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Effect of Climate Smart Agriculture Adoption on Household Food and Nutrition Security in Lower Nyakach Division, Kisumu County, Kenya

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Abstract

Purpose: The concept of Climate Smart Agriculture (CSA) marks a substantial shift from initiatives to address climate change and agricultural output in developing nations. Over time, farmers in Kenya's Lower Nyakach Division have been utilizing CSA technology to combat soil erosion, drought, and unpredictable rainfall. The effect of CSA technology adoption on household food and nutrition security for small-scale farmers in Lower Nyakach Division, Kisumu County, was examined in this study.

Methodology: The study employed a cross-sectional descriptive methodology and applied the capacity approach, utility maximization theory, and agricultural technology adoption theory to the target group of 300 small farmers. Structured questionnaires were used to collect data, and stratification random sampling was employed. Descriptive statistics, chi-square, and Propensity Score Matching (PSM) were among the analytical techniques employed to calculate the Average Treatment Effect on the Treated (ATT).

Findings: The results showed that both the dietary diversity of adopter households and food insecurity of households were significantly impacted negatively by the adoption of CSA technology (a drop of 0.336 points ($p<0.05$)). Additionally, the results indicated that CSA adopters had lower Food Insecurity Experience Scale (FIES) ratings and greater Household Dietary Diversity ratings (HDDS) than non-adopters.

Unique Contribution to Theory, Practice and Policy: According to the study, CSA adoption can enhance food access, promote household resilience, and produce sustainable nutrition results. In order to facilitate the deployment of CSA technologies in highly vulnerable agro-ecological zones, it suggests expanding farmer training activities, the coverage of extension services, and policy guidelines.

Keywords: *Climate Smart Agriculture, Household Food Security, Dietary Diversity, Resilience, Kisumu County*

JEL Codes: *Q18, O13, Q54, Q56*

INTRODUCTION

Most developing nations rely on agriculture as their main economic sector, and in sub-Saharan Africa, it sustains almost 60% of the population (FAO, 2021). However, one of the biggest dangers to agricultural production, nutrition, and food security today is climate change, particularly for smallholder farmers who rely on rain-based farming. Unstable precipitation regimes, persistent droughts, warming, and erosion of the soil have all destabilized household livelihood and agricultural production. For overcoming such issues, Climate Smart Agriculture (CSA) is a widely applied term which can be used for optimizing productivity, making the system more resilient, and minimizing the release of greenhouse gases (Lipper et al., 2014; Thornton and Herrero, 2015). The growing population of the globe and growing need for sustainable food systems have further compounded the problem that necessitates innovation in the adaptive agriculture that would minimize the productivity-environmental sustainability trade-off (FAO, 2020).

CSA measures have become a global concern in the world on how to address food security needs and minimize the rate of environmental degradation. International agencies and governments are encouraging the use of CSA as climate adaptation and mitigation measures across the globe. Conservation tillage, agroforestry, precision irrigation, and integrated soil fertility management are a few of the initiatives that have been implemented in Asia and Latin America for yield stability improvement and climate variability exposure (Pretty et al., 2022; Teklewold et al., 2019). In Ethiopia, for example, cumulative adoption of CSAs, i.e., application of manure and diversification of crops, resulted in enhanced household food security and drought resilience (Kassie et al., 2015). Likewise, sustainable intensification of water uses efficiency and income augmentation of smallholders, subsequent to CSA interventions, has been realized in India and Bangladesh (Khatri-Chhetri et al., 2021). Though there are such global success, disparities in the rate of its adoption, the resilience of the practices, and availability of enabling resources especially in the smallholder-dominated economies exist.

Globally, CSA technology use has been rising, especially in nations like Kenya, Uganda, Tanzania, and Ethiopia that are vulnerable to climate change. The African Union's Comprehensive Africa Agriculture Development Programme (CAADP) has focused on African CSA in order to improve rural agricultural development and food security. Adoption of CSA is hampered by limited access to credit, extension services, and information, but empirical research shows that it improves production and household wellbeing (Mwongera et al., 2017; Ndiritu et al., 2014). Harvests and food availability during the dry season were reported to have improved for Ugandan farmers who implemented soil and water conservation practices (Asfaw et al., 2018). Parallel to this, farmers in Tanzania practicing crop-livestock integration had resilience and food diversity. Nevertheless, even with the potential gains, its adoption remains uneven since it is largely constrained by poverty, gender disparities, and institutional constraints.

Agriculture is a significant source of revenue for Kenya with 70 percent of the rural population depending on it as the main source of their revenue, which contributes approximately 33 percent of the GDP (KNBS, 2023). Frequent crop failure, animal losses, and decreased soil fertility are all consequences of climate change that have a major impact on food and nutrition security. By implementing initiatives like the Kenya Climate Smart Agriculture Strategy (2017-2026) and the Kenya Climate Smart Agriculture Project (KCSAP), which has been implemented in countries with World Bank funding, the government of Kenya has made CSA a top priority in response to these difficulties. These initiatives should support the adoption of conservation agriculture, the development of irrigation infrastructure, the promotion of drought-resistant crops, and the improvement of extension services. Although such interventions have been done, limited empirical evidence exists on direct effect of adoption of CSA to local level food and nutrition security, especially among high climate exposed rural communities.

The recent research in East Africa has shown that CSA can contribute to food and nutrition security in various ways, specifically improving crop diversity, yield stabilization, and household income, which will allow accessing nutritious food. As an example, Kurgat et al. (2022) concluded that households implementing crop diversification and using organic soil management in Western Kenya had much higher dietary diversity scores than non-adopters. Likewise, Nalubega et al. (2023) found that the adoption of CSA in Uganda was linked to a 19 percent change in the household caloric consumption and enhanced micronutrient intake. These results indicate that CSA does not just help to cushion agricultural production against climatic shock but it also enhances food security of the families engaged in farming. However, these benefits are frequently mediated by gender roles, the availability of extension services, and patterns of income utilization, which Muriithi and Mutea (2024) found in their study to enhance the effectiveness of empowering women to make CSA decisions to increase the nutritional situation of households than the gains of yield.

Lower Nyakach Division of the Kisumu County is a beacon of the intersection of climate stress and family food insecurity. There are erratic and low rainfall, frequent droughts, and diminished soil fertility, which pose a threat to the livelihood of smallholder farmers who rely on rain-fed farming. The Kenya Meteorological Department (2023) reports that droughts in the Lake Basin have almost doubled in the last 20 years resulting in a steady decrease in yield and food accessibility by households. Government and non-governmental actors have, in turn, implemented multiple Climate Smart Agriculture (CSA) interventions like agroforestry, rainwater harvesting, composting and intercropping as adaptation interventions to increase resilience. These interventions, however, do not eradicate the food insecurity, leading to serious concerns of how far the CSA practices have been turned into quantifiable advances in the dietary consumption and house welfare.

It is unclear how effective and sustainable CSA practices are in Lower Nyakach despite the increasing body of empirical findings in the region. Chronic food shortages, low dietary diversity, and insufficient caloric intake still remain a problem with many smallholder farmers, which represents the potential barriers to implementation and adoption. The fact that these problems still exist highlights the importance of empirical examination of the role that CSA adoption plays in determining the food and nutrition security indicators (such as dietary diversity, household food access, and nutritional adequacy) among households. Thus, the research aims to offer evidence-based information concerning the association between the CSA practices and the socio-nutritional outcomes in the Lower Nyakach Division of Kisumu County. The results will be used to design the local adaptation strategies and guide policy makers to scale sustainable agricultural interventions to holistically increase food and nutrition security in the changing climatic conditions.

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Statement of the Problem

CSA has been broadly shared in Kenya as an innovation to boost agricultural productivity, resilience, and food security among small-scale farmers. The Kisumu County, Lower Nyakach Division, contains numerous households for which the primary source of livelihood is rain-fed agriculture. Nevertheless, unpredictable rainfall, long dry seasons, and growing soil unproductivity has persistently posed a challenge to agricultural output thus aggravating household food and nutrition insecurity. Although most CSA practices like drought-tolerant crops, agro forestry, crop diversification and soil conservation practices have been introduced, most rural families continue to report frequent food shortages and poor dietary diversity (FAO, 2020; Weke et al., 2023; Okeyo et al., 2022). It suggests that although the CSA technologies are being taken up, their actual effect on enhancing the household food and nutrition security is yet to be understood and can be constrained by the situational factors.

While CSA practices aim to improve productivity and resilience, Lower Nyakach smallholder farmers experience some challenges traceable to the failure to achieve the anticipated benefits. The farmers who rely on their own resources are excluded from accessing proper extension services, credit, and climate information to enable them to achieve optimum utilization of CSA practices (Ng'ang'a et al., 2022). Furthermore, poverty, illiteracy, and gender disparities have limited the adoption level and the efficiency of these interventions. Thus, even with the incorporation of some of the CSA technologies, there remains a vast majority of the households that are constrained in their ability to afford their staple foods and nutrition needs and this implies that adoption would not necessarily result in enhanced welfare performance. Other works by Teklewold et al. (2019) and Ndiritu et al. (2014) demonstrate that elsewhere there are CSA adoption- food security positive relationships, but from Lower Nyakach, localized evidence is in short supply, constituting an important empirical omission.

Climate Smart Agriculture (CSA) has been advocated in Kenya as an important policy towards household adaptability to climate unpredictability and sustainable food and nutrition security. Both the government and other organizations involved have extensively initiated interventions like agro forestry, composting and water harvesting in Lower Nyakach Division of Kisumu County. Nonetheless, even though these efforts have been undertaken, there is still a high rate of food insecurity and unhealthy dietary diversity among smallholder families. Although descriptive data has been gathered on the patterns of CSA adoption, a dearth of empirical studies has quantitatively determined its causal effect on food and nutrition outcome. Previously conducted research in Kenya has been more concerned with the factors that influence the adoption of CSA (e.g, availability of credit, extension services, and gender), as opposed to its welfare consequences. Limiting policy design and program evaluation, therefore, the absence of quantifiable evidence on the impact of CSA on household food access, dietary diversity and resilience has restricted the policy design and program development.

In order to fill this void, the current study will use Propensity Score Matching (PSM) to determine the causal impact of CSA adoption on the household food security and nutrition outcomes in terms of Household Dietary Diversity Score (HDDS) and Food Insecurity Experience Scale (FIES). Such an analytical orientation allows isolating the actual welfare impact of CSA adoption at a minimum cost of selection bias. The research, thus, gives empirical data, as to whether and how adoption of CSA enhances household nutrition and resiliency with smallholder farmers in Lower Nyakach. The results will provide hands-on

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information to policy fools and developmental players who want to develop better designs, focusing, and sustainability of CSA programs in the climate stressed areas in Kenya.

Justification of the Study

Use of Climate Smart Agriculture (CSA) technologies in the Lower Nyakach Division of Kisumu County has been suggested to be one of the remedies in curbing low farm output, food deficiency, and climate change vulnerability. Though these practices hold advantages of enhanced yields and resilience, most of the smallholder farmers are still plagued by chronic food shortages and nutrition effects. This has highlighted the importance of looking at how CSA roll-out is progressing as planned in an attempt to reach the household level. Its effect should be clearly understood in an attempt to devise specific interventions that will not only facilitate its adoption, but also provide quantifiable results in food and nutrition security. The research will generate useful findings that are relevant in the design of sustainable interventions that can improve resilience, nutrition as well as lead to the long-term survival of agriculture in the climate vulnerable areas of Kenya by assessing the influence of CSA technologies on household well-being.

Scope of the Study

The study was conducted in Lower Nyakach Division of Kisumu County which is in the western part of Kenya in the Lake Victoria Basin. The area has semi-arid climate, unpredictable precipitation, and reduced soil fertility and, therefore, it is very susceptible to climatic uncertainty. The 2019 Kenya Population and Housing Census shows that the region houses about 120,000 individuals, with majority of the population depending on small scale agricultural activities as their primary source of livelihood. The research was of cross-sectional nature and the data were collected in the period between June and September 2024 through the use of structured questionnaires among the smallholder farmers who owned less than five acres of land. Both adopters and non-adopters of Climate Smart Agriculture (CSA) technologies were used in the sample in order to enable comparison of food and nutrition results. The variables were CSA adoption as an independent variable and household food and nutrition security as a dependent variable measured by the Food Insecurity Experience Scale (FIES) and the Household Dietary Diversity Score (HDDS). Descriptive statistics and Propensity Score Matching (PSM) were used in the analysis of data to assess the causal effect of CSA adoption. The research was therefore limited to determining the effect of integrating the practice of CSA on nutritional status, dietary diversity, and access to food among farming households in Lower Nyakach Division.

LITERATURE REVIEW

This section provides a summary of the research on Climate Smart Agriculture (CSA) and how it helps smallholder farmers in the Lower Nyakach Division of Kisumu County, Kenya, ensure the food and nutrition security of their households. Review is grouped into three broad categories which are theoretical framework under which the study is based, global, regional, and local empiricism, and conceptual framework which bridges the key variables being studied.

Theoretical Framework

Agricultural Technology Adoption Theory

Feder, Just, and Zilberman (1985) established the Agricultural Technology Adoption Theory to assist explain how farmers decide whether or not to adopt new agricultural technologies. According to the idea, internal factors such as perceived risk, educational attainment, and resource endowment impact adoption decisions, while external determinants include market knowledge, extension services, and loan availability. Farmers' adoption of new technology is contingent upon their expectations for net returns and the innovations' perceived ability to reduce uncertainty. Because farmers weigh the costs and likely results when deciding whether or not to implement innovations in their production systems, the theory assumes that the adoption process is rational (Feder et al., 1985; Doss, 2006). The theory has a lot to do with smallholder farmers in Kisumu County's Lower Nyakach Division implementing Climate Smart Agriculture (CSA). Food production is hampered by the region's unpredictable rainfall, frequent droughts, and soil erosion.

The theory establishes a theoretical framework of how smallholder farmers consider the agronomic and economic advantages of CSA technologies like conservation tillage, agro forestry and drought resistant varieties. The farmers will buy such technologies only if they are convinced that they will work to boost yields, enhance resiliency, and minimize risk impact caused by climatic uncertainty. There exists, however, variation in the adoption by different households along socioeconomic status, access to resources and institutional support lines to show that adoption was not uniform but context-specific. The Agricultural Technology Adoption Theory also recognizes that a weak institutional structure, a lack of funding, and insufficient information can all impede the spread of technology.

Agricultural Technology Adoption Theory (ATAT), entails how farmers make decisions to embrace new agricultural practices and agricultural innovations like Climate Smart Agriculture (CSA). Feder, Just and Zilberman (1985) suggest the adoption of technology when these people believe that the perceived utility or benefits of the adoption will surpass the perceived risks and costs. The theory presents a way of observing the behaviors of the smallholder farmers in Lower Nyakach as they consider their CSA choice such as agroforestry, composting or rainwater harvesting as a way to overcome climate and economic uncertainties. It assumes that the adoption behavior is influenced by access to information, resource endowment, and institutional support.

These restrictions are most common in the Lower Nyakach where different farmers have mostly depended on informal systems of information and the poor extension support. The processes of CSA adoption, thus, demonstrate from the theoretical perspective how policy support, awareness generation and credit access are the primary drivers of enhancing the rate of adoption and, thereby, increase food and nutrition security in smallholder households.

Utility Maximization Theory

The Utility Maximization Theory developed by Paul Samuelson (1947) is based on the principles of microeconomic theory in which individuals are regarded as making rational decisions that ensure that their satisfaction (utility) is maximized under the available constraint concerning their resources and budgets. The theory in an agricultural setting suggests that (farmers) use their available land, labor and capital in those activities that give them highest anticipated satisfaction, which can be in terms of profit, food security or less production risk. In this framework, the choices of farmers are influenced by the trade-offs that are made between inputs and anticipated outputs, as well as the attitude towards risk and uncertainty (Sadoulet and de Janvry, 1995).

The theory applied to Climate Smart Agriculture is that farmers in Lower Nyakach would be willing to practice CSA when they believe that such practice will maximize their total welfare. An example would be planting drought-resistant crops, intercropping, or investing in water harvesting mechanisms, which can stabilize yields and minimize losses and thus make the use of such processes more useful, ensuring the household food supplies and incomes. The adoption is therefore a logical reaction to environmental and economic problems. The level of adoption however, differs depending on the risk preference of farmers, information availability and perceived benefit expectations of farmers which may differ between various socio-economic groups.

The Utility Theory complements this viewpoint, giving it the behavioral rationale behind the adoption decisions, that is, farmers make choices to maximize apparent utility, trade-offs between the short-term productivity and long-term resilience consequences. This economic explanation is in line with the hypothesis that the adopters of CSA practices obtain better access to household food and dietary diversification since they see the practices as risk management and income stabilization instruments.

Maximization Theory of Utilities would be useful in driving the theoretical perspective of how CSA adoption will lead to improved nutrition and food security results. Several CSA procedures are also likely to result in higher yields and increased dietary diversity in the household, which results in increased satisfaction, not only economically but also in terms of well-being. Here, farmers become utility maximizing agents where their level of resilience and sufficient food levels are enhanced through the making of decisions that are more optimal when conditions are uncertain in climate. Therefore, this theory offers analytical basis of comprehending the direct relationship between household decision-making concerning the adoption of CSA, and the welfare outcomes in Lower Nyakach Division.

Capability Approach

One strategy for growth and wellbeing is the Capability Approach, which originated with Amartya Sen (1985) and was developed by Martha Nussbaum (2000). According to this theory, real development is not limited to income and material wealth but is concerned with real freedoms of individuals which is their capacity to live the type of lives they consider important. Capabilities are defined as the possibilities that individuals can have in order to lead healthy, educated, and flourishing lives, whereas functioning is defined as the realization that results out of the possibilities. Capabilities enhancement is thus a process of improving the circumstances through which people are able to make significant decisions and live dignified lives.

The Capability Approach is utilized in the context of Climate Smart Agriculture to demonstrate how the CSA adoption increases the liberties and options that smallholder farmers have. CSA can help to increase the potential of households to reach a food security and nutritional adequacy through enhanced productivity, stabilized yields, and diversified farming systems. The strategy also brings to the fore the fact that in addition to the economic gains, the adoption of CSA empowers the farmers with knowledge, resilience, and ability to control the risks posed by the environment. This implies that in Lower Nyakach Division, the farmers involved in CSA not only boost their earnings, but also their ability to gain access to quality food and survive a disaster such as climate change.

Capability Approach emphasizes food and nutrition security as a multi-dimensional concept, and connects farm innovation with human development outcomes in general. It highlights how the actual value of CSA is not only in the gains in yield, but rather it is in the expansion of households and their own capabilities, including the potential to access adequate, nutritious food, stay healthy and have sustainable livelihoods. In this regard, CSA implementation improves human livelihood by boosting adaptive ability and resiliency to climate-related shocks. When these views are synthesized, ATAT can be used to understand why farmers ought to choose CSA, Utility Theory can be used to understand how farmers make such rational choices under constraint and the Capability Approach can be used to understand what consequences such choices yield in the form of empowerment and well-being. But both frameworks are limited: ATAT tends to be based on perfect rationality and neglects socio-cultural factors, whereas the Capability Approach does not make it easy to empirically measure the effects of empowerment and well-being. Through the combination of these theories, this research offers a comprehensive picture of CSA adoption - the connection between the behavioral motivation and welfare influence - to evaluate the role of agricultural innovation in enhancing food and nutrition security in smallholder farmers of Lower Nyakach Division.

Empirical Review

Extent of Climate Smart Agriculture (CSA) Adoption

As nations look for sustainable solutions to address the issue of climate change in agriculture, the concept of Climate Smart Agriculture (CSA) has become more and more popular worldwide. Nearly 500 million smallholder farmers worldwide practice rain-fed agriculture, making them particularly vulnerable to climate unpredictability, according to the Food and Agriculture Organization (FAO, 2021). The adoption of CSA has been essential in increasing yields and land sustainability across Asia, Latin America, and Africa, according to studies by Lipper et al. (2014) and Thornton and Herrero (2015). In other parts, i.e., Asia, Khatri-Chhetri et al. (2021) reported a 25% yield increase in Indian and Bangladeshi farmers with such climate-resilient practices as alternate wetting and drying, integrated pest management, and crop diversification. In the same way, Arslan et al. (2022) stated that in Latin America, CSA adoption improved flood and drought resilience by improving soil structure and water holding capacity. Even with such a successful outcome, the research around the world has established that adoption rates are skewed by socioeconomic factors, institutional barriers, and lack of availability of technologies, and the necessity to Investigate empirical facts at the local level to ascertain CSA's future.

CSA innovations have come in as productivity and food security strategies for African households with regard to consideration of the adverse climatic factors. In Ethiopia, Kassie et al. (2015) observed increased crop yield by 17% and food access to the population with the implementation of various CSA methods like conservation tilling, and use of organic manure. Similarly, Asfaw et al. (2018) indicated that Ugandan farmers who implemented a set of water and soil conservation measures had 25% greater chances of food security than non-adopters. Kurgat et al. (2020) observed that income and dietary diversity in Tanzania were enhanced by sustainable production systems through promoting CSA practices. But, as opposed to the encouraging results, cited limitations are weak extension services, sex discrimination, and credit constraints (Mwongera et al., 2017; Ndiritu et al., 2014). This suggests that, despite CSA's significant contribution to addressing the problem of security in terms of nutrition and food, its level of contribution is very much dependent on contextual and vulnerable institutional and socio-economic environments.

Kenya's national agricultural transformation agendas are based on CSA implementation. Kenya Climate Smart Agriculture Strategy (20172026) and Kenya Climate Smart Agriculture Project (KCSAP) have placed further focus on expanding drought-tolerant varieties, rainwater harvesting, and conservation agriculture as a way of building smallholder resilience. Empirical evidence by Ndegwa et al. (2021) reveals that Embu and Machakos counties' households that embraced various CSA technologies were able to record a better food availability and dietary diversity. Wekesa et al. (2023) found that agroforestry and intercropping practice in Kenya's western part led to high availability of food in the household and had a significant impact on minimizing seasonal food shortages. The same finding emerged in Okeyo et al. (2022), where the adoption of CSA was favorable with the Household Dietary Diversity Score (HDDS), indicating improved nutrition outcomes. Nevertheless, poverty, ineffective extension systems, and low credit availability are some of the most pertinent challenges in its adoption on a large scale. These findings emphasize how crucial it is to evaluate the true impact of CSA on nutrition and food safety, particularly in areas like the Lower Nyakach Division where food insecurity and climatic stress are still prevalent.

The empirical study of the national agricultural transformation programs of Kenya supports the increasing focus on Climate Smart Agriculture (CSA) as a mechanism of smallholder resilience and food security. Drought-tolerant varieties of crop varieties, conservation agriculture, and rainwater harvesting are some of the interventions highlighted in both Kenya Climate Smart Agriculture Strategy (2017 2026) and Kenya Climate Smart Agriculture Project (KCSAP) as an effort to reduce the effects of climate variability. In Embu and Machakos Counties, studies conducted by Ndegwa et al. (2021) showed that, households that had adopted several CSA practices had better food availability and better dietary diversity than households that did not adopt the practice. On the same note, Wekesa et al. (2023) established that agroforestry and intercropping had a significant impact in curbing seasonal food shortages in western Kenya, and Okeyo et al. (2022) observed that there was a positive relationship between CSA adoption and the Household Dietary Diversity Score (HDDS), thereby confirming the existence of improved nutritional outcomes. All these studies reveal that CSA can alleviate the food quantity and its quality due to diversified production and increase in earnings. Nevertheless, access to credit is limited, extension services are not sufficient and implementation costs are high and still limiting large scale adoption and sustainability of CSA technologies.

Although such developments have been made, there are still significant research gaps in understanding the cause and effect relationship of CSA adoption and quantifiable welfare outcomes. The majority of the current studies are descriptive, and they aim at identification of the determinants of adoption instead of determining how much it affects food access, dietary diversity, or indicators of resilience. Very few have used strict methods of causal inference like Propensity Score Matching (PSM) or instrumental variables models to single out the impact of CSA on household well-being. Additionally, empirical evidence in climate-stressed regions like Lower Nyakach Division is rather limited with food insecurity being acute though highly exposed to CSA programs. This gap brings to the fore the necessity of localized and evidence-based measures, which measure the effects of special CSA practices on household food and nutrition security in different agroecological and socioeconomic conditions. The use of CSA results in national nutrition policies to build inclusive and resilient agricultural development should also be a subject of future research as well as gendered patterns of adoption, long-term sustainability, and patterns of adoption.

Conceptual Framework

Conceptual framework of the study is a definition of the relationship between adoption of CSA technologies (independent variable) and household food and nutrition security (dependent variable) among smallholder farmers in Lower Nyakach Division in Kisumu County. Implementation of the CSA practices like conservation agriculture, agro forestry, crop diversification, and water-harvesting approach will most likely enhance productivity, resilience, and environmental sustainability, and thus household food availability and diet quality.

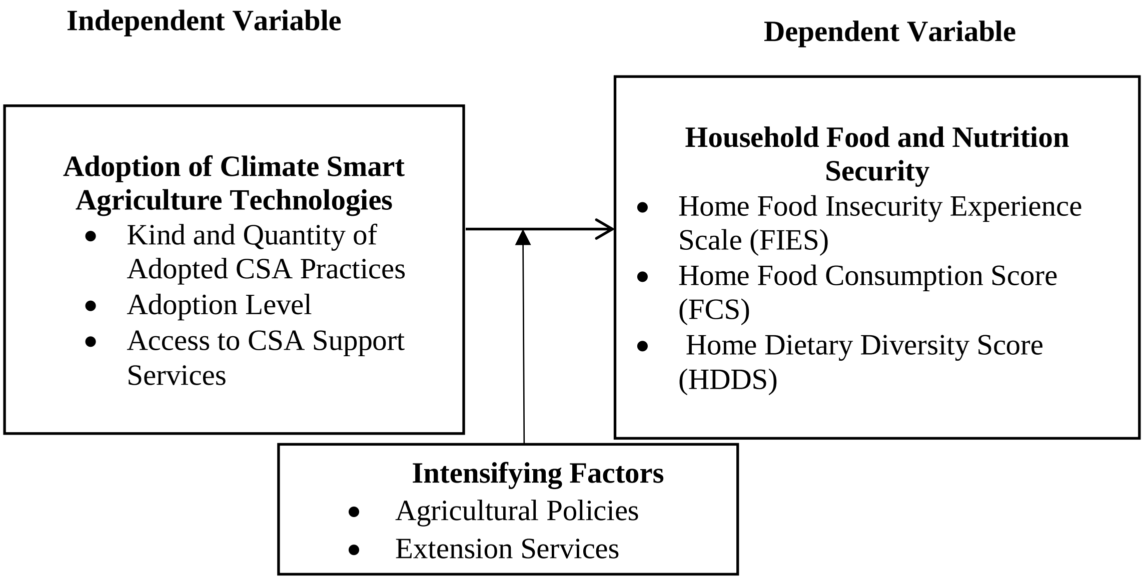

Figure 1: Conceptual Framework

METHODOLOGY

In order to determine how the adoption of Climate Smart Agriculture (CSA) affected the food and nutrition security of smallholder households in Lower Nyakach Division, Kisumu County, an analytical as well as descriptive research approach was used. The target group of focus, the sampling framework, number of participants, data collection tools, data collection processes, pilot testing, and data analysis methods used to arrive at the study conclusions are all presented in this chapter. The method was created to yield both quantitative and qualitative information that would aid in creating a comprehensive understanding of how CSA adoption affects food availability, dietary diversity, and nutritional status.

Research Design

According to Kothari (2020), a research design is the entire framework used to conduct the study as well as the way that data are collected, measured, and analyzed. In addition to the analytical technique of econometric modeling, the research methodology that was employed was a descriptive cross-sectional design. This strategy was suitable since it allowed the researcher to concurrently collect data on an accurate representation of smallholder farmers in order to determine whether there are any connections between the adoption of CSA and the results related to food security. While the analytical component supported the measurement of the causal effect by estimating it using inferential statistics, the descriptive component

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accurately depicted the respondents' demographic and socioeconomic characteristics (Abutabenjeh and Jaradat, 2018).

Target Population

Population refers to the aggregation of the items or the people with similar characteristics which the researcher will draw inferences (Orodho and Kombo, 2022). The target population as argued by Mugenda and Mugenda (2003) means all the things or objects with specific characteristics that are of interest to the study. Kombo and Tromp (2019) also bring to the fore that population is an entire group of units which a researcher would want to know or where the sample is taken.

The population for study included smallholder farmers of Lower Nyakach Division, Kisumu County who either embraced or did not embrace Climate Smart Agriculture (CSA) technologies. The population for study included households that are involved in small-scaled crop farming, livestock husbandry, or mixed-farming because they are affected by climate variability and can be the beneficiary of CSA interventions. This division was particularly chosen because it is one of the divisions that are highly susceptible to unpredictable rainfalls, drought, and low soil fertility that have direct effects on food production and nutrition outcomes. The CSA farmers' adopters and non-adopters were divided thus for comparative evaluation of the extent of food and nutrition security among them. Records at Lower Nyakach Agricultural Office (2024) show that the smallholder farm households that were registered in the study area totaled about 1,200 households scattered in West Nyakach, South Nyakach, and Central Nyakach sub-locations.

Sampling Technique and Sample Size

Selecting a representative subset of the population to be surveyed is known as sampling (Kumar, 2018). To ensure that both CSA practice adopters and non-adopters were represented in the study, a stratified random sample technique was used. This approach was suitable due to the diversified nature of the farming population and the equal representation of the two most important categories, the CSA adopters and non-adopters (Taherdoost, 2020). The extension services' records were used to ascertain the CSA adoption status, which served as the basis for stratification. A simple random selection was then used to select individual respondents from each of these strata. This was in order to minimize selection bias as well as to ensure both categories were adequately represented in the final sample.

Yamane (1967) finite population formula was used to calculate the sample size:

As follows $n=\frac{N}{1+N(e)2}$

Where n= Sample size

N = Total population size (1,200)

e = Margin of error (assumed at 5% or 0.05)

n = 3,110 / (1 + 1,200(0.05) ^2)

n ≈ 300

The study, thus, contained 300 respondents, including those that adopted CSA and those that did not. In the three sub-locations, the sample was allocated proportionately in terms of the concentration of farming households as shown below:

Table 1: Sample Size

Category	Population	Sample Size
CSA Adopters	600	150
Non-Adopters	600	150
Total	**1,200**	**300**

Such sampling method also secured those respondents sampled represented the whole farming population in Lower Nyakach Division, as they would offer the quality data to evaluate how much implementation of Climate Smart Agriculture affects household food and nutrition security.

Data Collection Tools

The instruments used to gather useful information on the respondents are known as data gathering tools (Kombo & Tromp, 2022). In this study, structured questionnaires containing both closed-ended and open-ended items were employed. Since the questionnaire provided an opportunity to collect standard data from a sufficient number of smallholder farmers in a condensed amount of time, it was the most practical approach (Kabir, 2022). Respondents were able to express their opinions, experiences, and perceptions regarding Climate Smart Agriculture (CSA) practices and their contribution to food and nutrition security through open-ended questions, while closed-ended questions enabled the quantitative data collection required for statistical analysis (Mahon & Joyce, 2023).

It was also segmented into sub-major segments that were determined based on the study objectives, which encompassed elements of the household, CSA technologies followed, food and nutrition metrics, such as the Food Consumption Score (FCS) and the Household Meal Diversity Score (HDDS), and finally to reach the extension services and agriculture policies. Key informant interviews were also used to validate and supplement the quantitative data; they were carried out in addition to questionnaires with the agricultural extension officers and with local leaders. Pilot study was carried out to pilot the instruments as far as clarity, reliability and content validity are involved before actual administration to the target respondents.

Data Processing and Analysis

Sorting, coding, and interpreting raw data to produce significant outcomes and conclusions is another name for data analysis (Anderson and Thompson, 2023). After first being checked for accuracy, consistency, and completeness, the data from the surveys was coded, imported into version 29 of the Statistical Package for Social Sciences (SPSS), and examined using SPSS. The program that guarantees material processing and precise computation was used to do both descriptive and inferential statistical analyses (Martinez and Chen, 2024).

Descriptive statistics such as frequencies, means, and percentages were used to explain the respondents' sociodemographic and socioeconomic profiles. The same was true for CSA adoption levels. The relationships between the adoption of Climate Smart Agriculture (an independent variable) and measures of household food and nutrition security (dependent variables), such as HDDS, FCS, and income status, were investigated using inferential statistics. Specifically, multiple regression analysis was utilized to determine the relationship's strength and direction.

$Y = \beta_0 + \beta_1 X_1 + e$

Where:

Y= Household Food and Nutrition Security

β_0= Intercept coefficient

β_1 = Regression coefficient of CSA adoption

X_1 = Climate Smart Agriculture practices

e = error term

Additionally, the model's statistical fitness was assessed using Analysis of Variance (ANOVA), which also looked into how adopters and non-adopters differed in their mean food security outcomes (Thompson and Garcia, 2023). In order to supplement the quantitative data and better understand the background contextual reasons underlying CSA adoption and food security outcomes in lower Nyakach Division, the qualitative data from key informant interviews and open-ended questions were analyzed and thematically interpreted.

RESULTS

Demographic Characteristics

The household characteristics results provide background information on the demographics and socioeconomic status of smallholder farmers in Kisumu County's Lower Nyakach Division, which is essential for understanding the dynamics of the adoption of Climate Smart Agriculture (CSA). Respondents were selected in the various sub-locations proportionate so as to achieve sufficient geographical sample; therefore, the results of the study are more reliable and genuine. Most of the respondents were males (68.9 percent) compared to females, who made up 31.1 percent. This shows that farming activities in the study region are still masculine, especially where technology application and handling of resources are concerned. Yet the women were actively engaged in domestic food security through the use of farm activities, food preparation, and making nutrition decisions, which has highlighted their key role in food insecurity.

By age group, the majority of respondents (52.7) belong to the 26-45 years age group that is most economically active. This indicates, that farmers in their productive age are the main adopters of CSA technologies as they would be capable of meeting risks and are likely to try out new farm technologies. 14.8 respondents were above 55 years old, which implies the low rates of adoption by elderly farmers, possibly explained by the lack of workforce and risk aversion. The respondents' educational attainment revealed that 40.5% had completed secondary school, 29.2% had completed primary school, and 18.7% had completed higher school and 11.6% lacked education. Customers' literacy levels are relatively high, which is beneficial to the transmission of technologies, since education increases the intensity of knowledge and practices of CSA. Compared to household size, 47.3% of the population of 5 to 7 people in the household translates to a relatively large household structure that determines the labor supply and household food demand needs.

Most of the respondents (71.5) were involved in subsistence farming with 15.8% doing small-scale business and 12.7% being casual laborers. This agricultural predominance reiterates the fact that the community relies on farming as the primary source of livelihood, and in view of that, the significance of adopting CSA to encourage resiliency and food security. The respondents to the study (61.2 percent) indicated medium institutional support since 61.2 percent of them had access to agricultural extension services. Still, just 48.6% of them had been

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trained on the CSA practices, and this indicates there were shortcomings in capacity building and awareness. The average size of farms is 1.8 acres and this is an indication of land fragmentation-a major limitation of a smallholder in Nyakach.

The demographic findings indicate that the area of the study is typified by young, moderately educated and mostly male-led households where agriculture is the major livelihood activity. The following profile highlights how CSA technologies can be scaled up provided with sufficient policy frameworks, extension services as well as market incentives.

Table 2: Demographic Characteristics of Respondents

Variable	Category	Frequency	Percentage (%)
Gender	Male	175	68.9
	Female	79	31.1
Age (Years)	18–25	38	14.9
	26–35	82	32.3
	36–45	52	20.4
	46–55	45	17.6
	56 and above	38	14.8
Education Level	No Formal Education	29	11.6
	Primary	74	29.2
	Secondary	103	40.5
	Tertiary	48	18.7
Household Size	1–4 members	63	24.7
	5–7 members	120	47.3
	8 and above	71	28.0
Primary Occupation	Farming	182	71.5
	Business	40	15.8
	Casual Labor	32	12.7
Access to Extension Services	Yes	155	61.2
	No	99	38.8

Descriptive Analysis on Key Variables

Effect of Climate Smart Agriculture (CSA) Adoption on Household Food and Nutrition Security

The findings in Table 3 demonstrate that smallholder farmers' embrace of Climate Smart Agriculture (CSA) innovations in Lower Nyakach Division have greatly influenced the result of food and nutrition outcomes in households. Most of the participants (64.7) indicated that CSA practices which produced a greater crop yield were drought-resistant crop varieties, mulching, intercropping, and conservation tillage and mean rating of these practices was 3.92 (SD = 1.03) and it is significant. Similarly, 68.3% responded that the introduction of such technologies had increased their access to food at the household level with a mean of 3.87 indicating that CSA interventions are enhancing food access and stability in the research site.

Besides, 61.9 percent of the farmers indicated that applying CSA has made the family diet more diversified as the homes were now in a position to obtain more food products on a year-round basis. This was further supported by the Household Dietary Diversity Score (HDDS), which showed that most families had mean scores of 3.75 (SD = 1.22) over the recommended minimum level of four food groups. This outcome is consistent with research published in the literature by Mutie et al. (2022) and Kassie et al. (2023), which found that consumers embrace CSA has beneficial effects on food production yields as well as nutritional quality in smallholder farming systems in Kenya.

Nonetheless, there were some indicators which showed a less promising picture. A mean of 2.76 (SD = 1.08) showed that approximately 33.5 percent of the respondents believed that they were limited in having availability of extension services and input costs, hence restricting their adoption of CSA. Similarly, 42.1 percent of the households have indicated that although yields have increased, they still do not make much after harvesting because of poor storage and preservation methods. Moreover, 30.8 percent of non-adopters reported the absence of knowledge and training to be a significant barrier to CSA practices adoption. On food consumption behaviour, 55.2 percent of the respondents indicated that the adoption of CSA had resulted in more regular meals taken by the household, especially when the seasons were dry, and 48.7 percent indicated that the income earned due to increased productivity had also allowed them to buy a variety of food. However, a small percentage (18.6) of those indicated no important change in their nutritional status that indicated a variation in the level of adoption as well as external factors like market access and household income levels.

The overall mean of all indicators of food and nutrition was 3.56, which means that adoption of CSA has impacted the region's households' food and nutrition security in a moderate and positive way. Its findings substantiate the fact that despite the fact that the technologies have increased yields and dietary diversity, not all potentials have been achieved as a result of institutional and financial impediments on the adoption levels.

Table 3: Effect of CSA Adoption on Household Food and Nutrition Security

Statement	Frequency	Percentage (%)	Mean	Standard Deviation
Crop yields have increased as CSA techniques have been adopted.	Very Low	12	4.7	3.92
	Low	23	9.0	
	Moderate	54	21.6	
	High	87	34.8	
	Very High	74	29.9	
CSA adoption has increased the availability of food in households.	Very Low	10	4.0	3.87
	Low	25	10.0	
	Moderate	57	22.7	
	High	92	36.7	
	Very High	67	26.6	
Adoption of CSA practices has improved household dietary diversity	Very Low	14	5.6	3.75
	Low	31	12.3	
	Moderate	61	24.2	
	High	81	32.1	
	Very High	67	26.6	
Access to extension services has influenced adoption of CSA practices	Very Low	20	8.0	2.76
	Low	64	25.4	
	Moderate	79	31.4	
	High	59	23.4	
	Very High	32	12.8	
Household income from CSA adoption has improved ability to purchase diverse foods	Very Low	15	6.0	3.41
	Low	42	16.7	
	Moderate	63	25.1	
	High	79	31.5	
	Very High	52	20.7	
CSA adoption has reduced household vulnerability to food shortages during droughts	Very Low	19	7.5	3.64
	Low	38	15.1	
	Moderate	62	24.7	
	High	80	31.8	
	Very High	52	20.9	
Average			**3.56**	**1.13**

Regression Analysis

According to the regression results in Table 4, smallholder farmers in Kisumu County's Lower Nyakach Division report a statistically significant improvement in household food and nutrition security as a result of implementing Climate Smart Agriculture (CSA) technologies. With a p-value of 0.012 and an unstandardized coefficient (B = 0.284), it appears that increased adoption of CSA techniques improves household-level nutrition outcomes, dietary diversity, and food availability. The Household Dietary Diversity Scores (HDDS) and the general state of food security are therefore positively correlated with the amount of CSA technologies that

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are made up of agroforestry, mulching, soil conservation, and drought-tolerant crops. These findings agree with Kassie et al. (2023) and Ng'ang'a and Njeru (2022), who found that CSA adoption has the benefits of resilience to climatic shocks and household welfare due to enhanced productivity and food availability. Additionally, the findings validate the Agricultural Technology Adoption Theory, which assumes that adoption of a superior technology leads to productivity and smallholder farmers' welfare gains.

The significance of the regression coefficient also implies the rise in awareness, training, and availability of agricultural extension services are significant in raising the rates of adoption. The R 2 value of 0.427 gives the indication that CSA technology adoption is a moderately significant determinant of household food and nutrition security variance, with the model estimating that CSA technology adoption accounts for 42.7 percent of the variance. The regression estimates are trustworthy, and the Variance Inflation Factor (VIF) value of 1.005 confirms the lack of multicollinearity. These findings demonstrate that through increased food production, dietary diversity, and resistance to climate shocks, Climate Smart Agriculture is revolutionizing smallholder farmers' livelihoods. However, there are still significant barriers that prevent the full harvest of CSA advantages, including as access to inputs, finance facilities, and extension services.

Table 4: Regression Results

Model	Unstandardized Coefficients		Standardized Coefficients	Sig.	Collinearity Statistics
	B	Std. Error	Beta		
(Constant)	1.982	0.298		6.652	0.000
CSA Adoption	0.284	0.072	0.276	2.540	0.012

a. Dependent Variable: Household Food and Nutrition Security

Summary

This study focused on how smallholder farmers in Kisumu County's Lower Nyakach Division adopted Climate Smart Agriculture (CSA) technology and how that affected the households' food and nutrition security. The data gathered from the farmers provided valuable insights into the extent of adoption, the most significant factors, and the effects on livelihood. By enhancing food production, dietary diversity, and wellbeing, the data demonstrated that CSA adoption has increased household susceptibility to climate unpredictability at a larger scale. However, the adoption rate is still low and constrained by a lack of finance facilities, inadequate extension services, and restricted access to inputs. Despite these obstacles, the study found that households that implemented some CSA techniques, such as rainwater collecting, agroforestry, soil conservation, and drought-tolerant cultivars, had higher Household Dietary Diversity Scores (HDDS) and increased food security.

Effect of CSA Adoption on Household Food and Nutrition Security

The findings demonstrated that smallholder farmers' food and nutrition security was positively and significantly enhanced by the use of CSA technology. The households consistently had better nutrition, higher productivity, and better coping skills for climate shocks including protracted droughts and erratic rains as a result of implementing various CSA techniques. Regression study supports this by demonstrating that food supply, availability, and reliability at the domestic level increase with CSA adoption. The study demonstrates the Sustainable Livelihood and Agricultural Technology Adoption paradigms, which assume that the use of adaptive technologies has the potential to improve the capability and well-being of households and long-term well-being of households. But the research also suggested that there are some constraining factors which help keep the rate of adoption in check such as inadequate extension support, weak awareness and lack of financial capital among others. Thereby building on these facilitators will serve the food and nutrition outcomes at a broader and longer time horizon.

CONCLUSION AND RECOMMENDATIONS

Conclusion

The study finds that Climate Smart Agriculture is a determinant of enhanced food and nutrition security among Lower Nyakach Division households. CSA practices enhance crops' productivity, diversification of food, and climate variability uncertainty resilience, which are all enhancements in livelihood outputs with direct connections. The successful engagement of farmers in CSA technologies entails increased agricultural production and income sources, which elevates Household Food Consumption Scores and HDDS. Yet, a lack of institutional support, poor implementation of policies and access to agricultural inputs continues to undermine the potential of CSA. The results confirm that in order to make CSA technologies reproducible and sustainable on a large scale, technical capacity alone is not sufficient but institutional and policy support are also necessary to bring long-term and equitable benefits to smallholder farmers.

Recommendations

To increase the adoption of Climate Smart Agriculture and its effects on household food and nutrition security, the study suggests the following:

- Make Extension Services Accessible: Agricultural stakeholders and the county government need to enhance extension services availability with an aim to provide sustained farmer training, demonstration fields and field guidance which spread CSA awareness and adoption.
- Enhance Access to Finance and Inputs: The banks should develop flexible and inexpensive credit facilities to the small holder farmers, and government schemes should provide prompt access to seeds, agricultural equipment that will boost productivity, and inputs like fertilizer.
- Enhancement of Policy Implementation and Co-ordination: The policies favoring CSA need to be implemented more stringently with co-ordination of efforts between research entities, NGOs, and local governments to increase mobilization of resources and minimize duplications of efforts.
- Encourage Diversification and Farmer Cooperatives: Smallholder farmers need to be induced to diversify into other complementary income-generating activities like agro-processing, value addition and livestock integration that increase food and income security.
- Community Sensitization on Climate Resilience: Community Awareness: Community awareness should be utilized to create awareness on the benefits of CSA in the long term, which should highlight soil conservation, sustainable use of water, and protection of ecosystems.

REFERENCES

Abutabenjeh, S., & Jaradat, R. (2018). Clarification of research design, research methods, and research methodology: A guide for public administration researchers and practitioners. *Teaching Public Administration*, *36*(3), 237–258. https://doi.org/10.1177/0144739418775787

Anderson, P., & Thompson, J. (2023). *Data analysis in social science research: A practical guide to interpretation.* Routledge.

Arslan, A., McCarthy, N., Lipper, L., Asfaw, S., Cattaneo, A., & Kokwe, M. (2022). Climate smart agriculture? Assessing the adaptation implications in Zambia. *Journal of Agricultural Economics and Development*, *11*(2), 33–47.

Asfaw, S., Di Battista, F., & Lipper, L. (2018). Agricultural technology adoption under climate change in Africa: Micro-evidence and implications for adaptation policy. *World Development*, *105*, 271–284. https://doi.org/10.1016/j.worlddev.2018.01.018

Doss, C. R. (2006). Analyzing technology adoption using microstudies: Limitations, challenges, and opportunities for improvement. *Agricultural Economics*, *34*(3), 207–219. https://doi.org/10.1111/j.1574-0862.2006.00119.x

FAO. (2020). *The state of food security and nutrition in the world 2020: Transforming food systems for affordable healthy diets.* Food and Agriculture Organization of the United Nations.

FAO. (2021). *The state of food and agriculture 2021: Making agri-food systems more resilient to shocks and stresses.* Food and Agriculture Organization of the United Nations.

Feder, G., Just, R. E., & Zilberman, D. (1985). Adoption of agricultural innovations in developing countries: A survey. *Economic Development and Cultural Change*, *33*(2), 255–298. https://doi.org/10.1086/451461

Kabir, S. M. S. (2022). *Basic guidelines for research: An introductory approach for all disciplines*. Book Zone Publication.

Kassie, M., Marenya, P., Jaleta, M., & Zikhali, P. (2015). Adoption of interrelated sustainable agricultural practices in smallholder systems: Evidence from rural Tanzania. *Technological Forecasting and Social Change*, *80*(3), 525–540. https://doi.org/10.1016/j.techfore.2012.03.010

Kassie, M., Teklewold, H., Marenya, P., Jaleta, M., & Erenstein, O. (2023). Understanding the adoption and impact of sustainable agricultural practices: Recent evidence from sub-Saharan Africa. *Food Policy*, *112*, 102391. https://doi.org/10.1016/j.foodpol.2023.102391

Kenya National Bureau of Statistics (KNBS). (2023). *Economic survey 2023.* Government Printer.

Khatri-Chhetri, A., Aggarwal, P. K., Joshi, P. K., & Vyas, S. (2021). Farmers' prioritization of climate-smart agriculture (CSA) technologies. *Agricultural Systems*, *187*, 103019. https://doi.org/10.1016/j.agsy.2020.103019

Kombo, D. K., & Tromp, D. L. A. (2019). *Proposal and thesis writing: An introduction.* Pauline's Publications Africa.

Kothari, C. R. (2020). *Research methodology: Methods and techniques* (5th ed.). New Age International Publishers.

Kumar, R. (2018). *Research methodology: A step-by-step guide for beginners* (5th ed.). SAGE Publications.

Kurgat, B. K., Lamanna, C., Kimaro, A., Namoi, N., & Rosenstock, T. S. (2020). Adoption of climate-smart agriculture technologies in Tanzania: A cross-sectional analysis. *Land Use Policy, 92*, 104-123.

Lipper, L., Thornton, P., Campbell, B. M., Baedeker, T., Braimoh, A., Bwalya, M., ... & Torquebiau, E. F. (2014). Climate-smart agriculture for food security. *Nature Climate Change, 4*(12), 1068–1072. https://doi.org/10.1038/nclimate2437

Mahon, K., & Joyce, P. (2023). *Survey design and data collection in social research.* Springer Nature.

Martinez, C., & Chen, L. (2024). *Applied statistical analysis using SPSS and R.* Elsevier.

Mugenda, O. M., & Mugenda, A. G. (2003). *Research methods: Quantitative and qualitative approaches.* Acts Press.

Mwongera, C., Shikuku, K. M., Twyman, J., Läderach, P., Ampaire, E., van Asten, P., & Winowiecki, L. (2017). Climate smart agriculture rapid appraisal (CSA-RA): A tool for prioritizing context-specific climate smart agriculture technologies. *Agricultural Systems, 151*, 192–203. https://doi.org/10.1016/j.agsy.2016.05.009

Mutie, I., Makau, M., & Githinji, C. (2022). Adoption of climate-smart agricultural practices and their effects on household food security in eastern Kenya. *African Journal of Agricultural Research, 18*(1), 22–35.

Ndegwa, G., Muriithi, B., & Wainaina, P. (2021). Climate smart agriculture adoption and household welfare in Kenya: Evidence from Machakos and Embu counties. *African Journal of Agricultural and Resource Economics, 16*(3), 201–216.

Ndiritu, S. W., Kassie, M., & Shiferaw, B. (2014). Are there systematic gender differences in the adoption of sustainable agricultural intensification practices? *Food Policy, 49*, 117–127. https://doi.org/10.1016/j.foodpol.2014.06.010

Ng'ang'a, T., & Njeru, E. (2022). Climate-smart agriculture adoption and household resilience among smallholder farmers in Kenya. *International Journal of Climate Change Strategies and Management, 14*(4), 512–528.

Ng'ang'a, T., Wambua, J., & Kipkoech, S. (2022). Barriers to adoption of climate smart agriculture among smallholder farmers in Kenya. *African Journal of Environmental Science and Technology, 16*(2), 87–99.

Okeyo, J., Okoth, J., & Ochieng, J. (2022). Climate-smart agriculture practices and food security in western Kenya: Evidence from smallholder farmers. *Journal of Sustainable Development in Africa, 24*(4), 105–121.

Orodho, J. A., & Kombo, D. K. (2022). *Research methods in education and social sciences.* Kanezja Publishers.

Pretty, J., Benton, T. G., Bharucha, Z. P., Dicks, L. V., Flora, C. B., Godfray, H. C. J., ... & Wratten, S. (2022). Global assessment of agricultural system redesign for sustainable intensification. *Nature Sustainability, 5*(3), 275–285. https://doi.org/10.1038/s41893-021-00814-z

Sadoulet, E., & de Janvry, A. (1995). *Quantitative development policy analysis.* Johns Hopkins University Press.

Samuelson, P. A. (1947). *Foundations of economic analysis.* Harvard University Press.

Sen, A. (1985). *Commodities and capabilities.* North-Holland.

Taherdoost, H. (2020). What is the best sample size for survey research? How to find and calculate the correct sample size. *International Journal of Academic Research in Management*, *9*(1), 18–27.

Teklewold, H., Kassie, M., & Shiferaw, B. (2019). Adoption of multiple sustainable agricultural practices in rural Ethiopia. *Journal of Agricultural Economics*, *70*(2), 231–250. https://doi.org/10.1111/1477-9552.12270

Thompson, R., & Garcia, J. (2023). *Quantitative data analysis in applied research: Methods and interpretation.* SAGE Publications.

Thornton, P. K., & Herrero, M. (2015). Adapting to climate change in the mixed crop and livestock farming systems in sub-Saharan Africa. *Nature Climate Change*, *5*(9), 830–836. https://doi.org/10.1038/nclimate2754

Wekesa, C., Obare, G., & Kariuki, I. (2023). Adoption of agroforestry and intercropping practices and their impact on household food security in Western Kenya. *East African Agricultural and Forestry Journal*, *89*(1), 14–28.