EFFECT OF CLIMATE-SMART AGRICULTURE ON PROFITABILITY OF SMALLHOLDER POTATO AGRI-ENTERPRISES IN NYERI COUNTY, KENYA

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A Thesis Submitted to the Graduate School in Partial Fulfilment of the Requirements for the Master of Science Degree in Agri-enterprise Development of Egerton University

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DECLARATION AND RECOMMENDATION

Declaration:

This thesis is my original work and has not been presented at this university or any other for the award of a degree

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Recommendation:

This thesis has been submitted with our approval as university supervisors

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DEDICATION

This thesis is dedicated to my parents Mr and Mrs Anthony Kinyingi and my entire family, for their dedicated support and prayers.

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ABSTRACT

Climate change has affected the agricultural sector negatively resulting in income losses among farmers. To curb climate change effects, various agricultural stakeholders have recommended Climate-Smart Agriculture, Technology, and Innovation Management Practices (CSA TIMPs) as prerequisites for adaptation to climate change. Despite the availability of these innovations in Nyeri County, there is a significant underutilization of these services. The factors influencing the adoption of these innovations in Irish potato production, as well as their profitability in small-scale potato Agri-enterprises, remain unclear. This study seeks to address these knowledge gaps by investigating the Utilization of CSA TIMPs, identifying the determinants of their application, and assessing their profitability in the context of small-scale potato farming. The specific objectives of this study were to analyze the level of adoption vis a vis availability of CSA TIMPs among potato entrepreneurs, to evaluate the profitability of CSA TIMPs, and to analyze the determinants of adoption of CSA TIMPs among potato Agri-enterprises in Nyeri county. The study's sample size was 384 households in Kieni sub-County, Nyeri County. Qualitative and quantitative data were collected using semi-structured questionnaires. To assess the utilization of five CSA TIMPs; agro meteorology, and use of Information Communication Technology (ICT), group and cooperative membership, and proper post-harvest storage techniques were ranked using the Kendal rank correlation coefficient. A gross margin analysis was conducted to evaluate the profitability of the TIMPs and a multi-variate probit model to analyze the determinants of adoption of the TIMPs. The results indicated a strong positive correlation (Kendall's tau = 0.87) between the availability of CSA TIMPs and their utilization. T-test results showed that the adoption of CSA TIMPs, particularly agro-meteorological services, has a significant positive impact on profitability at the 5% significance level. Age, experience in potato farming, income, and size of potato Agrienterprises do play a role in the adoption of specific CSA TIMPs at 0.02**(5%), 0.09*(10%), 0.01*(10%) and 0.02** (1%) respectively. For interventions to address climate change to materialize, policymakers must consider the accessibility of various CSA facilities among farmers. CSA providers should also consider targeted training programs on CSA awareness, the Creation of experience-sharing platforms, and awareness campaigns to incentivize adoption. By implementing these recommendations, the adoption of CSA TIMPs can be enhanced across different demographic groups, leading to a more resilient and sustainable agricultural sector.

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LIST OF ABBREVIATIONS AND ACRONYMS

ACMAD: African Centre for Meteorological Application and Development

CAS: Climate Advisory Services

CBA: Cost-Benefit Analysis

CBOs: Community-Based Organizations

CCAFS: Climate Change Agriculture and Food Security

CGIAR: Consultative Group on International Agricultural Research

CIASA: Climate-based Information on Climate and Services for Africa

CSA: Climate-Smart Agriculture

GDP Gross Domestic Product

GFCS: Global Framework for Climate Services

ICPAC: Climate Prediction and Application Centre

ICT: Information and Communication Technology

IGAD: Inter-Governmental Agency on Development

IPCC: Intergovernmental Panel on Climate Change

KCSAP: Kenya Climate Smart Agriculture Project

KMD: Kenya Meteorological Department

KNBS: Kenya National Bureau of Statistics

NDMA: National Drought Management Authority

NGO: Non -Governmental Organizations

NMA: National Meteorology Agencies

NMHS: National Meteorological and Hydrological Services

SDGs: Sustainable Development Goals

SPSS: Statistical Package for Social Sciences

TIMPs: Technology Innovation and Management Practices

VIF: Variance Inflation Factor

WAI: Weighted Average Index

WEF: World Economic Forum

WMO: World Meteorological Organization

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Agriculture remains the key pillar of the economy in Sub-Saharan Africa. In Kenya, Agriculture contributes approximately 30% of the nation's GDP (FAO, 2017). Agri-enterprise development encompasses a wide range of activities related to the supply of inputs, production, processing, transportation, and marketing of agricultural-related products. The transition of agriculture from subsistence farming into commercial firms leads to the development of agrienterprises. Agri-enterprises are a major source of job creation, foreign exchange, food security, and raw materials for many industries. The majority of the people living in rural areas depend directly on agriculture as the main source of livelihood (FAO, 2017). Poverty is however rampant in rural areas, therefore building sustainable Agri-enterprises plays a pivotal role in eradicating poverty as well as improving their livelihoods. Among the many challenges facing the agricultural sector, climate change is a major challenge that needs to be addressed.

Climate change has occurred over time. The current rate and severity of climate change are overwhelming and causing widespread uncertainty. Climate change is a result of both natural and human causes. Climate change is evidenced by the increasing change in weather patterns, and the changes in sea levels, land surfaces, and ice sheets, that occur over decades or even longer time spans. An adjustment in the agricultural systems will be necessary to ensure food sufficiency (Serdeczny *et al.,* 2017). The increased unpredictability of weather patterns has ravaged the agricultural sector causing income losses among 500 million small-holder farmers in developing countries and consequently threatening their food security.

Climate change causes uncertainties that affect not only agricultural production but also distribution and marketing. Production activities are affected by challenges in input supply, while marketing challenges emanate from poor post-harvest storage techniques and processing activities (Bongaarts, 2019). Although farming communities have survived using traditional weather prediction techniques, rapid changes in weather patterns may render indigenous knowledge and traditional coping mechanisms obsolete.

According to a report by the Intergovernmental Panel on Climate Change (IPCC) human activities such as industrialization have heightened greenhouse gas emissions, from 35 billion tons of CO_2 in a year in the 1990s to around 50 billion tons of CO_2 now. Since the Industrial Revolution, human activity has raised greenhouse gas levels in the atmosphere, resulting in increased heat absorption and higher surface temperatures. Heat is absorbed by greenhouse gases in the atmosphere. Developing countries are at higher risk of experiencing the significant effects of climate change due to limited adaptive capacity.

Production of Irish potatoes, Kenya's second-most fundamental food crop, is impacted by climate change. Due to their sensitivity to rainfall and temperature fluctuations, potato yields are expected to decline by 22% in SSA, contributing to food insecurity (Ndegwa *et al.,* 2020). Between 2008 and 2018, the yield of Kenya's potato output generally decreased from 21.5 to 8.6 tons/ha, primarily due to the effects of climate change. In Kenya, there is an observed decline in potato production in the years 2017 and 2019 from 9.2 to 8.6 tones. The yields in the continent are meager at less than 20T tons per hectare for the country, compared to over 40 tons for developed regions like North America (FAO, 2020).

There is a gap between actual and expected potato yield, which could result from losses associated with low adoption of intelligent agriculture. This gap could be attributed to low-quality seeds, increased land sub-division, inadequate access to funds, and lack of training and support services. Smallholder farmers consequently produce little, which results in fewer earnings. Management of losses emanating from climate change is integral for adapting farming systems into sustainable enterprises. To boost farmers' resilience to climate change in Kenya, the government through the Kenya Climate Smart Project recommends applying CSA TIMPs to boost resilience and increase agricultural production.

The government, through various stakeholders, has relatively enhanced access to CSA TIMPs among farmers. CSA TIMPs services are offered through mobile phones, television, radio, and newspapers. Advisories on applying CSA TIMPs are provided daily, weekly, monthly, or seasonally. Other sources of CSA advisories are regional and social networks. Organizations offering climate information include; the National Drought Management Authority (NDMA), Kenya Meteorological Department (KMD), Non-governmental Organizations (NGOs), international development agencies, private organizations, Community Organizations (CBOs), and research institutions. Potato farmers can adopt CSA TIMPs that include; agro-meteorology, ICT platforms for marketing and input acquisition, application of appropriate fertilizers, proper postharvest storage, and membership in farmer groups and cooperatives.

Agro meteorology helps equip farmers with useful climate information on weather forecasting. Encompassed with the development of the ability to use market information services Agrientrepreneurs can make informed decisions on what, when, where, and how to embark on their farming activities. This study will focus on applying CSA TIMPs among potato farmers in Nyeri County, Kenya. Nyeri County is a major Irish potato producer. Small-scale agri-entrepreneurs dominate the production of potatoes for both consumption and commercial purposes. The potato value chain is an essential enterprise for the county as it contributes significantly to food security, income generation, and employment for many small-holder agri-entrepreneurs. Potato farming is hugely affected by climate change. Reay (2019) observed that climate change destroys over half of Africa's potato crops per season. Such losses pose a big threat to production capacity, and income losses potentially deprive farmers and their families of living.

Adopting CSA TIMPs at the farm level promises immense benefits that agricultural enterprises can leverage. However, their application, especially in Sub-Saharan Africa, is low. Various factors determine the adoption and dis-adoption of CSA TIMPs. Social-economic and Institutional factors such as; age, gender, access to extension services, access to markets, and membership in farmer groups influence the adoption of CSA TIMPs. However, the direction of influence of these factors varies depending on the farm's location and the availability of these technologies (Abegunde *et al.,* 2019). As various stakeholders across the globe increase their efforts to scale up the adoption of CSA TIMPs, it is crucial to understand factors that hinder their adoption. This study aimed to examine the utilization of CSA TIMPs, their profitability to potato agricultural enterprises, and factors that influence their adoption.

1.2 Statement of the Problem

CSA TIMPs aim to provide tangible solutions for agricultural entrepreneurs by delivering practical insights on weather, production, and market information. Such information helps the entrepreneur better understand the appropriate input to apply, production and marketing techniques. Despite the availability of these CSA innovations in Nyeri County, there is a significant underutilization of these services. The factors influencing the adoption of these innovations in Irish potato production, as well as their profitability in small-scale potato agri-enterprises, remain unclear. This study seeks to address these knowledge gaps by investigating the utilization of CSA TIMPs, identifying the determinants of their application, and assessing their profitability in the context of small-scale potato farming.

1.3 Objective

1.3.1 The general objective

The general objective of this study was to contribute to the enhanced utilization and adoption of Climate-Smart Agriculture (CSA) Technological Information and Management Platforms (TIMPs) in Nyeri County, with a specific focus on Irish potato production.

1.3.2 Specific objectives

i. To assess the utilization of CSA TIMPs available for potato entrepreneurs in Nyeri County ii. To analyze the determinants of adoption of CSA TIMPs among potato entrepreneurs in Nyeri County iii. To evaluate the profitability of CSA TIMPs on potato agri-enterprises in Nyeri county

1.4 Research Questions

i. What is the utilization level of CSA TIMPS among agri-enterprises?
ii. What are the determinants of the adoption of CSA TIMPs among potato agri-entrepreneurs?
iii. What is the effect of the adoption of CSA TIMPS on the profitability of potato agri-enterprises?

1.5 Justification of the Study

Irish potato is Kenya's third most consumed crop after maize and wheat. The sector plays a huge role in the social-economic development of most people in rural Kenya. The focus on the potato and potato value-added products is an important factor in economic development, creation of employment, and improvement the people's living standards. Improving the adaptive capacity of potato agri-enterprises to climate change is imperative in ensuring the development of sustainable agricultural enterprises in Kenya. CSA adaptive measures help reduce the negative impacts of climate change. Applying CSA in small-holder agriculture is essential in informing agri-entrepreneurs on appropriate farming decisions to mitigate climate risks.

Understanding factors that limit the adoption of CSA TIMPS is crucial to spur their Utilization. This study assesses the Utilization of CSA TIMPS, their profitability on agri-enterprises, and the factors determining the adoption and utilization of these technologies. Research findings from this study will be important to agricultural stakeholders such as the Nyeri County government, agribusiness policymakers, and other stakeholders in the KCSAP project on the factors that explain the low adoption of CSA TIMPs. Moreover, this study will contribute to the call by the IPCC to prioritize research that improves farmers' resilience to climate change in Africa. The study is relevant not only to the attainment of Sustainable Development Goals (SDGs) of ending hunger as envisioned in the 2030 vision strategic plan but also to help Kenya in its agenda on food security in the current Kenyan government agenda. The research findings will further provide more information on the existing literature on factors explaining the adoption and dis-adoption of CSA TIMPs. Finally, the outcomes of this study will be used as a future reference for researchers who will study the various aspects of CSA TIMPs

1.6 Scope and Limitations of the study

This research centered on the assessment of the utilization of Climate-Smart Agriculture, Technology, and Innovation Management Practices (CSA TIMPs) and their impact on small-holder potato Agri-enterprises in Nyeri County, Kenya, particularly within the confines of Kieni subCounty. The study situated itself within the context of the past 50 years, providing a contextual background to challenges arising from population growth, increased food and water demands, and heightened greenhouse gas emissions leading to climate change. A focused investigation was conducted into the adoption and profitability of five CSA TIMPs, encompassing agro meteorology, ICT utilization in marketing and input acquisition, group and cooperative membership, and proper post-harvest storage.

Furthermore, the study delved into the determinants of adoption, including demographic factors, resource accessibility, and farming experience. However, the study findings were findings generated were geographically specific to Nyeri County and may not be universally applicable across diverse regions. The sample size of 384 households in the Kieni sub-county introduced limitations to the generalizability of the study's conclusions. The reliance on self-reported data through questionnaires could introduce potential biases, impacting the accuracy of the findings.

1.7 Operational Definition of Terms and Concepts

Adaptation: This is the gradual process of adjusting and mitigating the effects of climate change.

Agri-enterprises: The term agri-enterprise within the context of the study refers to commercially oriented farmers who engage in farming as a business.

Agro-meteorology refers to the study and use of weather information in enhancing and expanding crops and increasing crop production.

CSA TIMPs: In the study, CSA TIMPs refer to Climate Smart Agriculture Technological Innovations and management practices.

Climate advisory services: Climate information with agronomic advice

Climate change: This is the alteration of the earth's climate due to atmospheric accumulation of greenhouse gases leading to "greenhouse effects" that set off a process that modifies Weather Patterns

CSA: agriculture that sustainably increases productivity, enhances resilience, reduces greenhouse gases, and enhances achievement of national food security and development

CSA Utilization: refers to the uptake and adoption of CSA TIMPS and practices

Profitability in an agri-enterprise refers to the financial gain or profit derived from agricultural activities. It is a measure of the economic success of a farming or agricultural business

Small-holder potato agri-entrepreneurs; are those potato agri-entrepreneurs working on land between 0.5 and 5 hectares. They grow root tubers, mixed cropping, and add potato value.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview of potato production

Irish potato production now ranks as the world's third most important food crop due to its role in reducing global food insecurity and growing relevance in sub-Saharan Africa (FAO, 2020). Several factors, including increased potato consumption and a desire for processed potato products, fuel the rising demand for potatoes in Africa. Due to its rapid development of a 90– 150day maturation period, Irish potatoes might be considered an immediate and cool-weather crop. For both day and night, it works well between 20 and 25 °C and below 20 °C, respectively. Nighttime temperatures of 23 °C restrict tuber formation and above restrict tuber formation. When extreme temperatures, plants suffer from heat stress, which can hasten the growth of some plants like melons, grapes, and tomatoes. Other crops, such as maize, wheat, and tomatoes, may yield less when this is present (Aggarwal & Singh, 2010).

Potatoes and other staple commodities, such as cereal grains, could become difficult to grow and unavailable. Li *et al.* (2018) assert that over the next 90 years, the development of these pests and illnesses will rise with rising temperatures (by roughly 1.9 °C), with a substantial impact on the potato industry. Any variation from the optimum caused by decreased rainfall during its bulking stage diminishes its output. Potato cultivation requires 500-750 mm during its 3–4.5 months growing cycle. The world's leading potato producers are China, India, and Ukraine. Potato production worldwide has steadily increased since 2000, increasing by more than 54% until 2017 (FAO, 2020).

Global agricultural production reaches 300 million metric tons, and more than one billion people consume potatoes. Global annual potato production has gradually decreased for the past few years. It is around a 257million tons, with a total production area of around 4.5 million ha. This decline is due to climate change effects, and the low adoption is a crucial contributor to the decline in potato production. China is the world's largest potato producer, and India is second, followed by Ukraine. China, India, and Ukraine produce the most potatoes, accounting for 93 million tones, 51 million tones, and 23 million tones, respectively, of the total amount paid globally, or 45%. Small-holder potato farmers are the main producers, accounting for approximately 80% of the country's production. Potatoes are produced primarily in high-altitude areas (1500-3000) meters above sea level in Kenya. Irish potato is cultivated both as a food crop and a cash crop. FAO says over 850,000 potato farmers globally employ about 2.5 million people in its value chain. Irish potato provides food and income for many families in rural Kenya. The potato value chain is vast, from the farm level to the market value-added products like (*crisps and chips*). The potato value chain employs many people in Kenya (FAO, 2020).

Like other regions of the world, the potato industry in Kenya has constantly been facing challenges that have seen a drop in production at 11% per year 1. According to a study by Reay (2019), the primary cause of the decline in production is climate change and climate variability. Other causes of the decline in production in Kenya and Sub-Saharan Africa are a lack of proper CSA techniques, such as; a lack of high-quality seeds and inputs, improper storage facilities, improper land management techniques, poor post-harvest storage techniques, and poor farm management. Lack of clean seeds, farm size, constant fluctuation in prices, crop diseases, lack of extension services, and climate change are significant constraints facing potatoes in Kenya (Jane *et al.,* 2013).

This study focused on applying CSA TIMPs among potato farmers in Nyeri County. CSA TIMPs help farmers combat climate change, increase their resilience and income, and boost the sustainability of their potato enterprises. CSA is a multi-faceted tool that focuses on three triple wins: increasing productivity, enhancing farmer resilience to climate change, and, where possible, reducing greenhouse gas emissions. These goals are intertwined and contribute to the achievement of national and global food security and economic development. Agri-entrepreneurs can utilize CSA advisory services to make more decisions on adaptation practices to apply to mitigate climate change (Attri, 2020).

Agri-entrepreneurs can make several CSA strategies upon receiving an advisory on weather and market patterns categorized into short- or long-term decisions (FAO, 2016). Agri-entrepreneurs can make tactical decisions; these are short-term decisions made in production within the growing season or on a sub-season basis. Tactical decisions assist in making strategic objectives for the farm. Examples of such decisions include; time to plant, whether or not to plant, scheduling of irrigation, the timing of chemical and fertilizer applications, harvesting decisions post-harvest storage, and markets.

Long-run decisions are the strategies that Agri-entrepreneurs can make across multiple seasons to enhance productivity and the enterprise's overall profitability. Long-term decisions can also help risk reduction and reduce the impact climate change poses on the environment. Such decisions could be building blocks on the general farm layout and the type and size of the equipment to purchase. How to practice tillage, the kind of irrigation equipment to buy, acquisition of fertilizers, chemicals, and herbicides, types of equipment to use in harvesting, scheduling of harvesting to meet market requirements and decisions related to a contract to price (Asfaw, 2017). Hence, this study sought to explain the need to integrate CSA into the potato value chain to increase productivity and resilience to climate change.

2.2 Effect of climate change on potato production.

Climate change is a shift in weather patterns and changes in seas, land surfaces, and ice sheets over decades or extended periods. Climate change is a result of natural and human causes. The IPCC defines climate change as a situation where a statistically significant change in mean climate persists for more than 30 years. Climate change has always occurred on Earth, as evidenced by the geological. However, climate change's current rate and severity are causing widespread worry. Since the Industrial Revolution, human activity has raised greenhouse gas levels in the atmosphere, resulting in increased heat absorption and higher surface temperatures. Greenhouse gases absorb heat in the atmosphere. Aerosols in the atmosphere affect climate by scattering and absorbing solar and infrared energy and changing cloud microphysical and chemical characteristics.

Agriculture is considered one of the most critical sectors in the Kenyan economy. But, due to the possible impact of climate change in Kenya, the production rate of crops and agricultural commodities is expected to drop to a 13-19% reduction (Zaaboul, 2020). This agricultural sector is also estimated to lose about 22 million dollars in the crop industry as there will be an increased temperature and an elevated amount of Carbon dioxide released. In this case, agricultural commodities such as wheat, dairy, beef, and sugar will be affected its growth and grain yield. As climate change continues to destroy the agricultural and other sectors of the world, Kenya might also experience a disruption in food availability (Zaaboul, 2020).

Due to decreasing food production, access to quality food will be limited. The Kenyan government should create a plan to sustain the resources of the Kenyan countryside. This plan should be used until 2050 or more. Climate change will have a significant effect on Agrienterprises in Kenya as a result of overdependence on rain-fed agriculture in Kenya. Climate change effects will consequently affect economic and social systems. Climate change positively and negatively impacts location, timing, crop productivity, livestock, and fishery systems at local, national, and international levels.

Crop and livestock production declined significantly in many agricultural regions due to increased stress from pests and diseases, weeds, and other climate change-induced stresses (Godde *et al.,* 2021). The current loss and degradation of agricultural soil and water bodies due to increased changes in weather patterns will continue to challenge our rainfed agriculture unless farmers implement innovative conservation methods. The effects of climate change on agriculture will have a consequent impact on food security in Kenya and globally through a decline in crop yield and prices of food commodities. Climate change will affect agricultural products' transportation, storage, processing, and retailing (Godde *et al.,* 2021).

Climate change will affect local, regional, and global food security. Climate change effects can disrupt access to food and availability and consequently affect food quality (Reay, 2019). For example, projected changes in temperature levels, precipitation patterns, extreme weather events, and reductions in water resource availability may all result in reduced agricultural productivity. An increase in the severity and frequency of extreme weather events could also interrupt food delivery, resulting in increased spikes in food prices. Extreme weather events will be frequent in the future. Increased changes in temperature could contribute to food contamination and spoilage during storage or transportation. The effects of climate change on agriculture in Kenya are likely to be similar to those experienced globally. However, other stressors, such as population growth, affect countries differently and are likely to magnify the effect of climate change on food security. In developing countries, implementing climate-smart agricultural practices such as agrometeorology, crop management, and irrigation is more limited than in developed nations. Any climate-related disturbance to food distribution and transport, internationally or domestically, may have significant impacts not only on safety and quality but also on food access. For example, the food transportation system in Africa frequently moves large volumes of grain by water. In the case of an extreme weather event affecting a waterway, there are few, if any, alternate pathways for transport. Transportation changes such as these reduce the ability of farmers to export their grains to international markets and can affect global food prices. Impacts on the global food supply are of international concern as food shortages can cause humanitarian crises and national security concerns. They also can increase domestic food prices.

2.3 Climate Smart Agriculture

Climate-smart agriculture (CSA) is an approach that guides actions to transform agri-food systems toward green and climate-resilient practices. It supports internationally agreed goals such as the Sustainable Development Goals (SDGs) and the Paris Agreement. CSA aims to achieve three main objectives: Sustainable Productivity and Income: CSA seeks to increase agricultural productivity while ensuring economic viability for farmers. Climate Adaptation and Resilience: It focuses on building resilience to climate change impacts, such as extreme weather events and shifting growing conditions. Greenhouse Gas Mitigation: CSA aims to reduce emissions where possible, promoting practices that minimize the environmental footprint of agriculture1. CSA integrates science, policy, and practice to create a more sustainable and climate-resilient food system. It considers the local context and emphasizes better production, nutrition, environment, and equity for all.

Climate-smart agriculture (CSA) is a technique used in the agricultural system of climates that change over time (Khatri-Chhetri *et al.,* 2017). The method is applied to facilitate food security and give the necessary support in these regions. The approach focuses on fulfilling several objectives, including increasing food and income production, creating resilience to climatic changes, and reducing greenhouse emissions in greenhouses. It is the right approach because it assists stakeholders at local, national, and international levels in identifying the best strategies for agricultural production. The strategies are determined based on the environmental conditions and changes in the environment of the stakeholders. The CSA approach is currently being used in many nations to address the negative impacts of climate change.

Climate change has led to the introduction of technologies to address its effects on crop production. It has led to technological advancement in agrometeorology, the use of ICT in agricultural marketing, proper post-harvest storage techniques, and other production techniques such as minimum storage.

2.3.1Agrometeorology

Agrometeorology is a branch of applied meteorology that studies the physical conditions of a growing plant or animal organism's environment (Zhu *et al.,* 2021). It is an applied science concerned with the application of meteorology to the measurement and analysis of the physical environment in agricultural systems, or it is a science concerned with the relationship between weather/climatic conditions and agricultural production. Farmers plant crops at the optimal time for maximum yield; this helps to reduce crop losses due to excessive rainfall, cold/heatwaves, cyclones, and other factors. It uses short-, medium-, and long-range forecasts to assist in pest and disease forecasting, crop selection, irrigation, and other intercultural operations.

Agrometeorology focuses on developing weather-based farm operations that are efficient. It informs farmers when to prepare the land and cultivate or plant to avoid early or late planting. Agrometeorology helps use remote sensing to investigate crop weather relationships in all important crops and forecast crop yields using agro-climatic and spectral indices. Remote sensing can classify species, map soil properties, detect crop water stress, monitor crop diseases and weeds, and map crop yield (Zhu *et al.,* 2021).

Agro-meteorology helps to research a given area's climatic resources to plan effective crop rotations. Other applications of agro-meteorology include; preparing crop weather diagrams and crop weather calendars to investigate the link between weather conditions and the occurrence of pests and diseases in various crops. To define climatic/agroecological/agro-climatic zones to define agro-climatic analogs for effective and quick technology transfer to improve crop yields. Drought monitoring on a crop-by-crop basis for effective drought management. Using various weather and seasonal climate forecasts, develop weather-based agro advisories to sustain crop production. To look into the microclimatic aspects of the crop canopy to change them for better crop growth. Agro-meteorology is essential as it helps in timely plowing, harrowing, weeding, and other tasks. Reduces the loss of applied chemicals and fertilizers; avoids fertilizer and chemical spray during rainy seasons. It aids in planning cropping patterns and systems. Pest and disease outbreaks are reduced or eliminated. Agro-meteorology helps in the selection of sowing dates for optimum crop yield, avoiding and minimizing losses as a result of fires. Weather forecasting helps manage weather abnormalities such as cyclones, heavy rainfall, floods, and drought.

2.3.2 Use of ICT

The increasing adoption and availability of Information and Communication Technologies (ICTs), including web-based and mobile applications, present fresh opportunities for revolutionizing smallholder farming systems in Sub-Saharan Africa. Hopestone (2014) acknowledges the positive impacts of leveraging mobile phone technologies to assist smallholder farmers in Africa. ICT (Information and Communication Technologies) helps to address the growing demand for new approaches in agriculture. The use of Information and Communication Technologies (ICTs) plays a transformative role in climate-smart agriculture. These technologies provide real-time weather data, enhance precision farming, connect farmers to markets, deliver digital extension services, and improve financial inclusion. ICTs empower farmers, enhance resilience, and contribute to sustainable agriculture in the face of climate challenges.

ICT also helps empower the rural people by providing better access to natural resources, improved agricultural technologies, effective production strategies, markets, banking, and financial services which are usually overlooked in their sector. The main focus of ICT applications in agriculture is to meet the information needs of farmers. The farmers perceived market information, including daily updates on the prices of agricultural commodities in the local markets of the surrounding district, as one of the most relevant ICT services. The farmers enable them to sell at the markets where their goods would command the best prices. The information on animal husbandry and dairying was very much needed by most farmers and regarded as most appropriate to their needs (Bricker *et al.,* (2017).

The application of ICT requires multiple changes, however. Behavior changes are required for the farmers to integrate the solution into their agricultural works. Income is one of the barriers to this, so their economic status has to be improved. Farmers need the technical knowledge to use the different methods of ICT successfully. To create awareness, the agricultural universities must conduct more agricultural campaigns in the farmers' villages along with new subsidies. Even the government has to take some steps because the technology penetration and usage continue to evolve rapidly, while many have yet to reach rural farmers. It has to ensure low prices for broadband internet connection in rural areas (UNDP, 2010). They must foster public-private partnerships to make market and business information accessible and for cost arrangement. And ensure the availability of relevant information helpful to farmers.

2.3.3 Potato post-harvest technology

Proper post-harvest storage is a climate-smart agriculture practice. Proper post-harvest storage is a crucial climate-smart agriculture practice. It reduces crop losses due to pests, preserves nutritional quality, and adapts to changing climate conditions. Efficient storage methods minimize waste, reduce emissions, and contribute to food security Some practices in potato post-harvest storage include grading, packaging, and storage. Grading is the differentiation of quality for potatoes. Commercial potato Agri- enterprises should include more than 70 to 80% of well-shaped tubers, the brightness of the color (esp. reds, yellows, and whites), uniformity, firmness, freedom from adhering soil, freedom from bruising (black spot or shatter-bruising), scuffing or skinning, growth cracks, sprouting, insect damage, Rhizoctonia Black Scurf, decay, greening, or other defects. The farmers pack harvested potatoes in jute gunny bags. Pot storage requirements vary to store potatoes for different purposes (Pringle *et al.,* 2009).

The method generally used for the storage of potatoes is room storage. The room should have a high plinth and good ventilation; doors and ventilators fitted with insect-proof wire nets. Farmers also store potatoes in single layers of sand. Frequent examination is necessary to discard tubers showing rotting symptoms. One of the storage methods is the pit storage method. In this system, the tubers are stored in pits 60-75 cm deep 2.5 meters long, and 1 meter wide, made in a cool shady place. Water is sprinkled inside the pit to achieve the cooling effect. After two days, neem leaves, dry grass, or sugarcane trash is lined all around the pit from the inside. Bamboo chimneys of 1.5 meters in length are placed inside the pit 1 meter apart to facilitate evaporation of the moisture deposited due to the transpiration of the stored tubers. Pits are then filled with tubers leaving 15 cm on the top, followed by a one-foot layer of dry grass. A thatch is provided over the pit as protection from rain and sun (Pringle *et al.,* 2009).

2.3.4 Cooperatives

An agricultural cooperative is a group of farmers or organizations that work together to achieve their shared economic, social, and cultural goals and objectives through a democratically governed enterprise. These people have gained from and profited from it. These cooperatives aim to meet the social-economic and cultural requirements of their participants and the society in which they live. Cooperatives have a strong sense of community and a commitment to improving the areas where they function or serve.

Cooperatives offer individuals power over the firms they interact with the most if they shop, work, or provide for them. They also offer individuals power over essential things, increasing productivity, fostering creativity, and giving them a stake in the operation. Cooperatives are one of the most effective models for increasing agricultural and non-agricultural production through large-scale input exchange, participation in farm input distribution, and marketing (Zopounidis*,* 2018). Dairy and coffee industries are two examples. Cooperatives are vital for enhancing women's and men's working and living situations. Cooperatives make decisions that balance the need for profit with the welfare of their members and the community they serve because people own them by using the services they offer (Waktola, 2020).

Cooperatives aid in distributing, improving, and multiplying local knowledge, resources, and capital. Autonomous organizations extend to the community's weakest residents, providing them with basic infrastructure and opportunities for growth that other significant firms overlook. Regarding economic and social growth, cooperatives encourage the "full involvement of all people" and distribute globalization's advantages evenly. They contribute to long-term human development and are crucial in the fight against social marginalization (Zopounidis, 2018). Cooperatives sell their items at set prices that are managed and fixed and restrict the required goods. These efforts contribute to the battle against inflation and deflation. There is healthy interpersonal contact between society members and their employers. Other roles of cooperatives include; offering agricultural credits and financing in areas where the public and private sectors have been unable to help, giving strategic inputs to the agriculture sector while consumer societies can satisfy their consumption needs at reduced prices, offering cooperative banks with access to capital for their cooperatives' development requirements. Cooperatives should be encouraged in rural regions; cooperatives play a significant role (Miribung, 2020).

The government ensures people's and property's safety and provides and enacts regulations that allow businesses and cooperatives to thrive beyond the level of labor done just for the benefit of the individual and the advancement of society. The State has made it a policy to encourage the formation and expansion of cooperatives as a practical means of encouraging self-reliance and harnessing people's rights in the pursuit of sustainable growth and development. The State provides financial assistance to Cooperative Societies through Share Capital Contributions to improve their Share Capital base and allow them to conduct their business and create revenue to improve the income and socio-economic conditions of their poor tribal members (Dogarawa, 2012).

The Government gives a managerial subsidy to cooperative societies to help them fund part of their management costs. Cooperative societies are welfare organizations in which individuals join together to increase their income-generating ability in economic pursuits through collaborative efforts. The State Government provides financial aid to Cooperative Societies under various plans to help them achieve their goals. CSA TIMPs are, therefore, the recommended approach for agricultural productivity. The strategy focuses on using the best practices that consider the changes in climatic conditions. Climatic changes threaten agriculture productivity, and if CSA takes care of this, it assures continuous productivity.

Climate Smart agriculture can contribute to eradicating poverty, hunger, and other forms of malnutrition. Climatic Smart Agriculture can achieve changes in climatic conditions and food security. The good thing about the approach is that it reduces the agricultural system's vulnerability to climate change. It also ensures that the crops grown at different locations have adaptive features that can result in a high yield. Therefore, this reduces poverty and hunger eradicated. CSA also provides that agricultural policies are established in developing nations (Negin, 2009).

One of the opportunities of CSA is that it will increase the food supply. Besides, it will also ensure that the grown crops are resilient to climatic changes. It will also address the Green Revolution's shortcomings because the approach does not suggest using agricultural chemicals. However, CSA faces some challenges. One is that technological advancement does not work on the approach. The other problem to address is the different kinds of soil in different areas in the approach

In conclusion, climate-smart agriculture can address the shortcomings of the green revolution. Climate-smart agriculture does not suggest using chemicals in farming; hence, it prevents the issues of climate change in the surroundings. The fact that many pests and diseases are becoming resistant to pesticides and herbicides shows that the green revolution cannot rely upon them.

Climate-smart agriculture can assist in meeting the food demand of the growing population.

2.4 Utilization of CSA TIMPs

Farmers adjust to climate change in various ways. Numerous studies have identified various adaptation measures, including irrigation, adoption of improved varieties, crop insurance, conservation tillage, and livelihood diversification. Climate-smart agriculture (CSA), is one strategy advocated to help with adaptation and mitigation to climate change, which promotes resilience, adapts to climate change, increases sustainable agricultural production, improves food security, and increases farmer income, CSA comprises several technologies and practices (FAO, 2018). as a result, the government, development organizations, donors, and private businesses aid farmers in coping with and adapting to climate change while also enhancing productivity, building resilience, lowering GHG emissions, and increasing soil carbon sequestration (Zaaboul, 2020). Despite the potential advantages of CSA, its Utilization is modest, especially among smallholder farmers in SSA, including those in Kenya (Mulwa, 2017). While there is a growing body of research on the impact of farm and farmer traits on CSA adoption., there is little research on the impact of farmers' cognitive traits, which are behavioral or psychological and relate to learning and reasoning such as perception of costs and risks (Kangogo *et al.,* 2021). At least among these is the potato (Solanum tuberosum L.), one of the most significant non-grain crops in the world and the third-most consumed crop by humans after rice and wheat (Zhang *et al.,* 2016).

Over a billion people eat potatoes globally, producing 300 million metric tons yearly. Irish Potato yields worldwide could decrease by up to 32% without adaptation (Haverkort *et al.,* 2015). 2.5 million people work as service providers, transporters, wholesalers, processors, and retailers in Kenya, where over 800,000 small-holder farmers depend on the potato harvest (Ogola & Ouko, 2021). According to recent research, employing climate-smart adaptation strategies could increase potato yields from 10% to 17%. Although land under cultivation increased from 0.12 to 0.21 million hectares between 2009 and 2019, potato output decreased from 2.3 to 2 million tonnes (Ogola & Ouko, 2021).

Potato production declined due to a shortage of clean, certified seeds and increased pests and illnesses. Since potatoes are susceptible to weather fluctuation, using clean seed has been demonstrated to help farmers adapt to climate change (Okello *et al.,* 2019). Climate change is associated with increased crop pests and illnesses., low adoption of CSA technologies is related to some variables, including socio-economic status, farm characteristics, gender-specific factors, access to resources, access to agricultural and climate information services, institutional characteristics, and other cognitive characteristics of farmers, such as risk-taking behavior (Kurgat *et al.,* 2020).

Due to these restrictions, Climate-Smart Agriculture (CSA) compels farmers to use less effective conventional methods because they are unlikely to implement CSA technologies. Furthermore, CSA adoption in the production of cereals, mainly maize, wheat, and rice, has received much attention in studies by Kurgat et al. (2020), while only a small number of studies (Haverkort *et al.*, 2015) have focused on CSA. Access to CSA Technical Innovation and Management Practices (TIMPs) has been made easier for agri-entrepreneurs for their utilization. Among organizations offering CSA advisory services are the National Drought Management Authority (NDMA), Kenya Meteorological Department (KMD), non-governmental organizations (NGOs), community-based organizations (CBOs), international development agencies, private organizations, and research institutions. CSA advisory services are provided throughout the entire season.

Other sources of CSA advisories are regional and social networks. CSA TIMPs that potato farmers can adopt are; agro-meteorology, carbon financing, and ICT use in input acquisition and marketing activities. Other practices include; improved soil and land management techniques, the application of appropriate fertilizers, improved post-harvest storage, and membership in farmer groups and cooperatives. Agro-meteorology uses observed weather data to predict future weather patterns. Agro-meteorological platforms provide a medium for communicating the potential impacts of climate change to farmers for management decisions. Agro-meteorological information, climate information services, agro-weather observation and forecasting, and the development of the ability to use market information services help Agri-entrepreneurs decide on what, when, where, and how to embark on their farming activities.

Market information systems help bridge the gap between farms and the market. The continued interaction between Agri-entrepreneurs and the buyers of their products on social platforms will help them build relationships with input suppliers, service providers, and extension workers. Agrientrepreneurs will henceforth sell their goods at a profit. These interventions offer solutions to create sustainable Agri-Enterprises. CSA is a technique that will enable sustainable food systems to increase rural incomes. These will, in turn, contribute to Agri-Enterprise development. Farmers can learn about the most appropriate production techniques, input acquisition procedures, and the best soil and land management practices with these ICT platforms. Market information Agrienterprises can work effectively and efficiently by working closely with the buyers of their products through market information systems.

Other CSA management practices advocated for through the CSA concept include appropriate fertilizer application, appropriate storage, and forming farmer groups and cooperatives. CSA is a multi-faceted, iterative, continuous process that involves planning, implementation, monitoring, evaluation, interactive learning, sharing of knowledge, and advancement toward resilient agriculture and Agri-enterprise development (FAO, 2015). Limited information on the Utilization and adoption of CSA TIMPS and technologies exists. In Sub-Saharan Africa, there is little Utilization of CSA, constrained by multiple factors. Therefore, to enable large-scale Utilization of the services, it is imperative to understand the influential factors that affect technology adoption. CSA remains a concept that needs further elaboration and demonstration, especially in developing countries like Kenya. To achieve meaningful change and sustainable Agri-enterprises development, CSA requires support from research and development organizations, decisionmakers and policymakers, financing organizations, dedicated knowledge, and practical experience worth human resources. If these stakeholders support CSA, the results will increase Utilization among the enterprises.

CSA has to confront three practical approaches to achieve its objectives. The first approach is bringing together policymakers, Agri-entrepreneurs, and other stakeholders to identify, disseminate, and implement fruitful actions in light of delivering a remarkable difference. The second approach is shaping climate change and adjusting to variations by introducing innovative activities like mixed cropping, new varieties, and investing in infrastructure and context-specific policies. The third approach concerns human well-being and development in multifunctional strategies focusing on the general alleviation of living standards, forest, and environmental conservation services.

The emulsion of science with policies provides an appropriate framework for achieving CSA goals that might defer from country to country and globally from one place to another. The application of CSA is a prerequisite in ensuring adequate, nutritionally balanced food for the continuously increasing population and in the advent of climate change (Rosenstock *et al.,* 2019). The Global Alliance for Climate-Smart Agriculture (GACSA) recognizes CSA as an essential intervention strategy. Despite this recognition, adopting climate-smart services remains an ongoing and challenging process. There is a growing need to overcome these barriers and provide meaningful solutions that must respond to the needs of the local Agri-agri-entrepreneurs.

The development and dissemination of climate advisory services are challenging for particular reasons. First, CSA is a complex ensemble of actions. Understanding crop surfaces and their respective connection with climatic drivers is necessary. Such requires a solid interdisciplinary intervention. Secondly, all stakeholders involved must have adequate capacity to implement such interventions. There should also be a solid political will to execute climate-smart actions among small-holder Agri-entrepreneurs.

2.5 Effect of CSA TIMPs on Profitability of Potato Agri-enterprises

Potato farming has had its fair share of challenges arising from climate change. Global estimates show that climate change destroys over half of all potato crops (Reay, 2019).

Climate change has led to the declining incomes of over 500 million small-scale enterprises in developing countries (Lipper *et al.,* 2014). Such losses pose a significant problem for potato Agrientrepreneurs and their livelihoods. However, potato Agri-entrepreneurs and other food producers can implement some solutions to help prevent these problems. One such solution involves the application of CSA adaptation strategies. A climate-smart adaptation strategy is an approach to managing the effects of climate change on crop production that consists of adapting to climate change. It is essential to upscale the adoption of CSA TIMPS and practices to improve the resilience and livelihoods of Agri-entrepreneurs' farm families (Akinnagbe & Irohibe, 2015).

Various factors influence the Utilization of CSA among Agri-entrepreneurs. One such factor is the availability of credit, markets, social networks, education, and behavioral factors (Andati *et al.,* 2022). Previous studies have sighted economic returns and profitability among factors that explain the low adoption of CSA TIMPS. This study sought to investigate the profitability of CSA TIMPS in Agri-enterprises to ascertain whether profitability is a factor that could explain the low adoption of CSA TIMPS and technologies. The study uses a cost-benefit analysis (CBA) to investigate the profitability of CSA TIMPS (Sain *et al.,* 2017).

A cost-benefit analysis is a model applied to assessing how the cost of a project compares to its benefit to ensure that an enterprise makes the right decision on where it invests its resources. Cost analysis is a comparative evaluation method (Babigumira, 2018). The best situation to invest in a project is if the cost outweighs the benefits anticipated when the project is implemented (Savvides, 2005). Climate change has been a major issue in Agri-enterprise development. The cost analysis model represents an essential tool for use by agricultural economists in implementing CSA TIMPs.

Specifically, climate change has been a concern, and society is eager to find a reliable program that would help eradicate climate change.

Various CSA TIMPs consider the effects and benefits the process would bring upon implementation. Significant sources of climate change are air pollution resulting from a harmful chemical in gaseous form released into the atmosphere. According to Nawahda *et al.* (2013), most air pollutants are, therefore, gases which include: Carbon dioxide. The two primary activities that bring about an imbalance in the levels of carbon dioxide in the atmosphere are the burning of fossil fuels and deforestation. Such activities include the burning of plastics and spray cans. Other pollutants include hydrocarbons from petrol engines and suspended particulate matter in thermal power plants and diesel engines. Significant sources of climate change and actual & potential consequences of climate change on enterprise development.

In implementing a CSA TIMP, consider the costs incurred. In the process of adopting a CSA TIMP, costs and benefits accrued should be put into critical consideration. Among the factors that should be considered in adopting CSA TIMPs is their profitability. Although it is difficult to account for all costs involved, such costs should be documented where possible. Consequently, all tangible costs should be itemized regardless of how little the cost appears to be. However, leaving out the intangible cost is not prudent and should be itemized where possible. The Agri-prenuer should itemize the anticipated benefits to create a comparison list. A summation of the costs and the benefits should then be contrasted to determine the best decision.

The cost-benefit analysis will help compare which policies have favorable or unfavorable outcomes in mitigating climate change. Such information helps farmers measure the implication of each variable. Using a cost-benefit analysis plan helps consider the costs of different policies while developing regulations. The cost-benefit approach is a handy tool to inform the better decision that should be made. However, the tool is only practical and reliable partially.

Many researchers agree that it should be essential to decision-making, but it is inadequate. Some researchers propose that the standards approach is also practical and can be an alternative to the cost-benefit analysis. The tool identifies the gap in denying all the costs and benefits. The approach used is independent of the methodology used. The cost-benefit analysis is a method that enterprise developmental economists use to determine if the cost of a project to conserve the air is likely to bring more harm than good. The aim is to choose the decision that gives more benefits and outruns the cost of its implementation.

Previous studies have proposed the adoption of CSA TIMPS as a national policy initiative. A study by Ifeanyi-Obi *et al.* (2022) demonstrated that CSA TIMPS contributed to the profitability of maize production in Tanzania. To build more resilient and sustainable Agri-enterprises, various stakeholders recommend CSA TIMPS. CSA will, in the end, enhance agricultural productivity, improve farmers' resilience, and mitigate gas emissions from agricultural activities through agroforestry and the use of drought-tolerant, high-yielding, early-maturing varieties of crops. Other CSA TIMPS include water harvesting and soil fertility management like compost manure, sustainable irrigation, agro-meteorology, intercropping, crop rotation, and use of cover crops (Tennakoon & Hulu Galle, 2006).

There needs to be more information on the economic viability of CSA TIMPS in the context of potato Agri-entrepreneurs in Nyeri County, Kenya. Investigating and reporting on the profitability of CSA TIMPS will help improve the adoption of practices among Irish potato farmers in Kenya. Previous studies have used the CBA model to assess the economic viability of investment projects. CBA analysis helps investors allocate their resources more effectively. There are two types of CBA analysis. The "ex-ante" and the "post-ante" ex-ante are used to assess the economic viability of investment options or ongoing projects. The post-ante assesses the economic viability at the end of the project (Savvides, 2005). This study will adopt an ex-ante to determine the economic viability of CSA TIMPS among Irish potato farmers in Nyeri County.

2.6 Factors Determining Adoption of Climate-Smart Agricultural Practices

While economic returns and profitability of an enterprise could be the determining factors for adopting CSA TIMPS, social-economic factors have also been highlighted as factors contributing to the adoption of CSA TIMPS. The adoption of climate-smart agricultural practices depends on several factors. These include farm size, education level, awareness, access to information, risk perception, technology adoption, and policy advocacy. Educated farmers are more likely to be aware of climate change, access relevant information, and assess risks effectively. They can advocate for supportive policies and adopt innovative practices. In summary, education empowers farmers to adapt and implement climate-smart strategies efficiently.

Various studies have been done on socioeconomic factors influencing the adoption of climatesmart agricultural practices. According to a study by Abegunde *et al.* (*2*019), the factors determining the adoption of climate-smart farming practices by small-holder households in the Cetshwayo district, South Africa, the results showed that age, education level, income, and the farm's distance from a weather station influenced the adoption of CSA TIMPs. Other factors highlighted include contacts with extension agents, media exposure, the production level, membership in an agricultural grouping, and the general perception of the farmer on the effects of climate change. All of these significantly influenced the adoption of climate-smart advisory services.

2.6.1 Farmer's education level

Education is one of the most critical ways farmers can gain the abilities and knowledge to implement suggested technology on their farms. Farmers' education level significantly influences the adoption of climate-smart agriculture. There are several reasons for this such as; Awareness and Knowledge: Educated farmers are more likely to be aware of climate change and its impact on agriculture. They understand the benefits of climate-smart practices. Access to Information: Education improves access to extension services, workshops, and training. Informed farmers can adopt sustainable techniques. Educated farmers assess risks better. They are willing to try innovative practices. Technology Adoption: Literacy enables farmers to use digital tools and climate data. Education facilitates the adoption of precision farming. Policy Advocacy: Educated farmers can advocate for policies supporting climate-smart practices.

The education degree significantly impacts whether someone uses Climate-smart agricultural practices (Waaswa *et al.,* 2022). Farmers with the most education are more likely to make wiser choices and embrace new farming technologies fast. A greater degree of education promotes farming performance because it equips farmers to comprehend and use technical information, allowing them to respond intelligently to the growing body of agricultural research (International Centre for Tropical Agriculture (CIAT, 2017). Production and selling as agricultural skills are also tied to farmers' education. How gender disparity in farming activities is made possible by high literacy rates; as a result, everyone can use recommended Climate-smart agricultural practices, access new technologies, and evaluate them critically. In Wote, Kenya, it was discovered that there is a negative relationship between education level and adoption of technology (Brandt *et al.,* 2017). **2.6.2 Farm size**

The size of a farm significantly impacts a farmer's adoption of climate-smart agriculture practices. Small Farms are faced with challenges such as; Limited Resources: Smallholders may have fewer resources (land, capital, labor) to invest in new practices. Risk Aversion: Smaller farms may be risk-averse due to reliance on immediate income. Knowledge Gap: Access to information and training may be limited. On the contrary, large Farms benefit from; Economies of Scale: Larger farms can invest in technology infrastructure, and diversification: They can allocate land for different crops or livestock. Risk Tolerance: Larger farms may experiment with new methods. Medium Farms: Balancing Act: Medium-sized farms balance resources and risk. Adaptability: They can adopt climate-smart practices with moderate risk.

In summary, farm size influences adoption due to resource availability, risk tolerance, and access to knowledge

The study by Waibel *et al.* (2018) found a clear correlation between farm size and Climatesmart agricultural practices. They added that more giant farms would likely be among the first to adopt new technologies. Small-holder farmers' use of Climate-smart agricultural practices is also limited by the scattered land, preventing them from using economies of scale (Arslan *et al.,* 2014). The study further revealed that increasing farm size by one hectare improves the likelihood of implementing Climate-smart agricultural practices such as crop diversification, changing the planting date, and conservation agriculture. Additionally, research results suggested that largerscale farmers permit technology testing on a portion of their expansive farms without worrying about endangering the household's food security. In addition, the size of the farm is a significant determinant in the adoption of technology, according to a 2018 study by Kalungu and Leal Filho in Kenya.

2.6.3 Access to credit

Adopting climate-smart agricultural practices entails investing in technologies such as droughttolerant plants and irrigation infrastructure. Additionally, given that most farmers earn low wages, the availability of loans could significantly impact climate-smart agricultural practices negatively (Lipper, 2014). Conversely, having access to credit can enhance investments related to climatesmart agriculture. These investments generate revenue, influence farmers' participation in social networks, enhance their capacity to withstand extreme weather shocks, and increase their resilience (Asfaw *et al., 2017*). Access to financing is recognized as a crucial pillar that promotes the expansion of climate-smart agricultural practices in Kenya through the CGIAR's research program on climate change, agriculture, and food security (CCAFS) in East Africa (*CGIAR, 2017*).

2.6.4 Group membership

The local institutions are crucial to applying Climate-smart agricultural practices since they are made up of local participants who gather to pool resources that may be required to access and implement particular climate-smart agricultural practices. t makes it simpler to access both community-based and external resources (Aggarwal & Singh, 2010). According to Van Rijn *et al.* (2012), intracommunity cooperation and links to trust might result in withdrawal behavior, which lowers people's propensity to embrace and seek out new agricultural technologies. Or instance, a drought-resistant crop can be planted at the individual level with little to no institutional coordination. Nevertheless, research by Okello *et al.* (2018), provides proof of the significance of group activity in facilitating the adoption of Climate-smart agricultural practices. t enables risk sharing and allows people to accumulate assets that help them survive the shocks brought on by climate change.

2.6.5 Gender of the farmer

All development agencies have gender and climate change as top concerns. As a result of disparities in access to credit, extension services, and productive resources, men and women may perceive decision-making about climate change adaptation differently (Okello *et al.,* 2018). This explains the findings of Nyasimi *et al*. (2017), who discovered that men and women have different interests in Climate-smart agricultural practices in Lushoto, Tanzania. Men prefer chemical fertilizers, composting, agroforestry systems, and cut-and-carry feeding as Climate-smart agricultural practices, whereas women prefer intercropping crops.

According to the UNDP (2010), women participate in adaptation activities at a higher rate than men because they have a greater understanding of their immediate surroundings thanks to their experience in managing natural resources (such as water, forests, biodiversity, and soil) and their active participation in climate-sensitive jobs like farming and fishing. Climate-smart agricultural practices, such as conservation tillage, can raise the frequency of weeding, a task frequently carried out by women in Africa south of the Sahara. Unequal access to information and other resources like land due to property rights, social norms, and structures makes it more difficult for them to adopt specific Climate-smart agricultural practices. Or instance, in Kenya, norms and taboos prevent women from having the same access to markets, transportation, public assistance, financial resources, and agricultural equipment and input stores as men do (UN Women *et al.,* 2021).

2.6.6 The availability of income

The farmer's income is crucial for adopting Climate-smart agricultural practices because most are related to costs. According to Khatri-Chhetri *et al.* (2017), the technologies' price significantly impacts the farmers' willingness to pay for CSA technology. Therefore, having more access to Climate-smart agricultural practices is directly related to higher farmer revenue. o, certain Climatesmart agricultural practices might not be available to small-holder farmers with low revenues from low yields (Anuga *et al.,* 2019). Since they depend on agricultural production for their steady income, low-income households may need help transitioning from conventional agricultural techniques to Climate-smart agricultural practices like agroforestry (Arslan *et al.,* 2014).

High-budget farmers may have more information, making them less vulnerable to dangers. Additionally, when farmers have alternatives to farming, they can afford to plant trees on a limited amount of accessible land without jeopardizing the security of their household's food supply, and they can easily comply with the standards of agronomic practices (Deressa *et al.,* 2009). However, some Climate-smart agricultural practices may negatively impact high producers' revenue. In a study conducted in rural Kenya by Ochieng *et al.* (2017), it was discovered that high-income farmers tend to specialize in a single crop, which reduces their ability to rotate crop variety and instead produces monoculture.

Factors influencing adopting climate-smart agricultural practices in Mali are the area of residence, ethnicity, and the Agri-entrepreneur's perception of the applicability of climate advisory services (Ouédraogo *et al.,* 2019). The study further showed that both men and women had different needs for climate information services. Social-economic factors are the main determinants of adopting climate-smart advisory services in Ethiopia. Li *et al.* (2023), explored factors influencing the adoption of climate-smart adaptation strategies in northwestern areas of Ethiopia.

The study analyzed factors affecting climate-smart agricultural practices among potato Agrientrepreneurs in Narumoru and Mugunda Wards in the Kieni Sub-County. The variables included in the model were gender, educational level, age bracket, years of potato farming, and land ownership. Other farm characteristics were the size of the land under potato farming, membership in a producer group, access to credit/bank loans, access to extension services, access to market, proximity to a weather station, access to weather information, average seasonal income from potato farming and monthly income from other activities.

2.7 Theoretical Framework

2.7.1 Utility maximization theory

Utility maximization theory refers to consumers who benefit from their economic decisions. The art of decision-making focuses on the life choices one wants and the outcomes one expects from such decisions. The utility maximization problem is consumers' challenge in spending scarce resources and maximizing utility. It is an optimal decision problem (Li *et al.,* 2020).

Climate-smart adaptation practices are a form of risk management tool that covers a farmer towards unforeseen risks and, as such, reduces the marginal effect of the risk on the productivity of the farm. The study adopted a maximization utility function, given climate risk and the choice of adopting CSA TIMPs. The farmer is perceived to derive utility; in climate-smart practice, adaptation is stability in yields and a reduction in the impacts of the risk attached to the climatesmart adaptation strategy.

In this case, a rational farmer chooses a risk management strategy if the benefits accrued to adaptation are more than the benefits realized without the transformation of the strategy. The utility derived from implementing a strategy x (Ux) is determined by the revenues accrued after adopting a strategy, less the cost of adapting the approach. Given various risk aversion strategies, a farmer will choose a risk strategy y that yields higher utility than a risk aversion strategy x.

Let:

- (U(x)) represent the utility derived from implementing a specific strategy (such as CSA TIMPs).
- (R(x)) denote the revenues generated after adopting the strategy.
- (C(x)) represent the cost of adapting the approach.

The net utility ((U(x))) can be expressed as in equation 1 below:

$$U(x) = R(x) - C(x) \tag{1}$$

The farmer will choose to adopt CSA TIMPs if:
$U(y) > U(x)$ where (y) represents an alternative risk strategy (e.g., adopting CSA TIMPs) and (x) represents a different risk aversion strategy (e.g., not adopting CSA TIMPs).

In summary, the farmer maximizes utility by comparing the benefits (revenues) and costs associated with different strategies, ultimately choosing the one that yields the highest net utility.

2.8 Conceptual Framework

In this study, the decision for an Agri-enterprise to adopt CSA TIMPs is assumed to be influenced by socioeconomic factors; these include age, education, farming experience, farm size, and access to inputs and credit. Institutional factors include; extension services, group size, and credit access other factors that could influence the adoption of CSA TIMPs include; their availability, cost, accessibility, and complexity of CSA TIMPs. It is hypothesized that these factors would influence a farmer's decision to adopt CSA TIMPs or not, as shown in Figure 1 below. The framework suggests that these factors collectively contribute to the decision-making process of farmers regarding CSA adoption, which in turn impacts their income levels, highlighting the potential for increased profitability through CSA practices. The visual representation underscores the importance of socio-economic status, institutional support, and technological accessibility in enhancing the economic outcomes of small-holder farmers. Individuals who practice CSA TIMPs are expected to benefit. CSA TIMPs help farmers combat the impact of climate change, become more resilient, and increase their production and incomes. In conclusion, it is assumed that Agri-enterprises practicing CSA TIMPs would benefit from increased resilience when climate change ravages the agricultural sector, increasing their revenues. These would subsequently lead to increased profitability and performance.

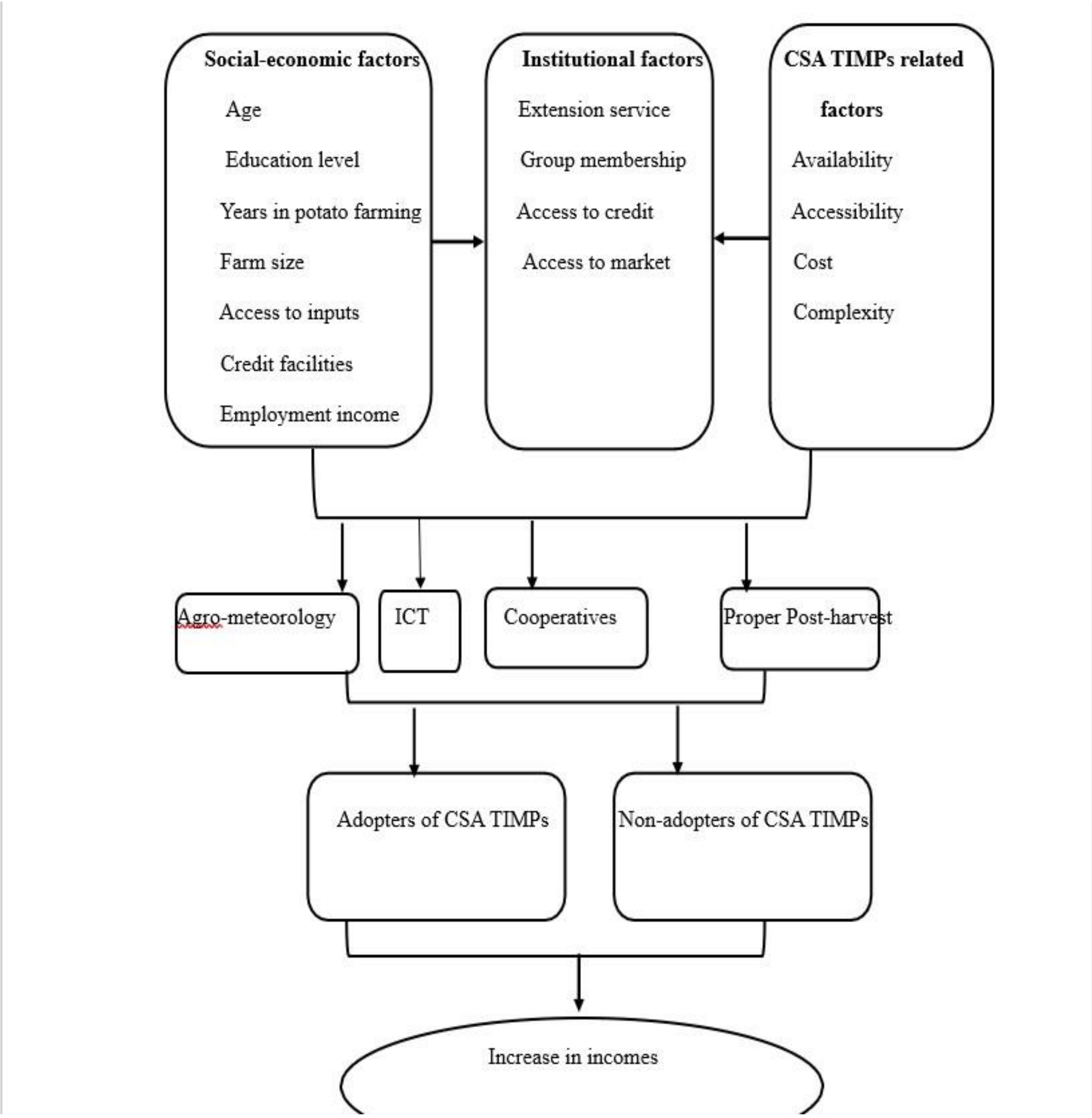

Figure 1: Conceptual Framework

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Study Area

The study was conducted in Kieni-sub-County, Nyeri County. Its geographical coordinates are 10 16' 46.111" N 360 47' 25.665" E. Kieni sub-County has eight wards with a total population of 198,901 (KNBS, 2019). The population density is high, and subsistence rain-fed root tubers and cereal cultivation are the primary livelihood sources. According to the Nyeri County Integrated Development Plan (NCDIP, 2017), agricultural landholdings are usually small; farm size per household ranges between 0.4 and 4.0 ha. However, the Zone has low rainfall levels, with 30% of the total distribution at about 1150 mm in annual precipitation. Most crops produced are under rain-fed agriculture because irrigated agriculture only accounts for less than 10% of the total cultivated area resulting in land abandonment and degradation.

The climate significantly impacts agriculture in Kieni Sub-County, Nyeri County, Kenya. Kieni experiences distinct wet and dry seasons. Adequate rainfall during planting and growing seasons is crucial for crop success. Optimal temperature ranges are essential for crop growth. Extreme heat or cold can affect yields and crop varieties. Kieni’s elevation affects temperature and precipitation. High-altitude areas may have different crops than lowlands. Climate influences soil moisture levels. Droughts can lead to water scarcity, affecting crop health. Climate affects pest prevalence. Warm, humid conditions can promote diseases and pests. Farmers adapt crops based on climate. Drought-resistant varieties are common. Understanding local climate variations helps farmers make informed decisions for sustainable agriculture. Rainfall and soil moisture levels are usually deficient, which justifies the need for Climate Smart Agricultural practices to cover income losses in the dry region. Maize, Irish potato, and cowpeas are major cereal crops dominating the Zone's commercial activities. The area has vast land resources and therefore remains an essential asset for the development of Kenya.

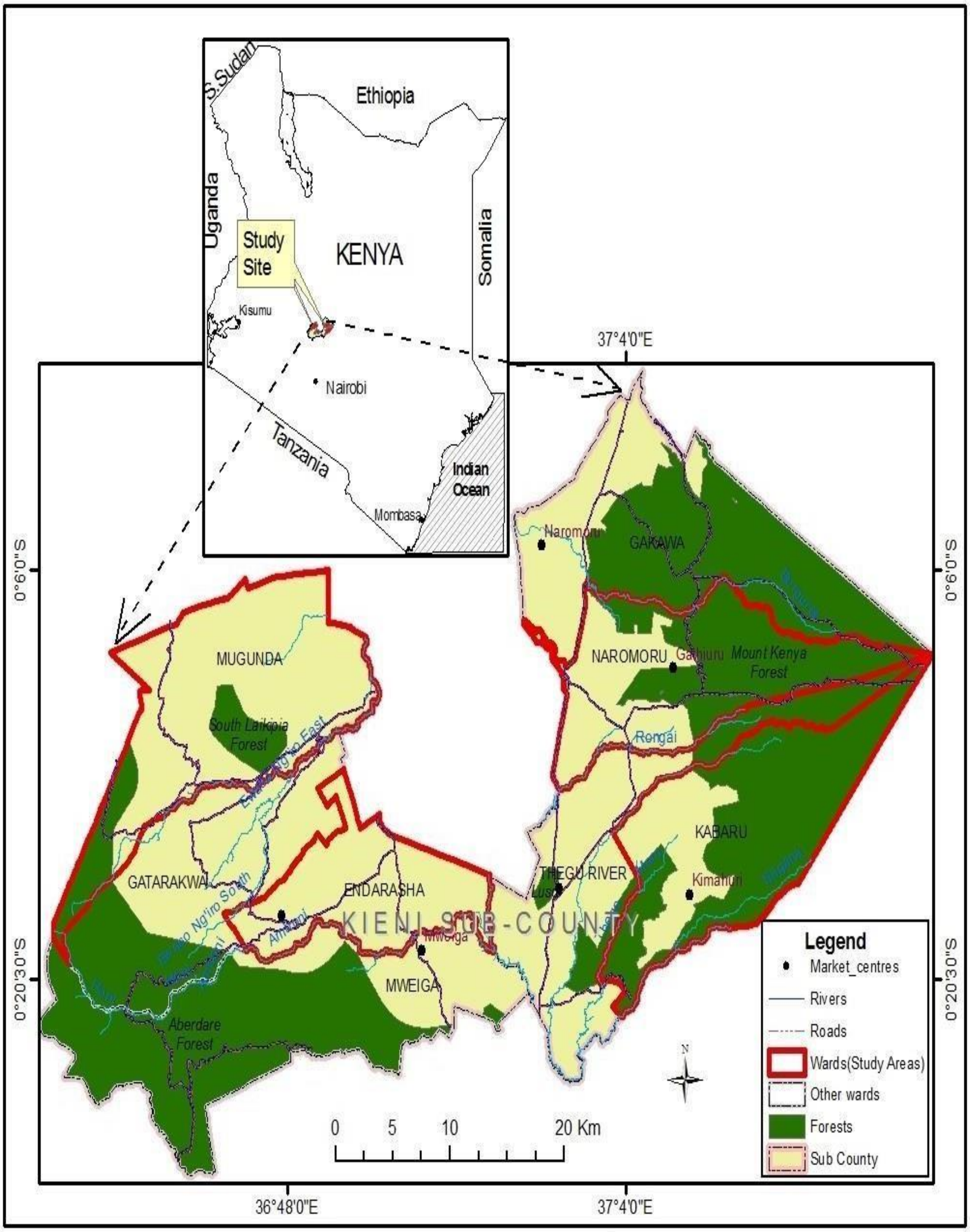

Figure 2: Kieni sub-county map

Source: Ministry of devolution and planning

3.2 Sampling Technique and Sample Size

The sampling unit of the study was the smallholder potato farmers along the supply chain in the Kieni sub-county. The determination of the sample size followed proportionate to size sampling methodology as specified by Cochran (1977) as follows.

$$N=\frac{(pq)z^2}{e^2} \quad (2)$$

Where;

N = desired sample size, z = standard value at a given confidence level

($\alpha = 0.05$), p = the fraction of the population (as a percentage) that

displays the attribute q =1-p, and e = desired level of precision, the

margin of error.

It was assumed that p=0.5, hence q=1-0.5=0.5, Z= 1.96 and E =0.05 (acceptable error). This resulted in a sample size of 384 by substituting the values in equation (2).

Sample respondents were selected using a multistage sampling technique. In the first stage, Nyeri County was purposively chosen because it is among the top three potato-producing regions coming third after Nyandarua and Meru counties (Muthoni *et al.,* 2017). Nyeri County has been experiencing constant variations in weather patterns. Kieni Sub-County was selected purposively in the second stage due to its location in the arid and semi-arid regions. In the third stage, two wards were chosen purposively. Finally, in the last step, the list of Agri- entrepreneurs obtained from the Kieni-East and West sub-counties was used to sample Agri- entrepreneurs who had adopted and non-adopters of the CSA strategy. A random sampling of 384 respondents from the two regions was made for this study.

3.3 Data Collection and Data Analysis

Primary data was collected on farm-level household data through a field survey using a structured questionnaire among sampled potato Agri-entrepreneurs in Kieni Sub-County, Nyeri County. Data was collected with the help of trained enumerators from the Mugunda and Narumoru wards. Semi-structured questionnaires were administered to the selected households. The survey instrument captured farm and farmer characteristics, climate-smart agricultural practices adopted by potato Agri- entrepreneurs in the county, and their profitability levels. Data collected were coded and analyzed by use of STATA statistical software. The specific statistical tests are presented as per the study objectives.

3.4 Validity and Reliability

A pilot study was conducted in Endarasha Ward since it has similar attributes to Mugunda and Narumoru Wards. The pilot study evaluated the feasibility, cost, and duration to improve the study design. Data collected were coded and analyzed by use of STATA statistical software. The specific statistical tests are presented as per the study objectives.

3.5 Analytical framework

3.5.1 Utilization of CSA TIMPs.

CSA TIMPS available for the farmer were correlated with CSA TIMPS adopted to determine their utilization by potato Agri-entrepreneurs. The Kendal rank correlation coefficient (tau) was used to rank the utilization of various climate technologies for climate-smart adaptation practices by potato Agri-entrepreneurs using the formula shown in equation 3.

$$\tau = \frac{n_c - n_d}{\frac{1}{2} n(n-1)} \quad (3)$$

where τ= tau rank correlation coefficient

n_c= Number of farmers aware of the technology

n_d= Number of farmers who adopted the technology

3.5.2 Assessing profitability of CSA TIMPs utilization on Potato Agri-enterprises

The gross margin analysis was used to assess the profitability levels for adopting the CSA TIMPs. Gross margin analysis is a financial metric that helps assess the profitability of a specific agricultural enterprise. It is calculated by subtracting the total variable costs from the total revenue generated. Variable costs refer to the expenses that fluctuate based on the level of production or the number of potatoes grown. These costs are directly related to the quantity of potatoes produced and can vary from season to season. Some key variable costs associated with potato production include the cost of seeds, cost of fertilizers, pesticides, labor, irrigation, storage and transport, harvesting, and marketing. The total revenue is the total sales from outputs.

Total revenue= (Quantity Harvested × Price per Unit). (4)

Gross Margin=Total Revenue−Variable Costs.

3.5.3 Factors Determining the Adoption of Climate-Smart Agriculture

Analyzing factors determining the adoption of a single or multiple TIMPS requires a multivariate probit (MVP) model. Due to the number of accessible TIMPs, adopting a CSA practice is a multiple-choice decision. In this case, a farmer's choice to utilize CSA is a multiplechoice decision and, as such, should be treated as a multivariate decision choice. The MVP is the most suitable model as it helps predict the factors determining the adoption of TIMPs themselves. It also evaluates the interconnectivity of different TIMPs by evaluating their correlations, unlike the multinomial logit model. The MVP model was adopted due to its computational ease and ability to predict diversified livelihoods by selecting the difference between the available strategies adopted by rural households. In this study, the MVP was adopted to analyze factors influencing a household's choice to adopt a certain CSA TIMP in light of the many choices available. The adoption of a CSA TIMP in the MVP model was described using a series of binary variables, CSAi. Each TIMP was assigned a unique index, taking values ranging from 1 to 5. X denotes the independent variables. Any TIMP adopted by an entrepreneur was represented by a random variable CSAi. In this model, an assumption was made that a farmer may opt for multiple TIMPs, which are hypothesized to depend on several factors, from household socioeconomic characteristics, resources, farmers' previous exposure to climate change, and access to extension services. The dependent variables characterize the MVP model (CSAijk) such that;

$$CSAijk = \beta k'Xijk + Uijk \quad k=1\ldots\ldots N \quad (5)$$

and

$$CSAijk = \{1 \text{ if } CSAijk>0, 0 \text{ if otherwise} \quad (6)$$

Where; βk is the vector of parameters to

be estimated

CSAijk = Dependent variables.

Equation 5 assumes the farmer is rational and has the latent variable (CSAijk). The latent variable captures all the unobservable preferences related to an nth choice of a CSA TIMP. In this study, an assumption was made that the latent variable was a combination of the farmer's socioeconomic characteristics, access to other sources of income, previous exposure to climate change, and access to extension services (Xijk), shown in Table 1. These are the variables that influence the consequential adoption of CSA TIMP. Unobserved preferences were captured by the error term Uijk. Due to the latent variable's nature, estimations of this study were based on observable discrete binary variables CSAijk which determined whether an Agri-entrepreneur adopts a CSA TIMP.

Table 1: Description of variables for the multivariate probit model

Variable	Description	Measurement	Expected sign
Dependent Variables			
ACT	Adoption of CSA TIMPs	Continuous	
Independent Variables			
Gen	Gender	Dummy 1=male, 0=female	+/-
Educ	Education level	Number of years	+
HHA	Age of the household head	Continuous	-
Of.F.inc	Off-farm income	Dummy 1=yes, 0=no	+
Yrs.	Yrs. of potato farming	Number of years	+
FS	Size of the farm	Acres	+
FIL	Farmer's income level	Continuous	+
Grp member	Group membership	Dummy 1=yes, 0=no	+
AES	Access to extension services	Dummy 1=yes, 0=no	+
AWI	Access to weather information	Dummy 1=yes, 0=no	+
ACC	Access to credit	Dummy 1=yes, 0=no	+
MP	Membership in a producer group	Dummy 1=yes, 0=no	+

CHAPTER FOUR

RESULTS AND DISCUSSION

This chapter presents results and discusses the findings on the effect of climate-smart agriculture on the profitability of small-holder potato Agri-enterprises in the Kieni Sub-County. It presents descriptive statistic results of significant social-economic categorical variables such as gender, age, education level, access to extension services, and credit concerning small-holder potato farmers' adoption strategies of CSA TIMPs. The CSA TIMPs considered for the study were the adoption of agro-meteorology, proper post-harvest practices, membership in cooperatives, and adoption of ICT in farm activities. The study considered farmers who knew CSA TIMPs and adopted them and those who had and chose not to adopt any of the services.

4.1 Descriptive statistics

4.1.1 Farmers' characteristics

Table 2 presents findings on the factors determining the adoption of CSA TIMPs based on the gender of the household head. Males have a higher percentage of adoption in agro-meteorology and proper post-harvest practices, while females lead in cooperative membership and ICT practices.

The chi-square values suggest that the differences in adoption rates between males and females are statistically significant for ICT practices at the 1% level, indicating a strong association between gender and adoption of this particular CSA TIMPs. The adoption rates for males are 46.9% for agro-meteorology, 63.24% for proper post-harvest practices, and 41.62% for cooperatives. For females, the rates are 53.1%, 36.76%, and 58.38% respectively.

A notable finding is a significant difference in ICT practices adoption, with females having a higher percentage (53.33%) compared to males (46.67%), as indicated by the chi-square value of 0.009***. This suggests that ICT practices may be more readily adopted by female farmers. (Orser et al., 2019) explores gender differences in ICT adoption, particularly in the context of womenowned small and medium-sized enterprises (SMEs). It discusses how gender influences impact resource availability and competitive advantage. The research emphasizes strategies to address gender barriers and promote inclusive ICT adoption.

Table 2: Descriptive for house-hold head

Agro-meteorology			Proper post-harvest practices		cooperatives		ICT practices	
Sex	Per cent	chi	Per cent	chi	Per cent	Chi	Percent	chi
Male	46.9	1.823	63.24	9.603	41.62	3.45	46.67	0.009***
Female	53.1		36.76		58.38		53.33	

Note: *** significant at 1%

4.1.2 Famers socio-economic characteristics

Table 3 presents farmers' socio-economic characteristics. The mean education level of the interviewed household heads was 7.65, with a standard deviation of 3.99. There was no statistically significant difference between the adoption of all of the CSA TIMPs and the education level of the household head.

The average age of household heads was 45.75, with a standard deviation of 15.14. There was a marginal significance level of 0.02** for the adoption of proper post-harvest technologies. Older farmers may have more experience and resources that would allow them more possibilities to try new post-harvest storage technologies as compared to younger farmers (Admassie & Ayele, 2011). Younger farmers were more likely to adopt ICT practices instead as they had more schooling, more innovation, and more exposure to access new information than the older generation (Miine *et al.,* 2023).

The mean number of years engaged in potato farming is 8.73, with a standard deviation of 7.76. The t-test result of 0.09* indicates a marginal significance level of 10%, suggesting a potential difference in the number of years engaged in potato farming between groups. Research shows that the number of years of experience in potato farming can impact the adoption of climate-smart agricultural practices. Previous studies have indicated a mixed relationship between farming experience and the adoption of innovative agricultural techniques.

For instance, a study by Wossen *et al.* (2017) found that farmers with more years of experience often exhibit resistance to change and may be less likely to adopt new practices, including climatesmart agricultural techniques. This resistance may stem from a reliance on traditional methods that have been successful in the past and a perception that new practices are risky or unnecessary.

Conversely, other research by Muriithi *et al.* (2022) has shown that farmers with extensive farming experience can be more open to innovation and may have the capacity to adapt quickly to new technologies and practices. This adaptability could stem from a deeper understanding of their local environment, resources, and market dynamics, which can enhance their ability to implement climate-smart agricultural practices effectively.

In the context of the study on the adoption of Agro-meteorology, proper post-harvest practices, group membership and cooperatives, and ICT practices, individuals with more years of experience in potato farming (as indicated by the significant positive correlation in the study) may have developed a better understanding of agricultural processes and challenges. This heightened knowledge base could potentially increase their readiness to embrace CSA TIMPs, seeing them as solutions to address evolving environmental and market conditions.

The average income is 7.95, with a standard deviation of 1.25. The t-test result of 0.00* suggests a highly significant difference in income between the groups at the 1% level. Income levels in potato farming can significantly influence the adoption of climate-smart agricultural practices, including those considered in the study such as agro-meteorology, proper post-harvest practices, group membership and cooperatives, and ICT practices. Various studies have highlighted the impact of income on farmers' ability to adopt innovative agricultural practices. Research conducted by Kangogo *et al.* (2021) demonstrated that higher income levels provide farmers with the financial resources necessary to invest in new technologies, inputs, and sustainable practices. Farmers with greater financial stability are more likely to take calculated risks associated with adopting climate-smart agricultural techniques. In contrast, a study by Wakweya (2023) found that low-income farmers may face barriers to adopting climate-smart agricultural practices due to limited financial capacity. These farmers may prioritize meeting immediate household needs over investing in long-term agricultural improvements, thereby hindering the adoption of sustainable farming methods.

In the context of the study on the adoption of agro-meteorology, proper post-harvest practices, group membership and cooperatives, and ICT practices, the significant positive correlation between income levels in potato farming and the adoption of these practices suggests that higherincome farmers may have the financial means to acquire and utilize technologies related to climatesmart agriculture effectively. They could afford the training, equipment, and inputs required for implementing these practices. On the other hand, farmers with lower incomes may require targeted support such as subsidies, access to credit, or value chain enhancements to enable them to overcome financial barriers and embrace sustainable agricultural practices. By addressing income disparities and providing tailored financial interventions, policymakers and development practitioners can foster greater adoption of climate-smart agricultural practices among smallholder farmers, leading to improved resilience, productivity, and sustainability within the agricultural sector.

The mean farm size is 0.75 hectares, with a standard deviation of 0.63. The t-test result of 0.02** indicates a significant difference in farm size between the groups at the 5% level. Farm size in potato farming can significantly influence the adoption of climate-smart agricultural practices, including those considered in the study such as agro-meteorology, proper post-harvest practices, group membership and cooperatives, and ICT practices. Previous research has highlighted the relationship between farm size and the adoption of agricultural innovations. Larger farm sizes may provide economies of scale, enabling farmers to invest in technologies, inputs, and practices that enhance productivity and sustainability. Previous studies by Balcha *et al.* (2023) on the adoption of climate agricultural practices have shown that farmers with larger land holdings are more likely to adopt climate-smart agricultural practices due to their capacity to spread costs over a larger production area and their potential for increased returns on investment.

Conversely, smaller-scale farmers may face challenges in adopting climate-smart practices due to limited financial resources, access to markets, and technical assistance. Research by Li *et al.* (2023) indicated that smallholder farmers often struggle to adopt new technologies and practices due to constraints associated with small farm sizes, including limited access to credit, information, and extension services. In the context of the study on the adoption of agro-meteorology, proper post-harvest practices, group membership and cooperatives, and ICT practices, the significant difference in farm size between groups (as indicated by the t-test result) suggests that farm size can influence the adoption of these practices among potato farmers. Larger farm sizes may allow farmers to implement agro-meteorological practices more effectively, invest in post-harvest technologies, engage in collective action through cooperatives, and leverage ICT tools for farm management and decision-making.

Table 3 Descriptive of the household head socioeconomic characteristics

Agro-meteorology				Proper harvest practices		post-group membership	ICT and cooperatives				'actices	
	Mean	Std. Dev	t-test	Mean	Std. Dev	t-test	Mean	Std. Dev	t-test	Mean	Std. Dev	t-test
Education	7.65	3.99	0.696	8.25	3.60	0.18	7.68	3.68	0.96	7.70	4.25	0.92
Age	45.75	15.14	0.414	41.99	14.45	0.02**	45.06	15.48	0.28	45.84	15.34	0.98
Potato farming in years	8.73	7.76	0.09*	7.47	6.13	0.18	8.44	8.17	0.67	7.69	5.71	0.19
Income	7.95	1.25	0.00*	7.89	0.86	0.44	8.13	1.12	0.04**	8.00	1.18	0.95
Farm size in hectares	0.75	0.63	0.02**	1.19	1.10	0***	0.60	0.51	0***	0.64	0.53	0.08*

Note * significant at 10%, ** significant at 5% *** significant at 1%

4.1.3 Institutional characteristics

The results on Institutional characteristics are shown in Table 4. Access to extension services is necessary for increased dissemination of CSA TIMPs. Forty-nine (49%) had access to agro- agrometeorological services, and 56% and 57% had access to cooperatives and ICT practices, respectively. Access to extension services is statistically significant at 1%. Extension services help farmers better understand CSA practices. Antwi-Agyei and Stringer (2021) found that agricultural extension agents in Ghana can better support smallholders in navigating and addressing the effects of climate change on food production. No significant associations were found between group membership and the adoption of all listed CSA TIMPs. However, collaboration and shared resources within groups might contribute to increased adoption rates. Group membership in agricultural cooperatives and organizations can play a crucial role in influencing the adoption of climate-smart agricultural practices, including those considered in the study such as agrometeorology, proper post-harvest practices, group membership and cooperatives, and ICT practices.

Previous studies have highlighted the positive impact of group membership on the adoption of sustainable agricultural practices. Research by Ogisi *et al.* (2023) shows that farmers who belong to agricultural groups are more likely to adopt climate-smart practices due to enhanced access to training, information, technologies, and collective decision-making processes. Participation in agricultural groups and cooperatives can provide smallholder farmers with various benefits, including increased bargaining power, access to markets, shared resources, and knowledge exchange. By fostering social capital and collaboration, group membership can create conducive environments for learning, innovation, and the adoption of climate-smart agricultural techniques. Farmers who are actively involved in agricultural groups may have higher levels of awareness, peer support, and access to resources that facilitate the adoption of climate-smart practices. Furthermore, group membership can also enhance farmers' resilience to climate change by enabling them to pool risks, adapt collectively to changing environmental conditions, and implement coordinated responses. Collaborative approaches fostered through group membership can lead to the scaling up of climate-smart agricultural practices and contribute to broader sustainable agricultural development outcomes.

There was a significant association between access to credit and the adoption of certain CSA TIMPs. Financial resources from credit access may influence the adoption of specific practices. Access to credit can significantly impact the adoption of CSA TIMPs, including those under consideration in the study such as agro-meteorology, proper post-harvest practices, group membership and cooperatives, and ICT practices. Previous studies have highlighted the importance of access to credit in facilitating the adoption of sustainable CSA practices. Research by Haryanto *et al.* (2023) has shown that farmers who have access to credit are more likely to invest in new technologies, inputs, and practices that improve productivity, resilience, and sustainability. Credit access enables farmers to overcome financial barriers and make necessary investments in sustainable agricultural innovations.

Farmers without access to credit may face challenges in adopting climate-smart practices due to limited resources and the inability to finance upfront costs associated with technology adoption, training, and inputs. Lack of credit access can hinder smallholder farmers from investing in climate-resilient farming techniques and hinder their ability to adapt to changing environmental conditions. In this study, there was a significant association between access to credit and the adoption of listed CSA TIMPs (as indicated by the chi-square results) suggesting that farmers with access to credit are more likely to adopt these practices compared to those without credit access. Access to credit can facilitate farmers in purchasing equipment for agro-meteorological monitoring, investing in post-harvest technologies, joining agricultural cooperatives, and utilizing ICT tools for improved farm management and decision-making. By providing financial resources, access to credit can empower farmers to implement climate-smart agricultural practices effectively, enhancing their resilience, productivity, and sustainability in the face of environmental challenges.

Table 4: Institutional Characteristics and CSA TIMPS

Access	Agro meteorology		Post-harvest practices		Cooperatives		ICT practices	
Extension services	Per cent	chi	Per cent	chi	Per cent	chi	Percent	chi
Yes	48.79	0.190	48.53	0.001 *	55.84	8.53	56.67	3.08
No	51.21		51.47		44.16		43.33	
Group membership **yes**	43.67	2.323	36.76	1.958	86.8	293.6	48.89	0.95
No	56.33		63.24		13.2		51.11	
Access to credit								
Yes	52.83	1.584	60.29	2.164	53.81	0.414	51.11	0.06*
No	47.17		39.71		46.19		48.89	

*** Significant at 1% level.

4.2Utilization of CSA TIMPs available for potato entrepreneurs in Nyeri County

To assess the utilization of various CSA TIMPs, CSA TIMPs available for farmers were correlated with CSA TIMPs adopted by potato Agri-entrepreneurs to determine the extent of Utilization. According to the study findings, 53.9% of the farmers were aware of a cooperative, 44.8% were aware of a proper post-harvest storage facility, and 30.5% of an ICT platform either for input acquisition or marketing, and only 18.23 were aware of agro-meteorological services. Seventeen point seven (17.7%) of potato farmers in Nyeri County adopted proper post-harvest practices, 8.33% adopted an ICT practice, 53.9% were in farmers' cooperatives, and 3.7% adopted agro-meteorological services.

Table [1]: awareness vis a vis adoption of CSA TIMPs

CSA TIMPs	Adopters	Non-adopters
Agrometeorological services	14	70
(ICT) tools for marketing and input acquisition	32	117
Post-harvest storage facilities	68	172
Cooperatives	197	207

Table 5: Kendal Tau's coefficient for access and adoption

	Accessed	Adopted
Accessed	1.000000	0.866667
Adopted	0.866667	1.000000

Awareness of agro-meteorological information is vital for farmers to make informed decisions related to crop management, irrigation, and pest control. It enables them to respond effectively to changing weather conditions and minimize risks associated with climate variability. Oladele *et al*. (2018) investigated the adoption of agro-weather tools for climate-

[1] **.2.1 Relationship between awareness and adoption of CSA TIMPs**

Table 7 below presents Kendal Tau's coefficient for access and adoption. Stata V.17 was used to compute the Kendal rank correlation coefficient (tau). CSA TIMPs availability was strongly correlated with CSA TIMPs adoption (0.87), as shown in Table 8. Awareness of Climate-Smart Agriculture (CSA) practices is crucial for enhancing the adoption of climate-smart agricultural techniques, including those under consideration in the study - agro-meteorology, proper postharvest practices, group membership and cooperatives, and ICT practices. The ability of farmers to access and engage with these practices can significantly influence the sustainability and productivity of their agricultural activities.

smart agriculture in Kenya and Ethiopia. The research focused on factors influencing farmers' use of various information sources, including short message service (SMS), newsletters, and radio. The study concurs that farmers who have access to weather information and forecasts are more likely to adopt climate-smart practices, leading to improved crop yields and resilience. Results concur with Amadu *et al.* (2019) who focused on socio-psychological drivers of farmers' adoption of climate-smart agricultural practices. The study sheds light on the importance of agro-meteorological information. CSA TIMPs play a crucial role in managing climatic shocks faced by smallholder farmers.

Access to knowledge and technologies for proper post-harvest handling, storage, and processing is essential for reducing food losses and enhancing quality. Farmers with access to training and resources on post-harvest practices are better equipped to adopt storage technologies, reduce waste, and improve the marketability of their produce. Mutungi *et al.* (2023) conducted a study focusing on maize-farming households in Tanzania, investigating the adoption of postharvest technologies such as mechanized shelling, drying tarpaulins, and airtight storage. These technologies address labor, product quality, and quantity concerns. The results show positive impacts on food security and welfare, including increased food availability, access, and household incomes.

Participation in agricultural groups and cooperatives provides farmers with opportunities for knowledge exchange, collective decision-making, and resource-sharing. This can enhance their access to CSA practices, training, and technologies. Collaborative efforts within groups can lead to increased adoption rates of climate-smart agricultural techniques and strengthen the resilience of farming communities. Li *et al.* (2023) literature review examines factors driving the adoption of climate-smart agricultural (CSA) practices. Among the influential variables, membership in farmers' organizations consistently impacts CSA practice adoption positively. By participating in such groups, farmers gain access to information, training, and collective decision-making, enhancing their ability to adopt climate-smart practices.

Consequently, Martey (2021) found the adoption of CSA practices and factors influencing it. Notably, social capital and access to agricultural training play crucial roles. Farmers who engage in agricultural groups or receive comprehensive training are better equipped to embrace CSA practices. These practices contribute to improved welfare and sustainable agriculture. Information and Communication Technology (ICT) tools can empower farmers with real-time data, market information, and decision-support systems. Access to mobile applications, remote sensing technologies, and digital platforms can facilitate the adoption of precision agriculture practices, efficient resource management, and climate-resilient farming methods. Farmers with access to ICT tools are more likely to integrate technology into their farming practices and enhance productivity. Andati *et al.* (2022) found that factors influencing CSA adoption included access to financing through mobile-based applications, gender, land size, trust in extension officers, household income, and farm characteristics.

4.3 Profitability of CSA TIMPs on potato Agri-enterprises in Nyeri County

Profitability in an agri-enterprise refers to the financial gain or profit derived from agricultural activities.

Variable Costs = Cost of Seed + Cost of Fertilizer + Cost of Pesticide + Cost of Fungicides + Cost of Manure

Substituting the provided values: Variable Costs= Ksh. 63397 as shown in Table 8.

Table 6:Total variable cost for Potato Production

	N	Minimum	Maximum	Mean	Std. Deviation
The total cost of seed	385	0	160000	28827.79	25038.094
Cost of fertilizer	385	3200	120000	17604.68	16380.898
The total cost of pesticide	385	0	7000	427.14	1044.300
Total cost fungicides	385	0	10000	584.55	1424.827
Total cost manure	385	0	80000	15952.99	8151.137
Total Cost				63397.15	

The total benefits accrued were the total income from the sale of potatoes. The income from potato farming, as sampled among the farmers, was summarized in Table 9.

Table 7: Income from Potato Farming for the 2019 long rains season

	N	Minimum	Maximum	Mean	Std. Deviation
Quantity harvested	385	40.00	1500.00	241.3377	207.79663
Price/kg	385	700	1200	1010.68	121.141
income	385	44000.00	1350000.00	236882.7273	192163.47053
Total cost	385	14400.00	550300.00	63397.15	67890.62376
Valid N (listwise)	385				

Gross Margin is calculated by subtracting the total variable costs from the total revenue. Gross

Margin=Total Revenue−Variable Costs

Gross Margin= (Quantity Harvested Price per kg) −Variable Costs

Substituting the provided values:
Gross Margin= (241.3377×1010.68) − (Variable Costs)

Gross Margin= Ksh 173,486

4.4 Effect of CSA TIMPs adoption on profitability and household income

Table 10 presents the impact of adopting various climate-smart practices on farmers' income, comparing adopters to non-adopters: Adopters of Agro-meteorological Services have a significantly higher mean income (Ksh 241,142.6) compared to non-adopters (Ksh 123,996.4), with a t-test result indicating statistical significance at the 5% level. A study conducted by Tarchiani *et al.* (2021) in the Sahelian rural areas of Burkina Faso demonstrated that the adoption of agrometeorological services can significantly improve agricultural productivity and sustainability. The study found that farmers who utilized these services saw a 40% reduction in production costs and a 41% increase in income. Additionally, there were environmental benefits, such as a 50% reduction in the use of fertilizers. This indicates that agro-meteorological services not only contribute to higher income but also to cost savings and environmental sustainability. Another case study by Nirwal *et al.* (2020) in the Aurangabad district of the Marathwada region in India assessed the economic benefits of farmers adopting Agro-meteorology Advisory Services (AAS). The study compared two groups of farmers: those who adopted AAS and those who did not. The net income of AAS farmers was significantly higher for crops like soybean and cotton + black gram, with additional benefits of 55.5% and 50.3%, respectively, compared to non-AAS farmers. This case study reinforces the notion that timely and accurate weather forecasts can lead to better crop growth, higher yields, and increased income. These studies corroborate the findings from the study showing that adopters of agro-meteorological services tend to have higher mean incomes than nonadopters. The adoption of such services enables farmers to make informed decisions, reduce risks associated with climate variability, and optimize their agricultural operations for better financial outcomes.

Post-harvest Practices: Adoption of proper post-harvest practices shows a substantial increase in mean income for adopters versus non-adopters highly significant at the 1% level. Several studies have demonstrated the positive impact of adopting proper post-harvest practices on farmers' income. A study done by Mutungi *et al.* (2023) in Tanzania on maize farming households investigated the adoption of post-harvest technologies like mechanized shelling, drying tarpaulins, and airtight storage in Tanzania1. It found that these technologies significantly increased household incomes by 112–155%. The adoption of drying tarpaulins and airtight storage also led to an increase in food availability by 18–27% and food access by 24–26%.

Similarly, a study conducted by Balana *et al.* (2022) on the impact of livelihoods through postharvest loss management indicated that the adoption of postharvest technologies (PHT) significantly increases net returns, thus improving livelihoods. The counterfactual impact analysis suggested that value chain actors who adopted PHT would have earned 7% lower net returns had they not used the technology. These studies corroborate the notion that proper post-harvest practices can lead to significant economic benefits for farmers, highlighting the importance of such practices in agricultural sustainability and economic development.

For farm groups, surprisingly, non-adopters have a higher mean income than adopters, with a significant difference at the 1% level, suggesting potential drawbacks or inefficiencies in these groups. A previous study conducted on farm groups' adoption and Impact of Improved Agricultural Technologies on Rural Poverty in Ethiopia revealed that adoption of improved agricultural technologies has a robust, significant, and positive impact on per capita consumption expenditure and a negative impact on the poverty status of households. This study suggests that adoption generally leads to better outcomes, but it does not directly address the scenario of non-adopters having higher incomes.

Table 8: Effect on income for adopters and non-adopters

Adopted	Obs	Mean	Std. Dev.	ttest	
Agro-metrological services	no	14	123996.4	87876.47	0.025
Yes		371	241142.6	193784.2	
Proper post-harvest practices	no	317	205729.2	123283.4	0***
Yes		68	382113.2	337576.1	
Farm groups and cooperatives	no	188	275150.3	210013.8	0.0001***
Yes		197	200363.5	165893.9	
ICT practices	no	295	243433.2	194279.5	0.2264
	yes	90	215411.7	184477.8	

Note: * significant at 10%, ** significant at 5% *** significant at 1%

Most studies generally support the notion that the adoption of agricultural practices and technologies leads to higher incomes for farmers. The scenario where non-adopters have higher incomes may be specific to certain contexts or types of farm groups and membership, possibly due to inefficiencies or other factors not captured in these studies. There is no significant difference in mean income between adopters and non-adopters of ICT practices, as indicated by the t-test result (p-value > 0.1). Overall, the findings suggest that while certain climate-smart practices like agrometeorological services and post-harvest practices can lead to higher incomes for adopters, the effectiveness of farm groups and ICT practices may vary or require further investigation to understand their impact on income.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The overall objective was to determine the effect of the adoption of CSA TIMPs on the profitability of potato Agri-enterprises in Kieni-Sub County. The specific objectives of the study were to; assess the Utilization of CSA TIMPs, analyze factors determining the adoption of CSA TIMPs, and determine the effect of CSA adoption on the profitability of smallholder potato agrienterprises. To achieve objectives, data was collected by the use of a questionnaire. Furthermore, to determine the profitability of CSA adoption a cost-benefit analysis was employed. The following are the key conclusions of the objectives of the study.

The study's findings on the Utilization of CSA TIMPs indicate a strong positive correlation (Kendall's tau = 0.87) between the accessibility of CSA TIMPs and their adoption. This suggests that when farmers have better access to CSA TIMPs, they are more likely to implement them. The significant relationship underscores the importance of access as a determinant of adoption, which in turn can lead to enhanced agricultural productivity and sustainability. Access to agrometeorological services, proper post-harvest technologies, farm groups and cooperatives, and ICT practices are all crucial components that contribute to the resilience and efficiency of farming operations. Each of these components plays a vital role in enabling farmers to make informed decisions, manage risks, reduce losses, and improve marketability, ultimately leading to increased income and food security.

The study's findings suggest that the adoption of CSA TIMPs is not significantly influenced by the education level of household heads. However, age and experience in farming do play a role in the adoption of specific CSA TIMPs. Older farmers are marginally more inclined to adopt proper post-harvest technologies, potentially due to their greater experience and resources. In contrast, younger farmers are more likely to embrace ICT practices, likely because of their higher levels of education, openness to innovation, and greater exposure to new information. The mixed relationship between farming experience and the adoption of innovative agricultural techniques indicates that while experience can provide valuable knowledge and resources, it can also lead to resistance to change due to a preference for traditional methods.

The collective evidence from the studies indicates that the adoption of Climate-Smart Agriculture (CSA) practices, particularly agro-meteorological services, has a significant positive impact on the profitability of smallholder potato agri-enterprises. Adopters of these services experience a substantial increase in mean income, reduced production costs, and environmental benefits. The correlation between the adoption of Agromet Advisory Services (AAS) and increased net income for specific crops further supports the conclusion that access to accurate weather information and forecasts is crucial for enhancing agricultural productivity and sustainability.

5.2 Recommendations

The following are the recommendations of this study:

Access to a CSA TIMP was strongly correlated to adopting a CSA TIMP. These findings underpin the importance of the government investing in infrastructures like meteorological departments, agricultural cooperatives, post-harvest storage facilities, and ICT services made available for the farmer. There is a need to sensitize farmers on the importance of adopting CSA TIMPs.The government and various stakeholders in the agricultural sector should focus on targeted training programs. Develop training programs tailored to different age groups, emphasizing the benefits and practicality of CSA TIMPs to overcome resistance to change. For older farmers, focus on demonstrating the long-term benefits and reliability of new post-harvest technologies. For younger farmers, leverage their openness to ICT by providing advanced training on the latest agricultural technologies.

Creation of experience-sharing platforms: Create platforms for intergenerational knowledge exchange where experienced farmers can share insights with younger farmers, and vice versa. Encourage mentorship programs where older farmers can guide younger ones in traditional farming wisdom, while younger farmers can introduce new technologies and practices.

Incentivize Adoption: Offer incentives such as subsidies or grants for farmers who adopt and implement CSA TIMPs, particularly for costly post-harvest technologies. Provide financial support for younger farmers to access advanced ICT tools for agriculture.

Awareness Campaigns: Conduct awareness campaigns to highlight the effectiveness and necessity of CSA TIMPs in addressing climate change challenges. Use success stories and case studies to illustrate the positive impact of CSA TIMPs on farm productivity and income. Research and Development: Invest in research to develop and refine CSA TIMPs that are cost-effective, easy to use, and adaptable to various farm sizes and types. Collaborate with agricultural research institutions to test and validate the effectiveness of CSA TIMPs in local contexts.

By implementing these recommendations, the adoption of CSA TIMPs can be enhanced across different demographic groups, leading to a more resilient and sustainable agricultural sector.

5.3 Areas for Further Research

i. Examine the long-term effects of agro-meteorological service adoption on income and productivity over multiple growing seasons.

ii. Investigate how farmers interpret and act upon agro-meteorological information, and identify factors that influence their decision-making processes.

iii. Study the impact of post-harvest practices on the entire value chain, from production to market access and consumer satisfaction.

iv. Investigate the role of gender and inclusivity in the success of farm groups and cooperatives in adopting CSA practices.

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APPENDICES

Appendix A: Questionnaire

Consent

My name is Gabriel Kinyingi Master of Science (Agri-Enterprise development) student at Egerton University. I am studying factors influencing access and use of Climate advisory services. I want to request your participation in the study. Your participation in this study is voluntary. Any information provided will be treated with the utmost confidentiality and used anonymously. The interview will take 20-35 minutes.

Section One: General Information

Questionnaire Number ______________	Date of the Interview -------/-----/------
Division…………………	Sub location…………………
Village…………………	

Section Two: Demographic & Farm characteristics of the Households

1) Gender: Male/Female?
2) Educational level: Primary/Secondary /Tertiary
3) Age: 18-35/36-60/Above 60
4) Years of potato farming: <15 yrs / <30 yrs/ >30yrs
5) Land ownership: Owner: Yes/No

   Communal Land: Yes/No

   Leased land: Yes/No

6) Size of land under potato farming

7) Average seasonal income from potato farming?
   Ksh. 0 -1000

Section three: Utilization of CSA TIMPs

1. Have you adopted any CSA TIMPs in your potato farming practices? (Yes/No)
2. If yes, which specific CSA TIMPs have you implemented?

i. Agro meteorology, ii. use of Information Communication Technology (ICT), iii. cooperative membership, iv. adoption of proper post-harvest storage techniques If no, what are the reasons for not adopting

CSA TIMPs?

Section 4: Determinants of Adoption

4. **Factors Influencing Adoption**:

- What factors influenced your decision to adopt CSA TIMPs? (e.g., knowledge, access to information, financial incentives, peer influence)
- Were there any barriers or challenges to adopting CSA TIMPs? **Section 5: Profitability Assessment**

5. **Revenue and Costs**:

- Estimate the following costs associated with adopting CSA TIMPs:

- Cost of seeds
- Cost of fertilizers
- Pesticide expenses
- Labor costs
- Irrigation expenses
- Storage and transport costs
- Harvesting costs
- Marketing expenses

Total revenue generated from potato sales:

- ✦ Quantity harvested (in kilograms or other units)
- ✦ Price per unit (selling price of potatoes)

6. **Profitability Evaluation**:

- o Calculate the gross margin using the formula: Gross Margin=Total Revenue−Variable Costs

Section 6: Benefits and Future Intentions

7. **Benefits and Intentions**:

- o What benefits have you observed from adopting CSA TIMPs? (e.g., increased yield, reduced input costs)
- o Are you planning to continue using CSA TIMPs in the future? If yes, what improvements or adjustments do you plan to make?

Appendix B: NACOSTI introductory letter

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OFFICE OF THE DIRECTOR GRADUATE SCHOOL

KM23/14699/18 **10th November, 2022**

Ref:…………………………………… **Date:………………………**

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

Dear Sir,

RE: REQUEST FOR RESEARCH PERMIT – MR. GABRIEL KINYUA KINYINGI REG. NO. KM23/14699/18

This is to introduce and confirm to you that the above named student is in the Department of Agricultural Economics & Agribusiness Management, Faculty of Agriculture, Egerton University.

He is a bona-fide registered M.Sc. student in this University. His research topic is **"Effects of Adopting Climate-Smart Agriculture Practices on Profitability of Small-holder Potato Agri-Enterprises in Nyeri County, Kenya"**

He is at the stage of collecting field data. Please issue him with a research permit to enable him undertake the studies.

Your kind assistance to him will be highly appreciated.

Yours faithfully,

DIRECTOR, BOARD OF POST GRADUATE STUDIES
11 NOV 2022
EGERTON UNIVERSITY

Prof. S. P. Nyalala
DEPUTY DIRECTOR, BOARD OF POSTGRADUATE STUDIES

SPN/en

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Appendix C: Research license

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: **312414**

Date of Issue: **21/February/2023**

RESEARCH LICENSE

This is to Certify that Mr.. Gabriel Kinyua Kinyua of Egerton University, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Nyeri on the topic: EFFECT OF CLIMATE-SMART AGRICULTURE ON PROFITABILITY OF SMALL-HOLDER POTATO AGRI-ENTERPRISES IN NYERI COUNTY, KENYA for the period ending : 21/February/2024.

License No: **NACOSTI/P/23/23680**

312414

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Appendix D: Research publication

E. Afri. Agri. For. J (2022,Volume 86 (3), Pg 245-251)

DETERMINANTS OF ADOPTION OF CLIMATE-SMART AGRICULTURE TECHNOLOGIES AMONG POTATO FARMERS IN KIENI SUB-COUNTY, NYERI COUNTY

G. Kinyua[#], E. Gathungu and A. Karanja
Egerton University, Department of Agribusiness and Agricultural Economics, P.O. Box 536-20115, Njoro, Nakuru, Kenya

ABSTRACT

Climate change threatens the transformation of subsistence agriculture into sustainable agribusinesses. To mitigate the effects of climate change and boost food security in Africa, various agricultural stakeholders have recommended Climate-Smart Agriculture, technologies, innovations, and management practices (CSA-TIMPs) as prerequisites for adaptation to climate change. Despite the potential of CSA-TIMPs in transforming farming systems into sustainable agri-enterprises in Kenya, their application at the farm level is limited. The factors influencing CSA-TIMPs adoption and application in farm decision-making are poorly understood, necessitating the current study. Understanding the factors that limit the adoption of CSA-TIMPs is crucial to accelerate their uptake. This paper presents findings on social-economic factors that influence the adoption of CSA-TIMPs among potato entrepreneurs in Nyeri County, Kenya. The study's sample size was 384 households in the Mugunda and Narumoru Wards of Nyeri County. A semi-structured questionnaire was used to collect qualitative and quantitative data. The multivariate probit (MVP) model was used to analyze factors determining the adoption of CSA-TIMPs. Results indicate that extension services, farm groups, credit facilities, farmers' income level, and access to agro-meteorological services positively influenced the adoption of CSA-TIMPs. Thus, policies to improve institutional support, such as extension services, credit facilities, and field demonstration technologies, are crucial to upscaling the adoption of CSA-TIMPs.

change has had a negative impact on agriculture. The increased unpredictability of weather patterns has ravaged the agricultural sector causing income losses among 500 million small-holder farmers in developing countries and consequently threatening their food security (Lipper *et al.*, 2017). Although traditional weather prediction techniques have helped farming communities survive, rapid changes in weather patterns may render indigenous knowledge and traditional coping mechanisms obsolete (Chattopadhyay and Chandras., 2008).

The Kenyan government has recommended the adoption of climate-smart agriculture technologies and innovation management practices (CSA-TIMPs) to boost farmers' resilience to climate change. Climate-smart agriculture (CSA) is agriculture that sustainably increases production by enhancing farmers' resilience to climate change and mitigating the emission of greenhouse gases (Olutola, 2021). Potato farmers can benefit from CSA-TIMPs such as agro-meteorology, sustainable soil and land management practices such as minimum tillage, fertilizer application, proper post-harvest storage, and membership in farmer groups and cooperatives (Ogola and Ouko, 2021).

Although adopting CSA-TIMPs at the farm level promises immense benefits for agricultural enterprises, their application is limited, especially in sub-Saharan Africa (Lipper *et al.*, 2017). Factors limiting their adoption in Nyeri County, Kenya, are poorly understood,