle they own, their overall household income, family size, and how easily they can access markets. In other words, for CSA to have the most significant impact, it's also essential to address these different factors.

2.13 Legal and Policy Frameworks on Climate-Smart Agriculture and Food Security in Kenya

2.13.1 The Constitution of Kenya (2010)

Chapter Five of the constitution of Kenya enshrines sustainable Natural Resource Management (NRM) principles. It mandates at least 10% national tree cover and recognizes the importance of indigenous knowledge for biodiversity and genetic resources. This constitutional framework lays the groundwork for sustainable agricultural practices.

Kenya's Constitution (2010) lays the groundwork for addressing climate change, particularly through its Bill of Rights, which guarantees a clean and healthy environment. Building on this foundation, the Climate Change Act of 2016 established a legal framework for a more robust national response to climate change. This Act aims to achieve low-carbon development through better regulations and mechanisms.

The Act sets up a governance structure for managing climate change in Kenya. The National Climate Change Council (NCCC), chaired by the President, oversees and coordinates these efforts. The Act also clarifies the roles of both national and county governments in implementing climate change actions throughout the country.

Furthermore, it outlines the responsibilities of NGOs in reporting and managing greenhouse gas emissions.

2.13.2 Kenya Vision 2030

Kenya's Vision 2030 recognizes climate change as a major challenge and aims to build the country's resilience. This includes strengthening institutions to handle adaptation efforts better. The Vision also aims to attract at least five clean energy projects each year for the next five years. The Water Catchment Management Initiative is a concrete example of this environmental commitment. Vision 2030 further outlines a comprehensive strategy to address climate change. This encompasses expanded and intensified irrigation systems, Improved seed quality and livestock productivity, Enhanced water management through increased storage and harvesting, Forest conservation via degraded area rehabilitation, and Establishment of compensation programs for environmental services. It also integrates climate change considerations into development planning and Promotion of adaptation activities in high-risk disaster zones (GoK, 2007).

2.13.3 National Climate Change Response Strategy (NCCRS, 2010)

Kenya's National Climate Change Response Strategy (NCCRS) is a roadmap for integrating climate concerns into national development, government planning, and budgeting (GoK, 2010a). The NCCRS outlines various strategies for adapting to and reducing the adverse effects of climate change on agriculture (GoK, 2010a). These include implementing innovative technologies like irrigation systems, improved crop varieties resistant to drought and pests, and disease-resistant livestock, encouraging farmers to diversify their income sources beyond agriculture. The NCCRS also advocates for adapting agricultural practices from similar environments that have successfully dealt with similar climates. They are strengthening early warning systems for droughts and providing seasonal forecasts to bolster food security.

2.13.4 National Food and Nutrition Policy (NFNP, 2011)

Kenya's National Food and Nutrition Security Policy (FNSP) tackles the entire issue of food security, aiming to ensure everyone has access to nutritious food. It recognizes the connection between food security and overcoming poverty. The FNSP identifies critical areas for government action, emphasizing everyone's right to food (GoK, 2011a).

Designed with a broad scope, the FNSP is a foundation for securing resources, promoting more critical interventions, and developing practical plans. These plans should be innovative, technically sound, and foster collaboration across different sectors, including the private sector. This collaborative approach is crucial for achieving a healthy, productive agricultural nation free from hunger. It envisions all sectors and citizens working together at the national, county, and community levels (GoK, 2011a).

2.13.5 National Climate Change Action Plan (2018-2022)

Kenya's National Climate Change Action Plan (NCCAP) is a five-year strategy (2018-2022) that tackles climate change with a two-pronged approach: adapting to its effects and reducing greenhouse gas emissions (GoK, 2018b). A robust legal framework backs this plan. Kenya's Climate Change Act of 2016, the first of its kind in Africa, requires the government to develop these action plans and integrate climate change considerations across all sectors.

The NCCAP 2018-2022 goes beyond just reducing emissions. It prioritizes a "low carbon climate resilient development" pathway, emphasizing sustainable development and strategies to help Kenya adapt to climate change. This approach recognizes the need to protect vulnerable groups, such as women, young people, and marginalized communities, from the worst effects of climate change.

The plan builds on the successes of the previous NCCAP (2013-2017), implements the Climate Change Act, and helps Kenya fulfill its commitments under the Paris Agreement (GoK, 2018b). In short, the NCCAP is a comprehensive strategy that positions Kenya as a leader in climate action on the African continent.

NCCAP 2018-2022 sets out seven priority climate action areas with adaptation and mitigation actions. Enabling actions are identified in the policy and regulatory environment, capacity building and knowledge management, technology and innovation, climate finance, measurement, reporting, and verification (MRV+). The NCCAP guides climate action across all sectors, including national and county governments, civil society organizations, and the private sector (GoK, 2018b). Kenya's Constitution (2010) recognizes that addressing climate change is a shared responsibility between national and county governments. The NCCAP reflects this by calling for coordinated implementation between these two levels.

2.13.6 Kenya Climate Smart Agriculture Strategy (KCSAS, 2017-2026)

Kenya's Climate-Smart Agriculture Strategy (KCSAS) is a direct response to the challenges of climate change. It aims to make farming more resistant to climate impacts while reducing greenhouse gas emissions from agriculture. This strategy can potentially improve Kenyans' food security and livelihoods overall. The specific objectives of the KCSAS are first to increase the ability of farmers, herders, and fisherfolk to adapt to and cope with the adverse effects of climate change. Secondly, develop methods to minimize greenhouse gas emissions caused by agricultural practices. Thirdly, regulations and institutions that support climate-smart agriculture should be established. Lastly, address other challenges that hinder the adoption of climate-smart agriculture. The KCSAS is a multi-pronged approach to tackling climate change in Kenya's agricultural sector, aiming for both environmental sustainability and improved livelihoods (GoK, 2017).

Kenya's Climate-Smart Agriculture Strategy (KCSAS) isn't just a plan. It's vital for achieving the country's commitments to reduce greenhouse gas emissions (NDCs), specifically in agriculture. This ambitious strategy will require significant domestic and international investment, with an estimated total cost of 5.0 billion US dollars by 2026. The KCSAS has a dual purpose: first, it builds resilience and adaptation, and second, it reduces emissions. The Kenyan government plans to mobilize funding for the KCSAS from various sources and establish precise mechanisms for accessing, distributing, and using these funds. The strategy also outlines a detailed implementation framework that assigns specific roles and responsibilities to different stakeholders (GoK, 2011b).

2.13.7 Agricultural Sector Development Strategy (ASDS)

Before 2010, the Kenyan government had used the Strategy for Revitalization of Agriculture 2004, but ASDS was later developed to replace it in 2010. ASDS 2010-2020 lays a comprehensive plan and agenda to ‘brand’ the agricultural Sector to be a significant player that contributes to realising the envisaged 10 percent annual economic growth rate under the economic pillar of Vision 2030.

The strategy's significant goals include improving productivity, commercialization, and competitiveness of agricultural commodities and enterprises and developing and managing major production factors. However, the effects of climate change while striving for better conditions will challenge the achieved economic growth. The ASDS

Policy proposes establishing a national irrigation framework: First, because most farming in the region is done under rain-fed agriculture, support is needed to protect the agricultural sector against further incidences of drought. Secondly, it would support the rehabilitation of forests and water catchment areas; third, it would enhance food security in the region and check desertification (GoK, 2010a).

In addition, the policy fosters the exploitation development of arid regions like Northern Kenya, details of which are under the National Policy for the Sustainable Development of Arid and Semi-Arid Lands. ASDS understands that structural changes in agriculture need fundamental shifts to address the dynamically developed issues concerning sustainable agriculture and climate change adaptation in Kenya (GoK, 2010a).

2.13.8 Climate Change Act of 2016

This Act seeks to establish policies for environmental sustainability, climate change, and low-carbon economy development. It aims to integrate Climate Change into development planning and management systems, increase disaster risk reduction/ Climate Change adaptive capacities of communities, and develop programs and policies to strengthen the human and ecological systems' abilities to cope with Climate Change impacts (GoK, 2006).

Furthermore, this act seeks to extend the mainstreaming and strengthening of the climate change disaster risk reduction through the strategies and actions of public and private entities and integrate intergenerational and gender perspectives into Climate Change adaptation and mitigation strategies, promoting the obligations and incentives for the private sector in support of achieving low carbon climate resilient development(GoK, 2006).

Also, it seeks to encourage, implement, and institutionalize low-carbon technologies in efficiency and reduce emission intensity by enabling approaches and innovative technologies for low-carbon and climate-resilient improvement, enabling public participation in climate change response through awareness, consultation, and information. Lastly, it is to ensure public and other financial resources are mobilized and managed for climate change response in a transparent manner, including providing for and facilitating mechanisms in climate change research and development, training and capacity building, and integrating the principle of sustainable development into planning for and decision regarding climate change response. Furthermore, to mainstream climate change within the exercise of power and functions across all government levels and to improve collaborative climate change governance between the national and county governments (GoK, 2006).

2.13.9 Kenya National Adaptation Plan 2015-2030

This national adaptation plan (NAP) would further strengthen what has been initiated and developed through this NCCRS and the subsequent NCCAP. Further, the framework underpins the adaptation part of Kenya’s INDC, which was communicated to the UNFCCC Secretariat. This NAP's vision is to compile nationally agreed objectives in adaptation spearheaded by macro-adaptation actions that link with economic sectors and county-level vulnerabilities to increase its long-term preparedness and adaptation capacity. This NAP outlines adaptation measures from 2015 to 2030 (GoK 2016a).

The NAP lies within the context of Kenya's Constitution and Vision 2030, which is Kenya's development blueprint. It is equally committed to the planning of the medium-term plan (MTP) and medium-term expenditure framework (MTEF). It also aligns with the Climate Change Act, passed into law in May 2016. In the case of the MTP II sectors, climate change adaptation is presented in drought risk management to eliminate drought emergencies, environments, water, energy, agriculture, livestock, and fisheries sectors. The main objective of some of these programs under these sectors is to build the resilience of the affected communities and systems to climate hazards.

The NAP offers a context under which Kenya has to operate in terms of national socio-economic aspects and probable future climate conditions, which the country has to factor in as it makes decisions on what to fund, plan for, and budget. A risk assessment is also done based on the hazards highlighted in the NCCAP, which include drought, floods, and rising sea levels (GoK, 2016a). As highlighted in the NCCAP and Climate Change Act, 2016, the NAP acknowledges the guidelines on governance and institutional arrangements for delivering adaptation actions. Since the main hazards are environmental-related, particularly drought, the NAP considers the NDMA as an important institution in improving adaptive capacity.

NDMA was established in 2011, and its primary functions include developing measures that ensure that even in the worst times, drought does not translate to famine and that any impacts of climate change are well managed. This NAP outlines nine macro adaptation measures and their national sub-measures distributed across 20 sectors, with short, medium, and long-term planning horizons. For each sector, the NAP outlines the gaps, estimates the costs of the proposed macro-level actions over the targeted period of 2030, and defines the major institutions that could facilitate implementation (GoK, 2016a).

2.13.10 Sessional Paper No. 5 of 2016 on National Climate Change Framework Policy

The Constitution of Kenya acknowledges this commitment in the Environment, Resources, and Sustainable Development section. Part of the goal of the Kenya Vision 2030, as stated in the Sessional Paper No. 10 of 2012, is to have Kenya become a middle-income country with all citizens enjoying a high-quality life by 2030. Climate change remains a formidable hurdle despite appreciable progress in achieving sustainable national development goals. This has thus established that Kenya remains choked in climate change, and this is a threat that threatens to compromise the achievement of development aspirations in the country in the future. Therefore, Kenya embarked on standard national planning to address climate change, marking a start with the formulation of the National Climate Change Response Strategy (NCCRS) in 2010. It was the initial joint plan and the national planning paper aimed explicitly at challenges and opportunities resulting from climate change. This was captured by the NCCRS, which deemed a broad national policy on climate change necessary by the government of Kenya (GoK, 2016b).

The development of this policy began when Kenya was formulating the National Climate Change Action Plan (NCCAP, 2013-2017), whose vision is to support the attainment of low carbon climate resilient development through the implementation of the NCCRS. Much of the material for this Policy has been either generated directly through NCCAP or been integrally influenced by it. The different governmental and non-governmental bodies have a vast list of interventions and programmes aimed at controlling the impact of climate change in Kenya. Still, they have been launched without a proper government policy guide, and thus, they seem to be more of a response than a planned and coordinated effort (GoK, 2016b).

Consequently, this Policy captures the Government's policy direction towards climate change with a mission of enhancing the country's vision of framing a deliberate, well-coordinated, and consolidated strategy to cope with the adverse impacts of climate change, which aims at minimizing the vulnerability and enhancing the resilience of the Kenyan people, property, environment, and economy. The policy will place Kenya within order to access the economic, social, and environmental opportunities for a change to a low-carbon, climate-resilient economy. This policy will ensure a common, well-coordinated, and well-planned approach to responding to the local, national, and international potential and threats of climate change. This can be done through the mainstreaming approach, which allows for incorporating climate change issues in the development planning, budgeting, and executing process (GoK, 2016b).

For this reason, this Policy seeks to outline broad policies and principles to inform the preparation and rolling out of coherent, targeted, measurable, and funded initiatives in addressing climate change through the conventional issuance of Climate Change Action Plans periodically. Through establishing this policy architecture, Kenya seeks to protect its citizens and the nation's lives, assets, and welfare in the current and emerging climate. This policy, therefore, aims to improve adaptability to climate risk, spur the development of resilience to climate fluctuations and change processes, and support a low-carbon development path (GoK, 2016b).

2.13.11 Kenya Nationally Determined Contributions (NDC)

Kenya's Updated Nationally Determined Contribution (Updated NDC) describes Kenya's mitigation and adaptation contribution from 2020 to 2030 and proposes priority mitigation and adaptation actions for the period. The Updated NDC proposes a more ambitious contribution relative to the first NDC, even though significant international support is required to exploit mitigation and adaptation potential to realize the overall NDC targets (GoK, 2020).

The updated NDC was based on the findings of the analysis during the NDC updating process. The study proved that, with substantial support, Kenya can meet and exceed the initial NDC mitigation target of reducing emissions by 30% relative to the Business as usual Scenario by 2030. In addition, it examines the climate projections and the associated impacts before proposing and identifying the priority adaptation actions. It also provides evidence-based recommendations for ambition enhancements in the updated NDC (GoK, 2020).

2.13.12 Agricultural Sector Transformation and Growth Strategy 2019-2029 (ASTGS)

This ten-year national plan, the Agricultural Sector Transformation and Growth Strategy (ASTGS) aims to modernize farming and ensure everyone has enough good food to eat, as the Constitution's Article 43 guarantees. To reach the overall goal, it establishes three anchors for the first 5 years as follows: (i) increase small-scale farmer, pastoralist, and fisher-folk incomes; (ii) increase agricultural output and value add; and (iii) increase household food resilience (GoK, 2019).

As action towards eradicating hunger, food insecurity, and malnutrition, the following actions of the ASTGS are proposed to be implemented. First, the governance and management of the current nationwide strategic food reserve should be redesigned to target a massive (approximately 4 million) number of vulnerable Kenyans. Secondly, improve the food security amongst the farmers, pastoralists, and fishing households in Arid and semi-arid regions through design by the community for the community in collaboration with development partners, the Government, and the private sector. Finally, the yield per farmer should be raised, and the focus on agricultural productivity should be changed from just for food consumption to an economically commercialized output (GoK, 2019).

2.13.13 Kenya Climate Smart Agriculture Implementation Framework 2018-2027

The Climate-Smart Agriculture Framework is intended to facilitate the delivery of CSA programmes at both the national and county governments to consider international climate imperatives and local realities in Kenya. Understanding that Kenya is a signatory to international treaties such as the Kyoto Protocol and the Paris Agreement, the Framework is aware of links between global commitments and Kenya's development priorities within Vision 2030, in which agriculture is a crucial sector.

The Framework is designed to capitalize on global opportunities for Kenya's farmers and open avenues for getting climate financing internationally with assistance from related sector players. It is to facilitate and achieve sustainable, low-carbon growth of agriculture that will feed the country while reducing the achievement of Kenya Vision 2030. This objective is to be achieved through four key components: first, the Institutional coordination component that will strengthen national inter-ministerial collaboration, enhance coordination between the national and county governments, and provide an enabling policy and institutional environment for the realization of the overall purpose of KCSAIF (GoK, 2018a).

Secondly, agricultural productivity and value chain integration are aimed at transforming Kenya's agricultural sector. This component encourages the development of efficient value chains, supporting a shift from subsistence farming to market-oriented production. Promoting innovative technologies and improved linkages envisions a competitive, modern agricultural industry that responds to market demand (GoK, 2018a).

Thirdly, it will be used in building resilience and mitigation actions, which seek to enhance resilience against climate impacts while providing co-benefits in mitigation. It addresses critical areas such as soil health, land degradation, water and natural resources management, and safety nets like insurance. Additionally, it emphasizes integrating adaptation and mitigation strategies (GoK, 2018a).

Lastly, CSA knowledge, extension, and agro-weather services should strengthen CSA communication and knowledge dissemination. This component supports the development of systems that provide timely information on CSA practices and agro-weather issues. It also aims to empower local stakeholders to adopt CSA-supportive methodologies and influence planning systems better to integrate climate-smart approaches (GoK, 2018a).

2.14 Models Reviewed Relevant to the Current Study

This section considered the framework that was used in this study. The conceptual models underpinning this study are the food security & Sustainable Livelihoods Models.

2.14.1 The Food Security Model

Food security refers to having complete physical and economic access to an ample supply of healthy and nutritious food for a well-balanced life (FAO, 1996: FAO, 2015). In accordance with Zhou *et al.*, (2017), food security can be evaluated through four crucial elements: the presence of an abundant food supply (availability), the ability to obtain the necessary amount of food (accessibility), the consistency of access (sustainability), and the presence of sufficient quantities of food with good quality (utilization).

The concept of food security has evolved and varies based on different approaches influenced by assessment methods and how farm measurements are conducted. In this study, the food security model was adopted to consider rural households' production and consumption practices. Food consumption was used as a metric to gauge utility, considering the satisfaction derived from taste and the health benefits of the food consumed by households (FAO, 2015).

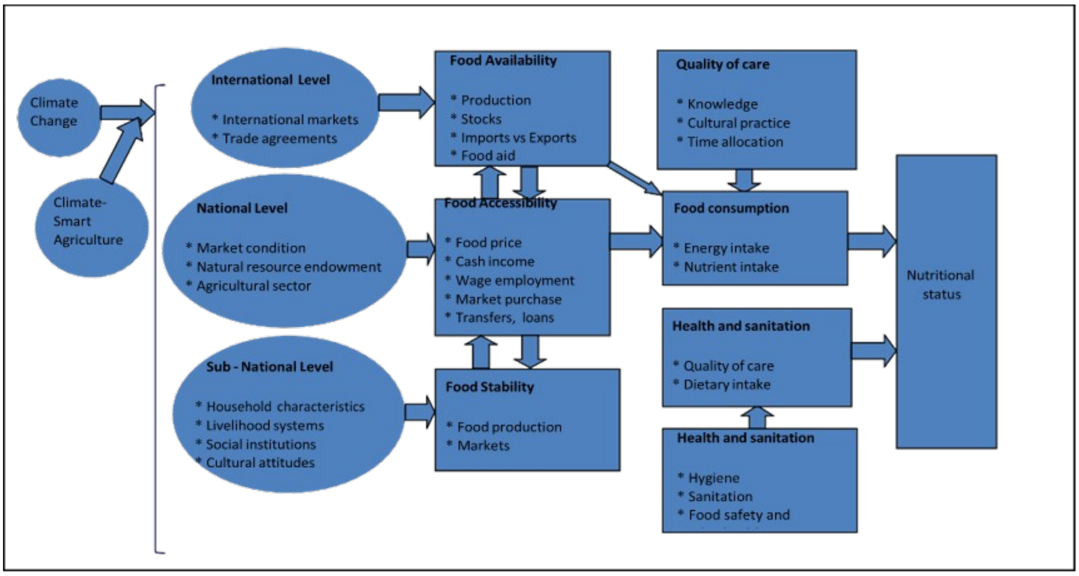


Figure 2.1: Food security framework model

Source: Adopted from FAO (2013)

2.14.2 Sustainable Livelihoods Framework (SLF)

Chambers & Conway (1992) state that a livelihood encompasses the essential skills, resources, entitlements, and activities required to maintain a particular way of life. Sustainability in livelihood is demonstrated when it can endure external pressures, recover from setbacks, preserve or enhance its skills, resources, and access, and provide future generations with opportunities for enduring well-being. Moreover, a sustainable livelihood contributes to the well-being of other livelihoods, both locally and globally, in the short and long term. The Sustainable Livelihoods Framework (SLF), designed to mitigate vulnerability, serves as the basis for assessing and planning for the susceptibility of smallholder farmers to climate change risks. Climate shocks are integral to the SLF and are recognized as a crucial component of the "vulnerability context."

Small-scale farmers in Nyamira County confront the vulnerability of climate change and necessitate strategies to adapt to these changes. Given their reliance on agriculture, this adaptation is crucial for sustaining their livelihoods. The Sustainable Livelihoods Framework (SLF) places significant emphasis on prioritizing livelihood assets. These factors, alternatively labelled as capital or building blocks of livelihoods, shape people's responses to the impacts of climate change. Burton *et al*., (2003), state that the foundational livelihood assets play a crucial role in determining individuals' lifestyles and their adaptive strategies to climate change. As opined by Cooper *et al*., (2008), an inverse correlation exists between the strength and diversity of the asset base and the population's capacity to adapt, as well as their levels of food security and the sustainability of their livelihoods.

The SLF categorizes the assets essential for livelihood generation into five capitals: human, natural, physical, social, and financial capital. Human capital encompasses education, training, and knowledge, which contribute to the capacity for work and adaptation and the ability to maintain good health and productivity (DFID, 1999). Collectively, these elements enable individuals to engage in various activities and accomplish goals. The people's structure, culture, and perspectives contribute significantly to understanding the existence of climate change and the adoption of relevant change. For example, skilled smallholder farmers with formal education and some training are in a better place to embrace new techniques, utilize modern equipment, and adopt climate-smart technologies and practices.

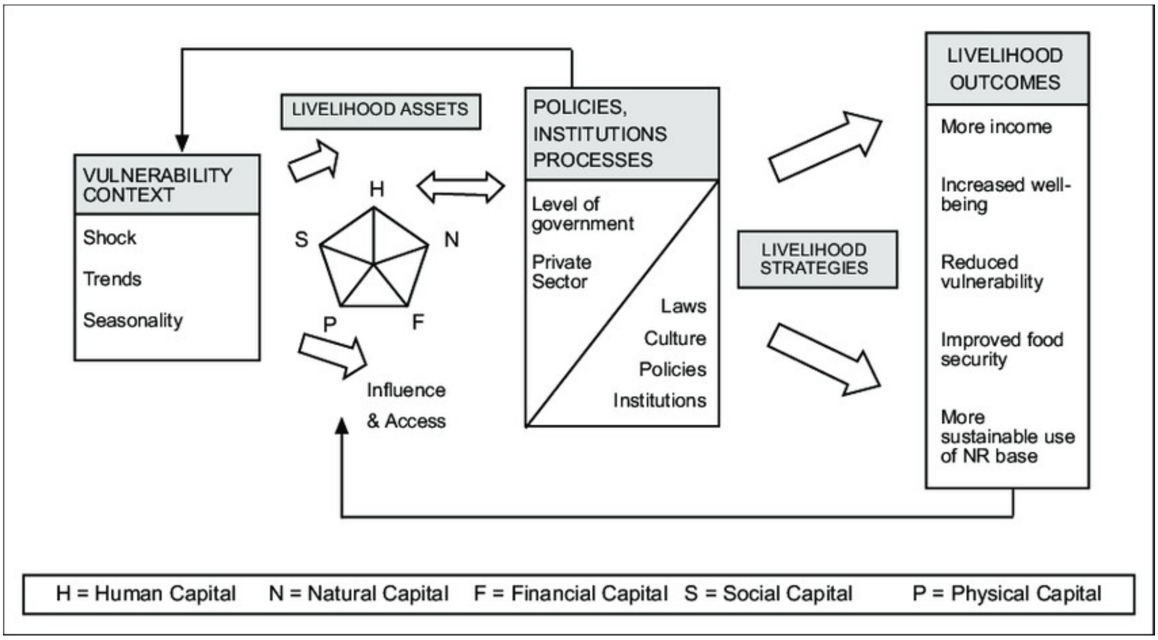


Figure 2.2: Sustainable livelihood framework

Source: Chambers & Conway, (1992)

Social capital may be defined as a significant class of resources that includes norms and networks on which individuals can draw when in a group with other people (Woolcock & Narayan, 2000; Adger *et al*., 2003). Through networks, individuals are involved in sharing information and disseminating risk, as well as making claims for reciprocation during a crisis. It has been argued that the network of social relations, reliance, mutual obligation, cooperation, and learning processes that help to build new rules to regulate relations contribute to the degree of adaptive capacity under climate change (Adger *et al*., 2003; Jaja & Dawson, 2014). This is especially true for the farmers who primarily operate within the small-scale farming category in Nyamira, primarily in the rural regions. Farmer groups, as well as local organizations, are essential when it comes to obtaining institutional access and claims rights.

Another fundamental component of livelihood source is natural capital, which, according to Ellis (2000), is the primary natural resource base on which smallholder farmers involved in agricultural production rely to support their livelihoods and obtain diverse resources for income and food. Some examples include land, forest, air, water, fish, livestock, pasture, and wild products. These can be agricultural land, pastureland, forestland, water resources, etc., and these natural resources are frequently commons, depending on the respective countries' conditions. Referring to the current practice of land subdivisions within the county, most individuals in farming accrue small tracts of land. Farmers, whether communal or private, practising natural resources for crop growing and rearing of animals need these resources.

There are two elements of physical capital, the first of which includes infrastructure resources and technology that includes tools and equipment for production, seeds, fertilizers, pesticides, traditional technology, and animals used in draught power (DFID, 1999). Sustainable infrastructure for human living includes transportation at reasonable prices, secure housing and buildings, adequate sufficient supply of water and sanitation, clean energy at reasonable prices, and information and communication. Various physical capitals exist in Nyamira County, including farm inputs that enable small-scale farmers to produce goods to support their everyday needs. However, it must be appreciated that specific areas within the county can undertake limitations in some forms of physical capital.

For shock-related coping, the type and extent of coping resources cannot be complete without a critical element, which is the financial capital in the form of cash or quickly accessible assets in the form of savings, credit, debt from formal or informal sources, as well as the remittance income. Although many commercial banks usually have little interest in giving out equipment for small-scale agriculture, micro-finance institutions have been instrumental in extending financial credits to farmers in developing nations.

2.15 Conceptual Framework

The theoretical framework employed in this investigation integrates various variables, including dependent, independent, and intervening factors, with inspiration drawn from both the Food Security model and the Sustainable Livelihood frameworks. The independent variable under scrutiny is climate-smart agriculture, while the dependent variable is food security. Within the independent variable, the dimensions encompass the specific type of CSA adopted, the level of CSA adoption, and the adoption trends of CSA practices. The dependent variable, food security, is evaluated by examining its fundamental pillars: food availability, accessibility, stability, and utilization.

The assessment of food availability deals with other parameters, including food production techniques, availability of productive resources and technologies, affordability of inputs, including labour, capital, and agricultural inputs, and availability of land, water, and ecosystem support. On the other hand, measuring food accessibility is also comprehensive. It has several facets, such as the extent to which women participate in matters concerning economic autonomy, earnings and sustenance, and income generation capacity of the household.

Food stability was assessed through several constructs, including the cultivation of climate-adaptive crops, the implementation of energy-efficient practices, farmers' utilization of coping strategies, and the formulation of preparedness plans to safeguard lives and assets in the face of environmental challenges. Regarding food utilization, the study evaluated access to clean water and sanitation facilities, shifts in dietary patterns, and the acquisition of skills and knowledge to promote optimal nutrition, ensure food safety, and maintain sanitation standards. The intervening variables will be the legal and regulatory frameworks for climate change and food security.

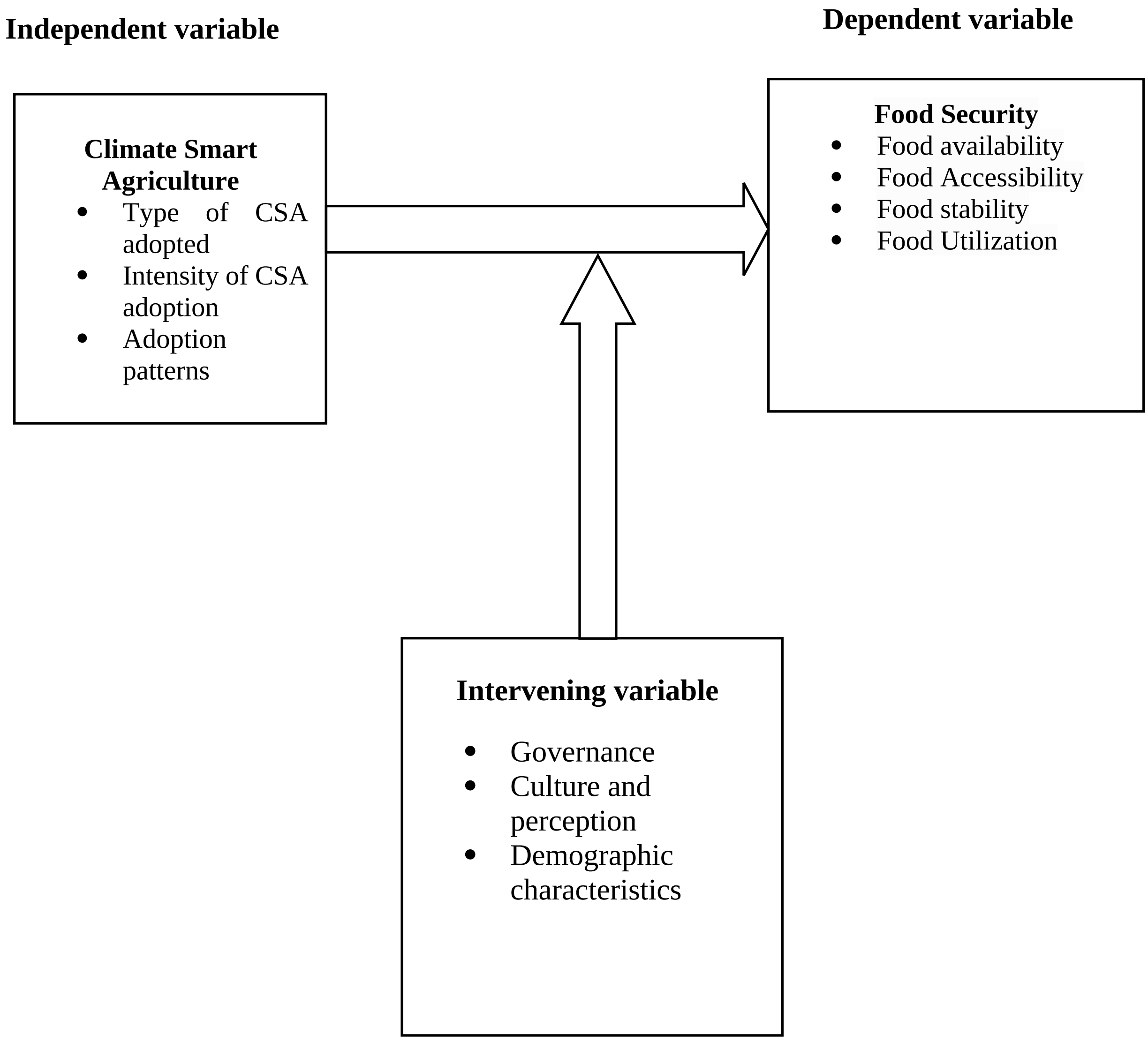


Figure 2.3: Conceptual framework model showing the interaction between the independent, dependent, and intervening variables

Source: Researcher (2023)

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter provides a comprehensive overview of the research methods and offers a foundational structure for the study. The chapter outlines the study area, study population, research design, sampling strategy, data collection instruments, validity and reliability, data analysis and presentation techniques, study limitations, study assumptions, and ethical considerations while conducting the study.

3.2 Study Area

Nyamira County is among the forty-seven counties in Kenya. From the North, it borders Homabay County, while to its West is Kisii County, Bomet County to the Southeast, and Kericho County to the east. Nyamira County covers an area of 899.4 square kilometres and is located between latitudes 0°30'0” and 1°0’0” South and longitudes 34°50'0” and 35° 0’0” East (Figure 3.1). Notably, the County does not share borders with any foreign nation and lacks significant water bodies within its territory (GoK, 2018c).

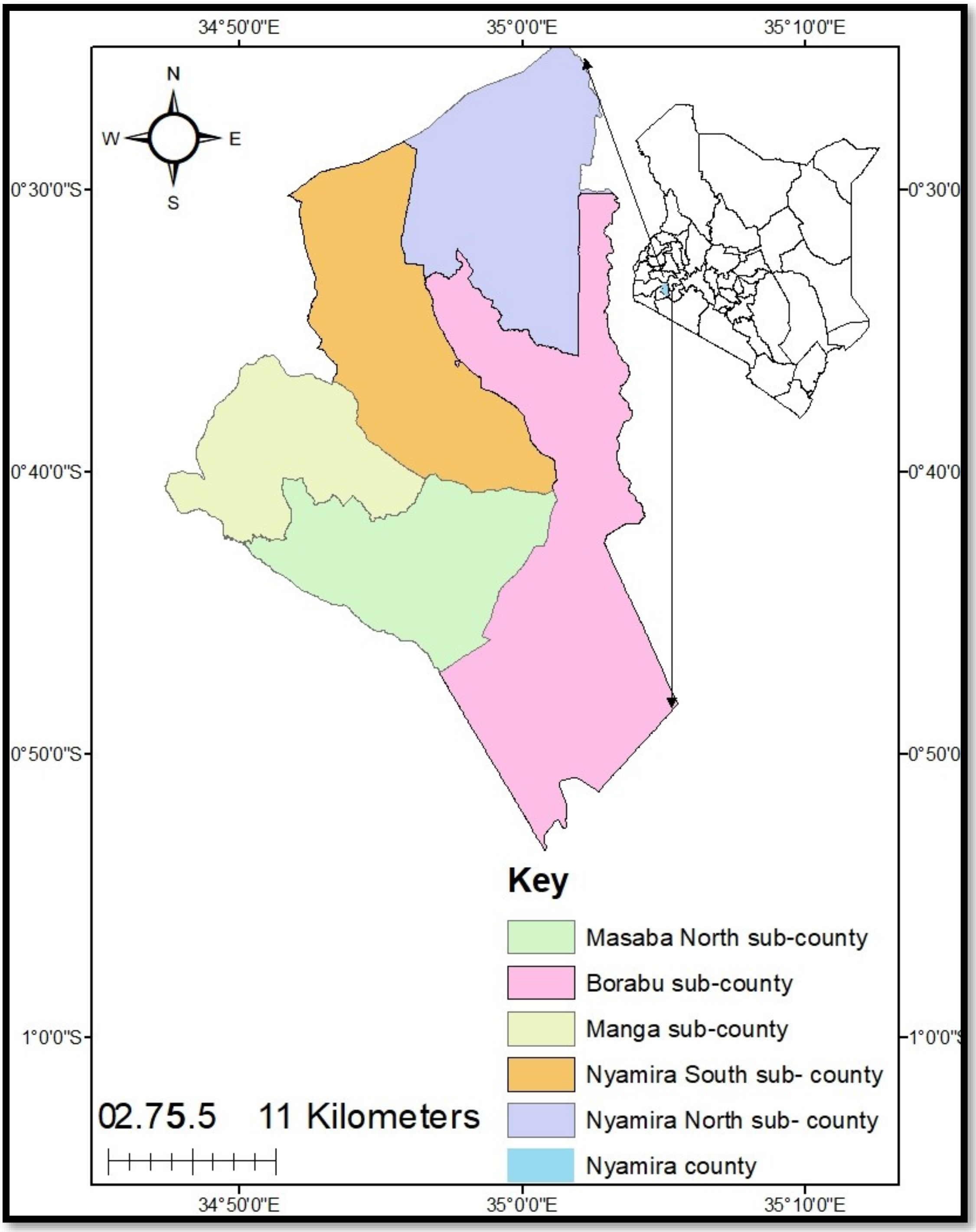


Figure 3.1: Map of the study area showing the geographical location of sub-counties of Nyamira County, Kenya

Source: Researcher (2023)

3.2.1 Administrative Boundaries

The County is divided into five administrative sub-counties: Nyamira South, Nyamira North, Manga, Borabu, and Masaba North. Borabu is the largest sub-county, with an estimated land area of 248 km^2, and Manga is the smallest, with an estimated land area of 111 km^2. The county is divided into four constituencies: Kitutu Masaba covers the administrative boundaries of Manga and Masaba North Sub-counties. West Mugirango covers the Nyamira South sub-county. North Mugirango covers the Nyamira North sub-county, except for the proposed Kiabonyoru division in the Nyamira North sub-county, which forms part of the Borabu constituency and covers the entire administrative boundary of the Borabu sub-county (GoK, 2018c: GoK, 2020). With 43 locations, 108 sub-locations, and 1,555 villages, the County is further divided into 14 divisions under the national government. In contrast, the County government has its administrative units further divided into 20 wards, as shown in Table 3.1 (GoK, 2018c).

Table 3.1: Nyamira County Administrative Units in numbers

Sub-county	Land area (km^2)	Divisions	Wards	Locations	Sub-locations	Villages
Nyamira south	179	2	5	7	19	381
Nyamira North	219.3	3	5	10	26	231
Borabu	248.3	3	4	5	15	233
Manga	111.3	3	3	9	22	367
Masaba North	141.5	3	3	12	26	343
Total	**899.4**	**14**	**20**	**43**	**108**	**1,555**

Source: GoK (2018c)

3.2.2 Population Size and Composition

Table 3.2 illustrates the population distribution across the various sub-counties within Nyamira County. The allocation of the County's population and the arrangement of settlements are shaped by factors such as infrastructure networks like roads, access to water and electricity, opportunities for gainful employment, and favourable climatic conditions (GoK, 2020).

Table 3.2: Population size based on gender per sub-county in Nyamira County, Kenya

Sub- county	Male	Female	Total
Borabu	36,736	36,431	73,167
Manga	44,868	49,339	94,207
Masaba North	52,884	58,974	111,858
Nyamira North	80,314	86,947	167,261
Nyamira South	76,105	82,965	159,070
Total	**290,907**	**314,656**	**605,563**

Source: GoK (2020)

As per the 2011 Urban Areas and Cities Act provisions, Nyamira County accommodates 54 market and small urban centres, which are yet to be categorized. Conversely, Nyamira, Keroka, and Nyansiongo emerge as the three principal urban centres in the County. Furthermore, there are several other urban areas, including Magombo, Ikonge, Manga, Chebilat, Ekerenyo, Nyamusi, Miruka, Kebirigo, Magwagwa, Metamaywa, and Mosobeti that are experiencing notable growth and necessitate careful urban planning and improved infrastructure (GoK, 2020).

3.2.3 Physical and Topographic features

Nyamira County is characterized by a predominantly hilly topography known as the "Gusii highlands." Prominent geographic features in the County include the Manga Ridge, Kiabonyoru, Kemasare, Nkoora, and Nyabisimba hills. The topography of the County is divided into two main zones, with elevations ranging from 1,250 meters to

2,100 meters above sea level. The lower zones consist of swamps, wetlands, and valley bottoms, while hills dominate the upper zones. The higher altitude of the County has facilitated tea cultivation, which serves as the primary cash crop and a significant source of income for the region (GoK, 2018c).

Nyamira County is blessed with a network of permanent rivers and streams, including Kemera, Sondu, Charachani, Eaka, Gucha (Kuja), Kijauri, Egesagane, Bisembe, Chirichiro, Ramacha, and Mogonga. These water bodies play a crucial role in the region's hydrology, as they all ultimately discharge their waters into Lake Victoria. Notably, the River Eaka holds particular significance for Nyamira residents as it is the County's water supply source. On the contrary, hydroelectric power generation in the Sondu River has a greater prospect. If this energy source is used correctly, it can positively contribute to the county's developmental growth and eradication of poverty. In the recent past, these rivers have been exposed to low levels of flow due to issues of environmental degradation, such as wrong farming methods and planting blue gum trees in catchment areas and banks of the rivers, respectively (GoK, 2018c).

3.2.4 Soils

Two significant types of soil predominantly characterize Nyamira County. The first and most common type is red volcanic soil, classified as Nitosols. These soils are deep, fertile, and well-drained, constituting approximately 85 percent of the soil composition in the County. They are highly suitable for agriculture. The remaining 15 percent of the soil in the County is primarily found in valley bottoms and swampy areas. These soils are particularly well suited for brick-making activities due to their characteristics. While the red volcanic soils are excellent for farming and crop cultivation, they pose challenges for construction and road maintenance, often making these endeavours more expensive, as noted by the Government of Kenya (GoK, 2018c).

3.2.5 Ecological Conditions

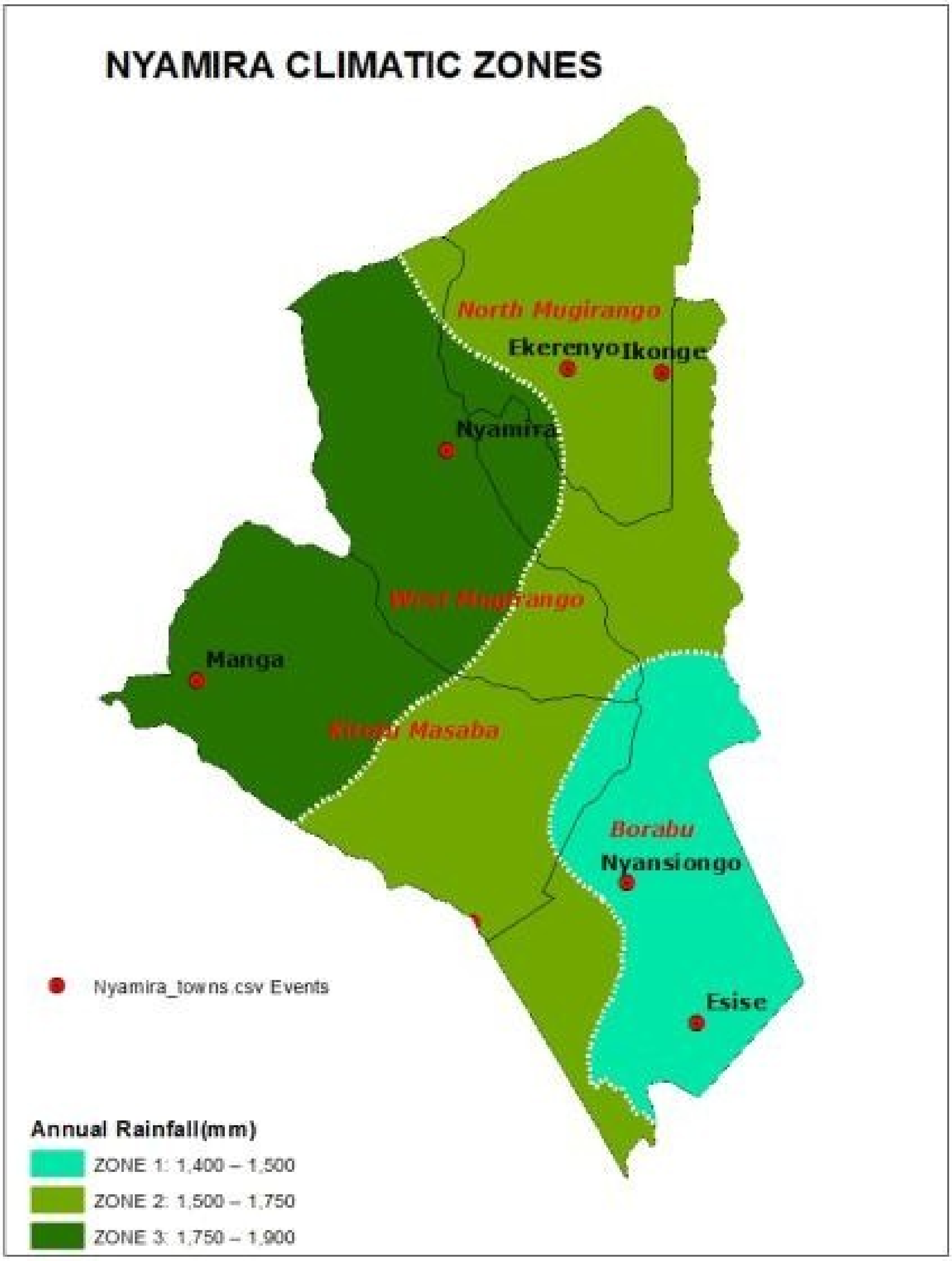
According to FAO (1996), agroecological zones (AEZ) are units used for mapping land resources, characterized by climate, landform, soils, and land cover attributes, each with a specific range of potential and land-use limitations. Nyamira County is divided into two major agro-ecological zones. The highland zones (LH1 and LH2) cover 82 percent of the County, while the upper midland zone (UM1, UM2, and UM3) accounts for the remaining 18 percent. Despite the evergreen vegetation within the County, no officially designated forests exist. The tree cover in the region is primarily composed of agroforestry, which has faced encroachment due to the high population pressure.

There is an urgent need to expand the forest cover across Nyamira County to address this issue. This expansion would serve as a source of timber and wood fuel, generating income for the community and contributing to poverty reduction. Particular emphasis is placed on promoting gravellier as a more beneficial option for farmers than blue gum trees, as emphasized by the Government of Kenya (GoK, 2018c).

3.2.6 Climatic Conditions

Nyamira County experiences a bimodal annual rainfall pattern characterized by well-distributed, reliable, and sufficient rainfall for various crops. The annual precipitation ranges from 1200 to 2100 mm yearly (Figure 3.2). The two distinct rainy seasons in the County are March to May (Long Rains season), receiving the highest amounts of rainfall with a rainfall peak in April, while October to December (short rains season) has relatively high amounts of rainfall registered annually with a seasonal monthly rainfall peak in November. These seasons lack a distinct dry spell separating them. The maximum daytime temperatures typically range around 28.7°C, while nighttime temperatures drop to about 10.1°C. This results in an average normal temperature of 19.4°C, creating favourable conditions for agricultural and livestock production (GoK, 2018c).

Figure 3.2: Nyamira County climatic zones



Source: GoK (2023)

Nyamira County holds significant potential for producing food crops and dairy products to meet local needs and supply neighbouring counties. Major cash crops in the County include tea, pyrethrum, coffee, bananas, and horticultural products, indicating a high potential for horticulture. In terms of food crops, maize, vegetables, beans, sweet potatoes, sorghum, cassava, and millet are among the main crops cultivated in the region (GoK, 2018c).

Despite changing climatic conditions, the diversity of food crops grown reflects the County's capacity for multifaceted agricultural production. However, climate change has disrupted the traditional bimodal rainfall pattern, making it challenging to predict the timing of short and long rains. This uncertainty affects farmers' planning and land preparation, reducing crop yields. Given the heavy reliance of small-scale farmers in Nyamira County on weather-dependent agriculture, adopting CSA practices is a solution to address the issue of low agricultural yields, ensuring sustainable food security within the County.

According to the GoK report of Nyamira County, department of environment (2023) on participatory climate risk assessment report, Nyamira County is divided into three major climatic zones, namely;

Zone 1 comprises the following wards: Borabu, Nyansiongo, Esise, and Mekenene. These zones experience an annual average rainfall of between 1400 and 1500mm. Zone 2 comprises Kiabonyoro, Rigoma, Gesima, Gachuba, Bosamaro, Itibo, Magwagwa, and Bokeira. The wards under this zone experience an annual average rainfall of between 1500 and 1750mm.

Zone 3: Kemera, Manga, Magombo, Bosamaro, Bonyamatuta, Bogichora, Township, Bomwagamo. Each zone has similar weather /climate characteristics. This zone has a long-term average annual rainfall of between 1750 and 1900mm.

3.2.7 Agriculture in the County

Agriculture is a cornerstone of Nyamira County's economy, with over 80% of the population engaged in various agricultural activities. This substantial involvement in agriculture is pivotal in driving the County's economic development and growth (GoK, 2018c). The County government has actively pursued measures and initiatives to enhance the agriculture sector since the inception of devolution. Collaborative efforts with the national government and stakeholders in the agriculture subsector have contributed to the overall successes witnessed in the past five years. Nevertheless, there remains significant untapped potential within the sector, with a specific focus on areas such as value addition and agribusiness (including cottage industry development), soil fertility improvement, pest and disease control, intensive crop production systems, climate change adaptation, and access to agricultural financing and credit. Additionally, support for extension services, food and nutrition security initiatives, and soil and water conservation programs.

Regarding agricultural produce, Nyamira County primarily focuses on food crops, including maize, sweet potatoes, beans, sorghum, finger millet, cassava, various fruits and vegetables, and other horticultural crops. The County also derives substantial income from cash crops such as tea, coffee, pyrethrum, avocado, and bananas (GoK, 2018c).

The area planted with food and cash crops has remained at 58,394 ha and 48,543 ha, respectively. This has been made possible by the County's generally favourable weather, the easy availability of labour, the ready market for crop products in the County's urban centres, and the area's proximity to other significant urban centres like Kisii, Oyugis, Kisumu, and Kericho. As a result, there are incentives for the agriculture subsector to grow. However, declining soil fertility, shrinking farm sizes, and competition from non-crop enterprises pose the biggest obstacles to commercializing most crop value chains. Each household has an average 0.70 Ha farm with food and cash crops. In some county areas, land has been excessively subdivided into economically insignificant units, while large-scale farm owners' land holdings still need to be developed. The sub-county of Borabu contains most of the country's large commercial farms (GoK, 2018c).

3.3 Study Population

The study population included all small-scale farmers in Nyamira County and other key stakeholders in climate-smart agriculture in the country. According to the 2019 Population and Housing Census report, the population of Nyamira County is 605,563 people, with males at 290,907, females at 314,656, and intersex 13 (GoK, 2020). The total number of households from the five sub-counties is summarized in Table 3.3. The study's target population comprised small-scale household heads who responded to the questions in the questionnaire (Appendix III).

Table 3.3: Number of households per sub-county in Nyamira County, Kenya

Sub-county	Wards	No. of households
Nyamira south	5	38,973
Nyamira North	5	40,446
Borabu	4	19,468
Manga	3	23,869
Masaba North	3	27,913
Total	**20**	**150,669**

Source: GoK (2020)

3.4 Research Design

The study utilized three different research designs: descriptive, correlational, and evaluation research designs, as outlined in Table 3.4. The descriptive research design was used for objectives one and two. According to Kothari (2004), a descriptive research design involves a systematic empirical investigation in which the researcher lacks direct control over independent variables because they have already occurred or are inherently unalterable. Furthermore, as Walingo and Ngaira (2008) suggested, descriptive research helps determine the frequency with which something happens or is related to something else. A correlational research design was utilized to examine the influence of CSA practices on household food security. Objective four, on the other hand, employed an evaluation research design. This design allowed for the evaluation of the effectiveness of CSA practices in strengthening food security among small-scale farmers in Nyamira County.

Table 3.4: Summary of specific objectives, measurable variables, and research designs

Specific objectives	Measurable variable/ indicators	Research design	Data analysis methods
Determine the impact of climate trends and patterns on food security among small-scale farmers in Nyamira County, Kenya.	Daily and seasonal amount of rainfall in mm Minimum daily temperature recordings in ^{0}C Maximum daily temperature recordings in ^{0}C	Descriptive survey	Descriptive Mann-Kendall (MK) test Time series analysis Spearman rank order correlation Thematic and narration analysis
Establish the existing Climate Smart Agriculture practices among small-scale farmers in Nyamira County, Kenya.	Type of CSA practice adopted Land size Access to CSA information Crops grown Number of CSA practices	Descriptive survey	Chi-square test Descriptive Thematic and narration analysis
Examine the influence of Climate Smart Agriculture practices on food security among small-scale farmers in Nyamira County, Kenya.	**Food availability** Food production practices Access to productive technologies and practices Access to fertile land **Food Accessibility** HDDS Household income **Food stability** Climate-adapted crops Energy efficient Coping strategies **Food Utilization** Access to clean water and sanitation Access to health facilities	Correlational	Descriptive Spearman rank order correlation Binary logistic model Thematic and narration analysis
Evaluate the effectiveness of climate-smart agriculture practices in strengthening food security among small-scale farmers in Nyamira County, Kenya.	Number of CSA practices Intensity of adoption (technologies adopted) Adopted strategies	Evaluation	Descriptive Document analysis

Source: Researcher (2023)

3.5 Sampling Strategy

Sampling involves choosing a representative subset from a larger target population to conduct a study to ascertain the specific characteristics of the entire population. The survey's sample size of households was determined using the Krejcie and Morgan formula (Krejcie & Morgan, 1970). Using the formula, a sample size of 384 was derived for the study. This formula is shown in Equation 3.1.

……………. Equation 3.1

S= 383.5263

S= 384 household heads

Where:

X^2 = table value of Chi-Square for 1 degree of freedom at the desired confidence level (in this case 3.84)

N = the population size, in this case 150,669

P = the population proportion (assumed to be 0.5 since this would provide the maximum sample size)

d – the degree of accuracy expressed as a proportion (0.05)

The selection process involved a multistage random sampling procedure based on the 2019 census of enumeration areas within the various sub-counties in Nyamira County, as indicated in Table 3.5. The formula for proportionate sampling is shown in Equation 3.2.

…………………………..Equation 3.2

Where:

nh = sample size of the stratum

Nh = Population size of the stratum

N = Total population size

n = Total sample size

Table 3.5: Distribution of respondents among the selected wards in Nyamira County, Kenya

Sub-county	Wards selected	Selected wards (30% of the total)	No. of households	Proportionate sample size (nh= Nh/N*n)
Nyamira south	Nyamaiya	1	14,114	120
	Bogichora	1	4,463	38
Nyamira North	Bokeira	1	5,464	46
	Bomwagamo	1	4,127	35
Borabu	Nyansiongo	1	5,972	51
Manga	Kemera	1	2,336	20
Masaba North	Gachuba	1	8,828	75
Total		**7**	**45,304**	**384**

Source: Researcher (2023); GoK, (2020)

The sample selection process involved multiple stages. In the first stage, all the sub-counties within Nyamira County were chosen using a census sampling method due to the county's various climatic and agro-ecological zones (AEZs). In the second stage, the study identified 30% of the total Wards in each sub-county. Mugenda & Mugenda (2003) opine that a 10-30% sample size is acceptable for qualitative research.

A random sampling technique selected the specific wards within each sub-county. For example, in the Nyamira South sub-county, Nyamaiya and Bosamaro wards were chosen; in the Nyamira North sub-county, Bokeira and Bomwagamo wards. In the Borabu sub-county, Nyansiongo Ward, the Manga sub-county, Kemera Ward, and the Masaba North sub-county, Gesima ward were selected for the study. In the third stage, households were selected from the chosen wards using systematic random sampling, with a proportionate sample size determined for each ward, as detailed in Table 3.5.

3.6 Data Collection Instruments

The data collection instruments used in this study for objectives two and three included interview guides, questionnaires, Focus Group Discussions, and observation checklists (Table 3.4), which constituted the primary data sources.

3.6.1 Primary Data Sources

3.6.1.1 Questionnaire

According to Kothari (2004), a questionnaire consists of a series of questions that are either printed or typed in a specific order. This study's questionnaire included closed- and open-ended questions on the various measurable variables (Appendix III). The questionnaires were the primary tool for collecting data from the household heads who were identified systematically. The questionnaire was used to collect data from the respondents for objectives two, three, and four.

The variables addressed by this tool include demographic characteristics of respondents, climate-smart agriculture practices, land size, crops grown, food consumption score, household food production, and clean drinking water. The developed questionnaire was then uploaded into the Open Data Kit (ODK) version 2023.2.4 on Android devices, which was used to collect the data. The research assistants were trained to use the Kobo Collect software using their smartphones, and the filled questionnaires were uploaded daily to a centralized server to which only the principal researcher had access.

3.6.1.2 Key Informant Interview Guide

Interview guides were used to collect data from the key informants selected purposefully for the study (Appendix IV). According to Frankel & Wallen (2000), interview schedules allow the participation of illiterate and literate respondents and clarify ambiguity. According to Kothari (2004), collecting data through an interview schedule involves the presentation of oral-verbal responses. This tool was used to collect data for objectives two and three. The variables that were addressed by this tool included climate-smart agriculture and food security. The method was used through personal interviews and telephone interviews. This study administered interview schedules to the County Ministry of Agriculture officials and small-scale farmers' groups on the issues of climate-smart agriculture and food security. The key informants were purposively selected in this study. The data obtained from the interview schedule was used to triangulate data in conjunction with other data from different tools.

3.6.1.3 Focus Group Discussions (FGDs) Guide

The focus group discussions allowed the researcher to collect qualitative data (Appendix V). The tool collected data on all of the study objectives. The participants were selected purposefully based on their knowledge and experience on climate-smart agriculture and food security issues. The quota sampling method was used to sample FGD participants. Three mixed-sex FGDs were undertaken, one with extension service providers from the Nyamira agriculture sector and the other with farmers from the two AEZs in Nyamira County. Data from the FGD was captured through audio recordings and notebooks, where the researcher took notes of the critical points during the sessions. The participants of the FGDs were selected through quota sampling. The data was used to triangulate the findings. This was done by quoting the group members' verbal responses during the discussion.

3.6.1.4 Observation Checklist

An observation checklist was also used to collect primary data (Appendix IV). According to Kothari (2004), "observation" means collecting information through the investigator's examination without interviewing the respondents. This method also involves observing behaviour and systematically recording the results of those observations. This helped the researcher overcome the disadvantages of questionnaires, FGDs, and interview schedules. The specific objective two was collected through this tool. The researcher observed the various climate-smart practices that the small-scale farmers had adopted within their farms and the livelihood diversification they used to ensure they were food secure. The information observed in the field was captured through photographs to show the various CSA practices adopted by small-scale farmers.

Table 3.6: Summary of study population, sample size, and data collection tools in Nyamira County, Kenya

population unit categories	Population size	Sample size determination	Sampling method	Sample size	Data collection tool
Household heads	150,669	Krejcie and Morgan's 1970 formula	Multi-stage	384	Questionnaire
Nyamira County Department of Agriculture, livestock & fisheries officials	10	30% of the population size	Purposive	3	Interview schedule
Nyamira County Department of Environment, water, mining & natural resources officials	10	30% of the population size	Purposive	3	Interview schedule
One acre fund officials	5	30% of the population size	Purposive	2	Interview schedule
KMD officials	5	30% of the population size	Purposive	2	Interview schedule
KARLO officials	10	30% of the population size	purposive	3	Interview schedule
Kenya Forestry Service officials	10	30% of the population size	Purposive	3	Interview schedule
The National Agricultural and Rural Inclusive Growth Project (NARIGP)	10	30% of the population size	Purposive	3	Interview schedule
KeFRI officials	10	30% of the population size	Purposive	3	Interview schedule
Three Focus Group Discussions (FGDs)		8-12	Quota	8-12	FGD guide
Observation			Purposive		Observation Checklist

Source: Researcher (2023)

3.6.2 Secondary Data Sources

A secondary data source was used to obtain climate data from Kenya Meteorological Department datasets. This was used to achieve objective one, which sought to determine the climate trends and patterns. Additionally, secondary data from books, journals, electronic data, dissertations, and theses were used to collect information on climate-smart agriculture and food security. The daily dataset for rainfall and daily minimum and maximum temperature obtained from KMD for Nyamira station was utilized from 1990 to 2019. The daily datasets for rainfall and temperature were manipulated into monthly and annual datasets for easy analysis. After that, the data sets were transferred from MS Excel to R-INSTAT software for analysis. The seasons were divided into four seasons: March-May (MAM), June-August (JJA), September-November (SON), and December-February (DJF). The dataset was then explored through Mann-Kendall to obtain the trends and patterns to achieve the study's first objective.

3.6.2.1 Missing Data

Nyamira meteorological station data used for this study had continuous datasets. However, for stations with limited missing data, gaps are filled using data from years with similar climatic characteristics. Alternatively, gaps could be filled using data from neighbouring stations (homogenous) within the same zone (Ogallo, 1980). Either of the two methods could be used based on the appropriateness of the specific case under consideration

3.7 Validity and Reliability Of Research Instruments

3.7.1 Validity

As described by Mugenda and Mugenda (2003), validity pertains to the precision and significance of inferences drawn from research findings. In contrast, according to Joppe (2000), validity relates to the accuracy of results and the extent to which the research effectively measures its intended objectives. To assess the validity of the research instruments, a pilot study was conducted in Kisii County, involving a 10% sample (38 households) selected from the total survey sample size, as outlined by Connelly (2008) and Moore *et al*., (2011). This is because Kisii County has ecological zones and climatic conditions similar to those in the study area. Therefore, the kinds of crops grown in the two counties are identical. This pilot study aimed to identify potential shortcomings in the research tools and highlight unclear or ambiguous items.

To strengthen the argument that these research instruments were valid, assistance from recognized professionals was sought. The tools developed were first taken to the Department of Disaster Management and Sustainable Development at Masinde Muliro University of Science and Technology, where some samples were shown to professionals in the discipline. Specifically, the Content Validity Index (CVI) was used quantitatively to assess the instruments' degree of validity. Therefore, the following formula was considered to determine the CVI for questionnaires, interview schedules, focus group discussions (FGDs), and observation checklists.

…………………… Equation 3.3

Where;

n = the number of items declared valid

N = total number of items

The Content Validity Index (CVI) was used to calculate the statistical proof of all the research tools. It was used to measure the items that were valid in the tools. Polit *et al*., (2001) state that CVI on consensus rather than consistency provides item and scale information (Polit *et al*., 2001). Therefore, the following formula was used for questionnaires, interview schedules, and observation checklists to calculate the CVI for the tools, as shown in Table 3.8.

Table 3.7: Determination of the Content Validity Index for data collection tools in Nyamira County, Kenya

Instrument	Section	Valid item	Invalid item	Total
Household Questionnaire	A	12	0	12
	B	5	2	7
	C	10	1	11
	D	6	2	6
	E	28	2	30
	F	7	1	6
	Total	**68**	**8**	**72**
Interview schedules	A	9	2	13
	B	6	1	7
	C	9	3	12
	D	10	2	12
	E	13	0	13
	F	11	1	13
	G	12	0	12
	Total	**61**	**7**	**69**
Observation Checklist	A	15	1	16
	Total	**15**	**1**	**16**

Source: Researcher (2023)

The calculated content validity index for the household questionnaire, interview schedules, and observation checklist are shown.

CVI (HHQ) =

CVI (IG) =

CVI (OC) =

The instruments are considered valid when the computed CVI exceeds 0.7 (Polit *et al*., 2001). Hence, the household questionnaire, interview schedules, and observation checklists were declared valid at 0.94, 0.88 and 0.94, respectively.

3.7.2 Reliability

A split-half reliability approach was employed to ensure the reliability of the questionnaires. During the pilot test, the researcher administered the entire instrument to a sample of 38 households possessing characteristics similar to those in the study area. This was done to identify any issues related to the questions, their sequence, and how responses were recorded. Consequently, the pilot study played a crucial role in rectifying errors and omissions in the questions and determining the research instruments' validity and reliability.

The spearman-brown prophecy formula was used to calculate the reliability. The questions were divided into odd and even-numbered, and the total scores were calculated. According to Fraenkel *et al*., (2012), the instrument is considered reliable if the results produce a reliability coefficient of > 0.6. The formula that was used to calculate reliability is as shown.

……………………… Equation 3.4

Where;

Re reliability

2r correlation coefficient of 1^{st} half.

1+r correlation coefficient of 2^{nd} half.

A high coefficient value shows that the items share a high degree of correlation among themselves; hence, the items are internally reliable. The instrument was separated into odd-numbered and even-numbered questions. A value greater than 0.6 shows the tools' high level of consistency. Following the pilot study, all the questions that were not well framed, wrongly numbered, and unclear were modified, and other questions that were not included were also added. All these modifications led to the formulation of the final questionnaire. Finally, incorporating the change made, the reliability percentage was determined, and a value of 0.7 was obtained. Hence, the instrument was deemed valid for research purposes.

3.8 Data Analysis and Presentation

This section explains how the researcher analyzed and presented the data collected. The study used descriptive and inferential statistics to analyze the data and draw conclusions. The analysis was done based on the different data types collected in the field. They included the primary and secondary data, as well as the binary logistic model that was used for the third objective.

3.8.1 Primary Data Analysis

The study adopted both descriptive and inferential statistics (Table 3.4). Survey data collected through the ODK software was retrieved from the ODK application, coded, and cleaned, after which it was imported into a Statistical Package for Social Sciences version 25 for analysis. The analysis involved generating frequency distributions and cross-tabulations. Thematic and narration analysis techniques were used to analyze data from Focus Group Discussions and key informants. Inferential statistics included chi-square tests and correlation analysis.

3.8.2 Mann-Kendall Nonparametric Test

Secondary data from KMD included a time series for climate trends and patterns. The Mann-Kendall (MK) test was employed to identify trends and patterns. As Yue et al. (2002) explained, the MK test is a non-parametric method used to identify trends in time series data without assuming that the trends are linear. This test can detect monotonic trends, either increasing or decreasing, in various data types, including climate, environmental, and hydrological data. Furthermore, the MK test assesses whether the observed trend is statistically significant (Asfaw *et al*., 2018). Mugalavai & Kipkorir (2013) further assert that the Mann-Kendall test can be applied to data that do not conform to a normal distribution. This test evaluates whether y-values increase or decrease over time through a nonparametric monotonic trend regression analysis.

The statistical test determined the S value (statistic value) and the Z value (probability value). A positive S value suggests an upward trend, a negative S value indicates a downward trend and a zero value signifies no trend (Ahmad *et al.*, 2015). The variance of the rainfall was calculated to obtain the Z value. Additionally, the probability value associated with the S value and the sample size were computed to assess the significance of the observed trend.

3.8.3 Binary Logistic Model Specifications

The Binary logistic model was used to examine the influence of CSA practices on household food security. The study established the household's food security based on the HDDS for the 12 food groups that were scored. The households that had consumed each food group scored one, while those who did not consume scored 0 (Table 3.8). Therefore, the maximum score was 12 for the households that consumed each food group. Several studies (Abegunde *et al.*, 2022; Omotayo *et al.*, 2022; Omotoso & Omotayo, 2024) highlight the importance of dietary diversity (DD) in assessing food security. These studies establish a scoring system for DD: scores of 3 indicate low diversity, scores of between 4-6 represent medium diversity, and a score of 7 signifies high dietary diversity.

Table 3.8: Dietary Diversity food groups estimation

S/no	Food Group	Examples	Yes=1 No=0

1	Cereals	corn/maize, rice, wheat, sorghum, millet, or any other grains or foods made from these (e.g., bread, noodles, porridge, or other grain products) + insert local foods, e.g., ugali, porridge, or past
2	White Roots And Tubers	white potatoes, white yam, white cassava, or other foods made from roots
3	Vegetables	pumpkin, carrot, squash, or sweet potato that are orange inside + other locally available vitamin A-rich vegetables (e.g., red sweet pepper)
4	Fruits	ripe mango, cantaloupe, apricot (fresh or dried), ripe papaya, dried peach, and 100% fruit juice made from these + other locally available vitamin A-rich fruits
5	Meat, poultry	beef, pork, lamb, goat, rabbit, chicken, duck, other birds, insects
6	Eggs	eggs from chicken, duck, guinea fowl, or any other egg
7	Fish And Seafood	fresh or dried fish or shellfish
8	Pulses, Legumes, Nuts And Seeds,	dried beans, dried peas, lentils, nuts, seeds, or foods made from these (e.g., hummus, peanut butter)
9	Milk And Milk Products	milk, cheese, yoghurt, or other milk products
10	Oils And Fats	oil, fats, or butter added to food or used for cooking
11	Sugar/honey	sugar, honey, sweetened soda or sweetened juice drinks, sugary foods such as chocolates, candies, cookies and cakes
12	Spices, Condiments, Beverages	spices (black pepper, salt), condiments (soy sauce, hot sauce), coffee, tea, alcoholic beverages

Source: Swindale & Bilinsky (2006)

3.9 Study Limitations

The study limitations and delimitations included the following:

i. Socio-economic and political factors not directly related to climate may also influence food security in Nyamira County, potentially confounding the relationship between climate trends and food security. This was overcome with the control for confounding variables through qualitative data to isolate the specific impact of climate trends on food security.

ii. Secondly, small-scale farmers may have limited knowledge or awareness of climate-smart agriculture practices, leading to underreporting or misrepresenting existing practices. This was overcome by intensive training of research assistants on CSA practices before going to the field.

iii. Thirdly, the respondents may not give credible responses on the influence of CSA practices on food security. This was overcome by using various data collection tools to verify and triangulate the information collected from the respondents.

iv. Lastly, there was a limitation regarding the confidentiality of the data collected, especially when dealing with sensitive information such as household income, land ownership, or health status. This was overcome through anonymization and de-identification of personally identifiable information to minimize the risk of data breaches.

3.10 Study Assumptions

The study made the following assumptions based on objectives;

i. The study assumed that all the study areas in the County had adopted Climate Smart Agriculture practices, and therefore, it could assess those practices.

ii. Secondly, the study assumed that climate change and variability have affected food security in the study.

iii. The third assumption is that CSA practices uniformly improve food security among small-scale farmers.

iv. Lastly, small-scale farmers in Nyamira County have equal access to resources and knowledge necessary for implementing CSA practices.

v. The study assumed that all farmers in Nyamira County are small-scale farmers.

3.11 Ethical Consideration

Before commencing data collection, the researcher completed all the necessary documentation, including preparing questionnaires and interview schedules. To facilitate the research process, the researcher obtained an introductory letter from the MMUST Postgraduate Studies Directorate (Appendix XIII). This letter proved valuable when seeking a research permit from the National Commission of Science, Technology, and Innovation (NACOSTI) (Appendix XIV) to collect field data for the study. Additionally, the researcher obtained permission from the County Commissioner (Appendix XV), the County director of Education of Nyamira County (Appendix XVI), and the County Secretary's approval letter (Appendix XVII), as well as local community leadership, to gather the required data.

It is important to note that the respondent's involvement in the study was voluntary, and they had the right to decline or withdraw their participation at any point. The researcher refrained from using any form of coercion to compel participants to take part in the study and provided them with a consent form (Appendix II). The decision to participate in the study rested solely with the individuals involved.

CHAPTER FOUR

RAINFALL AND TEMPERATURE TRENDS AND PATTERNS ON FOOD SECURITY AMONG SMALL-SCALE FARMERS IN NYAMIRA COUNTY, KENYA

4.1 Introduction

This chapter presents an analysis of objective one, which aimed to determine the rainfall and temperature trends and patterns in Nyamira County from 1990 to 2019. It kicks off by analyzing the demographic characteristics of the respondents. Subsequently, it transitions into the chapter, which examines rainfall and temperature, unveiling the patterns and trends that have shaped the climatic landscape over the past three decades.

4.2 Demographic Characteristics and Food Security

This section scrutinizes the demographic attributes of the study respondents within Nyamira County, Kenya. Commencing with an examination of the response rates to the questionnaire. The subsequent discourse sections present a comprehensive analysis of response return rate and demographic characteristics, encompassing variables such as gender, academic qualifications, age bracket, marital status, agricultural activities, household size, monthly income, and the land tenure system prevalent within their households, climate change and finally rainfall and temperature trends about the food security in Nyamira County, Kenya.

4.2.1 Gender of Respondents and Food Security

The study established the gender of respondents in the study area. As illustrated in Figure 4.1, the findings show that 53.2% (204) of them were males, while 46.8% (180) were females. A chi-square test was conducted to assess the significance of gender differences. The calculated value of indicates a statistically significant variation in gender among the respondents ($p < 0.000$). This is the scenario since the study was administering the questionnaires to the household heads who in the African society are mostly male, Nyamira County included.

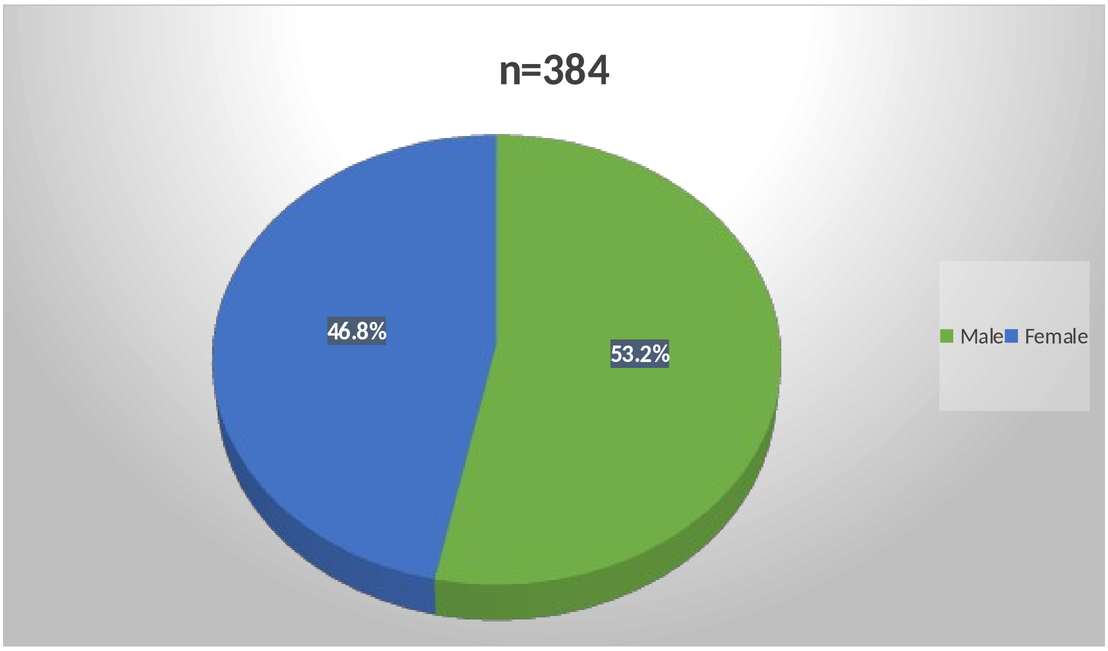


Figure 4.1: Gender of small-scale farmers in Nyamira County, Kenya

Source: Researcher (2023)

This demographic insight is pivotal in understanding the decision-making landscape in small-scale farming. Since men primarily hold the role of household head, they may have greater influence over farm management practices, including decisions related to CSA adoption. However, women in these households often play essential roles in agricultural activities and are directly impacted by food security issues. Therefore, this gender dynamic has implications for CSA uptake and effectiveness, as interventions may need to address the different roles, access to resources, and challenges both male and female farmers face.

Recognizing the significance of gender in this context underscores the need for gender-sensitive CSA policies and support mechanisms that actively engage both men and women. Such an approach could enhance the inclusivity and impact of CSA interventions, ultimately contributing to more resilient and sustainable food systems in Nyamira County and similar regions.

Nyang'au *et al*., (2021) assert that the males were the primary decision-makers over the land use in most households. The focus group discussions (FGDs) conducted showed that, in many cases, men play a pivotal role as primary decision-makers in land use in Nyamira County, Kenya. Therefore, their consultation is deemed essential, particularly during the planting season, to determine what crops will be planted and the specific locations for cultivation. Moreover, according to Kumba (2015), who did a study on the role of household characteristics in determining food security in Kisii Central Sub-County, Kenya, revealed that the gender of the household head significantly influences household dynamics, including farm management and income-generating prospects, consequently shaping household food security. The study findings revealed that males led 81.3% of households, while females led 18.7%.

Additionally, a study by Mairura et al., (2021) on determinants of farmers' perceptions of climate variability, mitigation, and adaptation strategies in the central highlands of Kenya found that there were more male-headed households than female-headed ones. Moreover, Amadu *et al*. (2020) posit that gender is a crucial factor influencing agricultural technology adoption. Women's engagement in agriculture is constrained by the dynamics of both on-farm and off-farm labour, as highlighted by Dimova *et al*., (2015), along with other factors such as limited access to land (Bhaumik *et al*., 2016).

Musafiri *et al*.'s (2022) research on the uptake of climate-smart agricultural practices among smallholder farmers in Western Kenya revealed that the gender of the household head had a detrimental effect on the intensity of Adoption of Climate-Smart Agriculture Practices (CSAPs). The findings indicated that households led by females were more inclined to intensify their agricultural practices than those led by males. This conforms with the results of this study.

A study by Agarwal (2018) highlights that women are critical in ensuring food security for families and nations. They take on multiple roles, acting as producers, managers of food within the household, and consumers. As producers, women constitute a substantial and growing proportion of agricultural workers, as more men than women tend to leave the agricultural sector first. In 2012, 43% of all farm workers in Asia and 47% in Africa were female, with percentages close to 50 or higher in Southeast and East Asia.

This is supported by Ingutia and Sumelius (2022), who suggest that in Africa, women typically face barriers to accessing resources and knowledge. This is attributed mainly to social and cultural norms that limit women's decision-making abilities, as well as their access to productive resources and specific agricultural technologies; hence, it influences food security in a household.

Their limited access to irrigation technologies hinders the pivotal role of women in providing food and water. However, their significant contribution underscores the necessity for their active participation in addressing food security challenges (Ingutia & Sumelius, 2022). Kassie *et al*., (2012) affirm that, as the primary food producers and significantly responsible for providing food for the households in both female and male-headed households, african women have limited access and control over agricultural assets and inputs compared to men, thus limiting their access to food production hence food insecurity in the households. The case for Nyamira County could be more exceptional since the women had unequal land access in the study area.

This is supported by Sherah and Theuri (2015), who identified a significant flaw in Kenyan agricultural policy, noting the oversight of the crucial role played by women in the production of the nation's food supply. Despite being responsible for the vast majority of food production for their families across the country, Kenyan women own only one percent of the land. Additionally, they receive less than seven percent of farm extension services and less than ten percent of the credit allocated to small-scale farmers. Furthermore, they often suffer from undernourishment, overwork, illiteracy, and lack of representation in Kenyan society.

Additionally, Zhou *et al*., (2019) discovered that gender played a significant role in food insecurity, with female-headed households being more prone to food insecurity, while male-headed households tended to be food secure. In addition, a study by Drammeh *et al*., (2019) underscores the significance of gender in food security, highlighting that women play a crucial role in ensuring food availability, accessibility, and utilization. They note that women contribute substantially to the production of cultivated foods in Sub-Saharan Africa. However, despite their contribution, females are more vulnerable to food insecurity than males.

Improving women’s access to land, livestock, education, financial services, extension services, technology, and employment opportunities in the rural sector would not only lead to increased productivity of these women. Still, it would also positively contribute toward improving agricultural production, food security, economic growth, and social development (FAO, 2011). These findings emphasize the importance of gender in attaining food security in households.

4.2.2 Household Head and Food Security in Nyamira County, Kenya

The study aimed to establish whether the respondent was a household head. From the findings in Figure 4.2, 75% (288) of the respondents were household heads of their respective households, while 25% (96) were not the households' heads. This distribution is crucial for understanding the potential impact of CSA interventions within households. Household heads typically control essential resources and make primary decisions regarding farming practices, which is vital in CSA adoption. Given that most respondents were household heads, these findings suggest a promising alignment between the target audience of CSA initiatives and the decision-makers within these households. Engaging this demographic directly in CSA training and support programs could lead to more effective implementation and wider adoption, enhancing food security outcomes for small-scale farmers in Nyamira County.

Moreover, understanding the role of non-household heads, comprising a quarter of the respondents, is equally essential. Although they may not be the primary decision-makers, they are often active participants in agricultural activities and can influence household practices indirectly. Thus, CSA initiatives would benefit from a holistic approach that considers the roles and contributions of household heads and other household members to maximize food security and resilience within these farming communities.

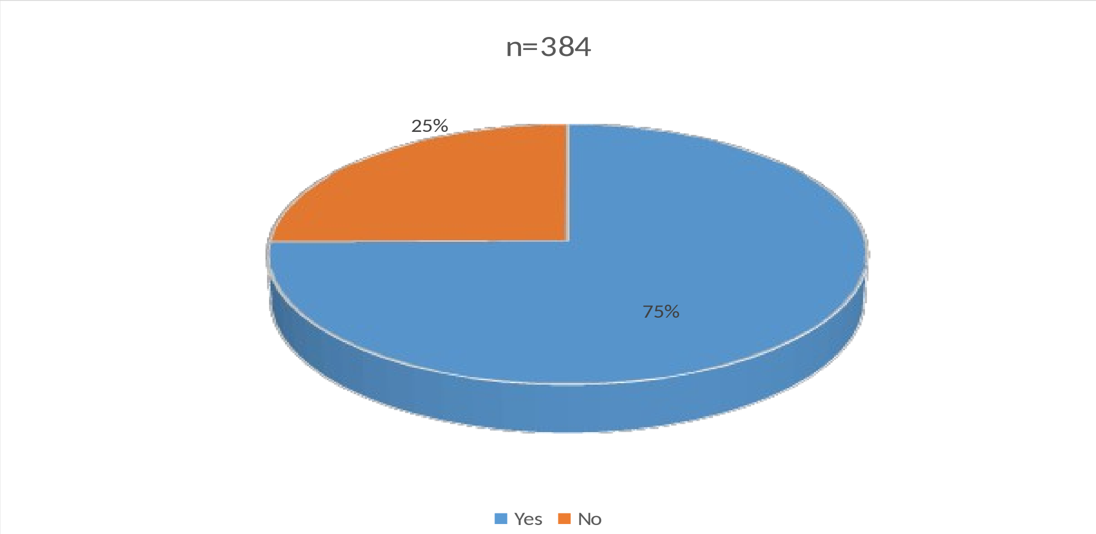


Figure 4.2: Household head of small-scale farmers in Nyamira County, Kenya

Source: Researcher (2023)

A Chi-Square test was performed to evaluate the significance of differences among household heads. The computed value of suggests no statistically significant variation in household heads among the respondents ($p > 0.212$).

This conforms to the study's ethics as the study intended to collect information from the household heads since they are the ones who make critical decisions in the family concerning farming practices within families, a pattern observed in African societies, including Nyamira County. This is in tandem with Nyang'au *et al.*, (2021), who assert that males are the main decision-makers over land use in most households and, therefore, the household head. The head of the household decides what is to be planted, when, and where; therefore, they are key to adopting the CSA practices.

Additionally, Kassie *et al.*, (2014) assert that because of multiple forms of inequality, female-headed households in rural areas in Kenya tend to be more vulnerable than male-headed households. They are also more susceptible to experiencing food insecurity and the non-monetary dimensions of poverty compared to male-headed households. According to Lutomia *et al*., (2019), in their study, male-headed households were more likely to stay in their existing food insecurity status or even experience a more severe category of food insecurity. This observation indicates that female household heads are crucial in mitigating food consumption shortages and enhancing household food security. Additionally, the study suggests that women-led households prioritize efforts to improve food security. Furthermore, this trend might be attributed to female-headed households being the predominant form of household leadership.

4.2.3 Land Size of Households and Food Security

The study determined the land sizes of the households in hectares. The findings are summarized in Figure 4.3. From the findings, 53.0 % (204) of the households had land size less than one hectare, followed by 43.0% (165) with between 2-4 hectares, and lastly, 4.1%(15) of them had between 5-7 hectares of land. A chi-square computed on the land size for households showed a statistically significant variation among the land sizes with with ($p < 0.000$).

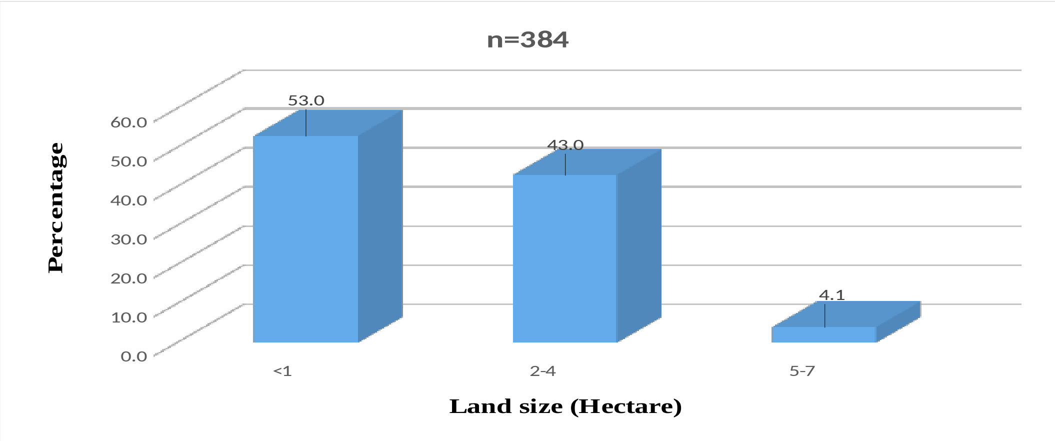


Figure 4.3: Land size of small-scale farmers in Nyamira County, Kenya

Source: Researcher (2023)

The results agree with the Nyamira County CIDP (2023) that found that in the Borabu Sub-county area, individual large-scale farmers typically own around 4 hectares, while small-scale farmers in other sub-counties average about 0.7 hectares. Many of these farm holdings are concentrated in areas with high agricultural potential.

These findings underscore a critical challenge for CSA adoption and food security among small-scale farmers in Nyamira County, where most households operate on minimal land. Smaller land sizes can limit the scope of agricultural diversification, soil conservation, and other CSA practices, which are essential for enhancing productivity and resilience to climate change. Consequently, households with less than one hectare may face more significant constraints in achieving food security and sustaining CSA practices effectively.

The statistical significance of these land size variations also points to the need for tailored CSA approaches that address the specific limitations faced by households with smaller plots. For instance, intensification practices, such as intercropping, soil management, and efficient water use, could be promoted among these farmers to optimize productivity on limited land. Conversely, households with larger parcels may have more flexibility to experiment with CSA practices like agroforestry or crop rotation. Addressing these differences in landholding capacities is vital to maximizing the benefits of CSA interventions and improving food security outcomes in the region.

Additionally, Wolde *et al*., (2020), in their study conducted in Ethiopia on Land size and landlessness as connotations for food security in rural low-income farmers, highlighted that households in the region were notably susceptible to food insecurity, primarily due to landlessness and land fragmentation. The insufficient size of land and its fragmentation emerged as the primary factors leading to decreased food production and lower income levels in these areas, making it challenging to produce an adequate quantity of food.

This is supported by Muhammad and Siddique's (2019) study conducted in Nigeria, which revealed that land size significantly influences food production. Consequently, households with larger farm sizes are expected to have greater food security than those with smaller farms. They hypothesized a positive correlation between food security and farm size. This is one of the contributors to food insecurity in Nyamira County since the land sizes are small due to over-fragmentation of the land due to population increase. This makes the households have small pieces of land that cannot produce enough food for the households, hence rendering them food insecure.

In Nyamira County, only Borabu Sub-County has large pieces of land, but most households practice large-scale cash crop cultivation. According to the Nyamira County Executive Committee Member (CECM) for agriculture noted that:

> "Most farmers have apportioned a lot of their land to cash crops with just minimal portions to food crops, endangering their ability to sustainably access food for their households (Deborah, October 18, 2023)."

4.2.4 Households Level of Education and Food Security in Nyamira County, Kenya

The research analyzed the educational qualifications of the participants in the study region. As shown in Figure 4.4, a considerable portion, comprising 43.5% (167), had completed primary education, closely followed by 43.2% (166) who had attained a secondary level of education. A smaller percentage, 9.2% (35), had reached university or tertiary education levels, while 3.0% (12) had no formal education. Additionally, 1.1% (4) had pursued postgraduate education.

These findings highlight a generally low level of higher education within the respondent population, which can have substantial implications for adopting innovative agricultural practices such as CSA. Individuals with primary or secondary education may possess foundational knowledge. Still, they could benefit from further training and capacity-building initiatives that enhance their understanding of sustainable farming practices, climate resilience, and market access.

The notable percentage of respondents with no formal education underscores the importance of designing educational programs that are accessible and relevant to this demographic. Tailoring CSA training to be practical and culturally relevant can empower these farmers to make informed agricultural practices and resource management decisions, ultimately contributing to improved food security.

Moreover, the relatively small number of participants with higher education indicates an opportunity for targeted interventions that engage educated individuals in knowledge dissemination and leadership roles within their communities. Such engagement can help bridge the gap between traditional practices and innovative CSA approaches, fostering a more resilient agricultural system in Nyamira County. Thus, the educational qualifications of respondents not only provide insights into the current capacity for adopting CSA and inform strategies for enhancing education and training initiatives tailored to the specific needs of small-scale farmers.

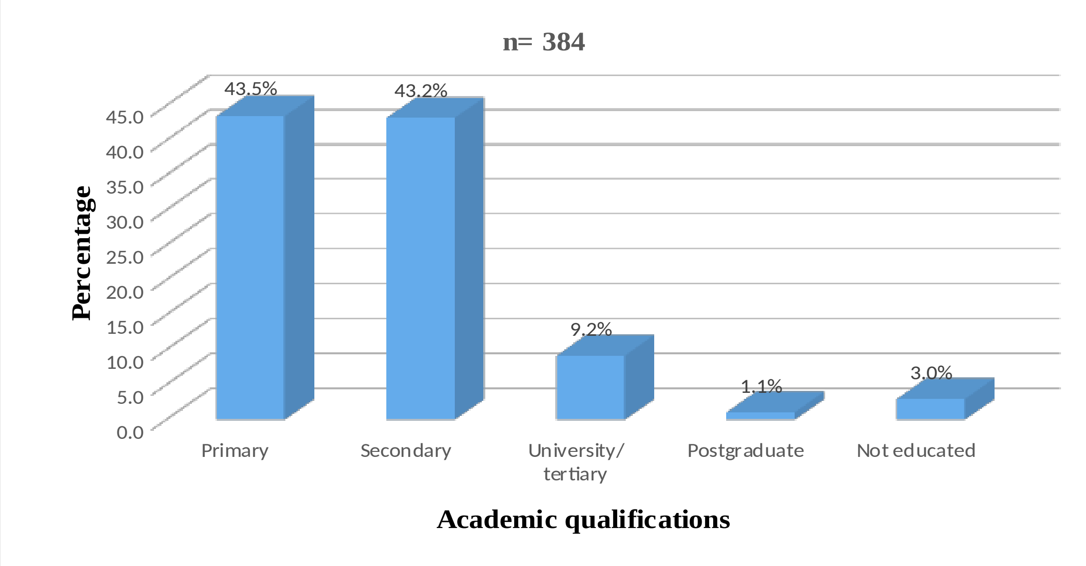


Figure 4.4: Education level of small-scale farmers in Nyamira County, Kenya

Source: Researcher (2023)

A chi-square test assessed the significance of differences in academic qualifications. The calculated value of indicates a statistically significant variation in academic qualification among the respondents ($p < 0.000$). The results align with the Mairura *et al*. (2021) study, which found that most farmers had attained primary and secondary level qualifications, totalling 79.4% of the farmers. Amir *et al*. (2020) and Mutunga *et al*. (2018) posit that higher educational attainment is likely to significantly impact the adoption of CSA practices, enhancing resilience against climate variability and change. Furthermore, Monirul *et al*., (2018) assert that the household head's educational attainment has a positive and significant relationship with household food security status.

Additionally, individuals with higher levels of education among the respondents are more likely to adopt CSA practices. This is attributed to their ability to receive, interpret, and comprehend pertinent information, enabling them to make informed decisions, as Ochieng *et al*. (2012) suggested. Furthermore, farmers with relatively advanced education are more likely to embrace technologies that enhance adaptation, given their capacity to perceive climate changes and access information (Nkonya *et al*., 2008). This is supported by a study conducted in Ethiopia by Kifle *et al*., (2022), which found that farmers with higher levels of education tend to be less risk-averse and more willing to adopt CSA practices compared to those with lower levels of education. This is because higher education levels expose a person to information and technology.

Moreover, as stated by Kurgat *et al*., (2020), it is emphasized that farmers with higher levels of education are inclined to participate more in off-farm activities, yielding increased returns on labour. These farmers tend to invest in technologies only when they promise superior returns. Conversely, educated farmers exhibit a greater capacity to comprehend the advantages of Climate-Smart Agriculture (CSA), potentially promoting its adoption. This was supported by Njogu *et al*., (2024), who assessed the determinants of scaling up pathways for adopted CSA Climate Smart Agricultural practices: Evidence from Climate Smart Villages in Nyando Basin, Kenya observed that the majority of farmers with low education level used more on indigenous knowledge, cultural beliefs and often related conventional knowledge with costs. One of the key informants in the study emphasized the importance of education in the adoption and utilization of CSA practices. The key informant stated that;

> "Masomo in kitu ya maana sana. Wakulima wenye wamesoma wanaelewa umuhimu and haja ya kutumia CSA (education is critical, and those farmers who are literate get to understand the importance and need to adopt CSA practices)" (interview with extension officer on 21st February 2024 conducted at the Nyamira Ministry of agriculture offices)

Nkomoki *et al*., (2019), in their research on factors linked with household food security in Zambia, found that household heads with higher levels of education were more likely to achieve food and nutrition security. This agrees with Kara & Kithu's (2020) study that revealed that 71.4% of households categorized as severely food insecure with hunger lacked formal education. Among households classified as moderately food insecure with hunger, the majority (52.5%) had attained primary education. Additionally, a significant portion (56.1%) of household heads with secondary education fell between food secure and food insecure without hunger. Conversely, most (70.2%) of household heads with post-secondary education were classified as food secure. These results suggest that enhancing the educational attainment of household heads contributes to improved household food security status in Yatta Sub-County. This emphasizes the importance of education in attaining food security in a household.

4.2.5 Age of Household Head and Food Security in Nyamira County, Kenya

The study also aimed to determine the age of the respondents. The findings are summarized in Figure 4.5. The findings show that 55% (212) were of age 36-50, 22.4% (87) were 51-65 years, 18.9% (73) were 18-35 years, and lastly, 3.2% (12) were over 66 years. The age bracket of 36-50 years is the age that is productive and actively involved in agriculture activities in Kenya. Chi-Square test was conducted to assess the significance of age bracket differences. The calculated value of indicated a statistically significant variation in age among the household heads ($p < 0.000$).

This significant finding underscores the importance of targeting the most productive age groups for CSA initiatives. The predominance of individuals aged 36 to 50 suggests that this demographic will likely be at the forefront of implementing innovative agricultural practices, as they possess the energy and motivation to engage in new methodologies to enhance productivity and resilience.

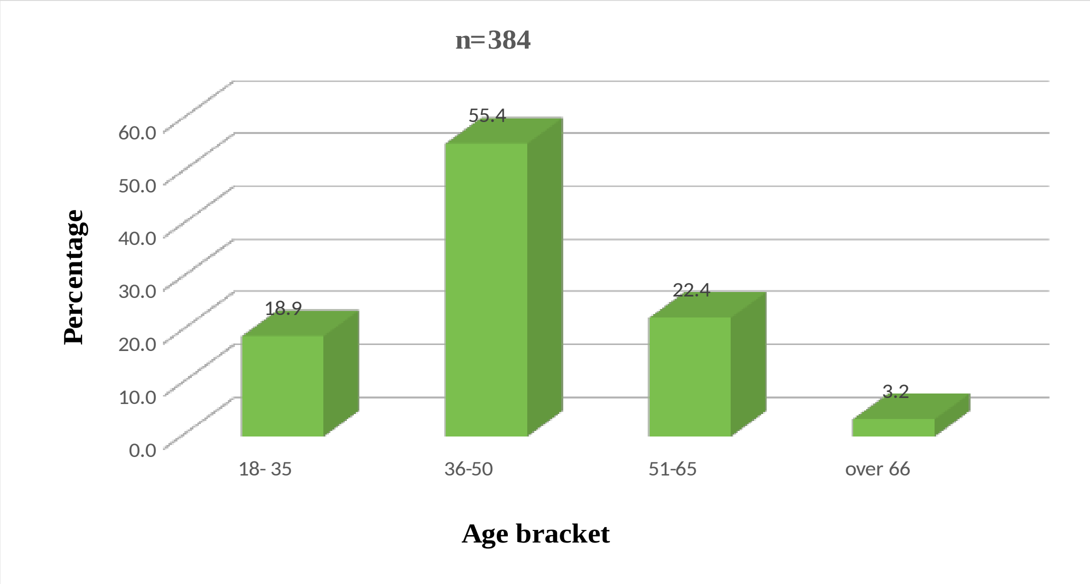


Figure 4.5: Age bracket of small-scale farmers in Nyamira County, Kenya

Source: Researcher (2023)

Moreover, the implications of these findings are twofold. Firstly, interventions promoting CSA should focus on this critical age group, leveraging their potential for leadership and influence within their communities. Tailored training and resources can empower these farmers to adopt CSA practices that improve their agricultural output and sustainability.

Secondly, the presence of younger respondents (18 to 35 years) indicates an opportunity for cultivating a new generation of farmers who are adaptable and open to innovative practices. Engaging this demographic through education and mentorship programs can foster a culture of sustainability and resilience in agriculture.

Conversely, the smaller percentage of older respondents (over 66 years) may have varying capacities for adopting new practices, and their traditional knowledge should also be respected and integrated into CSA strategies. This demographic diversity highlights the need for inclusive approaches that consider each age group's different experiences and capacities in promoting climate-smart agricultural practices and enhancing food security in Nyamira County.

Similarly, Mango *et al*., (2014), conducting a study in Zimbabwe, reveal and demonstrate that the householder's age and level of experience influence the household's food security. The education level of the household head is used as an index to knowledge, as the notion is that as the household head gains experience in farming, the amount of knowledge about food security issues is likely to rise. Similarly, Zhou *et al*. (2019) mentioned that age is another determinant that can influence household food security.

Tran *et al*., (2020) conducted research in Vietnam and revealed that the farmer's age emerged as a significant factor influencing the decision to embrace CSA. This observation is corroborated by a study by Mashi *et al*., (2022), which demonstrated that increased age among farmers corresponds to a higher level of awareness regarding CSA adaptation strategies.

The phenomenon is attributed to two main factors: most young people migrate from rural to urban areas in search of employment and improved prospects, leaving the elderly behind in rural settings. Secondly, the younger population tends to avoid engaging in farming activities, perceiving them as tasks reserved for the elderly and often associating them with dirtiness, hence unattractive. This is true with the findings of this study, which found that most household heads were between the ages of 36 and 50 years.

Additionally, according to Njora and Yilmaz, 2022, fewer young people are interested in farming in Kenya. In 1995, over 60% of young workers were in agriculture, but by 2020, that number had dropped to less than 28%. There are several reasons for this decline. Many young people see farming as outdated and unprofitable, and they prefer careers in business instead. This is a problem because young people could replace older farmers who are retiring (Gok, 2019).

In addition, other barriers make it hard for young people to get into farming. They often lack access to information on new technologies that can help them farm smarter in a changing climate. Some also have trouble getting land, financing, or the knowledge to use new technologies effectively. Even government programs that help young farmers can be poorly coordinated and difficult to navigate. Despite these challenges, young people are still a valuable resource for agriculture. They are innovative and energetic, and they could be a driving force behind new ways of farming that are better for the environment (Makau *et al*., 2023).

4.2.6 Marital Status of Respondents and Food Security in Nyamira County, Kenya

Another variable that the study measured was the marital status of the respondents. The findings are shown in Figure 4.6. The findings reveal that a substantial majority, 77.8% (299), of the respondents were married. This strong representation of married individuals highlights the importance of family and collective decision-making in agricultural practices, as these respondents are likely to collaborate with spouses and other family members in farming activities.

In addition to the married respondents, 14.1% (54) were widowed, while 6.5% (25) identified as single. A smaller proportion, 0.8% (3), reported being divorced or separated. These statistics indicate a predominantly stable family structure, which can facilitate the sharing of resources and responsibilities within households engaged in farming.

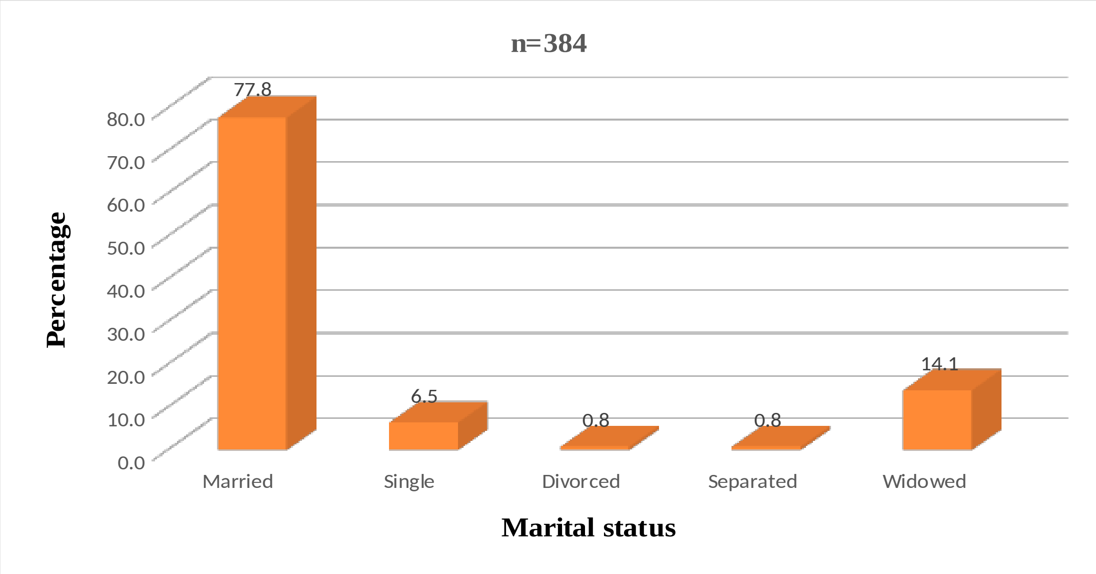


Figure 4.6: Marital status of small-scale farmers in Nyamira County, Kenya

Source: Researcher (2023)

The predominance of married individuals may affect adopting climate-smart agriculture (CSA) practices. Married respondents may be more inclined to invest in long-term agricultural strategies that support family well-being and food security, as collective family goals often influence their decisions. Furthermore, married couples may benefit from shared knowledge and experiences, enabling them to adopt CSA practices more effectively.

Conversely, the relatively smaller percentages of widowed, single, divorced, and separated individuals may face unique challenges in agricultural decision-making and resource management. For instance, widowed individuals may have to navigate farming alone, limiting their ability to adopt new practices due to a lack of support or collaboration. Similarly, single or divorced respondents may not have the same access to family resources and networks that can facilitate CSA adoption. A chi-square conducted to determine whether the different marital statuses were significant or not found a value of indicating a statistically significant variation in marital status among the household heads ($p < 0.000$).

The findings are in tandem with those of Nyang'au *et al*., (2021), which indicated that 81% of the respondents were married, 7.1% were single, and 11.7% were divorced, widowed, or separated. This shows a stable marriage situation in the area (Nyang'au *et al*., 2021). Additionally, this finding aligns with the findings reported by Girei *et al*., (2018), who suggested that married farmers are more likely to be dedicated to enhancing farm yields, hence food security, recognizing its critical role in sustaining their families.

4.2.7 Farming Activities Practiced and Food Security

The study established the farming activities that were practised in the study area. From Figure 4.7, 68.4% practised crop farming, 62.2% mixed farming, 42.2% livestock rearing, 36.6% cash crop farming, 7.5% horticulture farming, 0.6% apiculture and aquaculture farming. Additionally, other households practised agroforestry and vegetable farming in the study area.

These findings reflect a varied agricultural landscape, which is crucial for successfully implementing CSA strategies. The predominance of crop farming and mixed farming suggests that farmers are already accustomed to diverse agricultural practices, potentially easing the transition to more sustainable methods that enhance resilience against climate change. Integrating livestock and crop production can create synergies, such as utilizing livestock manure to improve soil fertility for crop production.

However, the relatively low participation in specialized farming activities like horticulture, apiculture, and aquaculture may indicate areas for potential growth and development. Introducing training and resources to encourage these practices could diversify income sources for farmers and improve overall food security. For instance, promoting horticulture could provide high-value crops more resilient to market fluctuations, while aquaculture and apiculture can offer alternative livelihoods that complement traditional farming.

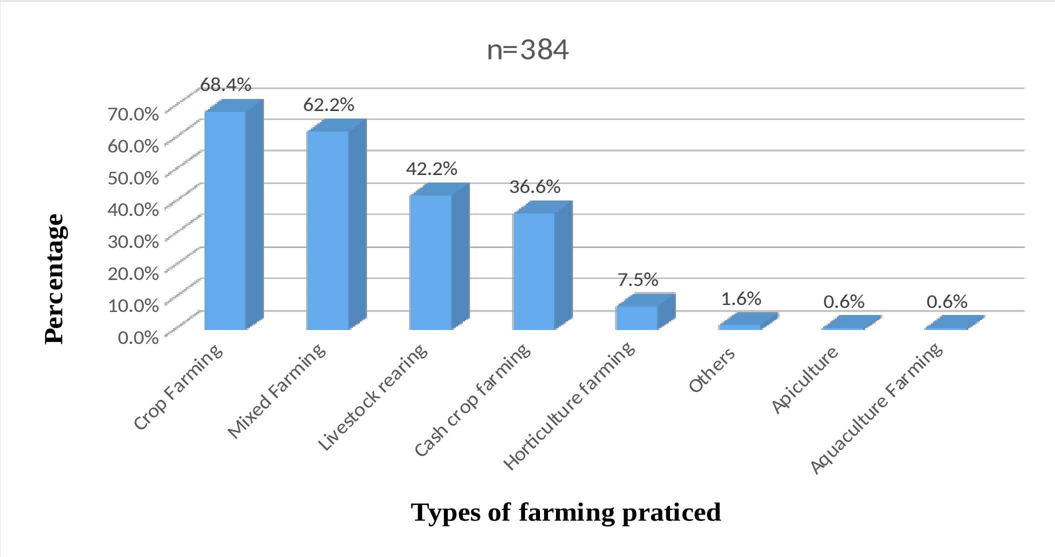


Figure 4.7: Farming practised by small-scale farmers in Nyamira County, Kenya

Source: Researcher (2023)

Understanding the farming activities prevalent in the area is vital for tailoring CSA interventions that align with local practices and preferences. Programs can effectively enhance productivity, sustainability, and food security among small-scale farmers in Nyamira County by fostering a holistic approach that integrates various farming methods.

According to Mango *et al*., (2018), diversifying crops offers small-scale farmers a wider range of dietary options, enhances their income, and bolsters nutrition security. In less marginal environments, the interaction between crops and livestock can lead to a sustainable rise in both food crop and livestock output. Within impoverished rural communities, livestock are frequently viewed as valuable assets. The accumulation of livestock enables financially disadvantaged households to venture into small enterprises, broaden their income sources, and alleviate poverty, all of which typically bolster food and nutritional security (Sekaran *et al*., 2021).

Waha *et al*., (2018) suggest that households with a wider array of farming activities tend to be more adept at fulfilling their consumption requirements. Enhanced farming diversity can positively affect household food security. However, this correlation is subject to various factors such as the household's market focus, ownership of livestock, availability of non-agricultural job opportunities, and the extent of land resources at their disposal. Their research revealed that food availability at the household level rises with farming diversity, regardless of factors like land area, ownership of livestock, and income from off-farm sources, albeit only up to a certain diversity threshold.

4.2.8 Household Size and Food Security

The research aimed to ascertain the household membership count, revealing that, on average, males and females constituted approximately two members each. Children below 18 years had an average of one member, while those above 65 years had an average of zero. Consequently, the average household size was four members (Table 4.1). These insights into household composition provide valuable context for examining agricultural practices and food security among small-scale farmers in Nyamira County. The average household size of four suggests a relatively small but potentially supportive family structure where resources, labour, and responsibilities can be shared among members. Such a configuration is likely beneficial for agricultural productivity, as family members can collaborate in various farming activities, enhancing efficiency and fostering a shared commitment to improving food security.

Table 4.1: Family size of small-scale farmers in Nyamira County, Kenya

Household size	Mean	Standard deviation
Males	2.48	1.39
Females	2.51	1.47
Children below 18 years	1.68	1.26
Members above 65 years	0.24	0.53

Source: Researcher (2023)

Ojo *et al*., (2023) assert that household size can influence household expenditure on food, clothing, and shelter. This finding aligns with Nyang'au *et al*.'s (2021) study, which reported an average family size of four in Kisii County, with most households ranging between four and six members. Marenya and Barrett (2007) assert that a larger family size is advantageous, as it provides the necessary labour for agricultural activities. Onyeneke *et al*., (2018) concurs that family size is a crucial determinant of CSA in southeast Nigeria. Musafiri *et al*., (2022) and Obi and Maya (2021) further assert that household size influences the adoption of CSA.

Additionally, Ngigi and Muange (2022), in their research investigating access to climate information services and climate-smart agriculture in Kenya with a gender-based analysis, present compelling results regarding the impact of household size on women. The study reveals that larger household size harms wives' adoption of various crop types. This suggests that a greater household size may increase the burden on women, particularly regarding family matters such as food preparation and childcare responsibilities (Ngigi and Muange, 2022).

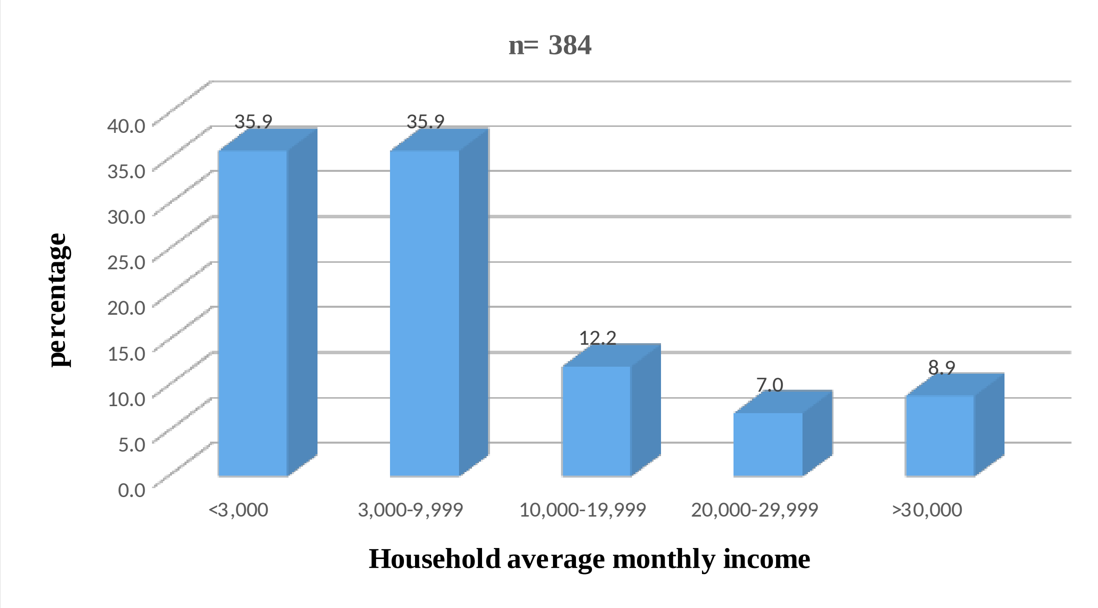
In their study, Drammeh *et al*., (2019) highlight household size as a critical factor influencing household food security. They emphasize that larger family sizes impose additional pressure on food consumption, making households more susceptible to food insecurity than those with smaller family sizes. This is because as the number of members in a family increases, there is always an increase in food. This is confirmed by Olayemi (2012), who studied the effect of family size on household food security in Osun State, Nigeria. The study concluded that large family size has a negative impact on house food security. Abebaw and Betru (2019) further emphasize the multiple factors influencing household food security in Ethiopia. Among these factors is household size, which plays a significant role in determining the level of food security within households.

Mekonnen et al. (2021) also identified a negative correlation between family size and food security. This means that larger families faced more significant challenges in securing food. As families grew, their farmland became fragmented, forcing them to change their cropping patterns. This competition for limited land resources also increased land degradation and conflicts.

Therefore, households without access to arable land and no off-farm employment are at risk of being food insecure. Furthermore, specific family members, such as expectant mothers, children, and the elderly, have unique dietary needs that must be addressed with specialized food. Consequently, households must consider the diverse nutritional requirements of their various members.

4.2.9 Household Income and Food Security in Nyamira County, Kenya

The study determined the household income of the various respondents in the study area. The results are presented in Figure 4.8. The findings show that those who earned less than 3,000 shillings (<22 USD) per month were 35.9% (138), and 3,000-9,999 shillings (22-76 USD) were also 35.9% (138). The population that earned 10,000-19,999 shillings (76-153 USD) was 12.2% (47). Those who were earning more than 30,000 shillings (229 USD) were 8.9% (34), and lastly, 7.0% (27) were earning 20,000-29,999 shillings (153-229 USD) per month.



***conversion rate: 1 USD= 130 Kenyan shillings**

Figure 4.8: Household monthly income of small-scale farmers in Nyamira County, Kenya

Source: Researcher (2023)

A Chi-Square test was performed to evaluate the significance of variations in household income. The calculated value of suggests a statistically significant difference in household income among the survey participants ($p < 0.000$). These findings highlight the prevalence of low-income levels among small-scale farmers in the study area, which can significantly impact their ability to adopt climate-smart agriculture (CSA) practices. Low-income limits access to essential resources such as quality seeds, fertilizers, and technology critical for improving agricultural productivity and resilience. Furthermore, limited financial resources can hinder farmers' capacity to invest in sustainable practices that may initially require higher upfront costs but yield long-term benefits.

The equal distribution of respondents earning less than 10,000 shillings underscores a potential vulnerability in the agricultural sector, as these income levels may not sufficiently cover household needs or allow for savings and reinvestment in farming activities. Addressing this income disparity is essential for fostering a supportive environment for CSA adoption, which could ultimately enhance food security.

To effectively engage these farmers, targeted interventions that provide financial support, access to credit, and training in income-generating activities are necessary. Such initiatives could empower small-scale farmers to improve their economic standing, facilitating their participation in CSA programs. By enhancing income levels, the community can better equip itself to face the challenges of climate change and ensure sustainable food production in Nyamira County.

These findings are similar to those of Nyang'au *et al*., (2021), who found that the average household income per month in Kisii County for the sampled households was Ksh. 6,271.68 (47.97 USD), with a standard deviation of Ksh. 7,599.11 (58.12 USD). Maguza-Tembo *et al*., (2017) contend that higher-income households are more prone to adaptation, given their greater financial capacity to purchase essential agricultural inputs and invest in practices that demand substantial capital.

4.2.10 Household Land Tenure System and Food Security in Nyamira County, Kenya

The study established the type of land tenure system in the study area. The findings are shown in Figure 4.9. From the findings, 97.6% (375) of the respondents had a freehold land tenure system while 1.6% (6) was leasehold, and finally, 0.8% (3) was communal land. The predominance of freehold land tenure suggests a level of security and ownership that can encourage farmers to invest in their land, adopt sustainable practices, and make long-term improvements. Freehold tenure often incentivises individuals to implement climate-smart agricultural practices since they can reap the benefits of their investments over time. This stability is vital for promoting soil conservation, agroforestry, and other techniques that enhance resilience to climate variability.

However, the low representation of leasehold and communal land tenure systems indicates a limited diversity in land ownership arrangements. Leasehold systems can sometimes offer flexibility and access to larger plots for agricultural production, while communal systems may promote collective resource management. The lack of these tenure types may constrain opportunities for certain types of farming arrangements or cooperative agricultural practices, which could be beneficial in adapting to climate challenges.

These findings highlight the need for policies that support land tenure security and promote sustainable land management practices among small-scale farmers. Ensuring that equitable and supportive land tenure systems can facilitate the adoption of CSA initiatives, which are critical for enhancing food security in the region. Moreover, educating farmers about their rights and responsibilities under different tenure systems can further empower them to optimize land use and invest in sustainable agricultural practices. Understanding the land tenure landscape is essential for tailoring interventions that enhance productivity and resilience among small-scale farmers in Nyamira County.

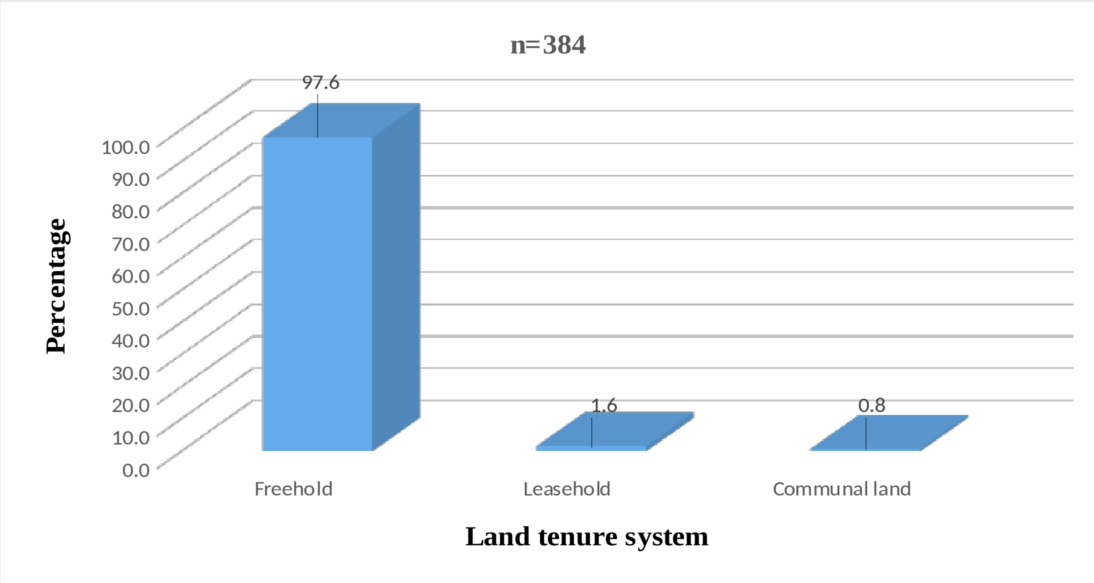


Figure 4.9: Land tenure system of small-scale farmers in Nyamira County, Kenya

Source: Researcher (2023)

A Chi-Square test was performed to evaluate the significance of variations in the land tenure system. The calculated value of suggests a statistically significant difference in the land tenure system among the survey participants ($p < 0.000$). This aligns with the Nyamira County CIDP (2018), which indicates that over 70% of the land in Nyamira County is categorized as freehold. Most leasehold land is in urban areas, market centres, and settlement schemes within the Borabu sub-county. Public land constitutes less than 10% of the total land in the County. Additionally, Aryal *et al*., (2018) emphasize that various characteristics of farm plots, including size, tenure status, availability of irrigation, soil fertility, depth, slope, and distance from the homestead, significantly impact farmers' choices regarding technology adoption. A study by Ndung'u et al. (2023) revealed that freehold land tenure might encourage farmers to make long-term investments in their lands, such as agroforestry and soil and water conservation (SWCs) practices.

Deng *et al*., (2020) highlight that secure land rights are essential for food security. This access allows people to farm the land effectively. As Nara *et al*., (2020) found, how land ownership is structured within a household (the land tenure system) significantly impacts their ability to achieve food security. This is because the system dictates how much land they can farm and how securely they can invest in its productivity. The importance of land tenure systems for food security is further emphasized by the experiences shared during focus group discussions. Participants highlighted that land ownership rights dictate what crops can be grown. Those with secure ownership, like freehold, can plant any crop regardless of how long it takes to mature because they know they have long-term access to the land. In contrast, farmers with leased land must choose crops that will mature within the lease period, potentially limiting their options and ability to grow more profitable or nutritious crops.

4.2.11 Correlation between Demographic Characteristics of Respondents and CSA Practices

The study established the correlation between the demographic characteristics of respondents and the CSA practices adopted. The findings are shown in Table 4.2.

Table 4.2: Correlation analysis of small-scale farmers' demographic characteristics and CSA practices in Nyamira County, Kenya

		Mixed cropping	Agroforestry	Crop rotation	Cover cropping	Organic farming	Drought resistant crops	Water harvesting	ISFM
Gender	Pearson Correlation	-.137**	-.036	-.140**	-.016	-.042	-.048	.001	-.087
	Sig. (2-tailed)	.008	.485	.007	.762	.418	.355	.990	.095
	N	384	384	384	384	384	384	384	384
land size(Hectare)	Pearson Correlation	.225**	.312**	.207**	.132*	.304**	.185**	.184**	.152**
	Sig. (2-tailed)	.000	.000	.000	.011	.000	.000	.000	.003
	N	384	384	384	384	384	384	384	384
Education levels	Pearson Correlation	-.042	-.046	-.029	-.096	-.133*	-.125*	-.091	-.045
	Sig. (2-tailed)	.419	.375	.577	.064	.010	.016	.080	.385
	N	384	384	384	384	384	384	384	384
Age bracket (years)	Pearson Correlation	.006	-.040	-.078	-.083	-.047	-.013	-.004	.048
	Sig. (2-tailed)	.903	.443	.132	.112	.370	.800	.931	.353
	N	384	384	384	384	384	384	384	384
Marital status	Pearson Correlation	-.034	-.039	-.016	.065	.060	.125*	.116*	-.003
	Sig. (2-tailed)	.515	.453	.758	.214	.250	.016	.025	.948
	N	384	384	384	384	384	384	384	384
HH income	Pearson Correlation	.122*	.294**	.097	.040	.097	-.002	.223**	.055
	Sig. (2-tailed)	.019	.000	.061	.442	.063	.963	.000	.295
	N	384	384	384	384	384	384	384	384
Land tenure system	Pearson Correlation	-.138**	.108*	.098	-.062	-.102*	-.022	-.052	.007
	Sig. (2-tailed)	.008	.038	.059	.235	.049	.669	.322	.891
	N	384	384	384	384	384	384	384	370

* Correlation is significant at the 0.05 level (2-tailed)

** Correlation is significant at the 0.01 level (2-tailed)

Source: Researcher (2023)

The findings indicate that gender plays a role in adopting certain agricultural practices. Specifically, mixed cropping and crop rotation exhibit a negative correlation with gender (Pearson Correlation = -0.137 and -0.140, respectively), both of which are statistically significant ($p < 0.01$). This suggests that males may be more actively involved in these practices than females, highlighting a potential gender disparity in agricultural engagement. A notable positive relationship exists between land size and several sustainable practices. The correlation with agroforestry (0.312), drought-resistant crops (0.185), and water harvesting (0.184) is particularly strong and statistically significant ($p < 0.01$). This indicates that farmers with more extensive land holdings are more likely to adopt these practices, potentially due to the resources and space available to implement them effectively.

The study revealed weak correlations between age and adopting sustainable practices, indicating that age may not significantly influence farmers' choices in agricultural methods. This suggests that other factors may be more pivotal in determining which practices are adopted. Interestingly, marital status shows a positive correlation with the adoption of drought-resistant crops (0.125) and ISFM (0.116), both statistically significant ($p < 0.05$). This finding implies that married individuals may be more inclined to adopt these practices due to shared resources and collaborative decision-making within households. Household income has a strong positive correlation with several sustainable practices, including agroforestry (0.294) and water harvesting (0.223), both significant at $p < 0.01$. This suggests that higher household income enables farmers to access the necessary resources for implementing these sustainable practices, thus enhancing their potential for success.

The study also examined the type of land tenure system and its relationship with sustainable practices. A significant negative correlation with mixed cropping (-0.138) and a positive correlation with agroforestry (0.108) were observed, indicating that land tenure type may influence the agricultural practices adopted by farmers. For instance, freehold land might be more conducive to mixed cropping, while agroforestry may be more prevalent in other land tenure arrangements. This agrees with a study by Makate *et al*., (2019), which underscores the importance of land size in adopting multiple CSA innovations. This is further emphasized by the Abegunde *et al*., (2019) study, which found that the size of farmland was statistically significant and positively correlated with the level of CSA adoption.

Additionally, a study by Aryal *et al*., (2018) highlights the importance of land size in adopting most CSA practices. Those with a larger land size tend to adopt more CSA practices than those with smaller land sizes. This is because some crop management practices require land for one to adopt. A bigger land size will lead to the household adopting various CSA practices on the same piece of land.

Education level significantly correlated with organic farming and the adoption of drought-resistant crops. The other CSA practices had a negative correlation with the education level of the household head, meaning that as one's education increases, one will not likely adopt the various CSA practices. On the other hand, the age of the respondents had no significant correlation with the different CSA practices adopted by the farmers. The marital status of the household head had a significant correlation with drought-resistant crops and water harvesting. Additionally, the household income of the respondents had a positive significant correlation with mixed cropping, agroforestry, and water harvesting. Lastly, the household tenure system significantly correlated with mixed cropping, agroforestry, and organic farming.

4.2.12 Period Stayed and Food Security

The study sought to determine the period the respondents stayed in the area. The findings are summarized in Figure 4.10. The findings show that 81.9% (314) have stayed in the area for over 16 years. This long-term residency indicates a deep-rooted connection to the land and the community, which can benefit the adoption of sustainable agricultural practices, as these individuals likely possess extensive local knowledge and experience. This was followed by those who had lived between 11 and 15 years, 6.8% (26). Only 8.1% (31) had lived between 6-10 years, 2.7% (11) had lived 1-5 years, and lastly, 0.5% (2) stayed less than one year in the area.

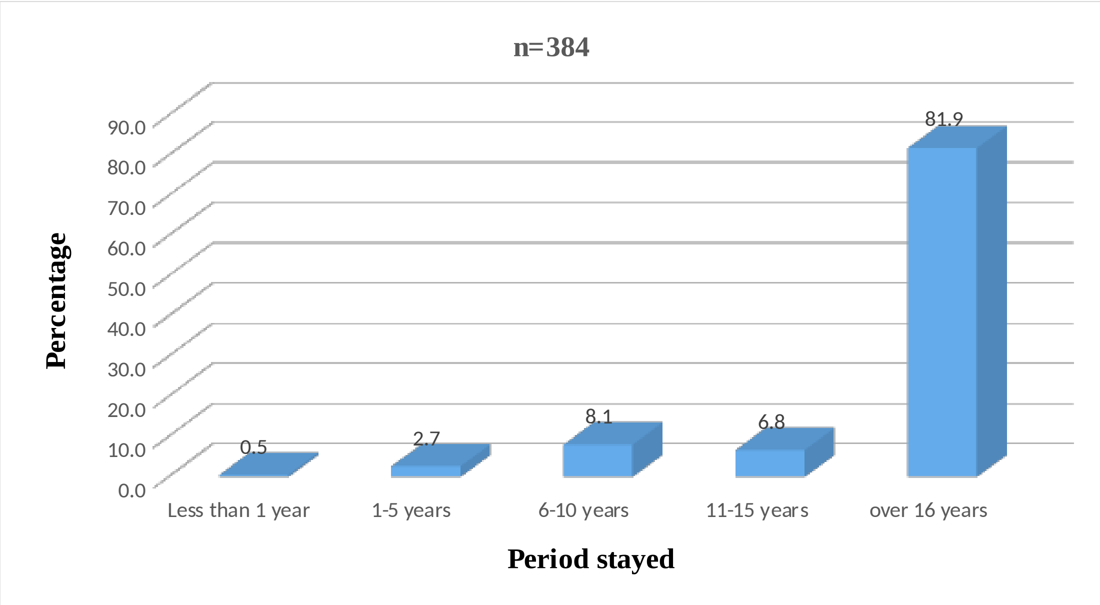


Figure 4.10: Period stayed by small-scale farmers in Nyamira County, Kenya

Source: Researcher (2023)

A chi-square test was performed to evaluate the significance of variations in the period that stayed in the study area. The calculated value of suggests a statistically significant difference in the period stayed in the study area among the respondents ($p < 0.000$). The results indicated that a majority of the participants had been residing in the area for over a decade, putting them in a favorable position to embrace diverse Climate-Smart Agriculture (CSA) practices. Furthermore, this prolonged stay implies that they had witnessed changes in climate during their time in the region. Implementing certain CSAs often takes time, and the extended residency of over a decade suggests that these individuals are well placed to adopt such practices, ultimately enhancing their food security.

Conversely, fewer recent arrivals may indicate a fresh perspective that could introduce new ideas and practices into the community. However, these newcomers may face challenges integrating into established social networks and adapting to the local agricultural context.

4.3 Rainfall and Temperature Trends and Patterns in Nyamira County, Kenya

4.3.1 Small-Scale Farmers' Opinions on Climate Change in Nyamira County, Kenya

The study also established the respondents' opinions concerning whether climate change was taking place in Nyamira County; the results are presented in Table 4.3. From the table, it can be observed that 60.8% (233) of the respondents agreed that climate change was happening in the study area, while 23.5% (90) strongly agreed with the statement. Other respondents disagreed 2.7% (11), strongly disagreed 0.5% (2), and the rest stated that they did not know at 12.4% (48). Therefore, the results show that more than half of the respondents agreed that climate change was already occurring in the study area.

Table 4.3: Likert scale responses by small-scale farmers on climate change in Nyamira County, Kenya

		Frequency	Percent
Valid	Strongly agree	90	23.5
	Agree	233	60.8
	Strongly Disagree	2	.5
	Disagree	11	2.7
	Don't know	48	12.4
	Total	**384**	**100.0**

Source: Researcher (2023)

The findings align with the conclusions of Autio *et al*.'s (2021) investigation into the barriers to adopting climate-smart agricultural practices among smallholder farmers in Southeast Kenya. According to the study, 92% of participants noted shifts in weather patterns over the last two decades, including heightened variability, rising temperatures, and diminished or unpredictable rainfall throughout the region.

Further, one of the key informants stated that;

> "There has been a change in rainfall patterns, like reduced rainfall, unpredictable rainfall, and short and unpredictable rains, which have affected agricultural activities" (**interview with key informant on 21st February 2024 at Nyamira County Ministry of Agriculture**).

In a focus group discussion, participants acknowledged the presence of climate change in Nyamira County. They observed changes in their local climate, including decreased rainfall, more frequent droughts, unpredictable weather, and rising temperatures, which aligns with the study's findings.

According to El Bilali *et al*., (2020), climate-induced changes in how food is produced (production systems) may also lead to changes in what people eat (dietary patterns) and food utilization. This disruption and the potential for climate change to destabilize and reduce resilience could have serious long-term consequences for food security.

Climate change seriously threatens food security, particularly in vulnerable regions like Sub-Saharan Africa and South Asia. El Bilali et al. (2020) study highlights how climate change disrupts food availability through declining crop yields and livestock productivity. This scarcity drives food prices, pushing it further out of reach for millions of low-income people struggling with food access. Climate change also impacts food utilization, jeopardizing the nutritional well-being of populations, especially children in poor households. Rising temperatures create ideal conditions for pathogens to thrive, while droughts worsen water quality and sanitation, increasing the risk of diarrheal diseases. Furthermore, climate variability and extreme weather events disrupt the stability of food systems. Fluctuations in seasonal patterns, declining ecosystem productivity, and unpredictable food supplies contribute to food insecurity (FAO, 2016).

A recent study by Kogo *et al*., (2021) in Kenya confirms that climate change and unpredictable weather patterns are significant threats to agriculture worldwide. Rising temperatures, altered rainfall patterns, rising sea levels, and increasing carbon dioxide all contribute to a harsh environment for growing crops. The study emphasizes that these factors will worsen food security, especially for vulnerable communities in Kenya's dry regions. Projections suggest that these climate variations will likely force farmers to adapt their planting methods and could significantly impact crop yields across different areas.

Climate change significantly threatens global food security, disrupting agricultural production and food markets. Lipper *et al*., (2014) warn that these disruptions threaten the ability to feed entire populations. Research by Myers *et al*., (2017) strengthens this concern, suggesting a near certainty of declining global crop production due to climate change. This decline mainly concerns Kenya and other regions reliant on rain-fed agriculture, as Omoyo *et al*., (2015) reaffirms. Climate, after all, is the critical ingredient for successful harvests. Historically, climate variability and change have been the most significant factors determining crop yields in Kenya and worldwide. In Uganda specifically, Mubiru *et al*., (2018) highlight that climate change and variability present new challenges. More frequent and intense droughts threaten agricultural livelihoods and food security.

The respondents who agreed that, in their opinion, there was a change in the trends of rainfall and temperature stated some of the trends they have experienced and observed. The responses are summarized in Table 4.4.

Table 4.4: Summary of the experienced changes by small-scale farmers in Nyamira County, Kenya

Change	**Frequency**	**Percentage**
Decrease in rainfall	104	32.69
Increased crop and livestock epidemics	66	20.71
Increasing temperature	64	20.06
Increased floods	44	13.92
Increased drought	30	9.39
Others	10	3.24
Total	**318**	**100**

*This was a skip logic question; N=318
Source: Researcher (2023)

The results revealed that 32.69% (101) of the participants reported reduced rainfall in the area. Following this, 20.71% (64) mentioned increased crop and livestock epidemics. Additional observed changes comprised 13.92% (43) reporting heightened occurrences of floods, and 9.39% (29) observed more frequent episodes of drought.

These results positively correlate with the data collected from KMD on rainfall and temperature.

This is in tandem with other studies that show a decline in crop yields due to rising temperatures and unpredictable rain patterns, as confirmed by a Ugandan study by Mubiru *et al*., (2018). This research found erratic rainfall patterns, including early or late starts and ends to rainy seasons, poor seasonal distribution of rain, and overall decreased rainfall. Farmers also reported variations in temperatures. According to the study, these climate changes bring new challenges and vulnerabilities with increased droughts, more frequent and intense pest and disease outbreaks, diminishing water sources, lack of pasture for livestock, and even more extreme weather events like bushfires and hailstorms. These factors disrupt agricultural production and food security, especially for regions reliant on rain-fed agriculture.

4.3.2 Small-Scale Farmers' Awareness of Climate Change and Food Security In Nyamira County, Kenya

The study sought to determine whether the respondents were aware of climate change. As presented in Figure 4.11, the findings show that 83.2% (319) of them knew what it was, while 16.8% (65) were unaware of climate change. This was to check if the respondents knew climate change was occurring and what adaptation strategies they had embraced to counter the effect. Therefore, the results confirm that the respondents, both men and female, were aware of climate change and its various impacts on food security in the area. However, there is a need to increase awareness among the farmers concerning climate change and variability in Nyamira County so that they can adopt CSA practices to avert the adverse effects of climate change.

4.5.

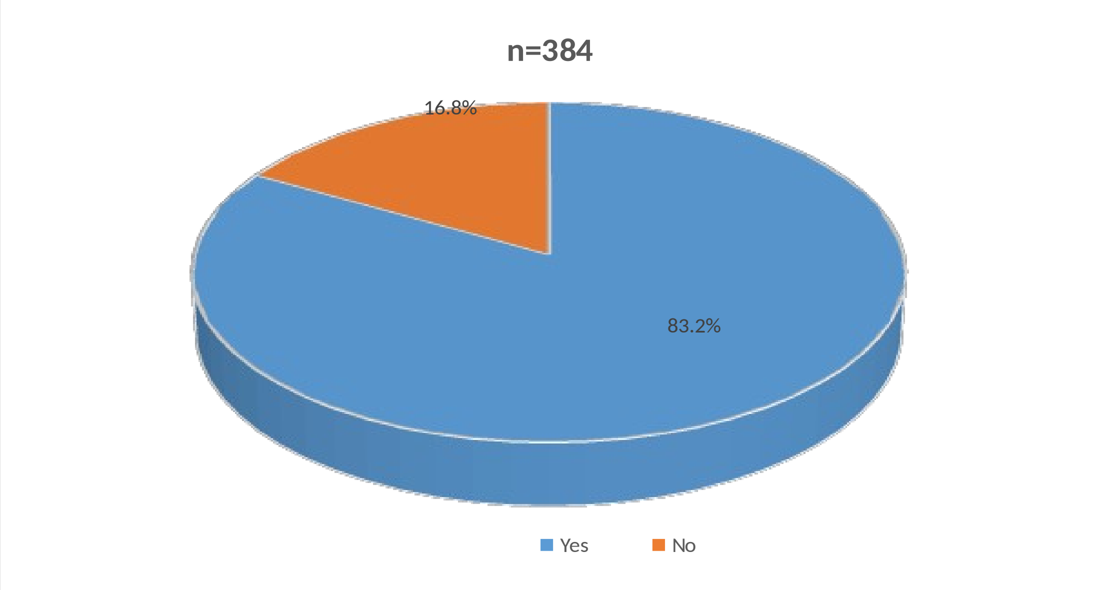


Figure 4.11: Awareness of climate change by small-scale farmers in Nyamira County, Kenya

Source: Researcher (2023)

Climate-smart agriculture (CSA) practices hold immense potential for improving food security, but their effectiveness hinges on awareness and adoption by farmers (Wekesa *et al.*, 2018). Household heads who lack knowledge about how climate change impacts food security are unlikely to utilize CSA strategies. This lack of awareness leaves households vulnerable to the adverse effects of climate change on food production. Therefore, building awareness and training farmers in CSA practices go hand-in-hand to ensure food security in a changing climate.

4.3.3 Small-Scale Farmers' Perception of Climate Change and Food Security in Nyamira County, Kenya

The respondents also identified several indicators they observed or experienced that led them to believe climate change is happening. These indicators are summarized in Table 4.5.

Table 4.5: Small-scale farmers' perception of climate change in Nyamira County, Kenya

Indicator	Frequency	Percentage
Reduced crop yields	178	46.35
Food insecurity	67	17.45
Water scarcity	53	13.80
Shifts in growing seasons	50	13.02
Increased crop and livestock diseases and epidemics	25	6.51
Livestock death	8	2.08
Increase in crop yields	2	0.52
Other effects(specify)	1	0.26
Total	**384**	**100**

Source: Researcher (2023)

From the findings, 46.4% (178) of the respondents indicated that they had experienced a reduction in crop yields from their farms, 17.4% (67) had issues of food insecurity, and 13.7% (53) said that there was water scarcity in the area. Others stated that there has been an increase in the amount of rainfall in the area and, therefore, thought that climate change was occurring. The results of this study agree with Autio *et al.*'s (2021) research, which pinpointed key obstacles stemming from climate variability, such as prolonged droughts, water scarcity, and unpredictable or diminished rainfall in the region. Consequently, these challenges resulted in minimal or absent yields for the farmers. A key informant opined that,

> Indeed, climate change was occurring in the County and stated that indicators like the emergence of new diseases, reduced crop yields in the farms, reduced rainfall, and increased temperature levels are some of the indicators of climate change.

4.3.4 Effect of Climate Change on Farming Practices and Food Security

The respondents were asked whether climate change has affected farming in any way in the study area. The respondents are summarized in Figure 4.12.

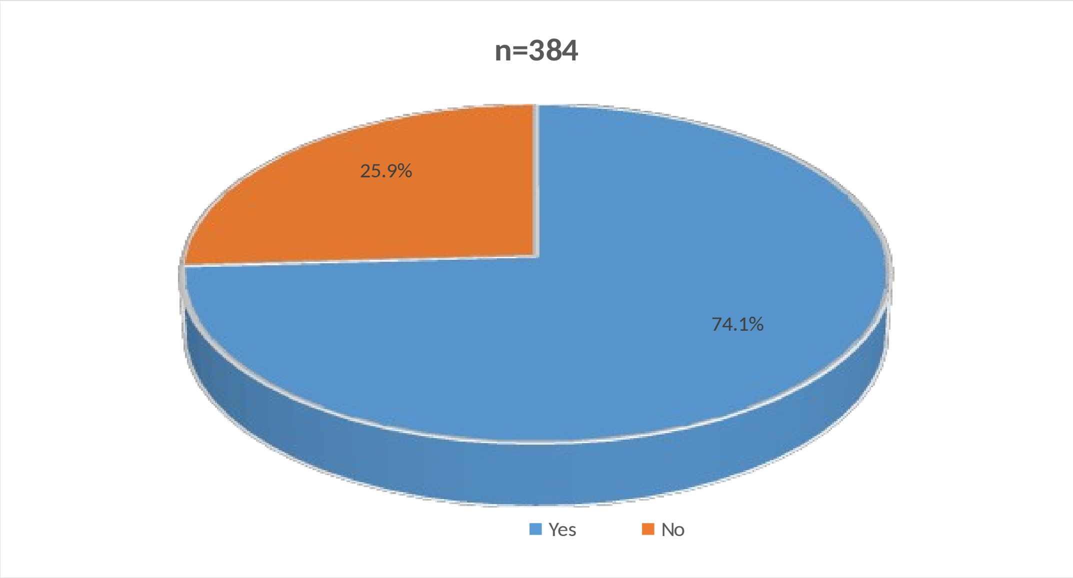


Figure 4.12: Effect of Climate change on farming by small-scale farmers in Nyamira County, Kenya

Source: Researcher (2023)

From the findings, it was observed that 74.1% (285) of the respondents agreed that climate change had affected their farming practices; on the other hand, 25.9% (99) disagreed with the same. The effects are shown in Table 4.4. This is in tandem with Mekonnen *et al*., (2021), who point out that climate change has a detrimental impact on food security for farmers. It reduces crop yields, making less food available, and affects their ability to access the food they produce. Key informants and focus group participants agreed that climate change has negatively influenced crop productivity within the region. Nyamira County Executive Committee Member (CECM) for agriculture asserts that;

> "The effects of climate change, compounded with poor farming practices and methodologies, contribute to poor yields and food insecurity. Sticking to traditional farming methods when the rain patterns are erratic with compromised soil fertility is hampering the production of crops, thus discouraging most farmers from farming food crops."

4.3.5 Rainfall Trends and Patterns

The climate trends and patterns were analysed using rainfall and temperature as the critical parameters in climate change studies. The climate data was analyzed based on the four seasons of planting in Nyamira station (MAM, JJA, SON, and DJF). The research aimed to analyze the precipitation trends and patterns in Nyamira station from 1990 to 2019 using gridded daily precipitation and temperature data obtained from the station. The rainfall data was sourced from the Kenya Meteorological Department (KMD). Figure 4.13 illustrates the study's findings, indicating a steady rise in the annual rainfall levels for Nyamira station.

The rainfall data shows an upward trajectory, represented by the linear trendline y=0.6467x+127.78. This trendline suggests a gradual increase in rainfall over the study period, with an exceptionally sharp spike in 2019, where rainfall levels exceeded 200 mm. However, the R-squared value 0.0668 indicates a weak correlation between time and rainfall increase. This suggests that while rainfall appears to be increasing, this pattern lacks strong statistical significance and may not be reliably predictive.

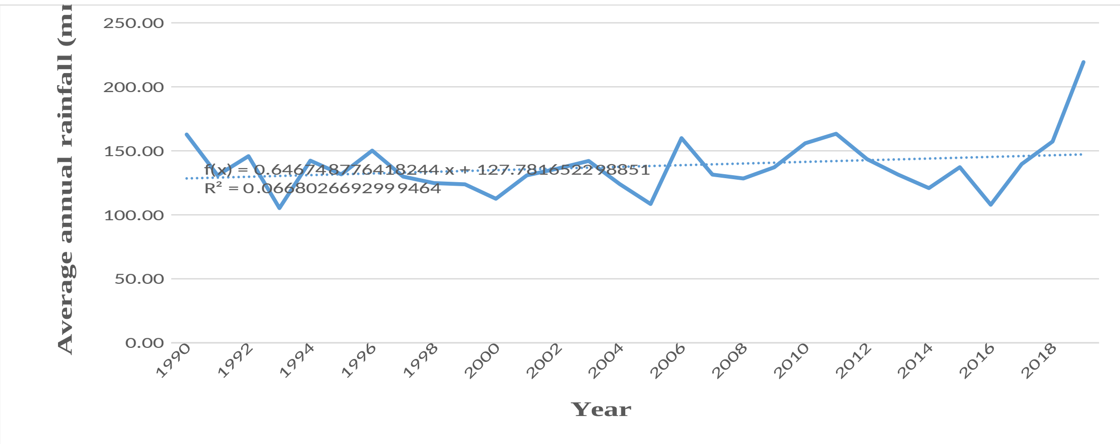


Figure 4.13: Time Series Analysis for average annual Rainfall received in the Nyamira station (1990-2019)

Source: Researcher (2023)

The rainfall trends were analysed based on the four seasons in the study area: MAM, JJA, SON, and DJF. The results are shown in Figures 4.14, 4.15, 4.16 and 4.17. Figure 4.14 shows that Nyamira station from 1990 to 2019 provides insight into seasonal rainfall trends, though the results reveal neither strong nor statistically significant patterns. In the Nyamira station (Figure 4.14), there is a slight upward trend in MAM rainfall, represented by the trendline $y=0.2769x+177.3$. However, the R-squared value of 0.0041 indicates that this increase is negligible. Rainfall levels in Nyamira fluctuate considerably from year to year, with sharp peaks and drops across the period under study. This variability suggests that while there may be occasional increases in rainfall, there is no consistent upward trajectory over time.

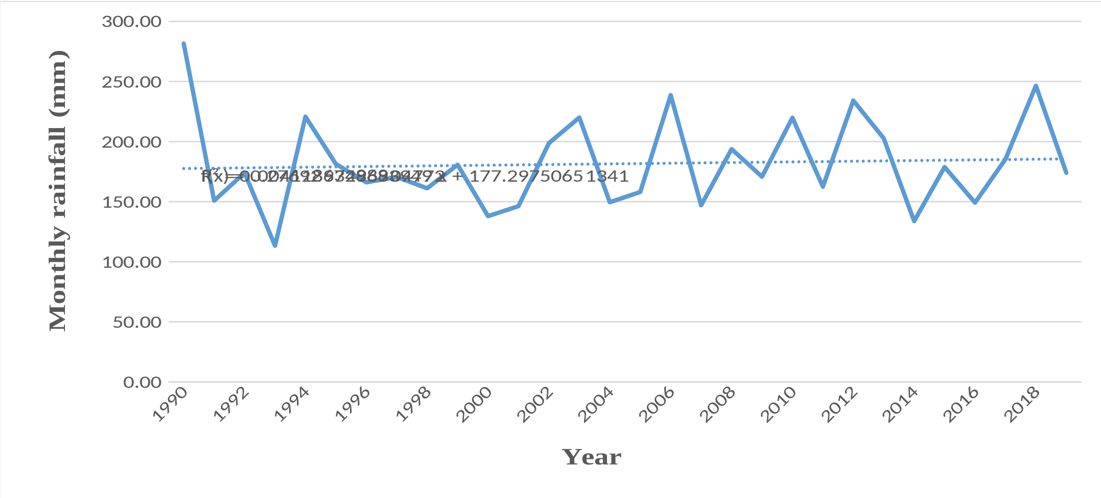


Figure 4.14: Time Series Analysis for Nyamira station for MAM season

Source: Researcher (2023)

Figure 4.15 shows the DJF rainfall for Nyamira. The data displays significant fluctuations, with periods of high and low rainfall. The trend line has a slight negative slope of -0.0085, as indicated by the equation $y=-0.0085x+97.773$ and an R^2 value of 6E-06. This minimal negative slope suggests a nearly flat trend over time, with almost no significant increase or decrease in rainfall.

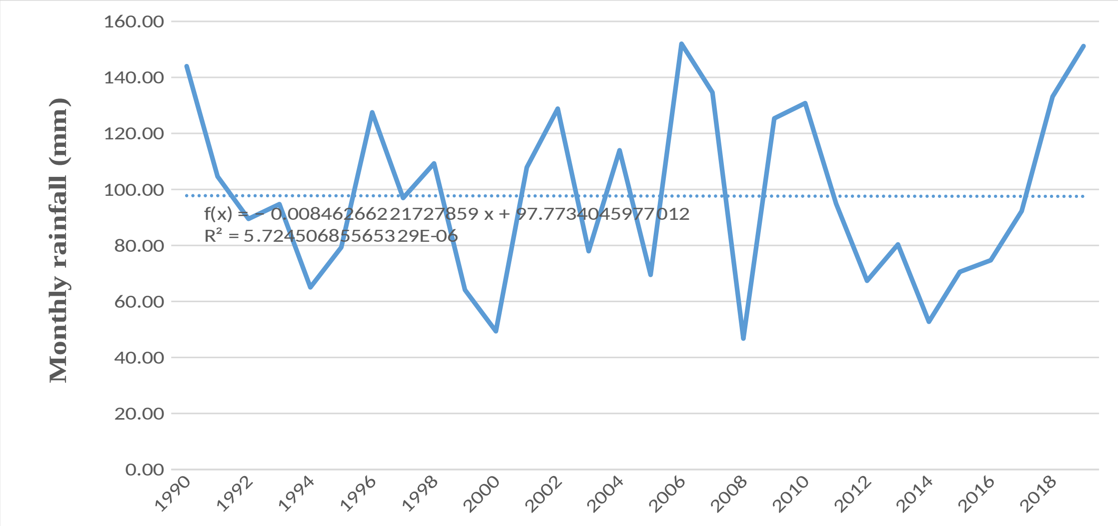


Figure 4.15: Time Series Analysis for Nyamira station for DJF season

Source: Researcher (2023)

The graph in Figure 4.16 shows the monthly rainfall in Nyamira over the years during the JJA period. The rainfall data exhibits variability, with several peaks and dips across the years. A trend line is included, with a slight positive slope of 0.109, suggesting a minimal upward trend in rainfall over the period. The y=0.109x+131.63 and R^2=0.0017 indicate that while there is a slight increase, it's not strongly correlated.

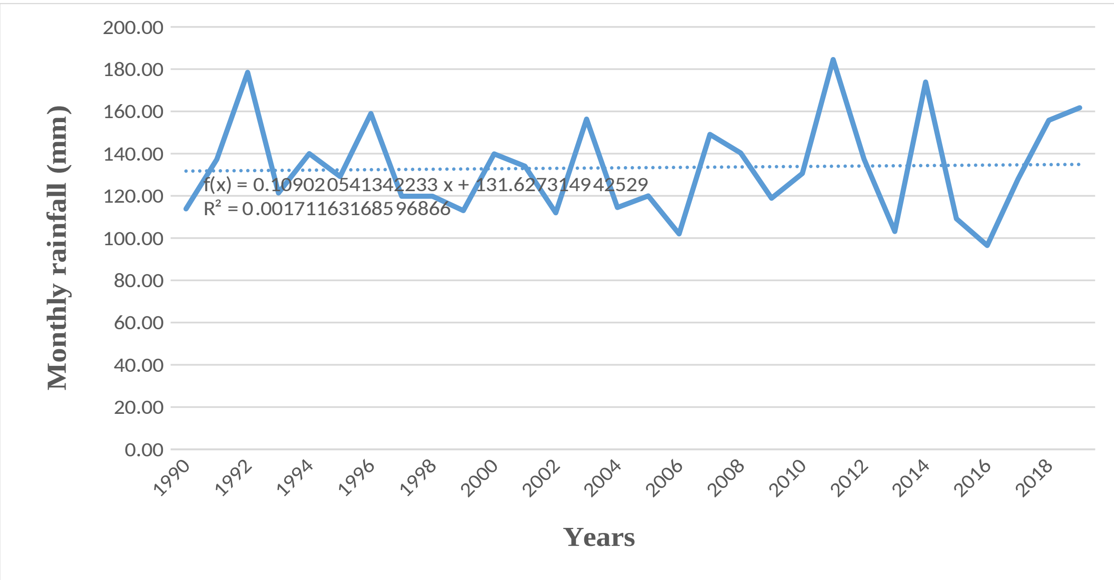


Figure 4.16: Time Series Analysis for Nyamira station for JJA season

Source: Researcher (2023)

Figure 4.17 displays the SON rainfall data for Nyamira. There is notable variability over the years, with a distinct spike towards the end of the period, suggesting a significant increase in rainfall in recent years. The trend line, with an equation of y=2.2095x+104.43 and an R^2 value of 0.1278, indicates a more noticeable upward trend compared to the JJA season in Nyamira. The higher slope (2.2095) and R^2 suggest a stronger increasing trend over time.

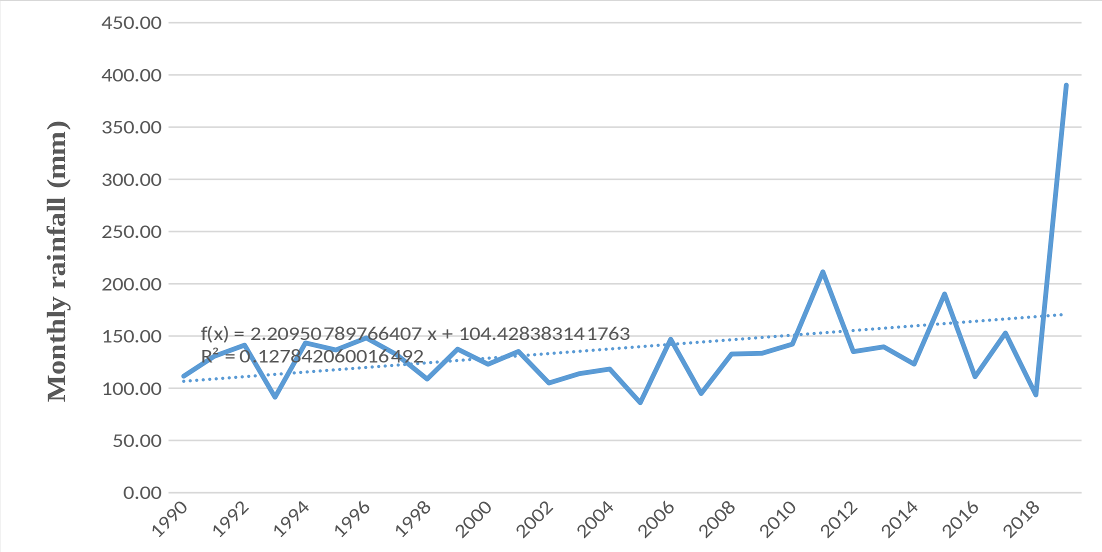


Figure 4.17: Time Series Analysis for the Nyamira station for SON season

Source: Researcher (2023)

4.3.6 Maximum and Minimum Temperature Trends and Patterns for Nyamira Station

Objective one sought to determine the impact of rainfall and temperature climate trends and patterns of Nyamira station for the period 1990-2019. The trends and patterns of both maximum and minimum temperatures for Nyamira station are shown in Figure 4.18. The mean annual temperature for Nyamira ranges from 19.04^{0}C (minimum) to 22.41^{0}C (maximum), with an average yearly temperature of 19.70^{0}C. Over the three-decade period, maximum temperatures exhibit a slight upward trend. The trendline with the linear equation y=0.0789x+24.264 and an R^2 value of 0.2522 suggests that maximum temperatures have been increasing at an average rate of about 0.0789 °C per year. Although the upward trend is apparent, the relatively low R^2 value indicates that the correlation between time and maximum temperature is weak, meaning considerable variability in the data isn't explained by this trend line. Notably, there is a distinct rise in maximum temperature around 2019, which may signal an anomaly or an emerging pattern of warmer years.

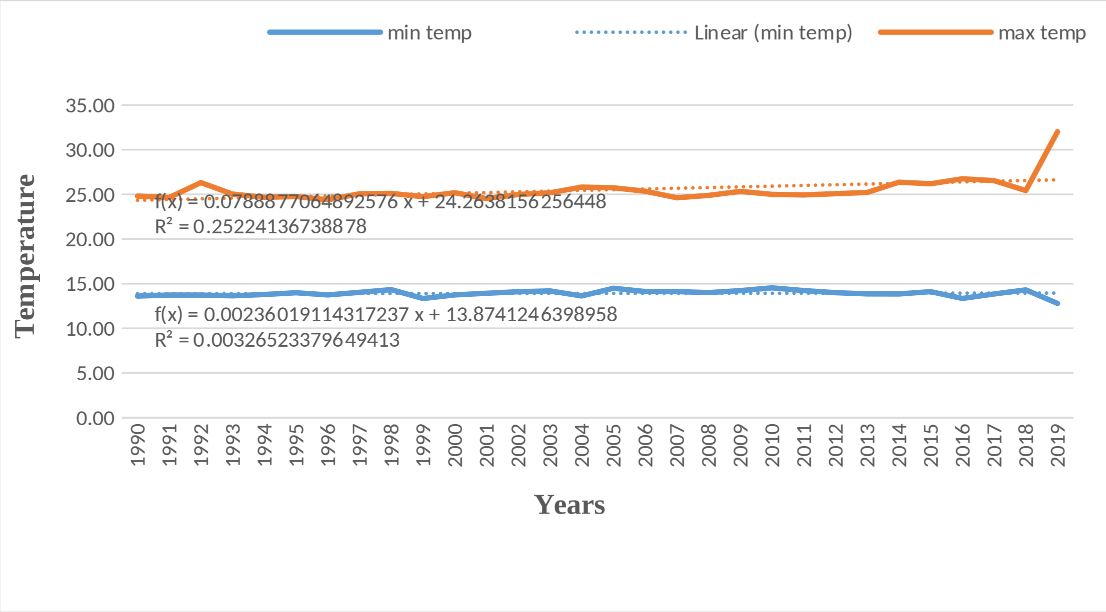


Figure 4.18: Time Series Analysis for Maximum and minimum temperature trends for Nyamira station (1990-2019)

Source: Researcher (2023)

On the other hand, for the minimum temperature for Nyamira station, the slope of the regression line was 0.0114 (Figure 4.18). This shows that the station is experiencing an upward trend for minimum temperature for the period under study. The dashed trend line for minimum temperature has the equation y=0.0024x+13.874 with an R^2 value of 0.0033. This equation indicates a negligible upward slope, implying that minimum temperatures have barely changed. The very low R^2 value reinforces this, suggesting no significant trend in minimum temperatures across these years. These results agree with

Yvonne *et al*.'s (2020) research, which investigated climate variable trends, specifically temperature and rainfall, and local perceptions of climate change in Lamu, Kenya.

Yvonne *et al*., (2020) found that a significant majority of respondents (96%) reported having observed changes in temperature in Lamu County over the preceding decade (2006 to 2016). This is in tandem with the findings from the interview with the key informants and the focus group discussion in the area, who stated that the area has been experiencing increased temperature over the years. Compared with the previous years, the temperature was not that high, a clear indicator of climate change in the area. Temperature is a key component in crop production; therefore, when the temperatures are high, crop productivity is impeded, reducing farm produce. This corresponds with the research conducted by Parthasarathi *et al.,* (2022), which identified that high-temperature situations lead to a significant reduction in yield.

Additionally, according to Samwel *et al*. (2021), a study conducted in Kisii County on the effects of climate variability on food security found that rising temperatures increase the atmosphere's capacity to hold water. This enhanced water-holding capacity leads to greater evapotranspiration from the surface, thereby reducing soil moisture. A lack of soil moisture can diminish agricultural production in Kisii County. This is similar to Nyamira County since it is also a food basket for Kenya, and the small-scale farmers depend on rain-fed agriculture. Additionally, higher temperatures are linked to increased crop pests and diseases, which negatively influence food production. Elevated temperatures also threaten underground water resources, such as springs and wetlands, by increasing evaporation rates, thus reducing water availability for irrigation (IPCC, 2014).

4.3.7 Mann- Kendall test for Rainfall and Temperature

Annual average readings of rainfall and minimum and maximum temperature were calculated for the Nyamira station and then analysed using the Mann-Kendall (MK) test. The analysis was based on the categories (MAM, JJA, SON, and DJF) of the growing season over the study area. Trend analysis of the analyzed seasons for the station showed increasing rainfall for MAM, SON, and DJF. During the JJA season, the station experienced a decreasing amount of rainfall.

The rainfall for the station changed either upward or downward, but the change was not significant since the p-values (MAM-0.5925, JJA- 0.9431, SON-0.3008 and DJF-0.9715) for the seasons were greater than 0.05 (Table 4.6). The Mann-Kendall analysis done on maximum and minimum temperature showed a rising trend for both maximum and minimum in the station, which was significant as the p-value was less than 0.05. Therefore, the data shows that there has been a statistically significant increase in maximum temperature at Nyamira station.

Table 4.6: Annual MK result of temperature and rainfall for Nyamira station

Variables	Statistic	Nyamira station
$\mathbf{R_{MAM}}$	Zs	0.53523
	p-value	0.5925
	S	3.100000e+01
	varS	3.141667e+03
	Tau	7.126437e-02
	n	30
$\mathbf{R_{JJA}}$	Zs	-0.071364
	p-value	0.9431
	S	-5.00000000
	varS	3141.66666667
	Tau	-0.01149425
	n	30
$\mathbf{R_{SON}}$	Zs	1.0348
	p-value	0.3008
	S	59.0000000
	varS	3141.6666667
	Tau	0.1356322
	n	30
$\mathbf{R_{DJF}}$	Zs	0.035682
	p-value	0.9715
	S	3.000000e+00
	varS	3.141667e+03
	Tau	6.896552e-03
	n	30
$\mathbf{T_{max}}$	Zs	3.4612
	p-value	**0.0005379***
	S	195.0000000
	varS	3141.6666667
	Tau	0.4482759
	n	30
$\mathbf{T_{min}}$	Zs	1.5343
	p-value	0.1249
	S	87.000
	varS	3141.667
	Tau	0.200
	n	30

***0.05 significance level**

Source: Researcher (2023)

CHAPTER FIVE

CLIMATE-SMART AGRICULTURE PRACTICES AMONG SMALL-SCALE FARMERS IN NYAMIRA COUNTY, KENYA

5.1 Introduction

This chapter aimed to identify the current Climate Smart Agriculture (CSA) practices adopted by small-scale farmers in Nyamira County, Kenya. It is organized into distinct sections covering different measurable indicators. The initial section focuses on assessing respondents' knowledge of CSA practices, followed by exploring the types of CSA practices, both conventional and indigenous, implemented in the study area. Subsequent sections delve into the CSA initiatives undertaken by both the county and national governments, the involvement of agencies supporting CSA practices in the county, the contributions of these agencies, the existence of CSA model farms, and finally, the lessons learned by farmers regarding CSA practices.

5.2 Knowledge Concerning Climate-Smart Smart Agriculture (CSA)

The study first sought to understand whether the respondents had any knowledge concerning CSA practices. The results are presented in Figure 5.1. From the findings, 54.9% (211) of the respondents stated that they knew CSA, while 45.1% (173) said they did not.

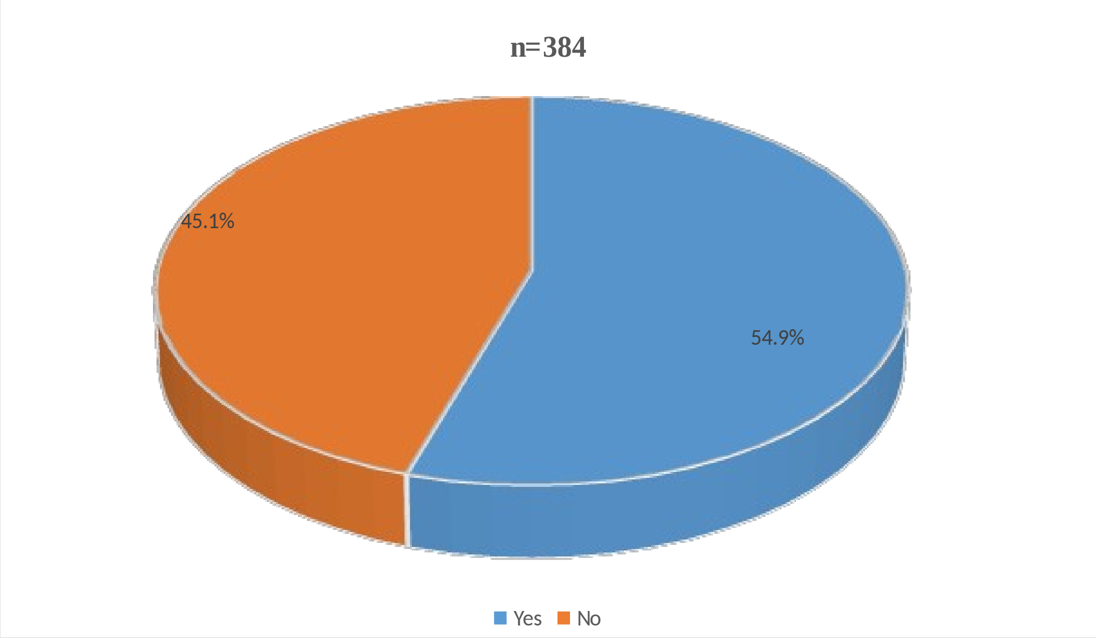


Figure 5.1: Knowledge concerning CSA practices by Small scale farmers in Nyamira County, Kenya

Source: Researcher (2023)

These findings are similar to Mujeyi *et al*. (2022), who observed that over 50% of the participants in the survey were familiar with CSA techniques, including practices like crop rotation, intercropping, manure, and minimum tillage. This is because some of these known CSA are inherent indigenous knowledge among African communities. Awareness of CSA practices is crucial to the level and intensity of farmers' adoption of them. Those unaware of the practices and their use will find it difficult to adopt such practices.

One of the key informants reported that;

> "Some farmers practice the CSA, but they are unaware that those are CSA practices. This is because they have been practising them in society for long."

5.3 Conventional and Indigenous CSA Practices Practiced in Nyamira County, Kenya

The study analyzed both conventional and indigenous CSA practices practised by small–scale farmers in Nyamira County, Kenya, to improve food security.

5.3.1 Conventional CSA Practices Practiced in Nyamira County, Kenya

The study established the conventional CSA practices the respondents practised on their farms. The findings are shown in Table 5.1. From the findings, those who practised mixed cropping were at 20.50% (230), crop rotation at 15.15% (170), agroforestry at 14.53% (163), water harvesting at 13.10% (147), organic farming at 10.52% (118), cover cropping 7.93% (89), drought resistant crops 7.49% (84) and lastly integrated soil fertility management 7.31% (82). Other respondents stated they had no land for cultivation and did not engage in CSA practices. Most respondents used a combination of more than one CSA practice.

Table 5.1: Conventional CSA Practices Practiced by Small-Scale Farmers in Nyamira County, Kenya

Conventional CSA practices	Frequency	Percentage
Mixed cropping	230	20.50
Crop rotation	170	15.15
Agroforestry	163	14.53
Water harvesting	147	13.10
Organic farming	118	10.52
Cover cropping	89	7.93
Drought resistant crops	84	7.49
Integrated soil fertility management	82	7.31
Others	39	3.48
Total		**100**

*Respondents selected multiple choices; N=384

Source: Researcher (2023)

A study by Kehinde *et al*. (2024) investigated how climate-smart farming practices (CSAPs) affect resource use by small rice farmers in Nigeria. Their findings showed that most CSAPs, except agroforestry, require more labour. Using organic manure and keeping crop residue can significantly reduce pesticide use, while no-till or minimal tillage farming practices can save on pesticides and fertilizers. However, the success of these practices might be limited by a lack of available labour, as many CSAPs are labour-intensive. Additionally, Mekonnen *et al*., (2021) found that farmers adopted various strategies to lessen the impacts of climate change in Ethiopia. These strategies included soil and water conservation, improved crop varieties, growing short-maturing varieties, livestock diversification, reducing livestock numbers, changing the planting and harvesting dates, irrigation, and diversifying the income sources. Some of the CSA practices adopted are shown in Plate 5.1.

Plate 5.1: Agroforestry Tree Nursery and mixed cropping at Nyamira County, Kenya

Source: Researcher (2024)

5.3.2 Indigenous Knowledge (IK) Strategies

The study sought to determine the indigenous knowledge strategies used to enhance food security in their households. The findings are summarized in Table 5.2. The results show that 19.27% (74) of the respondents used ash to deal with farm pests and diseases. Other IK strategies included cover cropping, crop rotation, crop diversification, and animal manure as fertilizer.

Table 5.2: Indigenous Knowledge Strategies employed by small scale farmers in Nyamira County, Kenya

IK strategy	Frequency	Percentage
Application of ash	74	19.27
Cover cropping	8	2.08
Crop rotation	9	2.34
Crops diversification	8	2.08
None	271	70.57
Use of animal manure	14	3.65
Total		**100**

Source: Researcher (2023)

According to Osunade (1994), IK is the institutionalized local knowledge built upon and passed on from generation to generation, usually by word of mouth. Amare *et al*. (2023) assert that indigenous communities possess adept skills in observing weather and climate conditions and exhibit the ability to adapt to changes through diverse adaptive strategies. Practices such as terracing, mulching, intercropping, ridge and contour ploughing, crop rotation, mixed farming, agroforestry, improved grazing, fallowing, weather forecasting, and water diversion ditch are among the tangible techniques encompassed in Climate-Smart Agriculture (CSA). These methods are crucial in enhancing climate resilience within smallholder farming communities. Furthermore, Amare *et al*. (2023) assert that emphasizing the significance of indigenous knowledge in addressing climate change holds the potential to make meaningful contributions to climate change adaptation within smallholder farming communities.

Mugambiwa's study in 2018, focusing on adaptation measures to preserve indigenous practices and utilize indigenous knowledge systems for climate change adaptation in the Mutoko rural district of Zimbabwe, identified strategies such as mulching, constructing spacious storage facilities for produce, and erecting temporary walls along riverbanks to store water during periods of river dryness. The study concluded that climate change adaptation measures employed by the community have significantly helped them to sustain their indigenous practices (Mugambiwa, 2018).

A research paper by Zwane and Masipa (2021) discusses the importance of traditional African knowledge for food security and environmental protection. They point out that even before the settlers arrived, these communities relied on this knowledge for food preservation, keeping birds away from crops, maintaining soil health, and treating animal wounds and illnesses. Additionally, a study by Muyambo *et al.*, (2017) documented how Zimbabwean farmers traditionally preserve their maize. The research found that farmers use wood ash to protect maize from weevils for an entire season. They reportedly employed pits for grain storage, keeping the maize safe for a whole season. This is in tandem with the findings of this study, which also found that 19.27 % (74) of the farmers used ash to ensure food security in their households.

Masango and Mbarika (2022) highlight a crucial traditional method for boosting food security: selecting indigenous seed varieties. This practice is further bolstered by the knowledge of rural communities, as documented by Tweheyo (2018). These communities possess knowledge of seeds resistant to drought and disease, acting as a built-in coping mechanism for harsh environments. Their experience allows them to identify seeds that thrive in specific soil types and select those that mature quickly and are ideal for recovering after droughts or other natural disasters.

Tweheyo (2018) further emphasizes the ingenuity of these communities by highlighting their traditional weather forecasting methods. These systems rely on keen observation of natural signs, like the migratory patterns of specific birds, water levels in particular wells or streams, earthquakes, rainbows, and the behaviour of certain tree species.

5.4 CSA Initiatives by the County and National Governments

The respondents were asked if the county and national governments had initiated some CSA initiatives in the area. The findings are shown in Figure 5.2. The findings show that 65.4% (251) of the respondents said there were no initiatives by the county and national governments in the study area to promote CSA. On the other hand, 34.6% (133) of the respondents agreed that there were some efforts by the county and national governments towards promoting CSA practices.

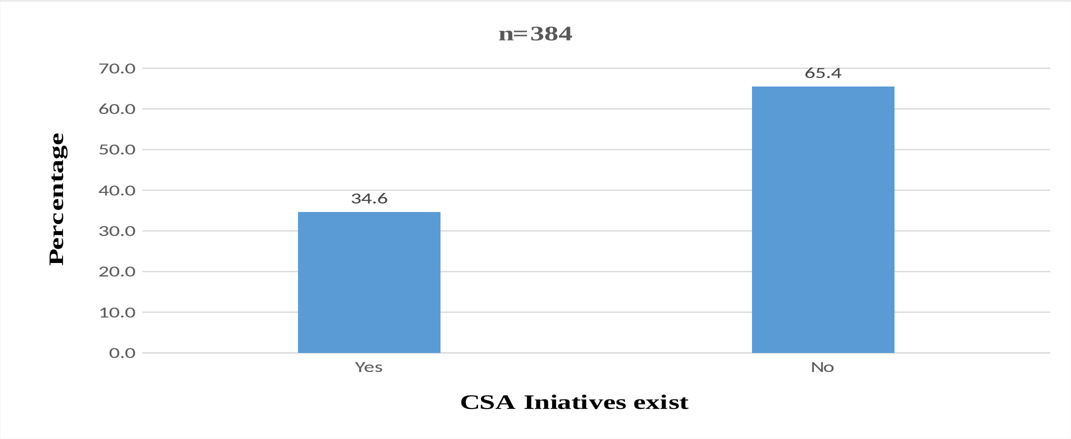


Figure 5.2: CSA initiatives by the County and national governments in Nyamira County, Kenya

Source: Researcher (2023)

5.4.1 Initiatives Provided by the County and National Governments

The various initiatives provided by the county and national governments are summarized in Table 5.3. The findings indicate that 23.38% (47) said they were giving agroforestry seedlings, 21.89% (44) farm inputs, 21.39% (43) drought-resistant seeds, 19.90% (40) capacity building and training, 11.44% (23) research and extension services, and 1.00% (2) enactment of CSA policies and laws, respectively.

Table 5.3: Initiatives provided by the County and National governments towards CSA in Nyamira County, Kenya

Initiatives	Frequency	Percentage
Providing agroforestry seedlings	31	23.38
Providing farm inputs	29	21.89
Providing drought-resistant seeds	28	21.39
Capacity Building and Training	26	19.90
Research and Extension services	15	11.44
CSA policies and laws	1	1.00
Other initiatives	1	1.00
Total		**100**

Source: Researcher (2023)

5.5 Agencies Supporting CSA Practices in Nyamira County, Kenya

The study established the various agencies supporting CSA practices in the study area. The findings are shown in Table 5.4. The findings show that the agencies involved with CSA in the county include a one-acre fund, county government through the Ministry of Agriculture, KALRO, World Bank, KTDA, National Government, Orphans Sacco, Wakulima, and Yeah Home Welfare. Those who said no agency was involved were 51.56 % (198), the highest. A study by Ndung'u et al. (2023) revealed that the agencies supporting CSA practices in Kakamega County were the international development partners, non-governmental organizations and research organizations.

Table 5.4: Agencies supporting CSA practices in Nyamira County, Kenya

Agency	Frequency	Percentage
None	198	51.56
One acre fund	76	19.79
NAGRIP	34	8.85
Do not know	32	8.33
The county government of Nyamira	20	5.21
KALRO	9	2.34
World bank	4	1.04
Agriculture training	3	0.78
KTDA	3	0.78
National government	2	0.52
Orphans Sacco	1	0.26
Wakulima Sacco	1	0.26
Yeah home welfare	1	0.26
Total		**100**

Source: Researcher (2023)

5.5.1 Contribution of the agencies towards capacity building on CSA practices

The study further determined the stated agencies' contribution towards building the respondents' capacity on CSA practices. The results are as indicated in Table 5.5.

Table 5.5: Contribution of the agencies on CSA practices in Nyamira County, Kenya

Contribution	Frequency	Percentage
Provision of fertilisers	30	7.67
Creating Awareness/ capacity building	65	16.62
Providing seedlings to the farmers	33	8.44
Conducting agricultural research	20	5.11
Do not know	15	3.84
None	228	58.31
Total		**100.00**

*Respondents selected multiple choices; N=384

Source: Researcher (2023)

The various contributions that the respondents highlighted included the provision of fertilizers to the farmers 7.67% (30), creating awareness of CSA 16.62% (65), provision of various seedlings to the farmers 8.44% (33), conducting research related to CSA

5.11% (20), and those who do not know were 3.84% (15). Lastly, 58.31% (228) said they had no contribution to CSA.

5.6 CSA Model Farms in Nyamira County, Kenya

The study sought to get the respondents' opinions concerning the CSA model farms in the study area. The findings are shown in Figure 5.3. From the findings, 71.9% (276) of the respondents said they had never heard of any CSA model farms in the county, while only 28.1% (108) agreed to have experienced demonstration farms promoting CSA practices in the area.

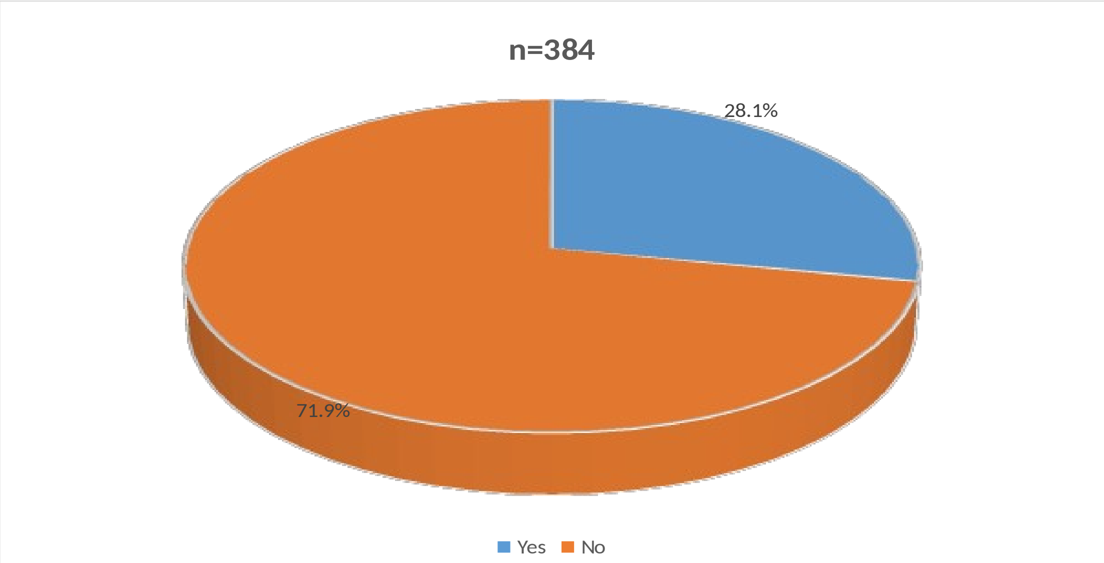


Figure 5.3: CSA model farms in Nyamira County, Kenya

Source: Researcher (2023)

5.6.1 Contribution of Model Farms on CSA Practices

The study further sought how the model farms promoted CSA practices in Nyamira County, Kenya. The findings are summarized in Table 5.6.

Table 5.6: Contribution of model farms on CSA practices in Nyamira County, Kenya

Activity	Frequency	Percentage
Forming farmer cooperative societies	49	45.28
Established farmer field schools	26	24.53
Established tree nurseries	25	23.58
Others	4	3.77
None	2	1.89
Promoting farming diversification	1	0.94
Total		**100**

Source: Researcher (2023)

The findings show that 45.28% (48) of the respondents stated that model farms have helped form farmer cooperative societies in the area, 24.53% (26) established farmer field schools, and 23.58% (25) established tree nurseries.

5.7 CSA Training among the Small-Scale Farmers in Nyamira County, Kenya

The study established whether the respondents had undergone any CSA training in the area. The findings from Figure 5.4 show that 80.5% (309) of them had not undergone any training, while 19.5% (75) had been trained in CSA practices.

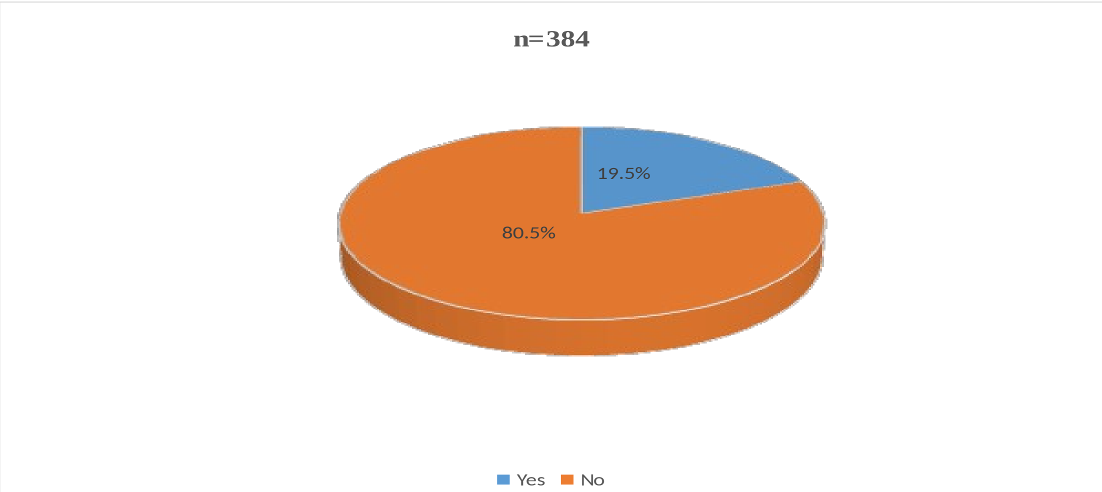


Figure 5.4: Training on CSA by the small-scale farmers in Nyamira County, Kenya

Source: Researcher (2023)

Additionally, the study established where those who agreed to have undergone training took place. The findings are summarized in Table 5.7. They show that a high percentage of the training occurred in public markets, school compounds, tea-buying centres, and Barnabus Owaro's model farm.

Table 5.7: The venues for CSA training in Nyamira County, Kenya

Place of training	Frequency	Percentage
At Barnabus Owaro's farm	10	15.38
At Marara primary school	1	1.54
At Nyansiongo center	3	4.62
At the coffee machine centre	1	1.54
Factory	1	1.54
Getari primary school	3	4.62
Within Household premises	5	7.69
Kemera Market centre	1	1.54
Public barazas	12	18.46
Miruka market	1	1.54
Nyamaiya police field	1	1.54
Nyangonko ELCK	1	1.54
Open market training	1	1.54
School fields	3	4.62
Tea buying centre	21	32.31
Total		**100.00**

Source: Researcher (2023)

5.7.1 Lessons learned from the training

The study established the lessons that the respondents learned when they attended the various CSA training in the respective venues. The findings are shown in Table 5.8. From the results, 72.14% (290) indicated that they learned how to identify crop varieties, 13.44% (43) how to time seasons for planting, and 10.62% (34) learned the identification of crop and livestock diseases as well as the use of agricultural subsidies.

Table 5.8: Lessons learned from the training attended in Nyamira County, Kenya

Lessons learned	Frequency	Percentage
Identifying crop varieties	290	72.14
Timing of seasons	43	10.70
Identification of crop and livestock diseases	34	8.46
Use of Agricultural subsidies, e.g., one-acre fund	34	8.46
Others, Specify	1	0.25
Total		**100.00**

*Respondents selected multiple choices; N=384

Source: Researcher (2023)

5.8 Benefits of CSA Adoption in Nyamira County, Kenya

The study investigated the benefits of adopting CSA Practices in Nyamira County, Kenya. The responses were captured using the Likert scale of 1-5, and the results are summarized in Table 5.9. The findings indicate that 49.74% of the respondents agreed that one of the benefits of CSA is to enhance resilience. Those who agreed to increase productivity were 53.39%, and 52.02% stated that CSA enhanced food security. Lastly, 52.86% of the respondents agreed that it helped efficiently use the natural resources. Therefore, those who had adopted CSA practices agreed to the three benefits of CSA.

Table 5.9: Benefits of CSA adoption by small-scale farmers expressed as a percentage in Nyamira County, Kenya

Benefit	Strongly agree	Agree	Strongly disagree	Disagree	Do not know	Total
Enhancing resilience to climate change	27.86	49.74	2.86	5.73	13.80	100
Increasing agricultural productivity	24.74	53.39	1.82	6.51	13.54	100
Enhancing food security	21.35	52.08	2.86	7.81	15.89	100
Efficient use of natural resources	20.57	52.86	4.69	4.43	17.45	100

Source: Researcher (2023)

5.9 Adopted CSA Practices and Climate Change Adaptation

The study established whether the adopted CSA practices have helped the respondents adapt to climate change. The results are presented in Figure 5.5. From the findings, 66.5% (255) of them agreed that the practices have helped them adapt to the changing climate. On the other hand, 33.5% (129) of them disagreed that CSA has not helped them cope with climate change.

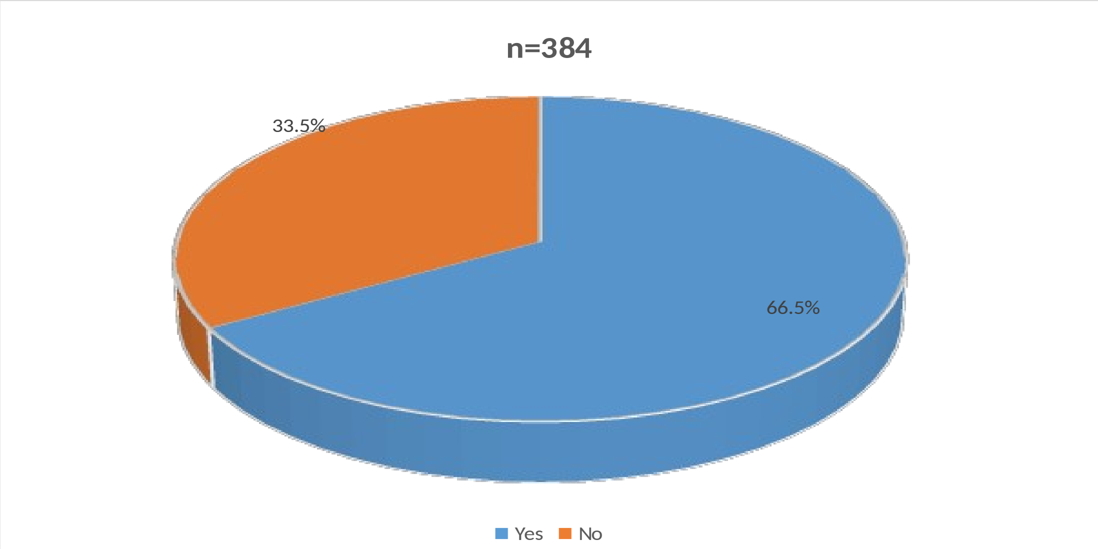


Figure 5.5: Contribution of CSA towards coping with climate change in Nyamira County, Kenya

Source: Researcher (2023)

CHAPTER SIX

CLIMATE SMART AGRICULTURE PRACTICES AND HOUSEHOLD FOOD SECURITY IN NYAMIRA COUNTY, KENYA

6.1: Introduction

This section sought to examine the influence of CSA practices on household food security in Nyamira County, Kenya. The chapter is organized into various sections with different measurable variables. The chapter also presents an analysis of the food security pillars, including food availability, accessibility, stability, and utilization.

6.2 Access to Arable Land

The respondents were asked whether they have access to agricultural land (arable land for cultivation). The findings are summarized in Figure 6.1. From the findings, 73.2 % (281) of the respondents had access to arable land for cultivation, while 26.8 % (103) had no access to land for cultivation.

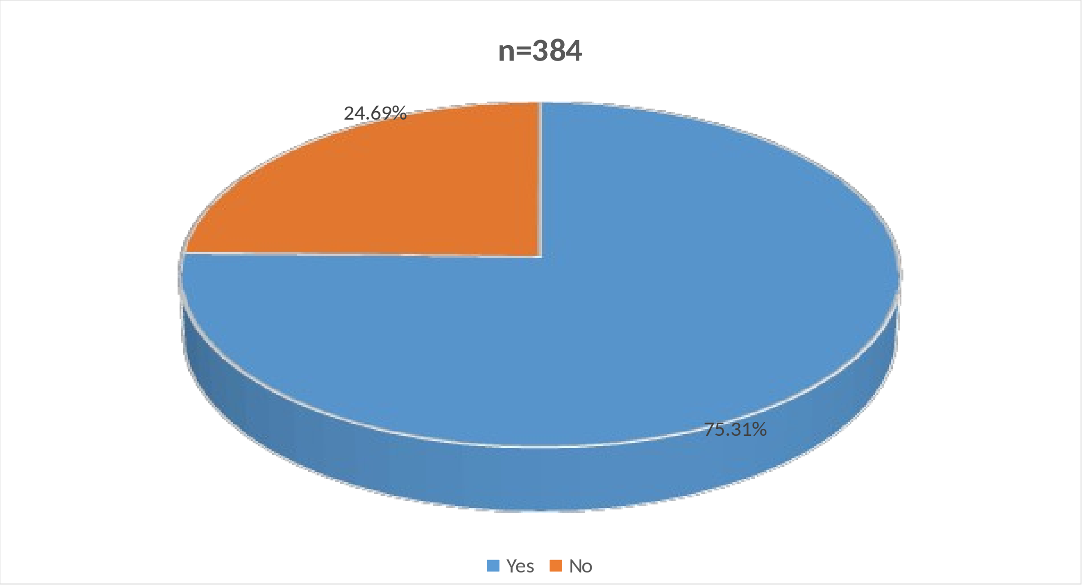


Figure 6.1: Access to arable land by small-scale farmers in Nyamira County, Kenya

Source: Researcher (2023)

The farmer's access to arable land is crucial in determining their capacity to embrace various CSA practices. This is because practices such as cropping, nutrient management, and soil and water management inherently rely on the availability of land for effective adoption. Households without adequate access to arable land will be limited on the intensity and diversity of the CSA practices they can adopt. Musafiri *et al*., (2022) posit that the presence of arable land positively impacts the adoption of CSA. The study's results indicate that smallholder farmers are more likely to adopt multiple CSA practices as the size of their arable land increases.

6.3 Crops Grown in Nyamira County, Kenya

The study established the various crops that the respondents grow on their farms. The findings are shown in Table 6.1. Maize and beans were the main crops grown at 29.67% (178) and 21.67% (130). Other crops that were also grown included vegetables at 18.33% (110), sweet potatoes at 11.67% (70), cassava at 2.33% (14), millet at 2.00% (12), and sorghum at 0.33% (2), respectively.

Table 6.1: Crops grown by small-scale farmers in Nyamira County, Kenya

Crops	Frequency	Percentage
Maize	178	29.67
Beans	130	21.67
Vegetables	110	18.33
Others	84	14.00
Sweet potatoes	70	11.67
Cassava	14	2.33
Millet	12	2.00
Sorghum	2	0.33
Total		**100**

*Respondents selected multiple choices; N=384
Source: Researcher (2023)

The other 14.00% (84) listed other crops grown. Some of the crops mentioned included bananas and sugarcane. According to Nyamira County CIDP (2023), maize is a primary staple crop in Nyamira, cultivated predominantly on a small scale across four Sub

Counties: Manga, Nyamira North, Nyamira South, and Masaba North. The typical farm sizes dedicated to maize range from 0.25 hectares to 0.75 hectares, except in Borabu Sub County, where production occurs on larger farms spanning from 4 hectares to 20 hectares. Like other food crops, maize undergoes two growing seasons annually, with the main season occurring from February to August and the shorter rainy season from September to December. The overall land area dedicated to maize cultivation has shown relatively stable trends (GoK, 2023). The report highlights climate change's impact on maize production in Nyamira County.

Beans represent another significant food crop that serves as a primary source of plant protein. They are primarily intercropped with maize, although some farmers opt to cultivate climbing beans independently during the short rains season. The predominant bean varieties in Nyamira County include *Mwitamania*, Rose Coco, Red Haricot, and Climbing Beans (particularly during the short rains season). While the acreage dedicated to beans is slightly less than that of maize, approximately 70% of farmers incorporate beans as an intercrop with maize. Local vegetables form an essential part of the economy of Nyamira County. The County is known for producing Black nightshade and spider flowers (*Chinsaga)*, which attract much demand from the local market and the major urban centres in Kenya.

According to the Nyamira CIDP (2023), finger millet, historically a significant crop, especially among the older generation, experienced a period of neglect where it received little attention. However, it is gradually gaining popularity with shifting dietary preferences and nutrition awareness. It has grown in all five sub-counties and is doing well due to favourable conditions. It is grown during the Long Rains (LR) and

Short Rains (SR) seasons. Additionally, sweet potato cultivation has become increasingly popular among farmers in Nyamira County, particularly in the lower regions such as Bomwagamo, Bokeria, Magwagwa, Bogichora, and Nyamaiya wards. Recognized as a vital food security crop, sweet potatoes thrive in areas with limited rainfall.

Another cultivated crop was Cassava, which is crucial as a food security crop, yet it has not gained widespread popularity among most farmers. This is primarily due to insufficient knowledge regarding its harvesting and utilization as food, often stemming from concerns about occasional cassava poisoning (Gok, 2023). Banana cultivation has been a longstanding practice in Nyamira, with the local green banana variety being the primary choice for farmers, commonly found in nearly every homestead. However, once popular, the sweet variety known as *Kisukari* has almost vanished due to its vulnerability to Panama disease (Gok, 2023). Despite this setback, banana production has steadily increased regarding the area dedicated to banana cultivation and the yields per unit area.

6.3.1 Quantity of the Crops Produced From the Farm in Nyamira County, Kenya

The study established the quantity of crops that the small-scale farmers produce during the short and long rains. The findings are presented in Table 6.2. The findings showed that the mean production of 90 kg bags by the small-scale farmers in Nyamira County for maize was 46.45 bags, beans were 20.58 bags, and vegetables were 12.17 bags. Other crops produced during the short rains were cassava at 1.29 bags, sweet potatoes at 5.87 bags, millet at 0.38 bags, and sorghum at 0.42 bags.

Table 6.2: Crops produced by small-scale farmers in Nyamira County during the short rains

Crops grown	Mean (90kg bags)
Maize	46.45
Beans	20.58
Cassava	1.29
Sweet potatoes	5.87
Vegetables	12.17
Millet	0.38
Sorghum	0.42

Source: Researcher (2023)

The survey participants also provided information on the quantity of 90kg bags produced in the long rainy season (Table 6.3). The results reveal that maize production was 86.65 bags, followed by beans at 34.26 bags, vegetables at 17.94 bags, sweet potatoes at 8.26 bags, cassava at 0.86 bags, millet at 0.63 bags, and sorghum at 0.62 bags.

Table 6.3: Crops produced by small-scale farmers in Nyamira County during the long rains season

Crop grown	Mean (90kg bags)
Maize	86.65
Beans	34.26
Cassava	0.86
Sweet potatoes	8.26
Vegetables	17.94
Millet	0.63
Sorghum	0.62

Source: Researcher (2023)

The study looked at yield production for 10 years, from 2012 to 2021, available on the Ministry of Agriculture and Livestock Development (MoAL) website. The results are presented in Table 6.4. From the estimates, 2012 and 2021 had the highest maize yield (2.02 tons/ ha) for the period under study. There was a decline in maize production in Nyamira County from 2012 to 2013, and then it increased in 2014. Since the start of the

NARIGP project in 2017, Maize production has increased gradually up to 2019 with a crop yield of 1.74 tons/ha. In 2020, there was a drop to 1.44 tons/ha, and then in 2021, the productivity again increased to 2.02 tons/ha.

On the other hand, bean yields were impressive in 2014 at 2.01 tons/ha. They dropped significantly in 2016 to just 0.49 tons/ha. Since the NARIGP project began, bean production has shown little change, with steady yields between 2017 and 2021.

Other crops like cassava have recorded low yields over the period, with 2018, 2019 and 2020 recording 0 tons/ha, while 2015,2016 and 2017 recorded the highest yield of cassava at 25 tons/ha. Irish potatoes have recorded a gradual yield increase from 9.15 tons/ha in 2012 to 10.86 tons/ha in 2021. Millet was relatively low, with a gradual increase from 2014 to 2016, with yields of 1.04 tons/ ha to 1.34 tons/ha. The year 2021 recorded the lowest millet yields at 0.66 tons/ha. Sweet potatoes have shown increased production, with 2019 recording the highest yields of 27.15 tons/ ha.

Table 6.4: Estimated Crop yields between 2012-2021 for Nyamira County expressed in Tons/ ha

Year	Maize	Beans	Cassava	Irish potatoes	Millet	Sweet potatoes
2012	2.02	0.8	10	9.15	0.67	11.7
2013	1.17	0.8	10	8.41	0.8	16.1
2014	1.5	2.01	2.78	5.99	1.04	10.8
2015	1.33	0.72	25	5.93	1.04	12.2
2016	1.45	0.49	25	5.91	1.34	16.88
2017	1.51	0.87	25	10.32	1.09	10.86
2018	1.72	0.73	0	9.27	0.72	10.51
2019	1.74	0.72	0	11.59	0.73	27.15
2020	1.44	0.83	0	10.85	1.36	10.88
2021	2.02	0.61	10	10.86	0.66	11.03
Mean	**1.59**	**0.858**	**10.778**	**8.828**	**0.945**	**13.811**

Source: GoK (2021)

6.4 Food Stocks in Households in Nyamira County, Kenya

The respondents were asked whether they had any food stocks in the household at the time of data collection. The responses are summarized in Figure 6.2. The findings show that 75.31% (289) of the respondents had food stocks, while 24.69% (95) had no food stocks in the households when the study was conducted.

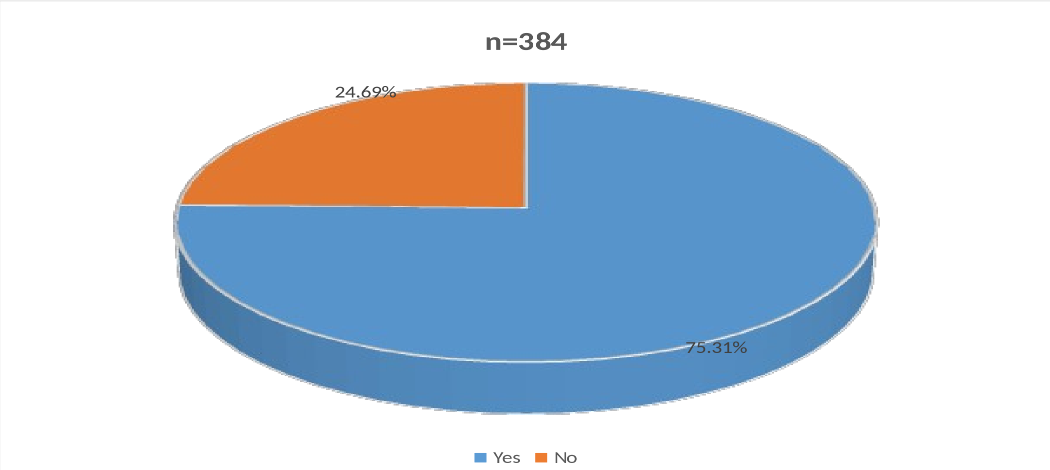


Figure 6.2: Food stocks by small-scale farmers in Nyamira County, Kenya

Source: Researcher (2023)

6.4.1 Source of Food Stocks in the Household

The study determined the source of the food stocks that the respondents had in households. This question gave the respondents the leeway to select more than one response on the food source, hence the fluctuation in the total frequency. The findings are summarized in Table 6.5. The findings revealed that 47.76% (235) of them produced their food from the farms they owned, 45.73% (225) from markets, and 3.66% (18) were as gifts. 2.85% (14) of the respondents had no food stocks or food source in the house.

Table 6.5: Source of food stocks by small-scale farmers in Nyamira County, Kenya

Source	Frequency	Percentage
Own production	235	47.76
Markets	225	45.73
Gifts	18	3.66
Others	14	2.85
Total		**100.00**

*Respondents selected multiple choices; N=384

Source: Researcher (2023)

The respondents were also asked about the periods for which the food stocks could last in the household. The findings showed that the average number of days the food stocks could last was 117, equivalent to four months.

6.5 Access to Farming Technologies and Practices for Increased Food Production

The respondents were asked whether they had access to farming technologies and practices to improve their food production. The findings are summarized in Figure 6.3. The results show that 52.2% (200) of the respondents had no access to farming technologies and practices; however, 47.8% (184) had access.

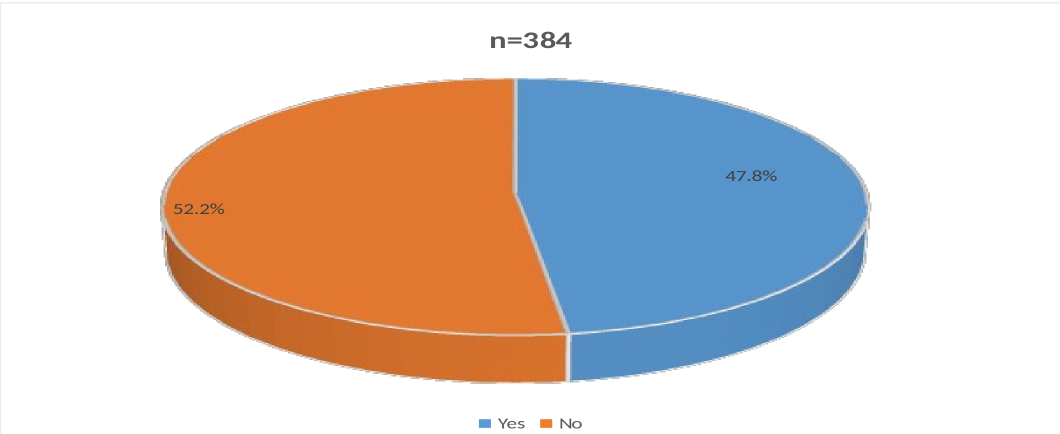


Figure 6.3: Access to farming technologies and practices by small-scale farmers in Nyamira County, Kenya

Source: Researcher (2023)

6.6 Income-Generating Activities for the Household in Nyamira County, Kenya

The study established the income-generating activities for the households. The question allowed the respondents to select more than one source of income for the household from the listed options. Table 6.6 summarizes the findings. The findings show that 26.90% and 23.57% depended on selling food and cash crops, respectively, to sustain themselves. Other income activities they depended on included non-agricultural wage labour at 19.31%, agricultural wage labour at 12.65%, salaries at 6.52%, gifts at 5.59%, and income from selling livestock products at 5.46%.

Table 6.6: Income-generating activities by small-scale farmers in Nyamira County, Kenya

Activity	Frequency	Percentage
Food crop production/sales (e.g., maize)	202	26.90
Cash crop production/sale (e.g., coffee, tea)	177	23.57
Non-agricultural wage labour (construction)	145	19.31
Agricultural wage labour	95	12.65
Salary	49	6.52
Gifts/begging	42	5.59
Income derived from the sale of livestock and animal products	41	5.46
Total		**100.00**

*Respondents selected multiple choices; N=384

Source: Researcher (2023)

Dedehouanou and McPeak (2020) found that income diversification improves food availability, accessibility, and utilization and builds a household's resilience. This is confirmed by Etea *et al*. (2019), who found a positive correlation between income diversification and food security in their research. This suggests that having multiple sources of income contributes to a more stable food supply.

6.7 Decision Maker on Food to be taken in the Household and Food Security

Respondents were queried regarding the primary decision-maker concerning the food to be taken in the household. As illustrated in Figure 6.4, the outcomes reveal that the predominant decision-maker is the female member, accounting for 63.2% (243). Subsequently, the entire family collectively contributes to decision-making in dietary matters, comprising 23.8% (91). Men constitute the third-highest percentage at 11.4%, with children representing the least influential demographic at 1.6% (50).

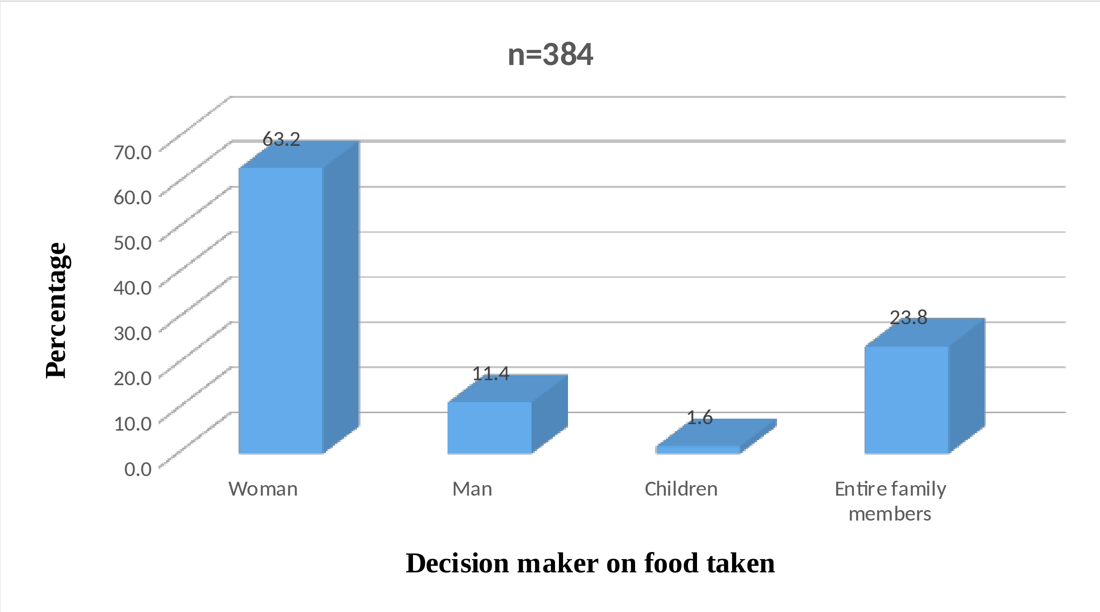


Figure 6.4: Decision maker on food to be taken in the household in Nyamira County, Kenya

Source: Researcher (2023)

Alonso *et al*. (2018) highlight the importance of decision-making power within a household. Who controls food choices – what is bought, produced, or distributed – significantly affects how cultural factors impact food security.

6.8. Amount Spent on Food per Month in Nyamira County, Kenya

The respondents were further asked to state, from their income, the average amount spent on food in a month. The summary is shown in Table 6.7. The results revealed that, on average, households spent 4,554.69 Kenya shillings (34 USD) on food per month. The findings indicate that 51.82% (199) of the respondents used between 500- 3,000 shillings (3-22 USD) per month on food. Those who spent between 3,001-5,000 shillings (22-38 USD) were 27.08% (104). Those who used 5,001-7,500 shillings (38-57 USD) were 8.85% (34). Those who spent 7,501-10,000 shillings (57-76 USD) were 7.81% (30). The remaining 4.43% (17) pay more than 10,000 shillings (>76 USD) per month on food.

Table 6.7: Summary of the amount spent on food by small-scale farmers per month in Nyamira County, Kenya

Amount spent	Frequency	Percentage
500-3,000	199	51.82
3,001-5,000	104	27.08
5,001-7,500	34	8.85
7,501-10,000	30	7.81
Above 10,000	17	4.43
Total	**384**	**100.0**

***Conversion rate: 1 USD= Ksh.130**

Source: Researcher (2023)

6.9 Purchase of Food in the Household

The study sought to determine whether the respondents could purchase food in the household without constraining other expenditures for the household. The respondents gave their responses, which are summarized in Figure 6.5. From the findings, 71.4% (274) said they could not purchase food without constraining other expenditures, while 28.6% (110) were contrary. This is alluded to by Deborah (2023), who stated:

> "Most farmers assume they will get money from cash crops to buy household food. However, with the current increase in food prices, it is impossible to sustain the right quantities of food with the recommended nutritional value when buying all the food for use at home. The same money earned from cash crops is used to meet other household financial needs like clothing, health care, and school fees, thus not enough to satisfactorily buy food throughout the year."

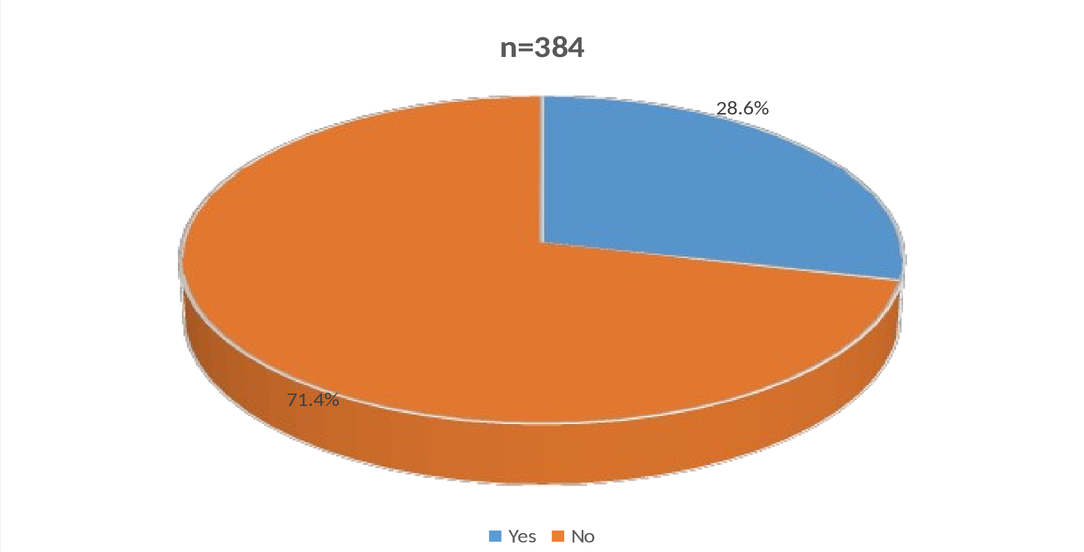


Figure 6.5: Purchase of food by small-scale farmers in Nyamira County, Kenya

Source: Researcher (2023)

6.10 Purchase Point of Essential Food Items in Nyamira County, Kenya

Respondents were further asked about their primary sources for procuring essential food items, with their responses delineated in Table 6.8. The results elucidated that a considerable majority, specifically 48.75% (313), opted to acquire food essentials from traditional markets. The subsequent preference was for retail shops, with 40.03% (257) favouring this avenue. In contrast, a smaller percentage, 10.90% (70), indicated their reliance on neighbours as a source for essential food items.

Table 6.8: Purchase point of essential food items by small-scale farmers in Nyamira County, Kenya

Point	Frequency	Percentage
Market	313	48.75
Shops	257	40.03
From Neighbour	70	10.90
Others	2	0.31
Total		**100.00**

*Respondents selected multiple choices; N=384

Source: Researcher (2023)

6.10.1 Accessibility of Food Items in Nyamira County, Kenya

Furthermore, respondents offered insights into the accessibility of food items in Nyamira County, Kenya. Figure 6.6 shows that a substantial majority, accounting for 72.2% (277), affirmed that food items are consistently accessible throughout the year. Conversely, 27.8% (107) held the contrary view, suggesting occasional challenges in accessing food items.

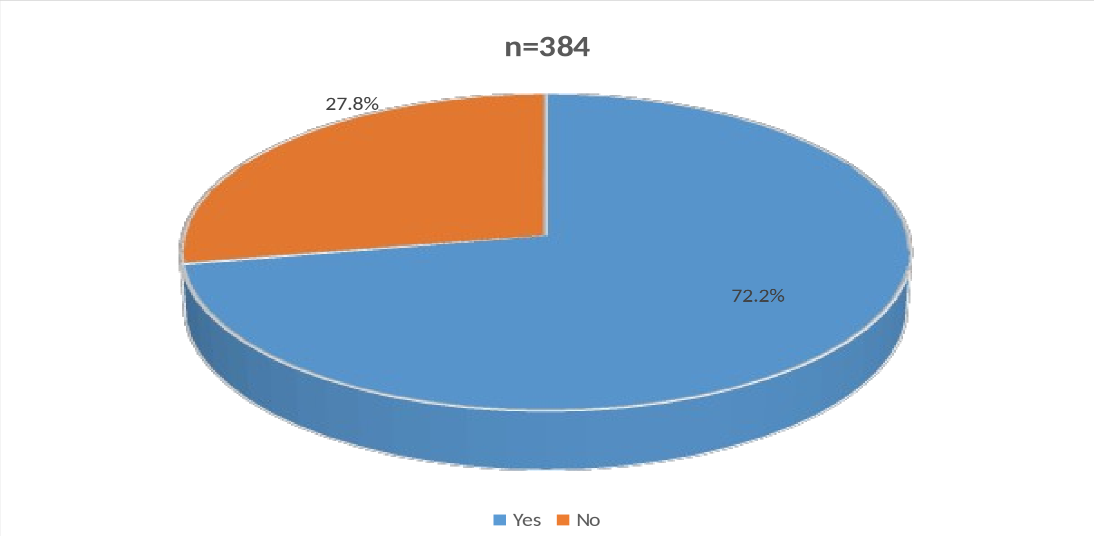


Figure 6.6: Accessibility of food items by small-scale farmers in Nyamira County, Kenya

Source: Researcher (2023)

6.10.2 Distance of Food Purchase Point from the House

The respondents provided information on the distance/ time taken from the house to reach the food purchase point. The findings are shown in Figure 6.7. The findings show that 63.0% (242) of them used approximately 15-60 minutes to reach the food purchase point, while 34.6% (133) spent more than one hour but less than two hours to get the purchase point. Only 1.6% (6) spent less than 15 minutes to the point, and 0.8% (3) spent more than two hours to the purchase point.

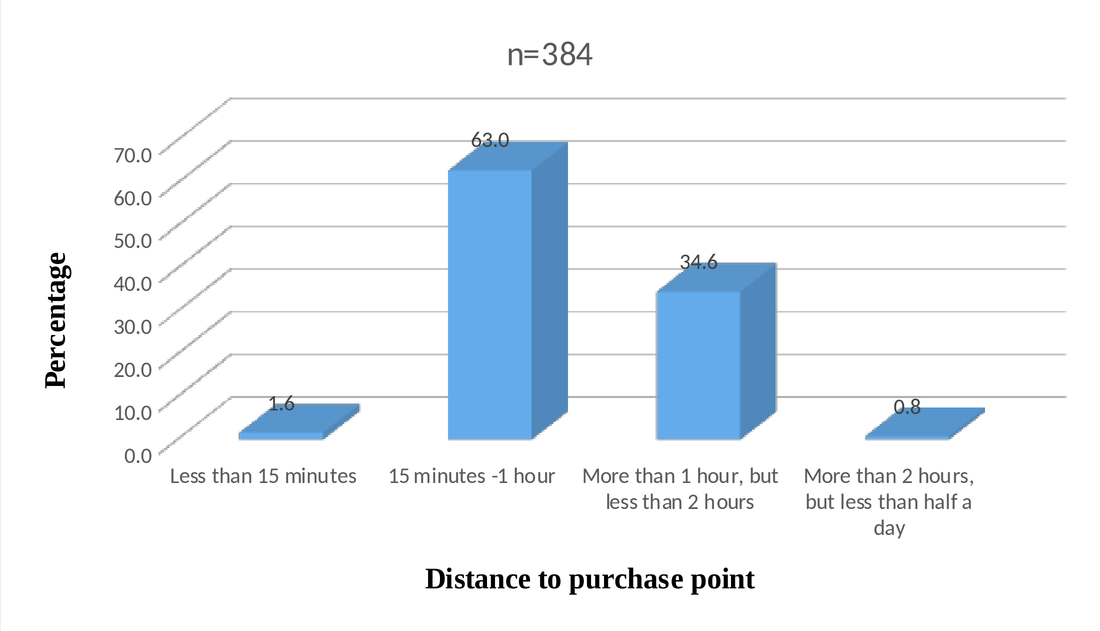


Figure 6.7: Time taken by small-scale farmers to the food purchase point in Nyamira County, Kenya

Source: Researcher, 2023

6.10.3 Challenges to Physical Access to the Purchase Point in Nyamira County, Kenya

The study investigated the constraints to physical access to the purchase point in the study area. This allowed the respondents to select more than one challenge they experienced. The findings are illustrated in Table 6.9. The findings revealed that the main challenge was lack of roads/ bad roads in the area at 32.30% (187), this was followed by long-distance at 24.70% (143), insecurity at 14.51% (84), weather conditions like floods at 12.78% (74), market not operational during some months at 5.87% (34). Only 9.50% (55) stated they were not experiencing any challenges accessing the food purchase point, while 0.35% (2) gave other challenges.

Table 6.9: Summary of challenges to physical access by small-scale farmers to food purchase point

Challenge	Frequency	Percentage
Lack of roads/bad road conditions	187	32.30
Long distance	143	24.70
Insecurity	84	14.51
Weather conditions (floods)	74	12.78
Not applicable	55	9.50
The market has not been operational for some months	34	5.87
Others	2	0.35
Total		**100.00**

*Respondents selected multiple choices; N=384

Source: Researcher (2023)

6.11 Number of Meals taken In the Household per Day

The researcher aimed to determine the number of meals the household could take daily. This was one of the variables used to determine the food accessibility in the households in Nyamira County, Kenya. From the findings in Figure 6.8, 52.2% (200) of them managed to have three meals a day, 41.6% (160) managed two meals per day, and 4.6% (18) managed one meal per day. The other group, which took more than three meals daily, constituted 1.6% (6).

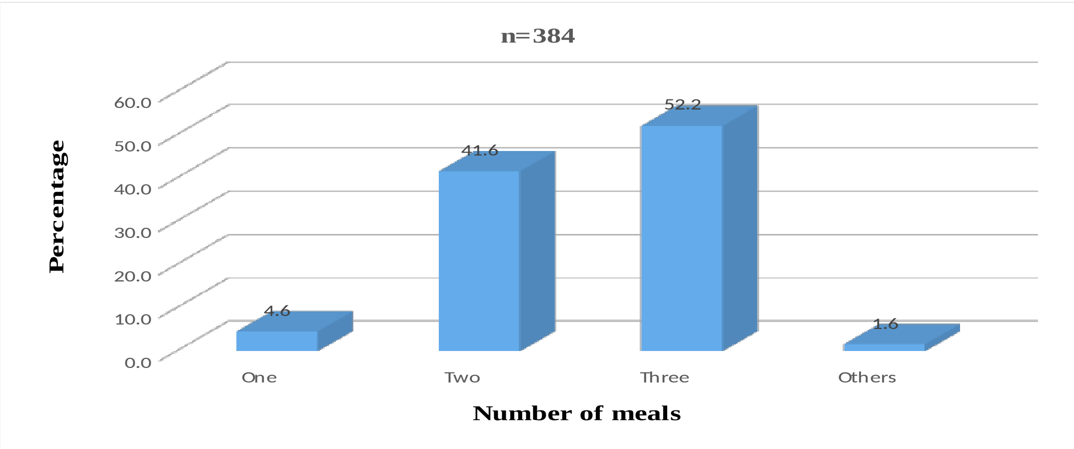


Figure 6.8: Number of meals taken per day by small-scale farmers in Nyamira County, Kenya

Source: Researcher, 2023

6.12: Household Food Security

The study established the household's food security based on the HDDS for the 12 food groups that were scored. Scores of 3 indicate low diversity, scores of between 4-6 represent medium diversity, and a score of 7 and above signifies high dietary diversity (Abegunde *et al*., 2022; Omotayo *et al*., 2022; Omotoso & Omotayo, 2024). Therefore, this study adopted this type of classification of the households into three categories, as shown in Table 6.10.

Table 6.10: HDDS categories classification of small-scale farmers in Nyamira County, Kenya

HDDS categories	Frequency		Percentage
Low dietary diversity	36		9.46
Medium dietary	135		35.14
High dietary	213		55.41
Total	**384**		**100**
The mean score of HDDS	**6.6**	**S.D**	**2.20**

Source: Researcher (2023)

Once the households were classified into the three dietary diversity shown in Table 6.9, they were further classified into two categories: food secure or food insecure, with the mean score of HDDS (mean= 6.6, S.D 2.2) as the reference point. Those with a score less than the mean were classified as food insecure, while those with a more than the mean were classified as food secure (Table 6.11).

Table 6.11: Classification of food security status of small-scale farmers in Nyamira County, Kenya

Food security status	Frequency	Percentage
Food secure	213	55.41
Food insecure	171	44.6
Total	**384**	**100.00**

Source: Researcher (2023)

A binary logistic model was conducted on the CSA practices the respondents had adopted and the household's food security. The model variables used in the model are shown in Table 6.12.

Table 6.12: Variable description used in the model

Variable	Description	Measurement
Foodsecurity	Food security status	1- Food secure, 0- food insecure
CSA1	Mixed Cropping	1 Yes, 0- no (Dummy)
CSA2	Agroforestry	1 Yes, 0- no (Dummy)
CSA3	Crop rotation	1 Yes, 0- no (Dummy)
CSA4	Cover cropping	1 Yes, 0- no (Dummy)
CSA5	Organic farming	1 Yes, 0- no (Dummy)
CSA6	Drought resistant crops	1 Yes, 0- no (Dummy)
CSA7	Water harvesting	1 Yes, 0- no (Dummy)
CSA8	Integrated soil fertility management	1 Yes, 0- no (Dummy)
CSA9	Others	1 Yes, 0- no (Dummy)

Source: Researcher, 2023

The study used the described variables in the model to determine the influence of CSA practices on household food security in Nyamira County, Kenya. The model's results are shown in Table 6.13.

A logistic regression was performed to ascertain the influence of the different CSA practices on household food security. The logistic regression model was statistically significant, $\chi^2 = 20.267$, $p < .05$. The model explained 71.0% (Nagelkerke R^2) of the variance in food security and correctly classified 61.4% of cases as either food secure or insecure. From the findings, as shown in Table 6.13, mixed cropping, crop rotation, organic farming, and cover cropping significantly influenced the household's food security ($p<0.05$). On the other hand, agroforestry, drought-resistant crops, water harvesting, and integrated soil fertility management had no significant influence on household food security.

One of the most notable findings is the positive association between mixed cropping and the outcome of interest. With a statistically significant coefficient of 0.045 ($p = 0.048$) and an odds ratio of 1.047, increasing the practice of mixed cropping can enhance the likelihood of achieving favourable outcomes related to climate-smart agriculture. This suggests that small-scale farmers who adopt mixed cropping may benefit from increased resilience and productivity, likely due to the diversified benefits of growing multiple crops simultaneously, which can improve soil health and reduce pest and disease pressure.

Similarly, crop rotation emerged as a significant factor influencing the outcome, with a coefficient of 0.518 ($p = 0.044$) and an odds ratio of 1.678. This indicates that implementing crop rotation improves soil fertility, reduces the build-up of pathogens, and enhances food security by allowing farmers to optimize crop yields over time. The significance of these practices highlights the potential for traditional agricultural methods to contribute positively to climate resilience.

Cover cropping also showed a positive and significant impact, with a coefficient of 0.331 and a highly significant p-value ($p < 0.001$). The odds ratio of 1.393 suggests that cover cropping may improve soil structure and fertility, reduce erosion, and enhance water retention, which is vital for sustainable agriculture in the face of climate variability. These benefits are crucial for small-scale farmers who often operate under resource constraints and face challenges related to climate change.

Conversely, organic farming was found to have a negative association with the outcome, indicated by a coefficient of -0.588 and a significance level of $p < 0.001$. The odds ratio of 0.556 suggests that while organic farming is often promoted for its environmental benefits, it may present challenges that hinder immediate productivity or profitability for small-scale farmers in this region. This finding invites further exploration into the barriers farmers face in transitioning to organic practices and how these might be addressed to ensure that organic farming can contribute to food security.

Integrated Soil Fertility Management (ISFM) also did not yield statistically significant results ($B = 0.241$, $p = 0.439$), indicating a need for further investigation into how this practice can be effectively promoted among farmers in Nyamira County. Additionally, the variable representing other unspecified agricultural practices was not statistically significant, highlighting the diversity of farming strategies and the complexities involved in assessing their impacts.

Table 6.13: Logit regression model analysis

Variables in the Equation							
		B	**S.E.**	**Wald**	**df**	**Sig.**	**Exp(B)**
Step 1[a]	Mixed cropping	.045	.294	.024	1	**.048**	1.047
	Agroforestry	-.198	.275	.519	1	.471	.820
	Crop rotation	.518	.257	4.053	1	**.044**	1.678
	Cover cropping	.331	.304	1.184	1	**.000**	1.393
	Organic farming	-.588	.348	2.858	1	**.001**	.556
	Drought resistant crops	-.353	.386	.833	1	.361	.703
	Water harvesting	-.406	.300	1.834	1	.176	.666
	Integrated soil fertility management (ISFM)	.241	.312	.598	1	.439	1.272
	Others	-.101	.403	.062	1	.803	.904
	Constant	.342	.301	1.292	1	.256	1.408

a. Variable(s) entered on step 1: Mixed cropping, Agroforestry, Crop rotation, Cover cropping, Organic farming, Drought resistant crops, water harvesting, integrated soil fertility management, others.

The study further established how the adoption of CSA has influenced food security in households in Nyamira County, Kenya, from small-scale farmers. Figure 6.9 shows the findings. Most respondents, 76.5% (294), stated that the CSA practices had influenced their households' food security. In comparison, 23.5% (90) said it had not influenced food security in their households.

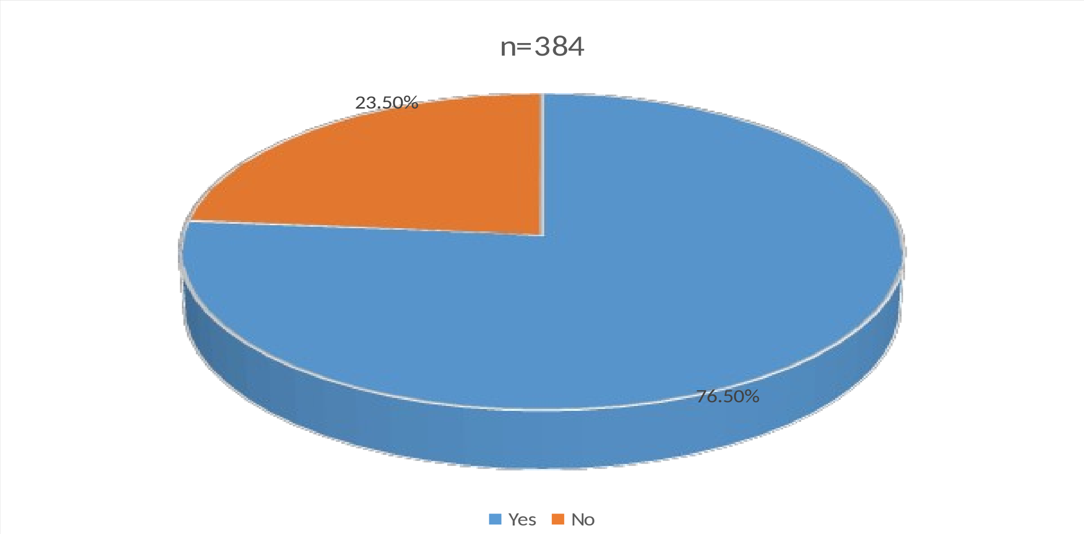


Figure 6.9 Impact of CSA on food security in Nyamira County, Kenya

Source: Researcher (2023)

Research conducted by Songok *et al*., (2011) revealed that the direct impacts of climate change on food security prompt households to employ a combination of indigenous and modern practices to adapt to climate change and manage the associated risks of food insecurity. A study by Omotoso and Omotayo (2024) also explored how implementing climate-smart agricultural practices in Nigeria can improve dietary diversity and food security. The research found that households practising climate-smart farming showed greater diversity in their food consumption and experienced enhanced food security.

The respondents were also asked how the CSA has influenced food security in the study area. The findings are summarized in Table 6.14. The findings revealed that 69.74%

(268) of the respondents agreed that CSA has improved food security among households, and 7.89% (30) stated that it has improved crop productivity. Others noted that it has led to proper utilization of the available resources and reduced expenditure on purchasing food items. This study's findings agree with a study by Zheng *et al*. (2024), which found that switching to climate-smart agriculture (CSA) practices often leads to bigger and more profitable farm harvests. This means farms get more crops, make more money, and use resources more effectively. Additionally, CSA practices make farms and the entire food system more adaptable by improving people's diets, reducing the risk of food shortages, and helping farmers cope with unpredictable weather. These practices are also good for the environment because they reduce greenhouse gasses and improve soil health.

Table 6.14: Impact of CSA on food security in Nyamira County, Kenya

Effect	Frequency	Percentage
Improved food security	268	69.74
Improved crop produce	30	7.89
Learned how to utilize available resources	5	1.32
Reduced expenditure on the purchase of food items	81	21.05
Total	**384**	**100**

Source: Researcher (2023)

6.13 Food Utilization

6.13.1 Main Source of Water

The study established the primary sources of water that the respondents were using in the study area. The findings are summarized in Table 6.15. The findings indicate that 32.66% (209) used rainwater, 19.84% (127) used water from protected well/ spring, 17.66% (113) used surface water like from rivers, dams, 15.00% (96) water from borehole fitted with a hand pump, 12.50% (80) was from water from open well/ spring, 1.88% (12) from piped water and lastly 0.47% (3) used other water sources.

Table 6.15: Water sources of small-scale farmers in Nyamira County, Kenya

Water source	Frequency	Percentage
Rainwater collected in a tank	209	32.66
Water from protected well/spring	127	19.84
Surface water (river, dam, runoff, etc.)	113	17.66
Water from a borehole fitted with a hand pump	96	15.00
Water from open well/spring	80	12.50
Piped water	12	1.88
Others	3	0.47
Total		**100**

*Respondents selected multiple choices; N=384
Source: Researcher (2023)

6.13.2 Water Treatment Methods

The study sought to determine the methods used to treat household drinking water. The findings are summarized in Figure 6.10. 64.6% (248) said they treated their water before drinking, while 35.4% (136) did not.

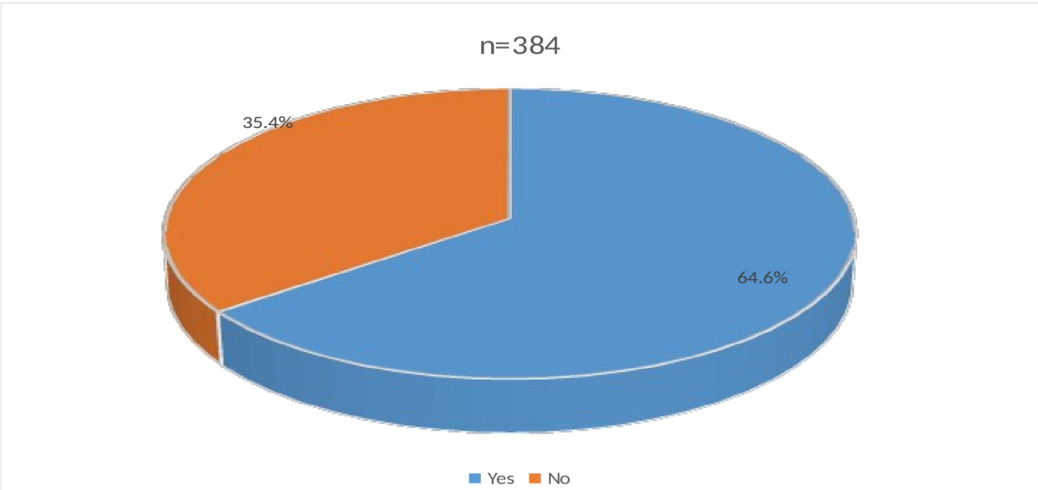


Figure 6.10: Treatment of drinking water by small-scale farmers in Nyamira County, Kenya

Source: Researcher (2023)

6.13.3 Methods of Treating Drinking Water

The study established the respondents' methods for treating their water before drinking. This question was dependent on whether a household treated its drinking water. The findings are shown in Table 6.16. A high percentage of the respondents treated water through boiling, 44.12% (109), 30.15% (75) treated through chlorination, and 5.88% (15) through filtration, while the rest did not treat the water. The other method they stated was the decantation method.

Table 6.16: Methods of water treatment by small-scale farmers in Nyamira County, Kenya

Method	Frequency	Percentage
By boiling	109	44.12
By chlorination (by adding water guard, Aquatab)	75	30.15
Do not treat	47	19.12
Filtration	15	5.88
Others	2	0.74
Total		**100**

*Respondents selected multiple choices; N=384

Source: Researcher (2023)

6.13.4 Methods of Water Storage

The survey sought information from household heads regarding their water storage practices after the purification process. The respondents selected all the methods they used to store water from the listed options. The tabulated results, as shown in Table 6.17, reveal that most respondents, comprising 66.09% (304), opt for small plastic containers and jerricans as their preferred means of water storage. In contrast, a minority of 15.87% (73) adheres to traditional pots, while 11.52% (53) favour open containers. Additionally, 5.87% (27) store water in roof tanks, with a negligible 0.65% (3) utilizing underground tanks for storage.

Table 6.17: Methods of water storage by small-scale farmers in Nyamira County, Kenya

Method	Frequency	Percentage
Small Plastic containers jerricans	304	66.09
Traditional ports	73	15.87
Open containers	53	11.52
Roof tank	27	5.87
Underground tank	3	0.65
Total		**100.00**

*Respondents selected multiple choices; N=384

Source: Researcher (2023)

The amount of water used per day in the households was determined. The findings revealed that, on average, each household used 219.71 litres of water daily.

6.14: Availability of a Toilet

The respondents were asked whether they had a toilet in their household. The responses provided are summarized in Figure 6.11. 98.4% (378) of them had toilets in their households, while 1.6% (6) had no toilets in their households.

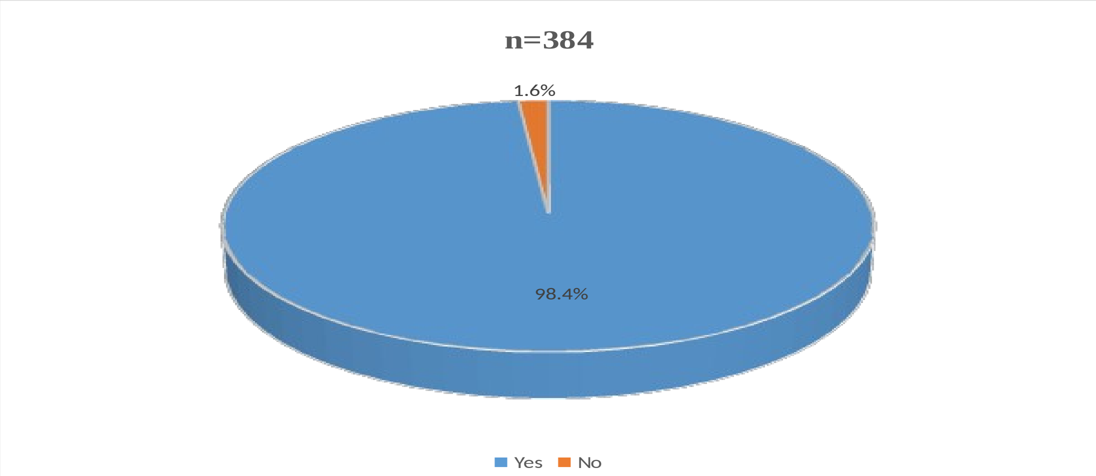


Figure 6.11: Availability of a toilet by small-scale farmers in Nyamira County, Kenya

Source: Researcher (2023)

6.14.1 Type of Toilet

Those respondents who had a toilet in their household were further required to provide information on the type of toilet that they used. This was a follow-up question for those who had agreed to have a toilet for the household. The findings are summarized in Table 6.18. The findings show that 73.12% (234) of the respondents used pit latrines with slabs, while 25% (80) used pit latrines without slabs, and 1.25% (4) used flush toilets.

Table 6.18: Type of toilet used by small-scale farmers in Nyamira County, Kenya

Type	Frequency	Percentage
Pit latrine with slab	278	73.58
Pit latrine without slab/open pit	95	25.16
Flush toilets	5	1.26
Total		**100.00**

*Respondents selected multiple choices; N=384

Source: Researcher (2023)

6.15 Treatment Facility

Participants were queried about the healthcare facilities sought by households in times of illness, and the outcomes are presented in Table 6.19. The respondents selected all the facilities they used for treatment purposes. The results elucidate that 72.77% (310) opted for public hospitals as their primary recourse when unwell. In contrast, a smaller percentage of 11.74% (50) sought medication over the counter, while a modest 7.28% (31) received treatment in private hospitals.

Table 6.19: Type of hospital used by small-scale farmers in Nyamira County, Kenya

Type of hospital	Frequency	Percentage
Public hospital	310	72.77
Over-the-counter treatment	50	11.74
Traditional healer	35	8.22
Private hospital	31	7.28
Total		**100.00**

*Respondents selected multiple choices; N=384

Source: Researcher (2023)

6.15.1 Distance between Home and Health Facility

The respondents were asked about the distance between their households and the nearest health facility. The results are presented in Figure 6.12. In a high frequency of 63.8% (245) households, the distance was between 2-5 km, while in 34.3% (132) respondents, it was less than one kilometre.

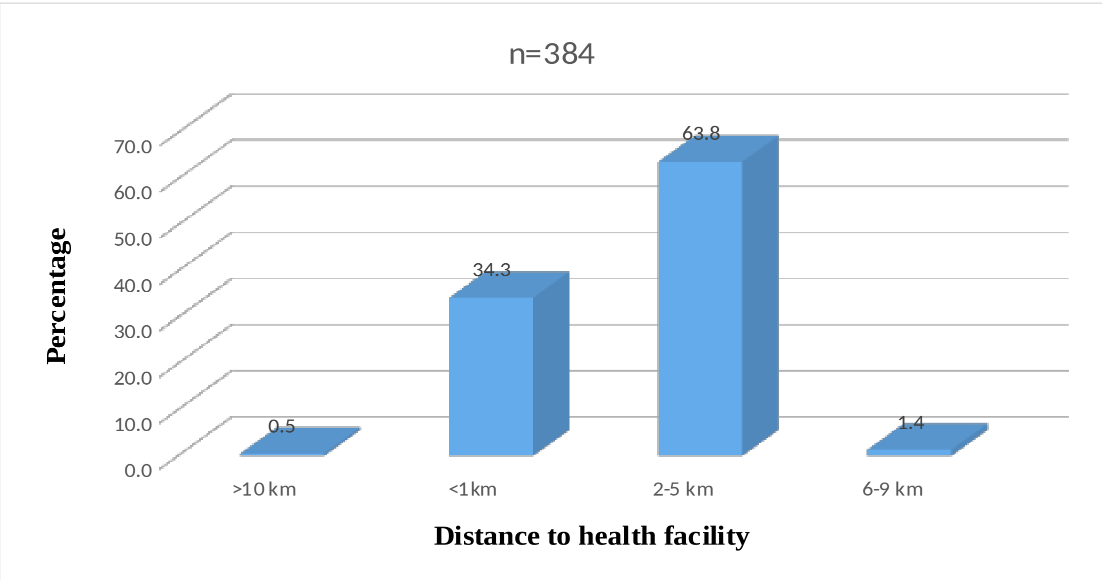


Figure 6.12: Distance between home and the nearest health facility by small-scale farmers in Nyamira County, Kenya

Source: Researcher (2023)

6.15.2 Health Insurance Policy

The researcher sought to determine the kind of health insurance the households used when visiting the health facilities. The findings are shown in Figure 6.13. From the findings, 73% (280) of the respondents had no health insurance policy, while only 27% (104) had at least one insurance policy.

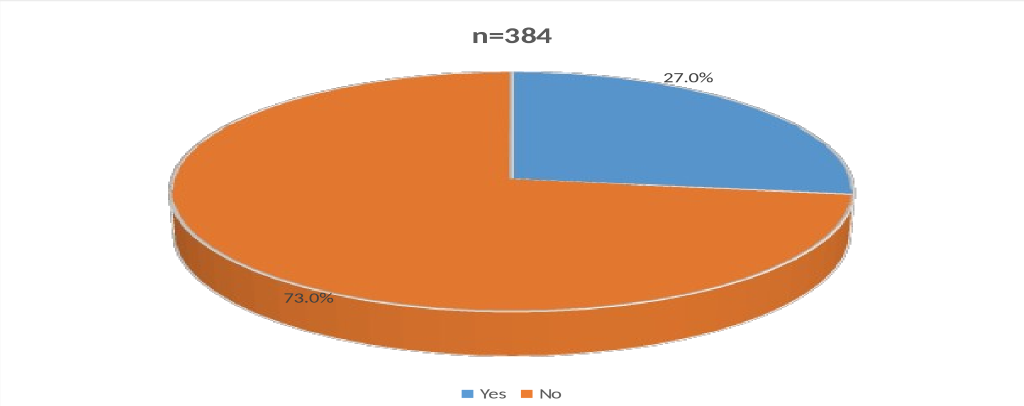


Figure 6:13 Health insurance policy used by small-scale farmers in Nyamira County, Kenya

Source: Researcher (2023)

6.15.3 Type of Health Insurance Policy

The respondents were asked what kind of health insurance policy they owned. The results are summarized in Table 6.20. The majority of the respondents used the National Health Insurance Fund (NHIF), at 88.7% (63), followed by those who used the Chai Sacco, at 7.0% (5). Others included AoN and ICEA, at 1.4% (1) each.

Table 6.20: Type of health insurance policy used by small-scale farmers in Nyamira County, Kenya

Health insurance	Frequency	Percentage
NHIF	92	88.73
Chai Sacco	7	7.04
AoN	1	1.41
Do not know	1	1.41

ICEA	1	1.41
Total		**100**

Source: Researcher (2023)

6.15.4 Challenges Encountered in Accessing Health Services

The responses to the challenges that the respondents encountered in accessing health services are summarized in Table 6.21. The respondents selected all the challenges that they were experiencing. Most respondents, 38.6% (150), experienced financial constraints in accessing health services. This was followed by 27.5% (107) who said drug shortages in health facilities were another challenge. Other challenges were poor roads, distance to the health facilities, long hospital queues, inadequate services, lack of communication, and striking doctors hindering access to health services.

Table 6.21: Summary of challenges experienced by small-scale farmers in accessing Health Facilities in Nyamira County, Kenya

Challenge	Frequency	Percentage
Poor roads	42	10.80
Distance	19	4.88
Drug shortages	107	27.51
Financial constraints	150	38.56
Long queues	11	2.83
Lack of communication	5	1.29
Inadequate services	11	2.83
None	42	10.80
Striking doctors	2	0.51
Total		**100**

*Respondents selected multiple choices; N=384

Source: Researcher (2023)

6.16 Type of Fuel Used for Cooking/Preparing Food

This investigation aimed to discern households' predominant fuel for cooking. The respondents picked all the fuel types they used to cook household food. The outcomes, systematically detailed in Table 6.22, revealed distinct fuel preferences. Notably, firewood emerged as the predominant choice, commanding a substantial majority at

95.31% (305). Following this, charcoal constituted the secondary selection, accounting for 33.75% (108), while LPG (liquefied petroleum gas) secured the third position with a prevalence of 23.75% (76). Kerosene/paraffin held a relatively lower but noteworthy usage rate at 10.94% (35), with electricity and biogas concluding the spectrum at 4.06% (13) and 1.56% (5), respectively. These findings contribute valuable insights into the diverse fuel preferences within households, thereby enriching our understanding of energy consumption patterns in domestic settings. These results are in tandem with the Nyamira County CIDP (2018), which found that firewood is the primary source of energy for cooking, with 48 percent of the population using it, while gas (LPG) constitutes 22 %.

Table 6.22: Types of fuels used by small-scale farmers in Nyamira County, Kenya

Fuel type	Frequency	Percentage
Firewood	305	56.27
Charcoal	108	19.93
LPG	76	14.02
Kerosene/ Paraffin	35	6.46
Electricity	13	2.40
Biogas	5	0.92
Total		**100**

*Respondents selected multiple choices; N=384
Source: Researcher (2023)

The study further established that most respondents, 58.92% (226), used only one fuel source. Others, 23.78% (91), used two fuel sources, 13.78% (53) used three sources, 2.97% (11) used four different sources, and 0.54% (2) used five different sources, as shown in Table 6.23.

Table 6.23: Number of fuel sources used by small-scale farmers in Nyamira County, Kenya

Number of fuel sources used		Frequency	Percent
Valid	1	226	58.92
	2	91	23.78
	3	53	13.78

4	11	2.97
5	2	0.54
Total	**384**	**100.0**

Source: Researcher (2023)

6.17 Strategies for Improving Food Security

The study established the different strategies used in the study area to improve food security. The findings are summarized in Table 6.24. The findings show that 27.5% (70) used mulching as an adaptation strategy, 16.9% (43) used mixed farming to combat climate change, 14.1% (36) practised mixed cropping,9.8% (25) used the traditional way of predicting weather), 7.1% (18) used organic manure in their farms as a strategy. Other strategies included crop rotation, cover cropping, timing seasons, and early and timely planting.

Table 6.24: Strategies used by small-scale farmers for improving food security in Nyamira County, Kenya

Adaptation Strategy	Frequency	Percentage
Mulching	70	27.5
Mixed farming	43	16.9
Mixed cropping	36	14.1
Traditional prediction of weather	25	9.8
Increased use of organic waste	18	7.1
Agroforestry	17	6.7
Use of ash	15	5.9
Integrated soil fertility	13	5.1
Timing seasons (Early and timely planting)	6	2.4
Cover cropping	4	1.6
Crop rotation	3	1.2
Learning from other successful farmers	3	1.2
Farming using bulls/cow	2	0.8
Total		**100**

Source: Researcher (2023)

Ogunyiola *et al*., (2022) highlight that traditional farming methods, such as intercropping techniques, have traditionally allowed African smallholder farmers to cultivate multiple food crops on the same piece of land to maximise income and improve soil quality. However, contemporary perspectives have labelled these practices as Climate-Smart Agriculture (CSA), as Chandra et al. (2017) observed. For instance, recent CSA strategies emphasize the advantages for smallholders in intercropping maize with either early or late-maturing soybean varieties. Similarly, although agroforestry has been a longstanding practice in Africa, new CSA approaches underscore the benefits for smallholder farmers when incorporating trees or shrubs into their agricultural fields.

According to Recha *et al*., (2017), planting field crops early, either before or right after the onset of the rains, is crucial for optimal use of the short rain season and efficiently utilizing accumulated nutrients, particularly nitrogen flush, from organic sources during the dry season. Farmers are increasingly adopting intercropping practices, incorporating a variety of crops such as maize, beans, cowpeas, green grams, sorghum, indigenous vegetables, and sweet potatoes (Recha *et al*., 2017).

Some farmers engage in mixed intercropping, planting different crops simultaneously, while others prefer relay intercropping and growing diverse crops at different times. Crop rotation involving legumes has gained popularity among farmers due to the nitrogen-fixing bacteria in legume roots, reducing the need for additional fertilizers. Intercropping offers various benefits, including preventing soil erosion and nutrient depletion, decreased risk of total crop failure, diverse products from the same land, weed suppression, and improved water use efficiency.

In accordance with the Government of Kenya (GoK, 2023), it was identified that in Nyamira County, existing climate risks pose significant challenges to agricultural productivity. To address these challenges, farmers have adopted various adaptation strategies. These strategies include rainwater harvesting, drilling shallow wells, sinking boreholes, and collecting water from springs, streams, and rivers to alleviate the impact of prolonged dry spells and erratic rainfall patterns. Moreover, farmers in the region employ various agricultural techniques to enhance resilience. These techniques include crop rotation, small-scale irrigation, cover cropping, livelihood diversification, and intercropping. Additionally, in response to the effects of dry spells, farmers implement measures such as planting early maturing crop varieties and cultivating drought-tolerant crops such as cassava and sweet potatoes as part of their adaptation strategies (GoK, 2023).

According to the GoK (2023) report, the elderly population in Nyamira County is notably affected by the challenges stemming from unpredictable and variable rainfall patterns. Consequently, elders in the region employ indigenous knowledge and traditional weather forecasting methods to mitigate these issues. In pest management, farmers in Nyamira County employ various methods, such as ash, powdered soaps, and manual handpicking, alongside some adoption of commercial insecticides. Through empirical observation, it has been revealed that specific techniques yield greater success than others in alleviating the impacts of climate change. Notably, land fallowing has been identified as a less effective strategy, attributed partly to the diminutive land parcel sizes prevalent in the county (GoK, 2023).

Additionally, the report highlights that adopting climate-smart agricultural practices faced obstacles due to insufficient extension services, thereby diminishing their efficacy. Furthermore, the prevalence of small land parcel sizes in Nyamira County results in limited use of push and pull technology despite its effectiveness in crop pest management. Instead, locally accessible and affordable methods such as soap and pepper concoctions are more widely utilized by farmers in the region (GoK, 2023).

CHAPTER SEVEN

EFFECTIVENESS OF CLIMATE-SMART AGRICULTURE PRACTICES IN STRENGTHENING FOOD SECURITY AMONG SMALL-SCALE FARMERS IN NYAMIRA COUNTY, KENYA

7.1 Introduction

This chapter analyses the fourth objective, which sought to evaluate the effectiveness of climate-smart agriculture practices in strengthening food security among small-scale farmers in Nyamira County, Kenya. The chapter is arranged into various sections that address the objective. The sections include strategies used for adapting to climate change and the impact of CSA on food security in Nyamira County, Kenya.

7.2 CSA Practices Adopted by Farmers in Nyamira County, Kenya

The study investigated the level of adoption of CSA among farmers in Nyamira County, Kenya. The respondents were required to answer the level through five Likert scale questions. The results are presented in Table 7.1. From the findings, 31.25% (116) of respondents had fully adopted mixed cropping, with a mean of 2.35. At the same time, integrated soil fertility management was the least adopted, with only 7.03% (26) respondents having it fully adopted, with a mean score of 3.07. A study by Ndung'u *et al*., (2023) investigated the factors influencing adopting climate-smart agriculture practices among smallholder farmers in Kakamega County, Kenya. They found that farmers most widely adopted practices that involved agroforestry, composting organic waste to improve soil health, and building structures to conserve soil and water. In contrast, farmers' practices like push-pull technology, conservation agriculture, and vermiculture were the least adopted.

Table 7.1: Adoption levels in percentage of CSA by far by small-scale farmers in Nyamira County, Kenya

Adoption level	Fully adopted	High adoption	Moderate adoption	Limited adoption	Not adopted	Mean	S. deviation
Mixed cropping	31.25	37.76	8.33	9.11	13.54	2.35	1.360
Agroforestry	22.14	36.98	12.76	9.64	18.49	2.65	1.405
Crop rotation	19.01	38.54	12.24	9.11	21.09	2.75	1.421
Cover cropping	10.16	33.33	16.15	14.32	26.04	3.12	1.383
Organic farming	11.46	38.80	21.09	10.16	18.49	2.85	1.290
Drought resistant crops	9.74	23.78	14.90	14.0	37.54	3.46	1.437
Water harvesting	14.06	43.75	16.15	8.33	17.71	2.72	1.312
Integrated soil fertility management	7.03	39.06	19.53	8.07	26.30	3.07	1.342

Source: Researcher (2023)

The highest level of adoption was observed in mixed cropping, with 31.25% of respondents fully adopting the practice and 37.76% reporting high adoption levels. This suggests a strong recognition of the benefits of mixed cropping, such as improved soil health and reduced pest pressures. The mean score of 2.35 indicates that farmers who practice mixed cropping may feel confident in its advantages. Yet, the standard deviation of 1.360 suggests differing experiences and levels of engagement with this practice across households. Available resources, land size, and individual farmer knowledge may influence this variance.

Agroforestry also showed promising adoption levels, with 22.14% of respondents fully adopting the practice and 36.98% indicating high adoption. The slightly higher mean score of 2.65 alongside a standard deviation of 1.405 points to a moderate enthusiasm among farmers for integrating trees with crops. However, barriers such as initial investment costs or the time required for trees to mature could impede wider adoption. Enhancing farmer education about the long-term benefits of agroforestry might promote greater uptake.

Crop rotation demonstrated similar trends, with 19.01% of respondents fully adopting it and 38.54% showing high adoption. The mean score of 2.75 and a standard deviation of 1.421 indicates that while many farmers appreciate the benefits of rotating crops, such as improved soil fertility and pest management, some may face challenges in implementing this practice consistently.

In contrast, cover cropping showed lower adoption rates, with only 10.16% of respondents fully adopting this practice. The mean score of 3.12, combined with a standard deviation of 1.383, suggests that while farmers recognize the potential benefits of cover crops like erosion control and nutrient replenishment, adoption is hindered, possibly due to a lack of knowledge or perceived complexity.

Organic farming practices had a moderate adoption level, with 11.46% fully adopting and 38.80% indicating high adoption. The mean score of 2.85 and the standard deviation of 1.290 reflect that while many farmers value organic practices, they may struggle with the transition due to challenges such as market access and the initial costs of organic inputs.

Drought-resistant crops had the lowest adoption, with only 9.74% fully adopting them. The mean score of 3.46, combined with a standard deviation of 1.437, indicates significant barriers to adoption, such as the availability of seed varieties and farmers' familiarity with the specific crops. Given the increasing threats posed by climate change, enhancing access to drought-resistant seeds and educating farmers on their cultivation could significantly improve food security in the region.

Water harvesting practices showed relatively higher adoption rates, with 14.06% fully adopting them and 43.75% indicating high adoption. A mean score of 2.72 and a standard deviation of 1.312 reflect a positive trend towards practices that manage water resources effectively, which is crucial in light of changing rainfall patterns. This area presents a significant opportunity for further development and support.

Finally, Integrated Soil Fertility Management (ISFM) exhibited lower adoption levels, with only 7.03% fully adopting the practice. The mean score of 3.07 and standard deviation of 1.342 indicate that while ISFM is recognized for its benefits, practical challenges, including lack of resources or training, may limit its adoption.

Plate 7.1 shows the various CSA practices that the small-scale farmers have adopted to combat and mitigate climate change in Nyamira County, Kenya. On the top left and right plates, the farmers have embraced mixed cropping by integrating crops like maize with vegetables and nappier grass for livestock. The bottom left plate shows a farmer who has adopted water harvesting to cope with climate change and variability. On the other hand, on the bottom right plate, the farmer has adopted agroforestry in the farm.

Plate 7.1: Mixed cropping and water harvesting practices adopted by small-scale farmers in Nyamira County, Kenya

Source: Researcher (2023)

7.2.1 Intensity of CSA Practices Adopted

The study determined the intensity of adoption of the CSA practices by small-scale farmers in Nyamira County, Kenya. As shown in Table 7.2, the finding reveals that 21.08% (81) of the farmers had adopted only one practice, and 17.30%(66) had adopted three different practices on the same farm. Others, 15.14% (58), adopted only two practices. The least were those who had not adopted any practice at 0.27% (1). On the flip coin, only 12.43% (48) indicated they had adopted other CSA practices that were not included in the study. This shows that at least 99% of farmers had adopted at least one CSA practice in their farms.

Table 7.2: Intensity of adoption among small-scale farmers in Nyamira County, Kenya

Number of CSA practices adopted	Frequency	Percentage
1	81	21.08
2	58	15.14
3	66	17.30
4	22	5.68
5	24	6.22
6	30	7.84
7	23	5.95
8	32	8.38
Others	48	12.43
Total	**384**	**100**

Source: Researcher (2023)

7.2.2 Ranking of CSA Practices

Respondents were tasked with ranking the various CSA practices they employed for prioritization. The study further scored the different CSA practices adopted by small-scale farmers. According to the results tabulated in Table 7.3, Mixed cropping emerged as the overwhelming favourite, with 70.05% of respondents selecting it as their first choice. This preference underscores the perceived benefits of mixed cropping in diversifying production and mitigating risks associated with climate variability. Additionally, mixed cropping maintained some preference as a second choice (6.25%) and even received support in subsequent rankings, reflecting its popularity among farmers as a foundational practice.

Agroforestry followed as a strong second choice, with 50.52% of respondents ranking it as their second choice. The practice aligns well with sustainable agricultural goals, enhancing biodiversity and improving soil quality. Its ranking indicates that many farmers view agroforestry as a viable option to complement their primary agricultural activities.

Crop rotation was selected by 5.99% of respondents as their first choice, but notably, it gained significant traction as a third choice (45.05%). While it may not be the most favoured practice, many farmers recognize its importance in maintaining soil health and controlling pests and diseases over time.

Cover cropping attracted moderate interest, with only 2.86% selecting it as their first choice but showing considerable potential as a fourth choice (43.49%). This may indicate a growing awareness of the benefits of cover crops in enhancing soil fertility and preventing erosion, though farmers may require more education on its implementation.

Organic farming was favoured by 1.56% of respondents as their first choice, but it gained attention as a fifth choice (43.23%), highlighting a niche interest in organic practices among the respondents. The lower first-choice ranking may reflect the challenges of transitioning to organic methods, such as access to organic inputs and market demand.

Drought-resistant crops were recognized as a crucial option, particularly in the context of climate variability. While only 1.30% ranked them as their first choice, the significant percentages in the later choices (31.77% as the eighth choice) suggest that they are considered an essential fallback or complementary strategy in the face of increasing drought conditions.

Water harvesting received modest interest as a first choice (6.25%) but ranked notably across the board, indicating a recognition of its importance in enhancing water availability for agricultural activities. The notable percentage of respondents placing it in the lower ranks (39.06% as the seventh choice) suggests that while it is valued, it may not be the immediate priority for many farmers.

Finally, Integrated Soil Fertility Management (ISFM) was less favoured overall, with 6.25% selecting it as the first choice and receiving considerable mention in the eighth choice (40.89%). This pattern may reflect farmers' lack of familiarity or understanding of ISFM practices.

Table 7.3: Ranking of CSA practices expressed as a percentage by Nyamira County small-scale farmers

CSA Practise	**1st choice**	**2nd choice**	**3rd choice**	**4th choice**	**5th choice**	**6th choice**	**7th choice**	**8th choice**
Mixed cropping	**70.05**	6.25	5.99	4.69	3.39	1.82	4.95	2.86
Agroforestry	5.99	**50.52**	14.06	7.55	4.17	7.29	6.51	4.17
Crop rotation	5.99	17.45	**45.05**	6.77	8.33	7.55	3.39	5.21
Cover cropping	2.86	5.21	9.64	**43.49**	12.50	8.85	9.38	8.07
Organic farming	1.56	4.43	9.38	20.31	**43.23**	10.42	6.77	4.17
Drought resistant crops	1.30	4.43	5.21	5.73	13.02	**26.82**	11.46	31.77
Water harvesting	6.25	9.38	8.07	8.33	9.90	15.89	**39.06**	2.86
Integrated soil fertility management	6.25	2.08	2.60	3.13	5.21	21.61	18.23	**40.89**
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Source: Researcher (2023)

7.3 Effectiveness of CSA Practices Adopted

The research examined the efficacy of the CSA practices implemented by the respondents. The outcomes are shown in Table 7.4. Mixed cropping emerged as the most favoured CSA practice, with 31.5% of respondents rating it as "very effective," while 44.8% considered it "effective." This high perceived effectiveness may be attributed to the practice's ability to enhance biodiversity, reduce pest outbreaks, and improve overall resilience against climate change. Only a small percentage, 2.6%, viewed it as "not effective," and 9.1% rated it as "less effective," while 12.0% indicated uncertainty. The overwhelming positivity surrounding mixed cropping underscores its popularity and successful integration into farming systems in the region.

Table 7.4: Efficacy of CSA practices adopted by small-scale farmers expressed as a percentage in Nyamira County, Kenya

IK-CSA Practice	Very effective	Effective	Not effective	Less effective	Do not know	Total
Mixed cropping	31.5	44.8	2.6	9.1	12.0	**100**
Crop rotation	19.01	44.01	8.85	12.76	15.36	**100**
Agroforestry	20.05	50.26	4.43	9.38	15.89	**100**
Traditional crop varieties	7.03	45.57	10.68	16.67	20.05	**100**
Organic farming	15.36	48.96	8.07	11.72	15.89	**100**
Cover cropping	12.76	42.19	11.98	14.58	18.49	**100**
Traditional weather forecasting	5.99	38.28	10.68	15.36	29.69	**100**
Traditional pest control	3.13	33.07	16.67	21.61	25.52	**100**

Source: Researcher (2023)

Crop rotation was perceived as effective by 19.01% of respondents, who classified it as "very effective" and 44.01% as "effective." However, a notable portion, 15.36%, indicated they did not know its effectiveness, which suggests a need for increased awareness and education about this practice. Only 8.85% viewed it as "ineffective," indicating that most farmers recognize its value, although a significant proportion remains uncertain about its full potential.

Agroforestry received a favourable evaluation, with 20.05% of farmers rating it as "very effective" and 50.26% as "effective." A high percentage of respondents recognized agroforestry's benefits, highlighting its role in improving soil health, providing shade, and enhancing farm biodiversity. The uncertainty among 15.89% of respondents suggests an opportunity for further training and outreach to maximize its benefits.

Regarding traditional crop varieties, 7.03% classified them as "very effective," and 45.57% as "effective." However, the proportion of respondents who expressed uncertainty (20.05%) reflects a gap in knowledge or confidence in these varieties' potential benefits, suggesting the need for more education regarding their resilience and adaptability to changing climate conditions.

Organic farming practices garnered a mixed response, with 15.36% rating it as "very effective" and 48.96% as "effective." The perceived effectiveness indicates a growing interest in organic methods among farmers. Nonetheless, 15.89% remained uncertain, which may highlight challenges in transitioning to organic practices or a lack of awareness about their advantages.

Cover cropping was seen as "very effective" by 12.76% and "effective" by 42.19%. However, the uncertainty surrounding its effectiveness (18.49%) suggests that while farmers recognize some benefits, more information and demonstration of this practice could enhance its adoption and perceived effectiveness.

Traditional weather forecasting methods received a low rating, with only 5.99% marking it as "very effective" and 38.28% as "effective." A significant percentage

(29.69%) were unsure about its effectiveness, indicating that reliance on these methods may diminish as farmers increasingly seek more reliable and scientifically-backed forecasting methods.

Traditional pest control methods received the lowest ratings, with 3.13% viewing them as "very effective." Many respondents were uncertain, with 25.52% indicating they did not know how effective these methods were. This uncertainty suggests a potential shift towards more modern pest management techniques, as traditional methods may be perceived as less reliable or effective.

7.4 Challenges to the Adoption of CSA Practices in Nyamira County, Kenya

The study sought to determine the challenges of adopting the CSA on their farms. The findings are summarized in Table 7.5. The main challenge to adopting the CSA among the respondents was smallholder farmers' inadequate knowledge of CSA technologies, at 59.69% (191), followed by Financial constraints, at 42.19% (135). They also listed the lack of appropriate policies and political will at 13.12% (42).

Table 7.5: Challenges to the adoption of the CSA practices by small-scale farmers in Nyamira County, Kenya

Challenge	Frequency	Percentage
Lack of knowledge of CSA technologies by smallholder farmers	191	43.51
Financial constraints	135	30.75
Others	46	10.48
Lack of appropriate policies and political will	42	9.57
Institutional constraints	25	5.69
Total		**100.00**

*Respondents selected multiple choices; N=384
Source: Researcher (2023)

This agrees with other studies that found resource limitations are a primary factor contributing to limited adoption rates. Moreover, socio-economic elements like intrahousehold resource limitations play a role in adopting CSA. Ragasa & Mazunda (2018) emphasize the impact of institutional factors, including land tenure, access to extension advice by both spouses in a household labour availability in female-headed households (Nyasimi & Huyer, 2017), and biophysical factors such as elevation, slope, and distance to a main road. These factors collectively influence farmers' decision-making processes about CSA adoption.

Another study by Autio *et al*. (2021) identified a lack of knowledge as the main reason for the low utilization level of several CSA technologies in Southeast Kenya. Furthermore, research conducted by Mujeyi *et al*. (2022) indicated that the uptake of CSA is notably influenced by factors such as proximity to paved roads, availability of weather information, the proportion of income derived from livestock, and possession of transportation assets.

Moreover, Ogunyiola *et al*. (2022), in their examination of smallholder farmers' involvement in CSA in Africa with a focus on the influence of local knowledge and upscaling, discovered that among the 30 studies reviewed, 21 identified various obstacles hindering farmers' adoption of CSA. These barriers encompassed challenges such as limited access to financial resources, insufficient agricultural inputs, land constraints, unfamiliarity with new commodity markets, and the high costs associated with agricultural inputs. Additionally, 18 studies underscored the significance of inadequate institutional support systems and incongruent governance arrangements as primary factors contributing to low CSA adoption among smallholder farmers.

CHAPTER EIGHT

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

8.1 Introduction

This chapter highlights the key findings, conclusions, and recommendations that have emerged from the review of previous chapters. It provides a summary description of the changes in rainfall patterns and temperature and the CSA practices that are being adopted in Nyamira County, Kenya. Afterwards, the analysis of how these factors influence the food security of small-scale farmers in the region is presented. Following up on the summary of findings, the chapter outlines the study's conclusions, where conclusions are given per the study objectives. This section then interprets the significance of the observed trends and their implications on the livelihoods of small-scale farmers. Eventually, the chapter suggests recommendations based on the findings. These recommendations provide actionable strategies for stakeholders, including policymakers, agricultural extension services, and farmers to enhance food security in the face of a changing climate and promote effective CSA practices.

8.2 Summary of Findings

The study makes the following summary as per each of the specific objectives;

The first objective sought to determine the rainfall and temperature trends and patterns in Nyamira County, Kenya, between 1990 and 2019. Trend analysis for the station revealed an increasing rainfall for MAM, SON, and DJF. During the JJA season, the station experienced a decreasing amount of rainfall. The temperature analysis at Nyamira revealed statistically significant trends (p-value < 0.05) for maximum temperature. There was also a significant upward trend in maximum temperature at the station.

The study's second objective sought to determine the existing Climate Smart Agriculture practices among small-scale farmers in Nyamira County, Kenya. The findings showed that the CSA practiced in the study area were: mixed cropping at 20.50% (230), crop rotation at 15.15% (170), agroforestry at 14.53% (163), water harvesting at 13.10% (147), organic farming at 10.52% (118), cover cropping 7.93% (89), drought resistant crops 7.49% (84) and lastly integrated soil fertility management 7.31% (82). However, the findings revealed that more than 50% of farmers used one or two CSA practices on the farms. The IK strategies the farmers used included using ash to deal with farm pests and diseases. Other IK strategies included cover cropping, crop rotation, crop diversification, and animal manure as fertilizer.

Thirdly, the research investigated the influence of CSA practices on household food security. The logistic regression model showed a statistically significant $\chi^2 = 20.267$, $p < .05$, between CSA practices and food security. The model explained 71.0% (Nagelkerke R^2) of the variance in food security and correctly classified 61.4% of cases as either food secure or insecure. From the findings, mixed cropping, crop rotation, organic farming, and cover cropping significantly influenced the household's food security ($p<0.05$). Conversely, agroforestry, drought-resistant crops, water harvesting, and integrated soil fertility management had no significant influence on household food security.

Finally, the research evaluated the effectiveness of CSA practices in improving food security in Nyamira County. The findings indicated that over 50% of the respondents acknowledged the effectiveness or high effectiveness of mixed cropping, crop rotation, agroforestry, traditional crop varieties, organic farming, and cover cropping. However, traditional weather forecasting and pest control were identified as ineffective.

8.3 Conclusions

This study concludes that Climate-Smart Agriculture (CSA) practices offer a viable pathway to achieving sustainable food security and resilience among small-scale farmers in Nyamira County. The study has identified specific CSA strategies that can be effectively adopted to enhance food security and improve the resilience of these farmers.

The study draws the following conclusions that align with the study's specific objectives.

i. The study concludes that there have been increased maximum and minimum temperatures in Nyamira County, indicating that it has experienced climate change, which calls for adaptation by adopting CSA practices. Additionally, there has been an increased rainfall trend in Nyamira station. This shows that the rainfall patterns are erratic and affect crop productivity in the region.

ii. The study revealed that respondents employed various CSA practices, such as mixed cropping, crop rotation, agroforestry, water harvesting, organic farming, cover cropping, drought-resistant crops, and integrated soil fertility management to help in achieving the pillar on productivity and reducing greenhouse gases from the atmosphere. This indicates that respondents had embraced practices for managing soil, water, land, and crops. Additionally, the respondents used other CSA practices that were not part of the scope of this study.

iii. Climate-smart agriculture (CSA) practices, such as mixed cropping, crop rotation, organic farming, and cover cropping, can significantly improve household food security through improved productivity. However, not all CSA practices influence household food security; for instance, agroforestry, using drought-resistant crops, water harvesting, and integrated soil fertility management did not significantly impact household food security in the study area.

iv. The effectiveness of the CSA practices varied considerably. Over half the respondents perceived practices like mixed cropping, crop rotation, and organic farming as highly effective, while traditional weather forecasting and pest control methods were considered ineffective.

8.4 Recommendations

The following recommendations are made based on the conclusions for each objective;

i. The study recommends continually researching and monitoring local climate patterns to understand and respond effectively to changing weather trends. Collaborating with the Kenya Meteorological Department, research institutions, policymakers, local communities, and environmental agencies can provide valuable data and insights to inform decision-making and adaptation strategies for farmers. Specifically, methods should be developed to mitigate and adapt to the effects of climate change, perceived through increased rainfall and temperature variability, which may affect various sectors such as agriculture.

ii. The study recommends facilitating knowledge-sharing and capacity-building initiatives to empower farmers with the skills and information needed to implement CSA practices effectively. This can involve organizing workshops, farmer field schools/ demonstration farms, and extension services focused on CSA techniques and their benefits in enhancing resilience to climate change.

iii. The Nyamira County agriculture department, in conjunction with the national government and non-governmental organizations, needs to promote the adoption of mixed cropping, crop rotation, organic farming, and cover cropping among smallholder farmers as critical climate-smart agriculture (CSA) practices to enhance household food security in the area.

iv. The study recommends that there is a need to prioritize the dissemination of knowledge and resources around CSA practices among farmers. This could involve farmer-training programs, extension services outreach, and creating informational materials in local languages to ensure that the practices adopted effectively strengthen food security among small-scale farmers in Nyamira County, Kenya.

8.5 Areas for Further Research

Based on the study findings, the study proposes the following study areas for future research;

i. Examine the potential for integrating modern climate information services with knowledge of CSA to provide actionable data for farmers.

ii. Conduct a longitudinal study to determine the implications of CSA practices on household food security for different seasons.

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APPENDICES

APPENDIX I

INTRODUCTORY LETTER

Dear respondent,

I am Otwori Dennis Otwori, a Masinde Muliro University of Science and Technology student undertaking a Doctor of Philosophy in Disaster Management and Sustainable Development. I am conducting academic research on **‘Climate-Smart Agriculture and Its Implications on Food Security among Small Scale Farmers in Nyamira County, Kenya’** to qualify for the award. The information you provide during this study will be confidential and entirely used for this research. I would appreciate it if you help me answer the questions in the questionnaire.

Yours sincerely,

Otwori Dennis Otwori

CDS/H/01-54121/2019

APPENDIX II

CONSENT FORM

I……………………………………………………………….., agree to participate in the research project titled **"Climate-Smart Agriculture and Its Implications on Food Security among Small Scale Farmers in Nyamira County, Kenya,"** conducted by **Otwori Dennis Otwori**, who has discussed the research project with me.

I have received, read, and kept a copy of the information letter or plain-language statement. I have had the opportunity to ask questions about this research and have received satisfactory answers. I understand the general purposes, risks, and methods of this research.

I consent to participate in the research project, and the following has been explained to me:

- My participation is entirely voluntary.
- The research may not be of direct benefit to me.
- My right to withdraw from the study at any time without any implications to me
- The risks including any possible inconvenience, discomfort, or harm as a consequence of my participation in the research project
- The steps that have been taken to minimize any possible risks
- What am I expected and required to do
- Whom should I contact for any complaints about the research or the conduct of the research?
- I can request a copy of the research findings and reports.
- Security and confidentiality of my personal information.

In addition, I consent to the following:

- Audio-visual recording of any part of or all research activities (if applicable)
- The results of this study will be published on the condition that my identity will not be revealed.

Name:____

Signature:………………………………

Date:……………………………………

APPENDIX III

HOUSEHOLD HEAD QUESTIONNAIRE

Section A: Demographic characteristics

Interviewer Name/Code:	**Questionnaire No:**	**Date:**
1. **Sub-county:** 1= Nyamira South [ ] 2=Nyamira North [ ] 3= Borabu [ ] 4= Manga [ ] 5= Masaba North [ ]	2. **Ward:**	3. **Gender:** 1= Male [ ]2 = Female [ ]

4. Are you head of household?	1= Yes [ ], 2 = No [ ]
5. Land size (hectare)	1= <1[ ], 2 = 2-4 [ ], 3 = 5-7 [ ], 4 = 8-10 [ ], 5 = >10 [ ]
6. Academic qualifications	1=not educated [ ], 2=Primary[ ], 3=Secondary[ ] , 4= Tertiary/ university[ ] Postgraduate [ ]
7. Age bracket (years)	1=18-35 yrs[ ], 2=36-50 yrs. [ ],3=51-65[ ] 4=above 66 yrs[ ] ____
8. Marital status	Single( ) married( ) divorced( ) separated( ) widowed ( )
9. Farming involved in	1= Livestock rearing ( ) 2=Crop Farming ( ) 3=Aquaculture Farming ( ) 4=Mixed Farming ( ) 5=Apiculture farming( ) 6= cash crop farming ( ) 7= Greenhouse farming 8= Horticulture farming 9= Others ()
10. Household size	1=Females [ ] 2=Males [ ] 3=No. below 18 [ ] 4=No. above 65 years [ ]________________________
11. HH Average monthly income	1= <3,000[ ] 2=3,000-9,999[ ] 3=10,000-19,999[ ] 4= 20,000 – 29,999[ ] 5= > 30,000[ ]
12. HH Land tenure system	1= Freehold [ ] 2= Leasehold [ ] 3=Communal land [ ] 4= Government [ ] 5= other specify______________________

Section B: Climate change

13. For how long have you stayed in this area?	Less than 1 year ( ) 1-5 years ( ) 6-10 years 11-15 years ( ) Over 16 years ( )
14. Have you experienced any trends in rainfall and temperature patterns in the past 5 to 10 years in this area?	Yes ( ) No ( )
15. If yes, what is the trend?	Increasing temperature ( ) increased droughts ( ) increased floods ( ) decrease in rainfall ( )

	increased crop and livestock epidemics ( ) Others ( )
16. Have you ever heard of the term climate change?	Yes ( ) No ( )
17. In your view, is climate change taking place?	Strongly agree ( ) Agree ( ) Strongly Disagree ( ) Disagree () Don't know ( )
18. Has climate change affected your farming practices?	Yes ( ) No ( )
19. If yes, explain how.	Reduced crop yields ( ) Livestock death ( ) Increased crop and livestock diseases and epidemics ( ) Food insecurity ( ) Other effects ( )

Section C: Climate-smart Agriculture Practices

20. Do you have any knowledge concerning CSA practices?	Yes ( ) No ( )
21. Which of CSA practices do you practice?	Mixed cropping ( ) Agroforestry ( ) Crop rotation ( ) Cover cropping ( ) Organic farming ( ) Drought resistant crops ( ) Water harvesting ( ) Integrated soil fertility management ( ) any other (specify)……………..
22. Have there been any initiatives by the county and national governments to promote CSA in this area?	Yes ( ) No ( )
23**.** If yes, name some of the initiatives.	Providing drought-resistant seeds ( ) providing agroforestry seedlings ( ) offering extension services ( ) providing farm inputs ( ) Other initiatives ( )
24. Name the state and non-state agencies supporting CSA in your locality.	
25. What is the contribution of these agencies towards building the capacity of CSA in the area?	
26**.** Have you ever heard of CSA model farms or CSA champions?	Yes ( ) No ( )
27. If yes, how have they assisted you in promoting CSA practices?	Established farmer field schools ( ) Established tree nurseries ( ) Forming farmer cooperative societies ( ) Other ( )
28. Have you undergone any training on the CSAs mentioned?	( ) Yes ( ) No
29. If yes, where did you do the training?	
30. What lessons were learnt from the training, if any?	Timing of seasons ( ) Identifying crop varieties ( ) Use of agricultural subsidies, e.g., One Acre Fund ( ) Identification of crop and livestock diseases ( ) Others, specify ( )

Section D: Level of adoption of CSA practices

31. Which CSA practices have you adopted/practiced on your farm? Use the Likert scale of 0- disagree, 1- Agree, and 2 don't know

Checklist of climate-smart practices	Strongly agree	Agree	Strongly disagree	Disagree	Don't know
Mixed cropping					
Agroforestry					
Crop rotation					
Cover cropping					
Organic farming					
Drought resistant crops					
Water harvesting					
Integrated soil fertility management					

32. Which CSA practices have you adopted other than the one stated above?.................
33. Would you say that the above-adopted technologies have helped you to cope with climate change? Yes( ) No ( )

34. Kindly rank the CSA practices based on your prioritization.

Checklist of climate-smart practices	Rank
Mixed cropping	
Agroforestry	
Crop rotation	
Cover cropping	
Organic farming	
Drought resistant crops	
Water harvesting	
Integrated soil fertility management	

35. On a Likert scale of 1-3, Do you agree that climate-smart practices adopted are beneficial in terms;

Benefit	Strongly Agree	Agree	Strongly Disagree	Disagree	Don't know
Enhancing resilience (adaptation) to climate change					
Increasing productivity					
Enhancing food security					
Efficient use of					

natural resources					

36. What are the challenges to the adoption of the CSA on your farm? Lack of appropriate policies and political goodwill () lack of knowledge of CSA technologies by smallholder farmers() institutional constraints () financial constraints( ) Others ( )

Section E: Food security

Section E1: Food availability

37. Do you have access to agricultural land (arable land for cultivation)?
    Yes ( ) No ( )
38. Indicate which crops are grown on the farm. Beans ( ) Maize ( ) Millet ( ) Sorghum ( ) vegetables ( ) cassava ( ) sweet potatoes ( ) Others (Specify)…………………..
39. What is the quantity of crops produced on the farm?

Food item	**Crop yield (90 Kg bags) (short rains)**	**Crop yield (90 Kg bags) (long rains)**
Beans		
Maize		
Millet		
Sorghum		
Vegetables		
Cassava		
Sweet potatoes		

40. Do you have any food stocks in your household at the moment? Yes ( ) No ( )
41. What was the source of these stocks? Own production ( ) Gifts ( ) Markets ( ) Other. Please specify…………
42. How long will these stocks last your household?......... days
43. Do you have access to farming technologies and practices to improve your production? Yes ( ) no ( )

Section E2: Food accessibility

44. What are the income-generating activities for your household?	Cash crop production/sale (e.g., coffee, tea) Food crop production/sales (e.g., maize) ( ) Income derived from the sale of livestock and animal products () Agricultural wage labour () Non-agricultural wage labour (construction…) ( ) Pension, government allowances () Salary ( ) Handicrafts ( ) Gifts/begging ( ) Food assistance ( ) Remittances ( ) Other (specify)………..
45. Who decides what to eat in the household?	Woman( ) man( ) children ( )entire family members ( )
46. What is the household income per month? ………………	<3000 () 4000-10000 () 11000-20000 () 21000-30000 () >31000 ()
47. From the stated income, how much do you spend on food in a month?	

48. Can you purchase food in the household without constraining other household expenditures?	Yes ( ) no( )
49. Where do you purchase your essential food items most often?	Market ( ) shops ( ) From neighbour ( ) other ()
50. Are food items accessible all year round?	Yes ( ) no( )
51. How far is the food purchase market from your house?	Less than 15 minutes ( ) 15 minutes -1 hour ( ) More than 1 hour, but less than 2 hours ( ) More than 2 hours, but less than half a day ( ) More than half a day( )
52. What are the constraints to physical access to the purchase point, if any?	Insecurity ( ) Long distance ( ) Lack of roads/bad road conditions ( ) Poor communication networks ( ) Weather conditions (floods) ( ) Other, specify ______________________ Not applicable( )

53. I want to ask you about the foods your household members have eaten in the last 24 hours. During this period, has your household eaten the following food items?

Question number	Food Group	Examples	YES=1 NO=0
1	CEREALS	corn/maize, rice, wheat, sorghum, millet, or any other grains or foods made from these (e.g., bread, noodles, porridge, or other grain products) + *insert local foods, e.g., ugali, nshima, porridge or paste*	
2	WHITE ROOTS AND TUBERS	white potatoes, white yam, white cassava, or other foods made from roots	
3	Vegetables	pumpkin, carrot, squash, or sweet potato that are orange inside + *other locally available vitamin A-rich vegetables (e.g., red sweet pepper)*	
4	FRUITS	ripe mango, cantaloupe, apricot (fresh or dried), ripe papaya, dried peach, and 100% fruit juice made from these + *other locally available vitamin A-rich fruits*	
5	Meat, poultry	beef, pork, lamb, goat, rabbit, game, chicken, duck, other birds, insects	
6	EGGS	eggs from chicken, duck, guinea fowl, or any other egg	
7	FISH AND SEAFOOD	fresh or dried fish or shellfish	
8	Pulses, LEGUMES, NUTS, AND SEEDS	dried beans, dried peas, lentils, nuts, seeds, or foods made from these (e.g., hummus, peanut butter)	
9	MILK AND MILK PRODUCTS	milk, cheese, yoghurt, or other milk products	
10	OILS AND FATS	oil, fats, or butter added to food or used for cooking	
11	Sugar/honey	sugar, honey, sweetened soda or sweetened juice drinks, sugary foods such as chocolates, candies, cookies and cakes	
12	SPICES, CONDIMENTS, BEVERAGES	spices (black pepper, salt), condiments (soy sauce, hot sauce), coffee, tea, alcoholic beverages	

54. How many meals can you afford per day in your household? One ( ) Two ( ) Three ( ) Other ( )

Section E3: Food utilization

55. What is the MAIN source of water for your household?	Piped water ( ) Water from an open well/spring ( ) Water from a protected well/spring ( ) Water from a borehole fitted with a hand pump () Surface water (river, dam, runoff, etc.) ( ) Rainwater collected in a tank () Other (specify) …………..
56. Does your household treat its drinking water?	Yes ( ) No ( )
57. How do you treat drinking water?	By chlorination (by adding water guard, aquatab, etc.) ( ) By boiling ( ) Please specify (others)………..
58. How do you store the water after treating it?	Plastic containers ( ) traditional ports storage tanks ( ) Open containers ( )
59. What is the amount of water used per day in your household? (in litres)......................	
60. Do you have a toilet?	Yes ( ) No ( )
61. If yes, what kind of toilet do you use?	Private latrine ( ) portable latrine ( ) Pit latrine Trench latrine ( ) Other: Please specify……………..
62. Where do you and members of your household MOSTLY go for treatment when sick?	Public hospital ( ) private hospital ( ) Traditional healer ( ) Over-the-counter treatment () Other. Please specify……….
63. What is the distance between your home and the nearest health facility?	< 1 km ( )2-5 km ( ) 6- 9 km ( ) >10 km ( )
64. Does a health insurance policy cover your household? If yes, name the policy.	
65. What challenges do you encounter in accessing health services?	
66. What type of fuel is MOSTLY used by your household for cooking/preparing food?	Electricity () LPG () Biogas () Kerosene/Paraffin () Charcoal () Firewood () Straw/shrubs/grass () Animal dung () No food is cooked in the household () Other: Please specify…………………

Section F: Effect of Indigenous knowledge CSA practices on food security

67. Which IK strategies are you using to adapt to climate change?.....................

68. In your opinion, has the indigenous knowledge of CSA influenced food security in your household? Yes ( ) No ( )
69. If yes, how?.................................
70. How effective are the following indigenous knowledge CSA practices adopted towards food security in your household? Use the Likert scale below.

IK CSA	**Very Effective**	**Effective**	**Not effective**	**Less effective**	**Don't know**
Mixed cropping					
Agroforestry					
Crop rotation					
Cover cropping					
Organic farming					
Local varieties					
Traditional pest control (e.g., use of ash)					
Traditional weather forecasting					

71. Which other indigenous knowledge strategies can be used to improve food security in your household?.......................
72. Which adaptive strategies have you adopted to mitigate the effects of climate change on your farm?

APPENDIX IV

KEY INFORMANT GUIDE FOR COUNTY DEPARTMENT OF AGRICULTURE, LIVESTOCK AND FISHERIES

1. Is climate change impacting the agriculture sector?
2. Do the households undergo training on agricultural practices?
3. What are the challenges to adopting new agricultural practices in the county?
4. What is the level of food security in the county?
5. How has climate change affected food security in the county?
6. Which measures has the government implemented to help farmers adapt to climate change?
7. Are the current strategies effective in ensuring food security in the county?
8. Do small-scale farmers have the ability to adapt to climate change?

APPENDIX V

KEY INFORMANT GUIDE FOR KENYA METEOROLOGICAL DEPARTMENT

1. What have been the trends and patterns in rainfall from 1990 to 2019 in Nyamira County?

2. What are the trends and patterns in temperature from 1990 to 2019 in Nyamira County?

3. How have rainfall and temperature trends affected food security in Nyamira County?

4. What indigenous knowledge practices are households using to increase productivity, adapt to climate change, and enhance food security?

5. Which climate-smart agriculture practices could farmers adopt to help mitigate the effects of climate change?

6. What adaptive strategies do small-scale farmers need to adopt to address climate change challenges effectively?

APPENDIX VI

KEY INFORMANT GUIDE FOR KENYA CLIMATE SMART AGRICULTURE PROJECT

1. Has Nyamira County experienced climate change? If so, how?
2. What impact has climate change had on the agriculture sector?
3. Which climate-smart agriculture practices are currently adopted by small-scale farmers?
4. Do households receive training on CSA practices?
5. What indigenous knowledge practices do households use to increase productivity, adapt to climate change, and enhance food security?
6. What challenges are faced in adopting CSA practices in the county?
7. Have CSA practices improved resilience to climate change, increased productivity, and enhanced food security?
8. How has climate change affected food security in Nyamira County?
9. What measures has the government implemented to support farmers in adopting CSA practices?
10. What other strategies are available to help households achieve food security?
11. Are the current strategies effective in promoting food security in the county?
12. Do small-scale farmers have the capacity to adapt to climate change?

APPENDIX VII

KEY INFORMANT GUIDE FOR KALRO

1. Is climate change impacting the agriculture sector?

2. Which Climate Smart agriculture practices are adopted by the households in the county?

3. Do the households undergo training on CSA practices?

4. Do you support small-scale farmers with climate-related inputs?

5. Which indigenous knowledge CSA practices do households use to increase productivity, adapt to climate change, and enhance food security?

6. Which climate-tolerant seeds do you give the farmers?

7. Have the CSA practices enhanced resilience (adaptation) to climate change, increased productivity, and food security among farmers?

8. How has climate change affected food security in the county? If yes, how?

9. Which measures have you implemented to ensure that the farmers adopt the CSA practices?

10. Which other strategies are available for the households to adopt to be food secure?

11. Are the current strategies effective in ensuring food security in the county?

12. Do small-scale farmers have the adaptive capacity to climate change?

APPENDIX VIII

KEY INFORMANT GUIDE FOR NGOS INVOLVED IN CSA

1. Has the county experienced climate change? If yes, how?

2. Is climate change impacting the agriculture sector?

3. Which Climate Smart agriculture practices are adopted by the households in the county?

4. Do the households undergo training on CSA practices?

5. Which indigenous knowledge CSA practices do households use to increase productivity, adapt to climate change, and enhance food security?

6. What are the challenges of CSA adoption in the County?

7. Have the CSA practices enhanced resilience (adaptation) to climate change, increased productivity, and food security?

8. What is the food security status in the county?

9. How has climate change affected food security in the county? If yes, how?

10. Which measures has the government implemented to ensure farmers adopt the CSA practices?

11. Which other strategies are available for the households to adopt to be food secure?

12. Are the current strategies effective in ensuring food security in the county?

13. Do small-scale farmers have the adaptive capacity to climate change?

APPENDIX IX

KEY INFORMANT GUIDE FOR KENYA FORESTRY SERVICE

1. Has the county experienced climate change? If yes, how?

2. Is climate change impacting the agriculture sector?

3. Which Climate Smart agriculture practices are adopted by the households in the county?

4. Do the households undergo training on CSA practices?

5. Which indigenous knowledge CSA practices do households use to increase productivity, adapt to climate change, and enhance food security?

6. What are the challenges of CSA adoption in the County?

7. Have the CSA practices enhanced resilience (adaptation) to climate change, increased productivity, and food security?

8. What is the food security status in the county?

9. How has climate change affected food security in the county? If yes, how?

10. Which measures has the government implemented to ensure farmers adopt the CSA practices?

11. Which other strategies are available for the households to adopt to be food secure?

12. Are the current strategies effective in ensuring food security in the county?

13. Do small-scale farmers have the adaptive capacity to climate change?

APPENDIX X

KEY INFORMANT GUIDE FOR KEFRI

1. Is climate change impacting the agriculture sector?
2. Which Climate Smart agriculture practices are adopted by the households in the county?
3. Do the households undergo training on CSA practices?
4. Which indigenous knowledge CSA practices do households use to increase productivity, adapt to climate change, and enhance food security?
5. What are the challenges of CSA adoption in the County?
6. Have the CSA practices enhanced resilience (adaptation) to climate change, increased productivity, and food security?
7. What is the food security status in the county?
8. How has climate change affected food security in the County? If yes, how?
9. Which measures has the government implemented to ensure farmers adopt the CSA practices?
10. Which other strategies are available for the households to adopt to be food secure?
11. Are the current strategies effective in ensuring food security in the county?
12. Do small-scale farmers have the adaptive capacity to climate change?

APPENDIX XI

FOCUS GROUP DISCUSSION GUIDE

1. Has the area experienced climate change?
2. What is the effect of climate change on food security?
3. Which indigenous knowledge CSA practices do households use to increase productivity, adapt to climate change, and enhance food security?
4. How has the households adapted to the climate change?
5. Have the households in this county adopted the CSA practices?
6. Are the households trained on the various technologies by the relevant authorities?
7. What is the impact of the CSA practices on food security?
8. Since the adoption of CSA practices, has food security improved in the County?
9. What is food security status in households with the changing climatic conditions?
10. Which other strategies can be used to ensure food security in the area?
11. What are the adaptive strategies small-scale farmers use to address climate change?
12. Can you rank the available strategies in order of priority?

APPENDIX XII

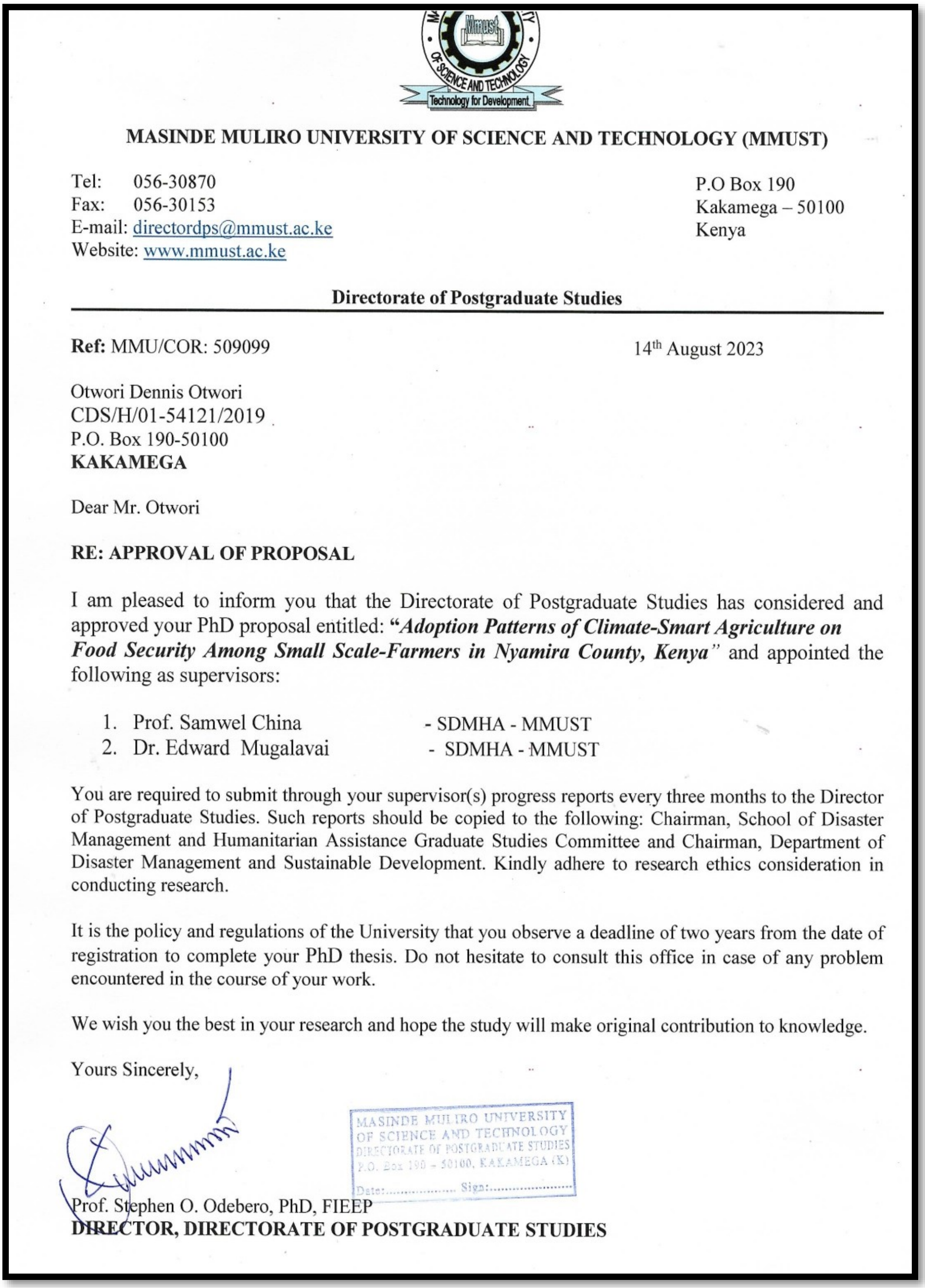
OBSERVATION CHECKLIST

The study will make the following observations relating to the CSA practices in households.

OBSERVATIONS (of climate-smart practices)	Quantity	Comment
Mixed cropping		
Integrated crop and livestock systems		
Agroforestry		
Irrigation		
Intercropping		
Crop rotation		
Mixed cropping		
Rainwater harvesting		
Greenhouse technology		
Soil and water conservation- construction of water retention structures		
Crops using little water		
Use of cover cropping		
Mulching		
Farmyard composting		
Biogas production		
Organic farming		

APPENDIX XIII

MMUST APPROVAL LETTER



MASINDE MULIRO UNIVERSITY OF SCIENCE AND TECHNOLOGY (MMUST)

Tel: 056-30870
Fax: 056-30153
E-mail: directordps@mmust.ac.ke
Website: www.mmust.ac.ke

P.O Box 190
Kakamega – 50100
Kenya

Directorate of Postgraduate Studies

Ref: MMU/COR: 509099

14th August 2023

Otwori Dennis Otwori
CDS/H/01-54121/2019
P.O. Box 190-50100
KAKAMEGA

Dear Mr. Otwori

RE: APPROVAL OF PROPOSAL

I am pleased to inform you that the Directorate of Postgraduate Studies has considered and approved your PhD proposal entitled: ***"Adoption Patterns of Climate-Smart Agriculture on Food Security Among Small Scale-Farmers in Nyamira County, Kenya"*** and appointed the following as supervisors:

1. Prof. Samwel China - SDMHA - MMUST
2. Dr. Edward Mugalavai - SDMHA - MMUST

You are required to submit through your supervisor(s) progress reports every three months to the Director of Postgraduate Studies. Such reports should be copied to the following: Chairman, School of Disaster Management and Humanitarian Assistance Graduate Studies Committee and Chairman, Department of Disaster Management and Sustainable Development. Kindly adhere to research ethics consideration in conducting research.

It is the policy and regulations of the University that you observe a deadline of two years from the date of registration to complete your PhD thesis. Do not hesitate to consult this office in case of any problem encountered in the course of your work.

We wish you the best in your research and hope the study will make original contribution to knowledge.

Yours Sincerely,

MASINDE MULIRO UNIVERSITY OF SCIENCE AND TECHNOLOGY
DIRECTORATE OF POSTGRADUATE STUDIES
P.O. Box 190 - 50100, KAKAMEGA (K)
Date:.................. Sign:.....................

Prof. Stephen O. Odebero, PhD, FIEEP
DIRECTOR, DIRECTORATE OF POSTGRADUATE STUDIES

APPENDIX XIV

NACOSTI PERMIT

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION

Ref No: **313666**

Date of Issue: **24/August/2023**

RESEARCH LICENSE

This is to Certify that Mr.. Otwori Otwori Dennis of Masinde Muliro University of Science and Technology, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Nyamira on the topic: ADOPTION PATTERNS OF CLIMATE-SMART AGRICULTURE ON FOOD SECURITY AMONG SMALL-SCALE FARMERS IN NYAMIRA COUNTY, KENYA for the period ending : 24/August/2024.

License No: **NACOSTI/P/23/28864**

313666

Applicant Identification Number

Director General

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION

Verification QR Code

NOTE: This is a computer generated License. To verify the authenticity of this document, Scan the QR Code using QR scanner application.

See overleaf for conditions

APPENDIX XV

NYAMIRA COUNTY COMMISSIONER APPROVAL LETTER

REPUBLIC OF KENYA

OFFICE OF THE PRESIDENT

Ministry of Interior and National Administration

Telephone: 020-2012491
Fax: 058-6144446
Email: ccnyamira@yahoo.com.
ccnyamira2012@gmail.com.

COUNTY COMMISSIONER
NYAMIRA COUNTY
P.O. BOX 2 - 40500
NYAMIRA

When replying please quote our

RE. NYRC/ED.2/VOL. IV/11

31ST AUGUST, 2023

THE COUNTY COMMISSIONERS
NYAMIRA

RE: RESEARCH AUTHORIZATION – MR. OTWORI OTWORI DENNIS – MASINDE MULIRO UNIVERSITY OF SCIENCE AND TECHNOLOGY

Reference is made to a letter Ref. No. NACOST/P/23/28864 from Director General NACOSTI dated **24th August, 2023 on the subject matter above**

You are hereby authorized ***to carry out research on "Adoption patterns of climate-smart Agriculture on food security among small-scale farmers in Nyamira County, Kenya".***

The planned research will be conducted in Nyamira County for the period ending ***24/August/2024***

Kindly accord him the necessary assistance he may require.

FLORENCE OBUNGA
FOR: COUNTY COMMISSIONER
NYAMIRA

Copy to: The County Director of Education,
NYAMIRA.

APPENDIX XVI

NYAMIRA COUNTY EDUCATION APPROVAL LETTER

REPUBLIC OF KENYA

MINISTRY OF EDUCATION

STATE DEPARTMENT of Early Learning and Basic Education

Telegram: "EDUCATION", Nyamira
Telephone: (058) 6144224
E-Mail. cdenyamiracounty@gmail.com
When replying please quote

COUNTY DIRECTOR OF EDUCATION
NYAMIRA COUNTY
P.O.BOX 745-40500
NYAMIRA

REF: NCEO/1/25/VOLIII/110

DATE: 19TH OCTOBER, 2023

TO WHOM IT MAY CONCERN

RE: AUTHORITY TO CONDUCT RESEARCH BY –MR.OTWORI OTWORI MASI – MASINDE MULIRO UNIVERSITY OF SCIENCE AND TECHNOLOGY.

Reference is made to the letter **Ref. No. NACOSTI/P/23/28864** dated **24th AUGUST, 2023** on the above mentioned subject matter. He has been given authority by the National Commission for Science, Technology and Innovation to carry out research on '***to carry out research on "Adoption pattern of climate ... Smart Agriculture on food security among small- scale farmers in Nyamira County, Kenya."***

The planned research will be conducted in Nyamira County for the period ending 24th August, 2024

Kindly accord him necessary assistance he may require.

COUNTY DIRECTOR
OF EDUCATION - NYAMIRA
P.O. Box 745 - 40500, NYAMIRA
SIGN:..............DATE:..................

Samson Wuapari (Mr.)
FOR: COUNTY DIRECTOR OF EDUCATION
NYAMIRA COUNTY

ISO 9001 SGS

APPENDIX XVII

COUNTY SECRETARY APPROVAL LETTER

REPUBLIC OF KENYA

Mobile: 0738727272/0735232323
E-mail: info@nyamira.go.ke
Website: http://www.nyamira.go.ke

P.O BOX 434 – 40500
NYAMIRA

COPY

COUNTY GOVERNMENT OF NYAMIRA
OFFICE OF THE COUNTY SECRETARY

Ref: NCG/CS/TRAIN/20/VOL IV/129

Date: 21/2/2024

County Chief Officer
Crops Production
Department of Agriculture, Livestock & Fisheries
Nyamira County

RE: AUTHORITY TO CONDUCT RESEARCH – OTWORI DENNIS OTWORI – REG. NO. CDS/H/01-54121/2019

The above named is a PhD student in the Masinde Muliro University of Science and Technology. He has been authorized to conduct research on "***Adoption Patterns of Climate-Smart Agriculture on food Security Among Small Scale-Farmers in Nyamira County, Kenya .***"

The purpose of this letter is to request you to accord him necessary assistance.

Dr. Jack Magara, FADI
County Secretary and Head of County Public Service
Nyamira County

CC:

County Executive Committee Member
Agriculture, Livestock & Fisheries
Nyamira County

Otwori Dennis Otwori
Reg. No. CDS/H/01-54121/2019