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The nature and extent of adoption of climate-smart agriculture technologies in Murang'a County, Kenya: A case of Kiharu Constituency.

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Abstract

Climate-smart farming, regenerative farming techniques and carbon farming are gaining popularity worldwide due to their potential to improve food and nutrition security. Kenya's agriculture is largely rain-fed and characterized by unreliable rainfall and high temperatures affecting production, quality and pricing. While there is evidence of opportunities presented by CSA supporting smallholders' adaptation to climate change, the rate of adoption remains low. The study, therefore, assessed the nature and extent of adoption of climate-smart agriculture (CSA) technologies and innovations taking Kiharu Constituency as a case. About 50 households were sampled and data were collected using questionnaires, interviews, observations and secondary sources. The descriptive analysis on collected data revealed that on average 63.55% of the farmers were aware of the CSA technologies while only 55.10% of farmers adopted them. The most adopted and utilized practices by more than 50% of the farmers include crop rotation, intercropping, terracing, ridging/furrowing, resilient crop varieties, irrigation, agroforestry, building gabions, forage conservation, and drought-tolerant animal breeds. The CSA technologies least adopted with less than 50% of the farmers utilising them include minimum tillage, mulching and planting pits. Further research on methods of enhancing the scalability of CSA technologies and innovations is vital for increasing awareness and uptake.

Keywords: Adoption; climate change; climate smart agriculture; food production; resilience

Introduction

Agriculture is an integral sector for global food security and economic development. It is a stimulus to economic growth, accounting for one-third of the worldwide Gross Domestic Product (World Bank, 2019; Amwata, 2020). Agriculture is one of the most effective weapons for ending extreme poverty, increasing shared prosperity, and feeding the 9.7 billion people predicted to exist by 2050 according to the United Nations Department for Economic and Social Affairs (2023). The growth in the sector is two to four times more effective than other sectors in generating income among the poor. According to research done by the World Bank in 2016 studies, the sector earned a living for approximately 65% of poor working adults in the world. Sustainable agriculture practices are thus gaining traction around the world as people become more aware of the need to protect the environment while also ensuring food security (Adebisi et al., 2022).

The current global trends in sustainable agriculture emphasises regenerative agricultural practices to promote soil health and the use of technologies that build soil organic matter such as mulching, crop rotation and minimum tillage. Climate-smart farming is also gaining traction, especially in efforts to withstand the stress of climate change, thus reducing the risk of crop failure. Carbon farming is also a center of focus as it has been identified as a key area in the generation of new and green revenue for the agricultural sector (FAO, 2016; World Bank, 2019).

Africa as a continent identifies agriculture as one of the key pillars in spurring socio-economic growth and development. However, Africa's agricultural sector is confronted with some challenges, including low productivity (Nyariki and Thirtle, 2000), limited market access, and climate change. In sub-Saharan Africa, agriculture accounts for about 30% of Gross Domestic Product (GDP), and more than 60% of the working population are smallholder farmers (Temple and Yearwood, 2016). In East Africa, Agriculture remains the backbone and the driving force for most economies accounting for greater percentages of their GDP contributors. Subsistence farming is practised by the rural population, which is primarily made up of smallholder farmers, and agriculture is a way of life for many (Palmer et al., 2023). Despite these sectoral challenges, there is growing interest in sustainable agriculture technologies and innovations, which have potential to enhance food security in the region (Giller et al.,2021; Arora, 2019).

Agriculture in Kenya is largely rain-fed and therefore sensitive to climate change and climate variability which hampers productivity (Amwata, 2020; Nyariki and Thirtle, 2000). Climate change is becoming a global concern occasioned by rising temperatures, declining rainfall amounts and variations in frequency and intensity of extreme climatic events such as drought thus affecting farming activities. Excessive rainfall and flooding significantly damage farmers' crops and pastures for livestock (Amwata and Nyariki, 2021). Furthermore, it has compromised food supply, access, and consumption for Kenya's ever-growing population (Ochieng and Mathenge, 2016). The sector is the backbone of the Kenyan economy, contributing approximately 33% of the GDP directly and 25% indirectly (ASTGS, 2018; FAO, 2020).

Climate change has driven farmers towards the adoption of sustainable agriculture practices in efforts to reduce severe climatic risks in agriculture, sustainably increase productivity and enhance resilience to climatic stresses, reduce greenhouse gas emissions, and protect the environment (Amwata et al., 2015; FAO, 2010; KCSAP, 2019). These practices include climate-smart agriculture, carbon farming, and regenerative farming to enhance production amidst the ever-changing climate.

Climate Smart Agriculture (CSA) is an integration of traditional and innovative technologies and practices aimed at achieving climate-resilient food production systems to address food security concerns of the ever-growing human population (KCSAP, 2019). Climate resilient agricultural practices and technologies such as crop rotation, minimum tillage, Zai pits, irrigation, and mixed cropping have been found to help increase crop yields, water, and nutrient use efficiency and reduce GHG emissions (Belay et al., 2023; Khatri-Chhetri et al., 2023). Further, the use of stress-tolerant seeds, irrigation, rainwater harvesting, extension officer-farmer linkages, and crop/livestock insurance have enhanced farmers 'resilience to climate change and variability (Khatri-Chhetri et al., 2023). These technologies and practices can be implemented singly or in combination. This study therefore focused on the assessment of the nature and extent of adoption of climate-smart agricultural technologies among farmers in the study area.

1. Literature Review and Theoretical Framework

The chapter describes the concept of agricultural productivity, climate-smart agriculture, policy interventions on CSA technologies and innovations, CSA technologies practiced in the study area, factors influencing the choice of CSA, challenges and opportunities, and the theoretical framework.

2.1 Literature review

The study's literature review is as presented below.

2.1.1 Concept of agricultural productivity

Agricultural productivity is defined as "output per unit of input" or "output per unit of land area". Increase in productivity i.e., crop productivity, livestock productivity, and fisheries is often considered to be the result of effective and efficient utilization of both physical and several non-physical factors of production (Dharmasiri, 2012). Productivity is critical in emphasizing the structure and challenges affecting agricultural production, prompting policymakers to propose appropriate policies. This concept is generally considered from two close interactions of both productivities of land and infrastructure and other factors engaged in agriculture to ensure optimal agricultural productivity is achieved (Dharmasiri, 2012).

Land is a fixed factor of production whose value is determined by the output per unit area of land. Producing agricultural goods requires a significant amount of labour and productivity is an important factor in this regard. It is evaluated by computing the labour input in terms of man-hours worked and the number of workers engaged in production vs. output. Training and increased incentives or compensation could boost agricultural labour productivity. Capital is also a very essential factor of production in agricultural productivity playing a vital role in providing a means of acquiring inputs such as seeds, fertilizers, pesticides, and irrigation equipment among others to be used in agricultural production (Singh and Raghubanshi, 2019). Entrepreneurship combines all the factors of production i.e., land, labour, and capital in production to earn a profit. Agricultural productivity heavily relies on these factors of production to ensure efficiency in food production.

2.1.2 Concept of Climate Smart Agriculture

Climate-smart agriculture is a comprehensive approach that guides actions and implementation of agricultural technologies and innovations to effectively and efficiently support development as well as guarantee food safety in the face of climate change (FAO, 2019). It refers to both on and off-farm mutually integrated agricultural strategies that incorporate technologies, policies, institutions, and investment to support agricultural production and ensure food safety amidst the threat of climate change (FAO, 2020). CSA champions three main objectives:

i) Sustainable increase in agricultural production and incomes

CSA focuses on increasing agricultural production and income, particularly from crops, livestock, and fish while minimizing environmental impact. Sustainable intensification of agricultural production systems requires efficient utilization of water, soils, and other natural resources, while also providing farmers with the necessary income to maintain investment levels in more resilient and productive food systems.

ii) Adapting and building resilience to climate change

The goal of CSA is to reduce farmers' vulnerability to short-term production and business risks while also increasing their capacity to embrace changes to farming operations and the long-term impacts of climate variability.

iii) Reducing greenhouse gas emissions

Climate-smart agriculture plays a major role in building resilience. Several agricultural practices and technologies contribute to both adaptation and mitigation goals, for example, farmers use reforestation programs to reduce land degradation while mitigating climate change impacts. Reforestation and afforestation result in increased production due to the influence of the microclimate. Practices that sustainably promote forest management can benefit local communities in a variety of ways. Improved land management has increased fodder production for livestock and additional income to farmers. Other benefits of reforestation include reduced land degradation and soil erosion, as well as improved water infiltration.

Conservation agriculture is a good climate-smart approach practice that aims to boost smallholder farms' production and profitability while also increasing their resilience to climate change. It is based on minimum soil disturbance, maintaining good rotations, intercropping, and relay cropping principles. These conservation agriculture practices contribute largely to saving the cost of production and promoting agricultural diversification.

2.1.3 Policy interventions on Climate Smart Agricultural technologies and innovations

CSA refers to both on and off-farm mutually integrated agricultural strategies that incorporate technologies, policies, institutions, and investment to support agricultural production and ensure food safety amidst the threat of climate change (FAO, 2020). The goal of CSA is to ensure a long-term increase in agricultural productivity and income generation, enhancing adaptation and resilience to climate change, and, where possible, reduction and/or elimination of greenhouse gas emissions.

The practices and innovations including policy interventions are some of the government interventions to reduce the adverse impacts on agricultural production. These practices are sector-specific though they link up mutually to improve agricultural production. Furthermore, the Kenya Climate-Smart Agriculture Implementation Framework, 2018-2027 (KCSAIF) is one of the policy frameworks developed to guide mainstreaming Climate-Smart Agriculture in agriculture and other related sectors. The Framework seeks to achieve climate-resilient and low-carbon-growth agriculture that guarantees food safety and contributes to Kenya Vision 2030 development goals and SDGs 1, 2, and 13. It enables stakeholders to identify agricultural strategies and innovations that are appropriate for their local conditions while also taking into account the social, economic, and environmental impact on the area of application. It aids in the identification of barriers to farmer adoption as well as appropriate solutions in the formulation of policies, strategies, activities, and incentive programs (FAO, 2019).

2.1.4 CSA practices and innovations practiced by farmers in the study area

Kenya's Ministry of Agriculture, Livestock, and Fisheries has launched over eleven CSA-related initiatives since 2001, the vast majority of which have been implemented in ASALs. CSA technologies and innovations help farmers build more resilience to the ever-changing climate. Farmers in Kiharu have been trained on the importance of incorporating agroforestry systems to reduce livestock feed costs and farmers' reliance on rangelands. The program also assists farmers in improving livestock management thus increasing production. Changing livestock production techniques help farmers produce more and higher-quality animals, reduce their reliance on degraded rangelands, and make better use of water for their livestock. The County Government of Murang’a has established Murang’a County Creameries with several cooling plants at different designated points within the County. The plant has been collecting milk from about 43,000 dairy farmers affiliated with about thirty-six (36) dairy cooperative societies spread all over the County since its formation in 2014.

Farmers have adopted water harvesting and supplemental irrigation technologies championed by the County allowing them to utilize rainwater, groundwater, and surface water which continues to be scarce and less reliable. Drought-tolerant and insect-resistant crop varieties aid farmers in increasing production.

Minimum tillage is also one of the CSA practices recommended for farmers in Kiharu to enhance climate resilience by reducing risks due to erratic rainfall. It implies minimum soil disturbance and encourages soil coverage through practices such as mulching to avoid nutrient and carbon losses, soil erosion, and contaminant accumulation in the soil. This contributes to improved soil structure, soil fertility, carbon sequestration, and soil water-holding capacity (Sapkota et al., 2015).

Site-specific nutrient management is among the CSA practices aimed at managing crop nutrients through maximizing the use of organic fertilizers and optimizing the use of chemical fertilizers, thereby enhancing resource use efficiency and lowering agricultural GHG emissions.

Furthermore, farmers have been sensitized on the adoption of seeds of stress-tolerant varieties such as rice varieties that are submergence tolerant, while other varieties are heat, temperature, and/or drought tolerant. Farmers' adaptation to climate risks such as drought, flood, heat, and temperature stress has increased due to their efficiency. Farmers have also been encouraged to use improved crop production techniques, such as higher-yielding and shorter-duration varieties, or those with resistance to specific climate shocks as well as improved crop nutrient management, farm diversification and intercropping, crop rotation, and increased cultivation of perennial crops.

Protected cultivation is one of the major practices that farmers are advised to undertake. Protected cultivation is a process of cultivating crops in a controlled environment in which temperature, light, humidity, and other factors can be adjusted to meet crop requirements. Kiharu farmers could tap the benefits from such cultivation, which includes forced ventilated greenhouses, naturally ventilated poly houses, insect-proof net houses, shade net houses, plastic tunnel and mulching, raised beds, trellising, and drip irrigation, in addition to crop health management. These practices can be used alone or in combination to provide optimal conditions for saving plants from harsh weather and extending the duration of cultivation or off-season crop production. Drip irrigation in raised beds covered with mulch films not only eliminates weeds but also keeps moisture in the soil for a longer period by minimizing evaporation losses.

In addition, other CSA interventions include post-harvest technologies and services. The agricultural sector suffers from high levels of post-harvest losses, particularly for harvested crops, due to ineffective value-chain arrangements and scarcity of post-harvest facilities. Farmers have been encouraged to use techniques and technologies aimed at reducing energy losses and increasing energy efficiency, such as the use of renewable energy applications such as solar panels biogas, and improved *Jikos.*

2.1.5 Choice of CSA practices and innovations among farmers in Murang'a

Climate-smart agriculture (CSA) employs a variety of agricultural technologies and innovations to increase sustainable productivity, improve resource-use efficiency, minimize risk and threat to climate variability, and decrease GHG emissions to the atmosphere. However, in practice, farmers' choices to adopt CSA practices and innovations are typically influenced by the benefits associated with these practices (Neufeldt et al., 2013).

Some CSA practices and innovations such as crop rotation and mixed cropping have been widely practiced over the years by farmers in Kenya with minimal knowledge of the benefits it brings in efforts to transform the agricultural sector amidst climate change concerns. Recent years have seen the promotion of relatively newer practices such as minimum tillage, laser land leveling, and site-specific nutrient management to combat the effects of climate change and build resilience to improve agricultural production. Despite the benefits of CSA, as well as ongoing support from national and international agricultural institutions such as FAO, farmer adoption remains varied and low (Palanisami et al., 2015).

As a result, the purpose of this research is to identify factors influencing the adoption of CSA and the extent of adoption by farmers. With this context in mind, the study focuses on major CSA technologies and innovations such as the use of seeds of stress-tolerant varieties, minimum tillage, Livestock breeding, Ecosystem-based Fisheries, Site-specific nutrient management, and laser land leveling, mixed cropping, crop diversification and supplemental irrigation among other soil conservation measures.

The decision to adopt a technology has been associated with earlier technologies adopted by farmers. The influence of various factors on the adoption decision can either be underestimated or overestimated due to technology interdependence (Kassie et al., 2013). A farmer is more likely to adopt a specific CSA technology or innovation especially if the benefit outweighs the cost of non-adoption.

When there are market imperfections and institutional failures, household characteristics like age, gender, and income levels frequently influence technology adoption decisions (Amwata and Mutavi, 2018; Sahin, 2006: Amwata and Nyariki, 2023). Adopting farm technology is usually part of a larger household strategy to improve livelihood.

Markets, institutional services, and training, as well as access to markets and other institutional services, all have a significant impact on CSA adoption via transaction costs. Market access by farmers traveling several kilometers to the village markets is a bigger challenge, while access to institutional services is proxied by the distance to the nearest agricultural extension officer and is critical in increasing adoption and innovation (Zougmoré et al., 2016).

Adoption is dependent on ease of access to information and regular training. Farmers in India whose adoption of CSA was pegged on access to information achieved approximately 12% higher net returns per hectare (Aryal et al., 2018). Farmers obtain information by relying on these sources; farmer-to-farmer communication, public extension service or research centers, and information and communication technology, but they primarily rely on one of these sources. Training in these areas also influences farmers' willingness to adopt technologies such as soil-water management, minimum tillage, and crop diversification.

Economic and social capital is also another factor that influences the adoption behaviour of CSA practices and innovations. Practices such as the adoption of biogas technology require huge capital requirements which is a challenge for most farmers. In this study, economic capital is defined as land ownership, livestock ownership, and household labour endowment, whereas social capital is defined as membership in village institutions such as farm cooperatives (Bryan et al., 2013; FAO, 2015).

Better organization and allocation of various forms of capital would improve efficiency, which is critical for the adoption and diffusion of interventions in the farming system to achieve the desired impact (Mutoko, 2014).

2.1.6 Challenges and opportunities

Historically, Murang'a County, and specifically Kiharu is known for its vast growth driven by agricultural activities. Farming is mainly practiced by small-scale farmers with coffee, tea, and horticultural products being the major crops grown for export. Another common practice in almost every homestead is dairy farming. Until 1989, when global prices fell, coffee farming was the main source of income for farmers in Murang'a County (Nyoike, 2015). Due to this decline in prices in the international markets, farmers have been sensitized to diversify their agricultural production and tap the potential of the land. Farmers have switched to growing other crops including avocados which fetch good prices in the international markets. Livestock production and Fish farming have not been left out though practiced on a small scale.

Additionally, farmers have faced the challenge of low production in the wake of the changing rainfall regimes and increasingly high temperatures. Climate change remains a major issue in the region and farmers are working hard to build resilience to the impacts of climate change variability. Other challenges faced by farmers include; inadequate agricultural information, pests and diseases, poor infrastructure i.e., roads and water, increased cost of inputs, soil nutrient deterioration, and use of obsolete technologies in production among others (Mutombo and Musarandega, 2023).

The County government has launched a program in which over 8,000 farmers received drought-resistant seeds to increase food production through the use of modern farming technology (Nyoike, 2015).

Furthermore, despite all of the interventions by national and county governments to ensure the supply of subsidized agricultural inputs, adequate extension knowledge, tools, techniques, and institutions that lower their risk of investing (crop and animal insurance), there is still little evidence of climate-smart agricultural technologies and innovations being adopted. The Kenya Vision 2030 envisages a food-secure nation. The government has invested in climate-smart agriculture to boost agricultural production and expects an improvement in the sector. As a result, the focus of this research is to assess the nature and extent of adoption of CSA technologies and innovations thus informing on better approaches to enhancing the scalability in Kiharu Constituency, Murang'a County.

2.2 Theoretical framework

Several theoretical models have been proposed by researchers to explain awareness and adoption of CSA technologies and innovations. Mainstreaming of these technologies and innovations is aimed at increasing farmers' agricultural production, enhancing resilience to climate change, and reducing greenhouse gas emissions. The study used the innovation-diffusion theory to explain the nature and extent of the adoption of CSA technologies and innovations.

The innovation-diffusion theory was developed by E.M. Rogers in 1962 as one of the theories that influences the adoption of CSA practices and innovations. The theory focuses on the empirical observation of significant differences in land and labour productivity among farmers. In addition, the theory aids in the dissemination of technologies that prove more reliable to farmers in terms of productivity in the face of climate change (Sahin, 2006).

The innovation-diffusion model explains the determinants of technology adoption (Sahin, 2006), with information access being a key determinant in enabling farmers to gain knowledge of an innovation/practice, informing their choices to adopt or reject it. The adoption perception model explains how farmers' adoption behaviour is influenced by the perceived attributes of the technology. According to the economic constraints model, inputs such as land, labour, and credit availability limit production flexibility and influence technology adoption (Mujeyi and Mudhara, 2020). This theory, therefore, created an understanding of how awareness and extent of adoption of CSA technologies and innovations could be achieved and factors that could enhance technology adoption.

2. Methodology

3.1 Study area

The study was conducted in Kiharu Constituency, Murang'a County, Kenya, historically. Murang'a County lies between latitudes 0^{o} 34' South and 1^{o} 7' South and longitudes 36^{o} East and 37^{o} 27' East and has seven sub-counties namely: Kiharu, Gatanga, Kigumo, Kandara, Mathioya, Kangema, and Maragwa (KNBS, 2019) as shown in Figure 2.1. The county is spatially expansive, spanning from an alpine zone defined by a tropical forest called the Aberdare Forest to semi-arid zones bordering Machakos and Embu Counties. The altitude ranges from 914 meters ASL in the lowlands East and 3,354 meters ASL in the highlands west along the slopes of the Aberdare Ranges. Most parts of the county have dissected terrain characterized by valleys and ridges which makes the zones prone to landslides and erosions. Kiharu has witnessed landslides in areas around *Githambo, Inoi, Gitugi, Kairo, and Mioro* villages and areas around Kiambuthia Secondary School leading to the destruction of crops and livestock farming activities.

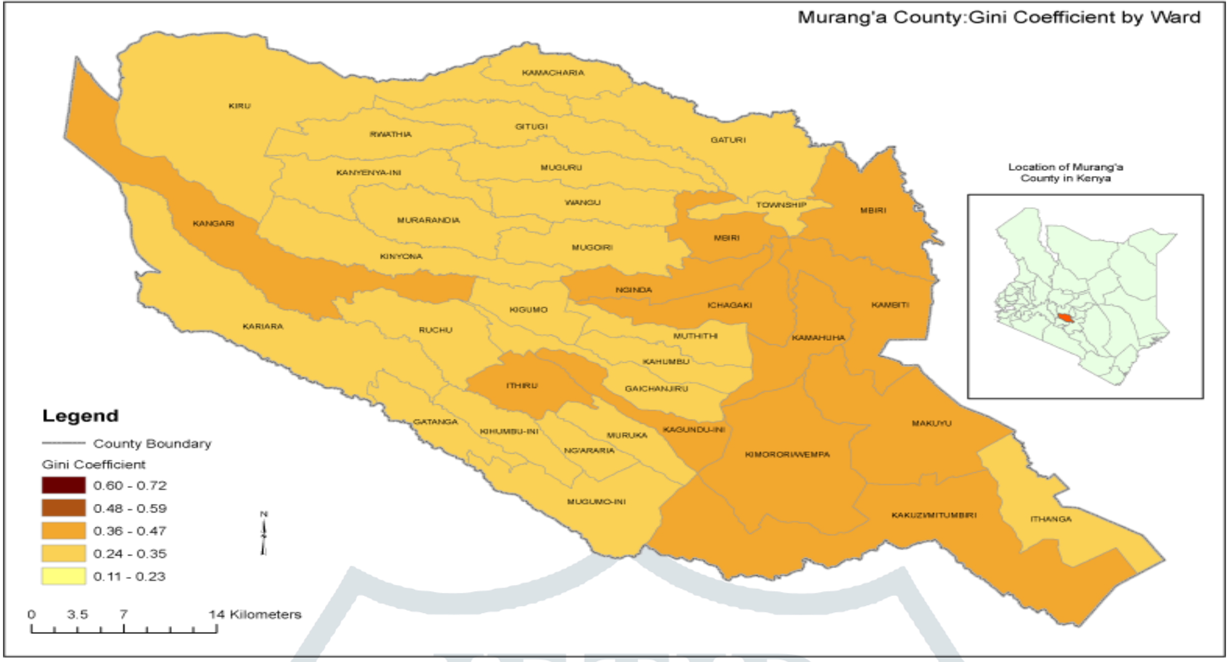

Figure 2.1: Map of Murang'a County. Source: Muranga.go.ke

The county is divided into three major climate areas. The western section, which includes Mathioya, Kangema, Gatanga, and the higher parts of Kigumo and Kandara, has an equatorial climate. Due to the influence of the Aberdares and Mt. Kenya, this region is often wet and humid. The central region has a subtropical climate, but the eastern region, which includes the lower parts of the Kigumo, Kandara, Kiharu, and Maragua constituencies, has arid weather and receives less rain. The highest prospective locations receive an average yearly rainfall of 1400mm to 1600mm. Low potential receives less than 900mm of rain each year. Rainfall in high and medium potential locations is consistent and evenly distributed throughout the year, and is sufficient for agricultural production (MCIDP 2022-2023).

The highest annual temperatures in the eastern lower parts range between 26° C and 30° C, while the minimum annual temperatures range between 14°C and 18°C (MCIDP 2022-2023). Variations in altitude, rainfall, and temperature between the highland and lowland, as well as changes in the underlying geology of both volcanic and basement system rocks, result in a wide range of soil types. Highland areas feature rich brown loamy soils that are ideal for growing tea, Coffee, maize, and dairy farming whereas the lower-lying soils are generally black cotton clay with seasonal impended drainage (GoK, 2010).

Kiharu comprises arid and semi-arid lands which have been utilized for various economic activities. Since the early 1980s, it has been well-known for the commercial production of tea and coffee for the export market. The rainy season lasts from March until May. The month of April has the most rainfall, and rainfall is extremely reliable during this month. The short rains are received during October and November as shown in Figure 2.2 (GoK, 2010).

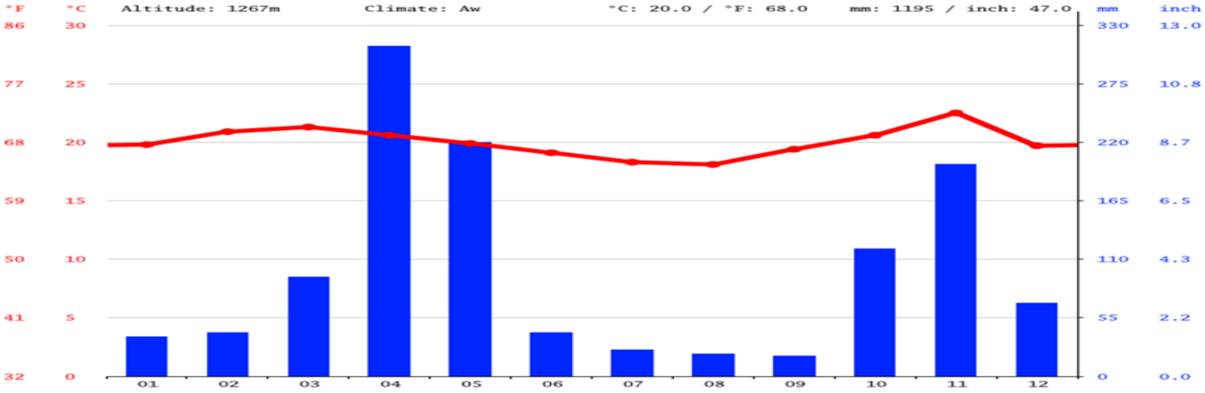

Figure 2. 2: Murang'a rainfall levels on monthly basis. Source: climate-data.org

3.2 Sampling and data collection

A random sampling method was used to sample 50 farmers from the study area. Quantitative and qualitative information was obtained using different data collection methods such as questionnaires, key informant interviews, focus group discussions, and secondary data collection. A total of fifty (50) copies of structured questionnaires were distributed to the farmers during the research. Forty-nine (49) questionnaires were properly completed and returned, while one questionnaire was not returned. According to Lund (2023), a response rate of approximately 60% for research is appropriate and helps reduce the problem of coverage error in the administration of questionnaires. Based on the findings, the study response rate was 98% which was higher than the recommended minimum of 60%, hence adequate for the study.

The study used a nominal scale (yes or no) to determine the nature and familiarity level of the CSA technologies and innovations adopted in the study area and subjected the data to descriptive and inferential analysis.

3.3 Data analysis

Descriptive statistics such as measures of central tendency, standard deviation and mean were computed. The generalized findings were then presented using tables.

3. Results and discussion

The objective of the study was to establish the nature and extent of the adoption of CSA technologies and innovations by the farmers in the study area. The farmers were identified and asked to provide information about the nature and extent of the adoption of all 15 selected CSA technologies and innovations.

4.1 Nature of CSA Technologies and Innovation

The CSA technologies were examined in order to determine their nature and familiarity level among the farmers in the study area.

4.1.1 Classification of CSA Technologies and Innovations

To begin with, the technologies were classified into five (5) categories of CSA based on FAO classification. The 15 CSA technologies and innovations were classified as shown in Table 4.1.

Table 4. 1: Classification of CSA Technologies and Innovations

Classification	CSA Technologies and innovations
Livestock management technologies	Animal insurance Drought tolerant animal breeds Forage conservation
Conservation agriculture	Crop rotation Minimum tillage Intercropping Agroforestry
Soil and water conservation	Terracing Mulching Irrigation Ridging/furrowing Planting pits (Zai) Building of gabions
Resilient crop varieties	Stress tolerant crops and varieties
Cropland management	Crop insurance

4.1.2 Farmers familiarity with selected CSA Technologies and Innovation

Furthermore, in order to determine the nature and familiarity level of the CSA technologies and innovations implemented, the study used a nominal scale (yes or no) as a question. The results are presented in Table 4.2.

Table 4. 2: Farmers familiarity with selected CSA Technologies and Innovation

Classification of CSA Technologies and Innovation	CSA Technologies and Innovation	Yes	No	Mean	Standard dev.
Livestock Management Technologies and Innovations	Animal insurance	26 (53.1)	23 (46.9)	1.47	0.50
	Drought tolerant animal breeds	28 (57.1)	21 (42.9)	1.43	0.50
	Forage conservation	32 (65.3)	17 (34.7)	1.35	0.48
Conservation Agriculture Technologies and Innovations	Crop Rotation	47 (95.9)	2 (4.1)	1.04	0.20
	Minimum Tillage	24 (49.0)	25 (51.0)	1.51	0.51
	Intercropping	49 (100.0)	0 (0.0)	1.00	0.00
	Agroforestry	27 (55.1)	22 (44.9)	1.45	0.50
Soil and water Conservation Technologies and Innovations	Terracing	40 (81.6)	9 (18.4)	1.18	0.39
	Ridging/ furrowing	31 (63.3)	18 (36.7)	1.37	0.49
	Mulching	31 (63.3)	18 (36.7)	1.37	0.49
	Irrigation	30 (61.2)	19 (38.8)	1.39	0.49
	Planting pits (Zai)	31 (63.3)	18 (36.7)	1.37	0.49
	Building of gabions	21 (42.9)	28 (57.1)	1.57	0.50
Resilient crop varieties	Stress tolerant crops and varieties	24 (49.0)	25 (51.0)	1.51	0.51
Soil and crop land management	Crop insurance	26 (53.1)	23 (46.9)	1.47	0.50

As indicated in Table 4.2, the nature and familiarity of the farmers with various CSA technologies and innovations varied. Crop rotation, intercropping, terracing, ridging/furrowing, mulching, crop insurance, irrigation, agroforestry, planting pits, animal insurance, forage conservation, and drought-tolerant animal breeds were among the technologies and innovations that received greater than 50% understanding.

In comparison to the other technologies under investigation, most farmers were aware of crop rotation, intercropping, and terracing practices. Crop rotation and intercropping are the most prevalent farming practices utilized by most farmers, based on the farmers' knowledge of them. Furthermore, given the geography of the study area, farmers were more experienced with terracing as a CSA practice, mostly used to prevent run-off downstream during torrential downpours, which could result in crop and livestock damage (Nyoike, 2015).

Minimum tillage, stress-tolerant crops and cultivars, and erecting gabions, on the other hand, received less than a 50% familiarity score as CSA technology. Surprisingly, all farmers identified intercropping as a CSA technology. The mean and standard deviation were 1.00 and 0.00 respectively.

According to Nyoike (2015), the study area is prone to landslides, which frequently result in crop destruction, including settlement in areas around Githambo and Inoi villages, Gitugi, Kairo, Mioro, and regions around Kiambuthia Secondary School. Crop destruction has consequences for pasture and other supplementary feeds for animals, and as a result of all these factors, terracing as a CSA technology is becoming more popular among farmers in the study area.

4.1.3 Sources of information

Farmers' access to information on the best agricultural activities is key to enhancing agricultural productivity. The study revealed that farmers' awareness was contributed by exposure to agricultural technologies and innovations through attending agricultural shows and exhibitions, field training, online platforms (google, YouTube, etc.), television, and reading literature such as books. The results were as shown in Figure 4.1.

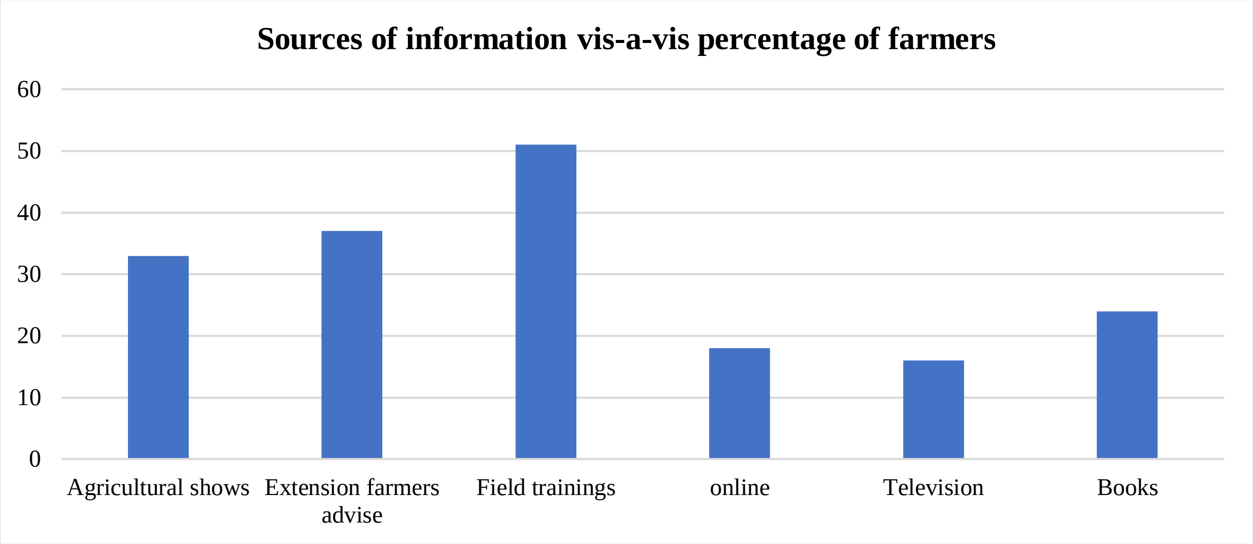

Figure 4. 1: Sources of information vis-a-vis percentage of farmers

Based on the results in Figure 4.1. the study established that awareness of CSA technologies and innovations was largely contributed through field training (51%). Training facilitates knowledge transfer through observation and practical hence most appreciated by farmers. On the contrary, awareness through television (16%) and online platforms (18%) were minimal perhaps because farmers devote much of their time to the farm and less time is left to watch television programmes and browse.

Murang'a County has a Farmers Agricultural Training Center - Mariira Farm based in Kigumo. This facility offers training and conducts agricultural shows and exhibitions annually to facilitate the dissemination of best farming practices across agriculture sub-sectors such as crops, livestock, fisheries, and apiary among others (MCIDP 2022-2027). The study revealed that field training, extension farmer advice, and agricultural shows and exhibitions were the main enablers to increased awareness and eventually adoption of the CSA technologies and innovations.

4.2 Extent of Adoption of CSA Technologies and Innovation

An analysis was carried out to establish the level of adoption of the various CSA technologies and innovations and their influence on agricultural production. The study adopted the nominal scale (yes or no) by way of question to determine the extent of adoption and usage of the CSA technologies and innovations deployed. The results are presented in Table 4.3.

Table 4. 3: Extent of Adoption of CSA Technologies and Innovation

Classification of CSA Technologies and Innovation	CSA Technologies and Innovation	Yes	No	Mean	Standard dev.
Livestock Management Technologies and Innovations	Animal insurance	0 (0.0)	49 (100.0)	2.00	0.00
	Drought tolerant animal breeds	26 (53.1)	23 (46.9)	1.47	0.50
	Forage conservation	32 (65.3)	17 (34.7)	1.35	0.48
Conservation Agriculture Technologies and Innovations	Crop Rotation	36 (73.5)	13 (26.5)	1.27	0.45
	Minimum Tillage	20 (40.8)	29 (59.2)	1.59	0.50
	Intercropping	35 (71.4)	14 (28.6)	1.29	0.46
	Agroforestry	25 (51.0)	24 (49.0)	1.49	0.51
Soil and water Conservation Technologies and Innovations	Terracing	45 (91.8)	4 (8.2)	1.08	0.28
	Ridging/ furrowing	32 (65.3)	17 (34.7)	1.35	0.48
	Mulching	22 (44.9)	27 (55.1)	1.55	0.50
	Irrigation	25 (51.0)	24 (49.0)	1.49	0.51
	Planting pits (Zai)	9 (18.4)	40 (81.6)	1.18	0.39
	Building of gabions	29 (59.2)	20 (40.8)	1.41	0.50
Resilient crop varieties	Stress tolerant crops and varieties	25 (51.0)	24 (49.0)	1.49	0.51
Soil and crop land management	Crop insurance	0 (0.0)	49 (100.0)	2.00	0.00

As shown in Table 4.3, terracing had the highest percentage of adopters, accounting for 91.8%. These findings correspond to those of Nyoike (2015), who discovered that given the geography of the study area, farmers were more experienced with terracing to manage the steep terrain and reduce run-off downstream during torrential downpours, which could result in crop and livestock loss (Nyoike, 2015).

Furthermore, crop rotation, intercropping, terracing, ridging/furrowing, stress-tolerant crops and varieties, irrigation, agroforestry, planting pits, building gabions, forage conservation, and drought-tolerant animal breeds were among the highly adopted technologies and innovations that received greater than 50% adoption.

On the other hand, minimum tillage, mulching and planting pits (Zai) received less than a 50% adoption rate among the farmers. Crop and animal insurance registered zero adoption, with a mean and standard deviation of 2 and 0 respectively. Crop and animal insurance reported zero adoption since most farmers lacked information on risk management plans for their agricultural production.

Based on the findings, on average, 63.55% of farmers were aware of the existence of CSA technologies. This awareness was attributed to the cascading of CSA technologies and innovations through the Kenya Climate Smart Agriculture Implementation Framework (KCSAP). The framework is aimed at upscaling, mainstreaming, and strengthening CSA and seed systems. It supports the generation and dissemination of improved agricultural technologies, innovations, and management practices.

Besides, 55.10% of the farmers adopted the technologies and innovations studied. Adoption rates varied as determined by the various socio-economic characteristics of household heads. Of the technologies studied, two technologies, i.e., animal and crop insurance had zero adoption while 13 technologies showed varied adoptions. The minimal adoption rates may have been contributed to the high costs involved and inadequate knowledge of the importance to the farmers.

Adoption based on classification of CSA technologies and innovations

The study further conducted an analysis of the adoption (%) based on the FAO classification of technologies and innovations to better understand the trends of adoption. The results are as presented in Figure 4.2.

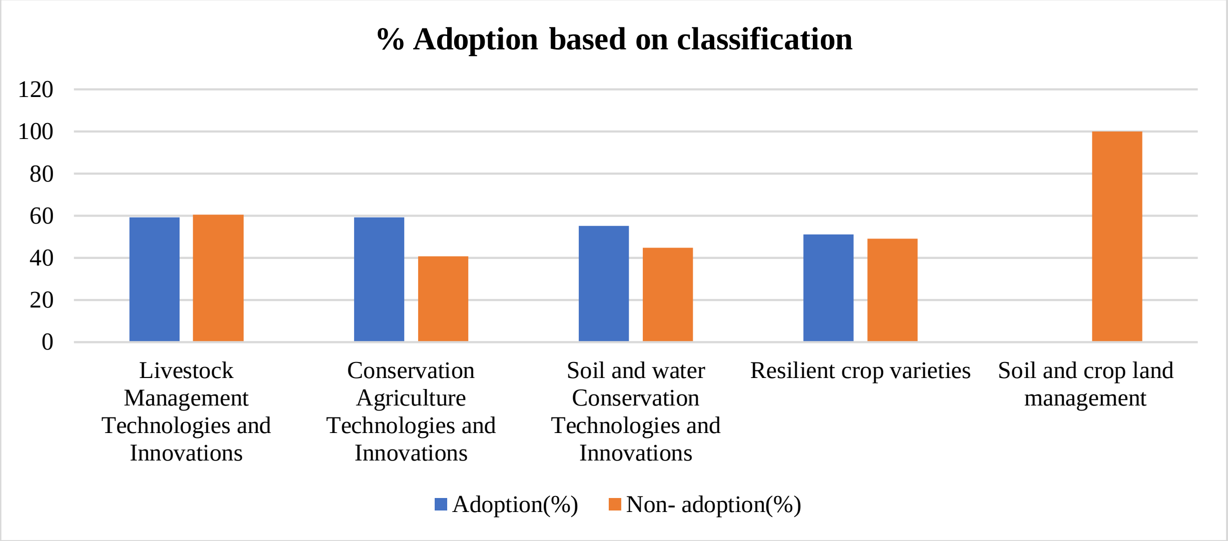

Figure 4. 2: Adoption based on classification

The analysis revealed that on average, Livestock Management (59.2%), conservation agriculture (59.2%), and soil and water conservation (55.1%) technologies and innovations were highly adopted by the farmers in the study area. However, soil and cropland management technologies were the least adopted by farmers. Farmers have not realized the importance of crop insurance as a CSA technology to help mitigate the impacts of crop failure as a result of flooding and landslides due to heavy rainfall or fluctuation of temperatures and increased pests and disease prevalence.

Factors influencing adoption of CSA technologies and innovations

According to the findings, the adoption of CSA technologies varied depending on the socio-economic characteristics of the farmers. These findings agreed with the study by Kurgat et al. (2020) on the adoption of climate-smart agriculture technologies in Tanzania. The researchers found that the adoption of CSA technologies was heavily dependent on the demographic characteristics of the farmers involved in the study sample. A multivariate probit model was used to evaluate the determinants of adoption and assess the synergies and trade-offs between five (5) CSA technologies (crop and livestock diversity, irrigation, chemical fertilizer application, and agroforestry). Household demographic characteristics such as age, gender, literacy levels, and occupation impact the study's choices regarding the adaptation of the different CSA technologies under consideration.

Source of information

Adoption is dependent on access to information and training received by farmers. Sapkota et al. (2018) found that farmers who use modern information and communication technology to get farm-related information had greater rice, wheat, and maize crop yields. Training and information access improve CSA uptake significantly. Farmers learned of the various CSA technologies and innovation methods from a variety of sources. Based on the findings, training, extension advice, and attendance to agricultural shows and exhibitions improved farmers' access to information hence enhancing adoption.

Gender of the farmers

Gender plays a crucial role in influencing the adoption of CSA technologies and innovations. The distribution of gender by respondents showed that a majority were male at 63% while the remaining 37% were female. There were more male respondents than females who took part in the study. The former is perceived to participate more in agricultural production activities than women because they have better access to resources and services such as land, finances, training, inputs, and equipment. However, in some circumstances, while men may have greater access to resources, women conduct the actual farming activities (Begho et al., 2022).

The findings are consistent with those of Maka et al. (2021), who conducted a study on the appraisal of climate-smart agriculture (CSA) practices among South African extension practitioners. According to the researcher, male participation in farming was higher, accounting for 56.2%, followed by female participation at 43.5%.

Literacy levels of the farmers

The findings of the study revealed that household heads i.e., those with at least a primary education level were more likely to understand and adopt the technologies and innovations. These farmers had non-farm income and a greater capacity to access, acquire, absorb, and adopt new technology and process new information (Aryal et al., 2018).

Age of the farmers

Farmers over the age of 55 have more exposure and experience in farming, have amassed more assets, and have established broad social networks, making them more likely to embrace technologies. However, their old age was associated with low energy, short-term investment plans, and more risk-averse resulting in lower adoption levels (Mutombo and Musarandega, 2023).

Middle-aged farmers between the ages of 36 and 45 were energetic, full of resources, and thus easily adopted CSA technologies, whereas those under the age of 35 had schooling and knowledge but fewer assets such as land and capital under their control to do farming, resulting in minimal adoption.

There exist gaps in policy and extension planning programs that can help to enlighten farmers on the adoption of animal and crop insurance and its importance as CSA. Inadequate levels of education, lack of access to information, and pressures on financial resources for some farmers reduce the rate of adoption of these technologies, especially those that require significant investment (Singh et al., 2023; Kurgat et al., 2020).

4. Conclusions and policy recommendations

Climate change continues to pose a direct and indirect threat to agricultural systems through linkages with other sectors of the economy hence a global concern. Climate-smart agriculture strategies have been suggested as a viable strategy for increasing agricultural production and incomes and enhancing food security and dietary diversity by preparing farmers to avert the negative impacts of climate change. The study concluded that boosting agricultural production in the face of climate change may be accomplished through CSA to end hunger, eradicate poverty, and enhance food security.

Generally, the four socio-economic characteristics, i.e., age, gender, level of education, and occupation greatly influenced the adoption of CSA technologies. However, CSA technologies and awareness did not translate to adoption and therefore the need to put in place initiatives to promote uptake. Concerted efforts are required from the National Government, Murang'a County Government, and development partners to strengthen awareness and adoption through capacity building and climate financing programmes. Enhancing access to inputs such as climate-resilient seeds and animal breeds, fertilizers, and other inputs through subsidy initiatives at close proximities to farmers will lessen the difficulty of unavailability during peak seasons. Strengthening capacity building through extension services to farmers and climate change financing will play a key role in creating awareness and uptake of these promising technologies and spur more innovations, thus helping production. Future research can also be conducted along with improved techniques in strengthening the scalability of CSA technologies and innovations.

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