

**ADOPTION OF CLIMATE-SMART AGRICULTURAL PRACTICES AND
RESILIENCE TO CLIMATE VARIABILITY OF SMALLHOLDER FARMERS. A
CASE OF “FROM CLIMATE VICTIMS TO CLIMATE HEROES” PROJECT IN
OMORO DISTRICT**

BY

MUKISA DANIEL

23/U/0439/MME/PS

**A DISSERTATION SUBMITTED TO THE FACULTY OF BUSINESS
AND DEVELOPMENT STUDIES IN PARTIAL FULFILMENT OF THE
REQUIREMENTS FOR THE AWARD OF THE DEGREE OF
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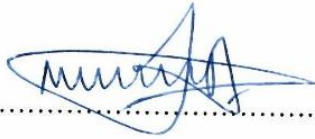
JUNE, 2026

DECLARATION

I, Mukisa Daniel, hereby declare that the study titled *“Adoption of Climate-smart agricultural practices and Resilience to Climate Variability among Smallholder Farmers: A Case of “From Climate Victims to Climate Heroes” Project in Omoro District”* is my original work. To the best of my knowledge, this study represents my original research, analysis, and synthesis, and it has not been submitted for any other degree or qualification.

I have appropriately acknowledged all sources and references used in the preparation of this study and have consistently adhered to ethical research practices. Any support or contributions from others have been duly recognized within the text.

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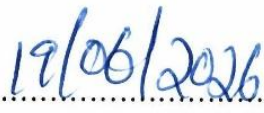
19TH JUNE 2026

Mukisa Daniel

23/U/0439/MME/PS

APPROVAL

This is to certify that the research work titled *“Adoption of Climate-smart agricultural practices and Resilience to Climate Variability among Smallholder Farmers: A Case of “From Climate Victims to Climate Heroes” Project in Omoro District”* has been executed under our supervision and guidance and is ready for assessment.

Signature:  Date: 

Assoc. Professor Olanya David Ross

Signature:  Date: 

Mr. Canwat Vincent

DEDICATION

I dedicate this work to my family; my parents, Mr. Mulomi Moses Idube and Mrs. Saaba Elizabeth, my brother, Dr. Mulomi Isaac Denis and my sisters, Eng. Mirembe Doreen and Ms. Saaba Jovia Ritah. Your love, strength, and quiet support have carried me through every stage of this journey. You have been my foundation and my motivation. This study reflects the values you've instilled in me, and I hope it makes you proud.

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LIST OF ABBREVIATIONS

CAADP	-	Climate-Smart Agriculture Alliance and the Comprehensive African Agricultural Development Programme
CO ₂	-	Carbondioxide
CSA	-	Climate-smart agriculture
DLG	-	District Local Government
NGO	-	Non-governmental Organization
PSM	-	Propensity Score Matching
SDG	-	Sustainable Development Goal

ABSTRACT

This study examined the effect of climate-smart agricultural practices on the resilience to Climate Variability of smallholder farmers, focusing on the “From Climate Victims to Climate Heroes” project in Omoro District, Uganda. This study addressed specific objectives that were to investigate the level of adoption of climate-smart agricultural practices, assess the level of resilience of smallholder farmers, and analyze the relationship between climate-smart agricultural adoption and resilience. A quantitative approach was employed using a quasi-experimental design. Data was collected from selected sub-counties in Omoro District, including Koro, Bobi, and Lakwana using questionnaire method. The Sample size comprised of 381 respondents combining beneficiaries and non-beneficiaries of the project. The results showed that beneficiaries were much more likely than non-beneficiaries to practice climate-smart farming, particularly agroforestry, mixed farming, and the adoption of climate-smart crop varieties, highlighting the success of the intervention in encouraging smallholder farmers to adopt climate-resilient agricultural practices. The intervention has a positive impact on strengthening the resilience of smallholder farmers to face climate challenges because the beneficiaries are more resilient than the non-beneficiaries, having higher production, higher income and better access to the carbon market. The outcomes for smallholder farmers are significantly better in the event of their participation in the “From Climate Victims to Climate Heroes” project, irrespective of the matching methodology, as they will get greater production, income and market access to the carbon market. The research suggests some specific actions that can be taken by governments, NGOs, research institutions and smallholder farmers. Governments should include climate-smart agriculture in national agricultural policy, enhance the infrastructure in rural areas, and enable smallholders to benefit from carbon markets. Participatory training and engagement of vulnerable groups should be the focus of NGOs. Research institutions are encouraged to experiment with context-specific climate-smart agriculture models and create resilience indicators. Smallholder farmers are advised to practice integrated farming methods, to organize themselves into groups and share their knowledge and experience so as to increase their capacity to respond collectively.

CHAPTER ONE

1.0 Introduction

Climate change is a serious problem for agricultural production, primarily for smallholder farmers mostly growing under rain-fed conditions and with few resources to adapt to climate change. Climate change has made the lives of these farmers more precarious and unpredictable, and climate-smart agriculture is a viable solution to bolster the resilience of these vulnerable farmers. These practices are not only in alignment with SDG13, but also act as an intervention to enable farmers to become drivers of adaptation and resilience in the face of climate scenarios.

The purpose of this study was to assess the extent of adoption and effects of climate-smart agricultural practices on the resilience to climate variability of smallholder farmers in Omoro District. The chapter gives a summary of the problem, background, purpose, objectives, research questions, significance, scope, conceptual framework and key terms.

1.1 Background

Globally, strengthening the resilience of smallholder farmers has become a major concern as climate change continues to threaten agricultural systems (Amede et al., 2023). In this context, resilience is defined as the ability of farming communities to weather climatic shocks, adjust to changes in climate and continue producing and living off the land (Kalogiannidis et al., 2023). According to Below et al., (2010), it was observed that smallholder farmers employ various strategies in coping with the risks associated with climate change including crop diversification, shifting planting dates and implementing soil conservation practices. These efforts contribute to resilience at the local level but can be constrained by economic and social factors. A study by Amjath-Babu et al., (2019) indicate that agricultural adaptation measures should be connected to national-level climate policies to boost climate resilient livelihoods. Likewise, support for smallholder farming systems with diversity, coupled with effective institutions and suitable technologies, is critical to ensure food security and resilience, as described by Harvey et al., (2018). Despite these advances, climate-smart agriculture is not being widely used, particularly in the low and middle-income countries. According to Aryal et al., (2020), barriers like low farmer awareness among others limit the scaling up of the use of CSA. However, improving smallholder resilience globally will not only be about technological solutions, it will also be about supportive environments, encompassing inclusive policies, access to knowledge and climate-savvy decision making.

In Africa, Enhancing the resilience of smallholder farmers is critical to securing Africa's food systems, which are very vulnerable to the effects of a changing climate and rely on rain-fed agriculture. Smallholders play a key role in food production across the continent, but repeated poor yields, food insecurity and food related livelihoods insecurity related to unpredictable weather has been reported by Abegunde et al., (2019). Lack of financial services, advanced technologies and access to reliable climate data also increases their vulnerability to drought, soil degradation and pest infestations (Heeb et al., 2019). Resilience is not just about enhancing physical capacity, but also about the effectiveness of social protection mechanisms, risk management systems, and institutions. This can be done through climate-smart agriculture. Agroforestry systems and better seed systems contribute to resilience by providing a buffer against climate-related shocks and climate stability of yields (Makate et al., 2018; Okyere et al., 2024). There are also regional efforts such as the African Climate-Smart Agriculture Alliance and the Comprehensive African Agricultural Development Programme (CAADP) initiatives that push for integration into national agricultural policies. Nevertheless, their adoption is not uniform as a result of cultural issues, poor agricultural support service and poor institutional coordination (Akinyi et al., 2021).

According to Amjath-Babu et al., (2019) it is important to institutionalize climate adaptation strategies at the policy level to reach vulnerable farming populations. A study conducted by Makate, (2019) demonstrated that integrated climate-smart agricultural practices such as conservation agriculture, agroforestry, and improved seed systems enhance resilience by improving soil health, buffering climate shocks, and ensuring yield stability.

In East Africa, smallholder farmers are being more and more impacted by frequent droughts, unpredictable rainfall and land degradation, among other challenges. Adaptations to climate risks include a combination of strategies used by farmers such as crop choice, fertilizer application, and diversification (Musafiri et al., 2022; Rubongoya, 2019). Smallholder farmers frequently, however, have significant challenges accessing adaptation resources and information. Conservation tillage, agroforestry and improved seed use are effective approaches to enhancing adaptive capacity in East Africa when implemented in local contexts and accompanied by participatory approaches (Dougill et al., 2021). The successful adoption of the climate smart agricultural practices is also associated with farmer education, extension services and market access (Chepkoech et al., 2020). Climate-smart agriculture practices in the region help to significantly enhance productivity and climate resilience, but there are implementation gaps as a result of weak institutional mechanisms (Aryal et al., 2021). To scale resilience

practices in East Africa, it needs local knowledge systems, inclusive approaches, and continued support from national and regional governance (Belay et al., 2022).

In Uganda, climate change is still a challenge to agricultural production in Uganda and, therefore, resilience of smallholder farmers is significant (Gottschalk, 2020). The sector accounts for over 70% of the population and the majority of the smallholders rely on rain-fed farming schemes which are exposed to droughts, erratic rainfall and temperature changes (Atube et al., 2021). These are compounded by the fact that modern inputs were not readily available, land tenure was insecure and farmers did not adopt adaptive technologies, affecting their ability to sustain productivity and recover from climate shocks (Nabikolo et al., 2012). Resilience, therefore, is about adapting to disruption and not just bouncing back from it, but also about changing agricultural systems to be better equipped to face future challenges.

A study by Oriangi et al., (2019) showed that the use of climate-smart agricultural practices has improved food security and income stability for smallholder farmers who participated in targeted programs. The spread of these practices has increased resilience, but problems with gender inequity, costs of technology and lack of institutional support are currently holding back progress. The time has come to put into practice enabling policies and capacity building, and gender-responsive strategies within climate-smart agriculture efforts for inclusive resilience in Uganda (Mubiru et al., 2018; Vincent, 2022).

The climate conditions in Omoro District remain severe and are still affecting the livelihoods of farmers, food availability and sustainability of the smallholder subsistence agriculture (Muwereza, 2024). Building the resilience of the society, its capacity to absorb, adapt to and recover from climate shocks is thus a priority. “From Climate Victims to Climate Heroes” project is a multi-dimensional approach to strengthening the resilience of farmers, undertaken by Solidaridad to solve these challenges. This project is implemented in Northern, West Nile, Western Central and Mt. Elgon Regions and is a five-year programme that is aimed at supporting smallholder coffee growers to adapt to climate stresses (e.g. droughts) through practical tools, knowledge and institutional support. The project supports resilience by engaging in climate-smart agriculture, incorporating agroforestry, and increasing access to local climate data and information, as well as through participation in global carbon markets through platforms such as Acorn. It additionally backs farmers financially in obtaining sustainable inputs and digitalizes the transmission of information on the impacts of climate change efficiently (Solidaridad, 2022). This intervention aimed to reduce farmers’ vulnerability

to climate risks while strengthening their adaptive capacity and long-term sustainability. Based on this background, the study sought to evaluate how the adoption of climate-smart agricultural practices has influenced the resilience to climate variability of smallholder farmers participating in the “From Climate Victims to Climate Heroes” project in Omoro District.

1.2 Problem statement

The impacts of climate variability are becoming more pronounced and are increasingly impacting on smallholder farmers' crop yields, food security and total resilience (Khumalo et al., 2024). The majority rely on traditional and rain-fed agricultural practices making them very vulnerable to weather related hazards like droughts and others (Atube et al., 2021). With the increased frequency and intensity of these climate shocks, farmers continue to be less able to cope and recover, leading to a decline in their resilience, poverty and food insecurity in the district (Muhanguzi et al., 2023).

The impact of these climatic changes on agriculture has been pronounced in northern Uganda, especially in terms of reduced crop productivity. However, in the last few years, crop production has been constrained by up to 16% in Omoro, which has resulted in increased food insecurity and economic instability among the farming population (Galema et al., 2024). Smallholder farmers, particularly women and marginalized groups, have shown to be less resilient due to lack of access to adaptive technologies, insufficient information about the use of climate-smart technologies, and insufficient support systems to enhance their resilience to climate challenges (Oriangi et al., 2019).

A number of initiatives have been instigated to enhance smallholder farmer's resilience, including the adoption of climate smart agriculture practices like the use of improved crop varieties, mixed farming and agroforestry (Nsobya, 2019; Okoth et al., 2024). The strategies are designed to increase productivity, minimize climate risk, and create sustainable agricultural systems with greater resilience to climate-related shocks and stresses. But the effect of these practices on the resilience of farmers is not well understood. This study thus sought to assess the effect of adoption of climate-smart agricultural practices on the resilience to climate variability of smallholder farmers under the “From Climate Victims to Climate Heroes” project in Omoro District.

1.3 Purpose of the study

The aim of the study was to evaluate the effect of climate-smart agricultural practices on resilience to climate variability among smallholder farmers, a case of “From Climate Victims to Climate Heroes” project in Omoro District.

1.4 Research objectives

- i. To investigate the level of adoption of climate-smart agricultural practices among the smallholder farmers in Omoro district.
- ii. To assess the level of resilience to climate variability among the smallholder farmers in Omoro district.
- iii. To assess the relationship between the adoption of climate smart agricultural practices and the resilience to climate variability among smallholder farmers in Omoro district.

1.5 Research questions

- i. What is the level of adoption of climate smart agricultural practices among smallholder farmers in Omoro district?
- ii. What is the level resilience to climate variability among smallholder farmers in Omoro district?
- iii. What is the relationship between the adoption of climate smart agricultural practices and the resilience to climate variability among farmers in Omoro district?

1.6 Scope of the Study

1.6.1 Time Scope

The study covered a period of five years, which corresponds with the duration of the “From Climate Victims to Climate Heroes” project to be rolled out in Omoro District. It was this time frame that was enough for climate-smart agriculture practices and its effects in the long-term on resilience to climate variability of smallholder farmers. Data collection, analysis, and report writing were conducted during the period of January to September 2025, which spans eight months.

1.6.2 Geographical Scope

The study was carried out at Omoro District in Northern Uganda, Uganda. This is made up of 12 sub-counties namely Bobi, Aremo, Koro, Labora, Abuga, Ongako, Orapwoyo, Lalogi,

Lakwaya, Lakwana, Akidi and Odek and a total of three town councils, namely Omoro, Acet and Palenga. The study targeted the three sub-counties namely Koro, Bobi and Lakwana, which had been chosen for their reliance on smallholder farming, vulnerability to climate risks and being a part of the “From Climate Victims to Climate Heroes” project.

1.6.3 Content Scope

The study analyzed the uptake of climate-smart agricultural practices by smallholder farmers who are part of the climate change adaptation project of "From Climate Victims to Climate Heroes". In particular, it analyzed the determinants of farmers' adoption of climate-smart agriculture practices and their effect on resilience to climate variability among the smallholder farmers. Demographic factors were also assessed for their influences on the adoption of these practices.

1.7 Significance of the Study

The results of this research can inform policy making, agricultural extension and development practitioners on the factors affecting the adaptation and implementation of climate-smart agricultural practices by smallholder farmers.

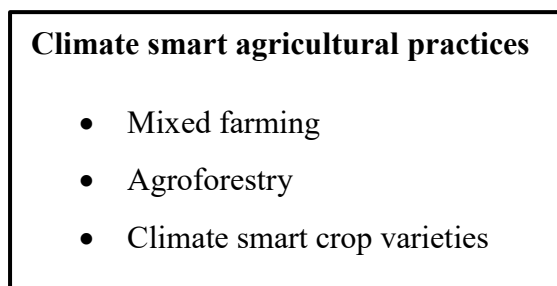
The findings provide guidance for developing specific policies and action to support resilient farming and sustainable agriculture.

The study will be useful to stakeholders that implement the “From Climate Victims to Climate Heroes” project as it will present the outcomes of the project and the challenges faced by smallholder farmers in implementing climate-smart agricultural practices.

The findings of this research will help advance the field of knowledge on climate-smart agriculture, adding to the existing body of empirical evidence that will enrich the academic discourse and guide future interventions to strengthen agricultural productivity and climate resilience.

1.8 Conceptual framework

Independent variable



Dependent Variable

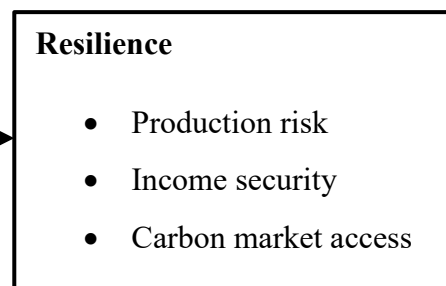


Figure 1: Conceptual framework

Source: Adapted from Ebi et al., (2018)

In the conceptual framework, the independent variable is the climate-smart agricultural practices and the dependent variable is the resilience of smallholder farmers. The study was based on agroecological practices, including agroforestry, climate resilient crop varieties and mixed farming. These approaches aim to strengthen farmers' adaptive capacity and reduce on the negative effects of climate change on the smallholder farmers.

Three indicators that is production risk, income security, and carbon market participation were used to gauge smallholder farmers' resilience to climate change. A reduction in production risk is achieved when farmers implement practices that protect their crops and livestock from climatic and environmental risks. Stability in yields and multiple sources of income provide income security. In the meantime, carbon markets offer an extra revenue stream and encourage more environmentally sustainable actions for mitigation and adaptation.

1.9 Definitions of the key terms

Mixed Farming

Mixed farming is an approach where crops and livestock are raised together on the same farm. This system helps diversify income, improve soil fertility through crop rotation, and make more meaningful use of available resources.

Agroforestry

Agroforestry involves integrating trees with crops or pasture on the same land. This practice promotes sustainable land use, increases productivity, and enhances ecological diversity.

Climate-Smart Crop Varieties

Climate-smart crop varieties refer to specially developed plants designed to endure climate-related stresses. They may be resistant to drought, heat, pests, or diseases, and often use nutrients more efficiently to maintain productivity under adverse conditions.

Production Risk

Production risk refers to the uncertainty in farming outcomes caused by factors such as unpredictable weather, pests, and diseases. This uncertainty affects farmers' ability to plan and manage resources effectively.

Income Security

Income security in agriculture refers to the reliability and stability of farmers' earnings. It depends on factors like market access, stable prices, availability of credit, and social protection mechanisms that shield farmers from financial shocks.

Carbon Market Access

Carbon market access is the ability of farmers or agricultural organizations to participate in carbon trading systems. By adopting practices that reduce greenhouse gas emissions or capture carbon, such as agroforestry or sustainable farming, farmers can earn carbon credits and generate additional income.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

The chapter presents the literature on climate-smart farming and resilience to climate variability of smallholder farmers. The aim is to provide theoretical and conceptual foundation for the study, gives the context to the climate-smart agricultural practices and how they impact farmers' ability to respond to climate change challenges. The chapter reviews existing academic literature and experiences to shed light on the link between climate-smart agriculture and resilience of smallholder farmers.

2.1 Theoretical Review

2.1.1 Adoption Theory

Adoption theory is a framework used to describe the mechanisms by which people or organizations adopt and adapt new behaviors, practices or technologies. It includes psychological, social and structural aspects that affect the willingness and ability of individuals to embrace an idea or action. The first researcher to make this point for adoption was Sastri, (1909), who argued that adoption is not simply the result of a random choice, but the culmination of an internal process, influenced by environmental and social factors. This theory has developed over time to include a variety of elements such as attitude, communication, access to information and support structures outside the organization.

A study by Blacket, (1996) cast a critical lens on the traditional models of adoption, taking note of those cases in which traditional models do not reflect contextual circumstances in which adoption decisions are made. Where social, economic, and institutional factors are identified to be barriers, people might not be willing to undertake practices that would be beneficial. This restriction highlights the need to recognize adoption as a process that varies by context and is complex. This is supported by Roach, (2024) who claims that adoption theory should be adaptable and sensitive to the specific context. He argues that the real-life adoption processes are not linear and can be a matter of backward and forward decision-making, negotiation and adaptation, depending on actual experiences.

There has been a recent development of literature that includes a behavioral dimension in the theory of adoption. In Ghana, for example, a study Atta-aidoo et al., (2022) used the theory of planned behavior to evaluate the adoption of climate-smart agriculture by smallholder farmers.

Their study showed that behavioral intentions based on attitudes, perceived behavioral control and social norms are important determinants of adoption. These results complement the traditional theory of adoption and add factors of the psychological process that can intervene in the adoption process. In the same way, the institutional aspect of adoption was highlighted by Elijah & Makungo, (2021). They found that institutional support, policy guidance, and participatory decision making played an important role in the adoption of recommended practices in their study of smallholder dairy systems in Kenya.

A timely and relevant information is one of the key factors contributing to the uptake of climate-smart agricultural practices. A study by Ouedraogo et al., (2022) noted that the demand for climate information by farmers is a strong determinant of farmers adoption decisions, especially where high climate variability and risk is present. Likewise, the relevance of decision-making and institutional support for successful adoption was evidenced in Southern Ethiopia by Belay et al., (2024) who reported that the adoption of climate smart practices significantly improved food security and livelihoods of households.

This study adopted an adoption theory approach to understanding the reasons farmers are willing to adopt climate-smart practices. It takes into account factors of personal motivation, social pressures, institutional guidance and access to information. The study used a combination of classical and modern approaches to the study of adoption to examine the ways in which these factors interact to produce resilience outcomes among smallholder farmers in climate-sensitive contexts.

2.1.2 Resilience Theory

Resilience theory was developed from systems thinking in the field of ecology, which applies to the ability of an ecological system to absorb shocks, reorganize, and retain its key functions without changing its structure or identity as a system (Smyntyna, 2015). The first applications that were made in the fields of environment and agriculture pointed to the resilience of a system of maintaining its main functions in face of shocks, particularly the ones related to climate change. It was subsequently developed in agriculture to consider not just ecological stability, but social and institutional aspects which allow systems to adapt and change in response to challenges (Borquez et al., 2017).

Integrating resilience theory with diffusion of innovations provides a useful framework for understanding the adoption of sustainable practices in the socio-ecological context, like perennial cropping systems (Atwell et al., (2009). Their research shows that, in addition to

ecological innovation, social receptivity and knowledge transfer is necessary to move towards more resilient farming systems. Likewise, Chillrud, (2017) challenged the use of resilience theory in development agendas related to agricultural development in response to climate change, arguing it was a policy buzzword or a workable framework. However, Chillrud noted it could be useful in helping to direct adaptive strategies if used with local knowledge.

Recent work has broadened the scope of resilience theory. Sundstrom et al., (2023) proposed the idea of coerced resilience, a kind of adaptation under pressure but not necessarily in a positive or voluntary way. This reflects the difficulty of resilience, particularly when constrained by systems, such as market volatility and climate stress. According to Yuniartanti et al., (2024) reviewed the evolution and application of resilience theory, highlighting the critical role of institutional, participatory planning and infrastructure for achieving sustainable resilience outcomes. The literature as a whole shows an increasing consensus about resilience as a dynamic capability and as a guiding principle for climate-adaptive strategies in agriculture.

The study is well grounded in the resilience theory, which aims to understand the processes of buffering and strengthening between adaptive practices and climatic shocks in smallholder systems, and to improve long-term sustainability. Resilience theory focuses on knowledge co-production and participatory approaches that are closely linked to the values of climate-smart agriculture that call for local ownership and adaptive learning. The study builds on climate-smart agriculture as a resilience-enhancing mechanism to adopt the call to use the resilience theory not as a theoretical lens, but as a lens for change at the grassroots.

2.2 Climate-smart agricultural practices

Climate-smart agriculture is a comprehensive strategy that seeks to transform food systems to be "climate smart" in order to achieve food security under climate change. It focuses on three core goals: Improving productivity and incomes; strengthening adaptation and resilience to the impacts of climate change; and reducing or removing greenhouse gas emissions (Abhilash et al., 2021). Practices such as mixed farming, agroforestry, and the adoption of climate-resilient crop varieties are particularly recognized for their effectiveness in consolidating the resilience of smallholder farmers.

2.2.1 Mixed farming

Mixed farming involves agricultural production of crops along with production of livestock and is considered as a traditional but highly effective approach to dealing with risks posed by

climate variability. Mixed farming has historically been shown to ensure food security in case of crop failure as it diversifies income sources, and also has the ability to increase soil fertility by nutrient recycling (Kumari et al., 2019). According to Bhattacharyya et al., (2020), mixed farming is ecologically efficient because various on-farm resources like animal traction, crop residues and manure are utilized efficiently. Both Kumari et al., (2019) and Bhattacharyya et al., (2020) highlight the income stability and environmental sustainability and soil health benefits of mixed agriculture. Their combined reflections contain the essence of this study, especially in the context of combined farming practices to improve resilience. The view on mixed farming as a productive practice that facilitates adaptation is very similar to the study objective, which is to test strategies to improve smallholder farmers' resilience.

In the Ugandan context, Gottschalk, (2020) provided evidence that mixed farming by smallholder farmers was effective in improving the adaptive capacity and food security of the households. The results are in line with the results of Baker et al., (2023) who emphasized that mixed farming practices have the potential to enhance climate resilience, especially if supported by local knowledge and policies. Crop-livestock integration can be a way to optimize land use and ensure sustainable income generation for farmers, particularly in rural communities that are at risk of climate-related shocks. The arguments of Baker et al., (2023) are complemented by the empirical findings of Gottschalk, (2020) who adds local specificity to the arguments. Both are about climate resilience and income diversification, with Baker et al. also adding policy support and indigenous knowledge. These synergies highlight the multiple advantages of mixed farming in line with the current study's aim to evaluate the contextual relevance and effectiveness of climate-smart agriculture practices in the context of smallholders.

According to Baker et al., (2023), institutional barriers, labour intensive and limited extension services are the major constraints. In a systematic review, Mizik, (2021) also indicated that while there is a great potential that mixed farming can present for small-scale farms, the key success factors include a conducive policy framework, acquiring knowledge and access to technology in the farm. In spite of these challenges, the mixed farming system can be a winning approach to climate-smart agriculture objectives, particularly in the case of farmers who work in resource-limited environments. The findings of both Baker et al., (2023) and Mizik, (2021) agree that the structural and institutional constraints are major obstacles limiting the adoption of mixed farming. Mizik's global perspective is complemented by regional nuances as provided by Baker et al., (2023). Their reflections highlight the need for creating certain environments,

which is one of the key elements explored in this study. There is little divergence in the geographical scope of analysis but both support the rationale for using institutional support as a variable in smallholder resilience, thereby justifying the inclusion of this variable in the current research framework.

2.2.2 Agroforestry

Agroforestry incorporates trees along with crops and livestock and has gained in popularity as a climate change mitigation and adaptation strategy for sustainable land-use. In Cameroon, its role in supporting farmers facing unpredictable rainfalls, boosting biodiversity and soil health has been emphasized by Awazi et al., (2021). Likewise, for ecological restoration and livelihood diversification, Riyadh et al., (2021) noted its advantages in Bangladesh. In both studies, agroforestry is shown to be versatile in terms of how it can contribute to both climate change risk mitigation and ecosystem restoration, especially in degraded areas, thereby highlighting its climate adaptation capacity in various geographical settings. These results show that agroforestry has a great potential to reduce smallholder farmers exposure to climate-related shocks, which is one of the focus of the present study.

Multiple environmental and productivity benefits also come from agroforestry. According to Rolo et al., (2023) soil structures were improved, organic matter and water holding capacity were improved and water was retained in the soil as a result of agroforestry. A study by Dissanayaka et al., (2023) reported that agroforestry in Sri Lankan coconut systems resulted in improvement of carbon sequestration, water conservation and shading from evapotranspiration during heat stress. All of these studies emphasize the contribution of agroforestry to soil health and to the protection of crops, thereby further solidifying its contributions to ecosystem services. This is consistent with the research's focus on climate adaptation strategies that also enhance natural resource management and smallholder productivity.

Contextual factors are crucial to the success of agroforestry. According to Ntawuruhunga et al., (2023) that agroforestry in general offers benefits however, these are greatly affected by local biophysical conditions, farmers' perception and institutional arrangements. Likewise, Burgess et al., (2022) highlighted that there is potential for improved outcomes if the agroforestry system is integrated with intercropping, particularly if there is the involvement of indigenous knowledge and participatory approaches. In sum, the findings from these studies highlight the need for local enabling environments, institutions, and cooperative approaches to

agroforestry practices to realize their benefits. This nuanced understanding is directly oriented towards the objective of this study.

Agroforestry implementation is sometimes constrained by the long gestation period before the start of returns from tree crops and insecure land tenure (Musafiri et al., 2022). However, with conditions like clear land rights, availability of quality seedlings and excellent extension services, agroforestry can be a game-changer climate-smart agricultural practice that enhances both ecosystem functions and farmer livelihoods (Mbanasor et al., 2024; Mensah et al., 2021). These studies therefore confirm that conducive land ownership and support by institutions are critical to the success of agroforestry. A study by Musafiri et al., (2022) speaks about the challenges of adoption while Mbanasor et al., (2024) and Mensah et al., (2021) speak about the possibilities of adoption in a supportive environment. The two views are in line with the aim of the present study.

2.2.3 Climate-smart crop varieties

The use of climate-smart crop varieties is one of the many mitigation strategies to address the impacts of climate stressors like droughts, heat and pests on farmers. According to Kumari et al., (2019), these varieties are genetically improved to resist environmental and biological pressures and produce more consistent yields in extreme situations. Likewise, Abhilash et al., (2021) point out their significance in supporting the productivity of farming systems when part of a larger and more comprehensive adaptation strategy. The two studies highlight the importance of better crop varieties to increase resistance to stress and stability of yields, which makes them a critical tool in building resilience for smallholder farmers.

Information on the advantages of climate-smart crop varieties is growing. In Kenya, Radeny et al., (2022) concluded that improved drought and pest resistant varieties were shown to improve food security, nutrition and yields of households, diversifying their income and reducing their risk. A study by Mbanasor et al., (2024) also reported in Nigeria that the farmers that practiced drought-tolerant maize and other improved seeds were more resilient and less vulnerable. Though both studies were carried out in different regions, they emphasize important findings like food security and income stability and emphasize the importance of climate smart seeds as instruments to build resilience for smallholder farmers.

But there are still uneven patterns of adoption. According to Diro et al., (2022), aspects such as education, access to extension services, and accessibility of inputs are critical determinants of adoption in Ethiopia. In Western Kenya, Musafiri et al., (2022) saw similar restraints, as

farmers are aware of the advantages of better seeds, but uptake is limited by constraints such as seed cost, availability, and insufficient knowledge transfer. Both studies point to socio-institutional issues as being important, and both indicate that technology adoption is not a simple process. This convergence emphasizes the need to measure adoption barriers, a direct outcome of which is the current study's goal.

A study by Mishra et al., (2025) recommended regular testing of the performance of climate-smart varieties so that they can continue to be effective in a changing climate. Acharyya, (2022) further highlighted the need to harmonize policies and subsidies to ensure equitable access to such technologies, especially in climate sensitive and out-of-reach areas. These studies, Mishra et al., (2025) and Acharyya, (2022) add a future-oriented view, highlighting policy coordination and the evolution over time of technologies. Their focus on monitoring and policy coherence complements the empirical adoption discussions in earlier studies. The scope of this currently ongoing study is reinforced by these policy considerations, in relation to institutional and policy support mechanisms on resilience building.

2.3 Resilience

Resilience is defined as the ability of smallholder farmers to anticipate, withstand, and recover from negative events and shocks as a result of climate change (Muhan, 2023). It is becoming recognized as a complex concept, with linkages to agricultural productivity and livelihoods and environmental sustainability. A study by Meuwissen et al., (2019) emphasize that resilience is not just about being able to withstand stressors, but also to adapt and change in response to stressors. There is a need to create a food system that is resilient, which should include ecological, economic and social aspects (Fan et al., 2021) and methods that give power to rural communities and address power inequalities in global food systems (Karoliina et al., 2023). While these studies vary in their conceptual framing, system integration and socio-political dynamics, all of these authors agree that holistic approaches to resilience are crucial. This view is similar to the current study, which looks at climate-smart agriculture as a means of improving resilience of smallholder farmers.

2.3.1 Production risk

Production risk is the risk of agricultural output that may suffer from problems arising from weather, pest, soil quality, and other environmental factors that impact the production of the product. Smallholder farmers are generally vulnerable to climate related shocks, which affect their food and income security (Tadesse & Ahmed, 2023). A study by Meuwissen et al., (2019)

developed a framework for assessing resilience of farming systems, with production risk being an important component that influences a farming system's capacity to cope with disturbances. They highlight the need for both short- and long-term interventions to build resilience. Crop diversification is an important risk reducing measure, as pointed by BIRTHAL & HAZRANA, (2019). A diverse range of crops provides farmers with some protection in case of a localized pest or weather event. Their work showed that in addition to production losses being reduced, diversified systems offer nutritional and market related advantages. These studies, MEUWISSEN et al., (2019) and TADESSE & AHMED, (2023) look at production risk from a systems resilience and climate-smart agriculture perspective, respectively, while BIRTHAL & HAZRANA, (2019) consider it from a pragmatic farm-level perspective of crop diversification. There is consensus that there is a need to decrease production variability, but they differ as to what can be done from a systemic perspective or even what can be done practically. This is in alignment with this current study.

A study of study TADESSE & AHMED, (2023) assessed the benefits of climate-smart agriculture on yield stability and the farmers' protection from climate-induced crop failure and concluded that interventions under climate-smart agriculture demonstrated positive impacts on yield stability and protection from crop failure due to climate change. Similarly, AGUILAR et al., (2022) noted that agroforestry and soil moisture conservation practices enabled smallholder to sustain production during droughts. Both studies highlight the importance of soil and water management; the first (Tadesse & Ahmed, 2023) on yield stability and resilient inputs, and the second (Aguilar et al., 2022) on integrating natural resource management. They complement each other in contributing to the implementation of climate-smart agriculture practices for mitigating production risks due to climate change, as this study focuses on climate-smart agriculture practices for enhancing the resilience of production.

According to Phiri et al., (2021), in Zimbabwe it was reported that the adoption of climate-smart agriculture in the district of Umguza resulted in better soil structure, water holding capacity and seasonality, which led to increased resilience. A study by Amede et al., (2023) highlighted the importance of incorporating indigenous knowledge with scientific farming techniques to boost resilience against production shocks in regions of irregular rainfall. Phiri et al., (2021) centre their work on formal practices of climate-smart agriculture while Amede et al., (2023) emphasize culturally-based, locally-appropriate methods. Both views highlight the importance of climate-smart agriculture for dealing with variability in rainfall and building soil and water resilience, providing a dual lens view of technical innovation and local

knowledge that is useful for the current research and its focus on production resilience for smallholder farmers.

According to Muhan, (2023), in sub-Saharan Africa resilience to production risks is dependent on institutional support, such as early-warning systems and extension services. This was echoed by Grzelczak et al., (2023) who called for coherent and context-specific measures of and actions for agricultural resilience in the context of climate risks. A study by Tariku & Kebede, (2024) found that the implementation of climate-smart technologies would need to be adapted to the local context and supported by institutional and financial mechanisms to be effective in reducing yield volatility. These sources move from the farm level practices to the enabling environment. Therefore, Muhan, (2023) highlights the importance of institutional infrastructure while Grzelczak et al., (2023) and Tariku & Kebede, (2024) focus on the need for specific frameworks and support mechanisms. They share a common recognition of the institutional aspect of resilience although vary in level of scope: services vs. frameworks vs. technology tailoring.

2.3.2 Income Security

Income security is the regularly available capacity of a household or person to generate sufficient and stable income over time despite environmental, market, and health shocks particularly for smallholder farmers. It allows for access to basic needs like food, healthcare, and education, an aspect of it that's essential in rural resilience (Williams et al., 2020). This is in line with the current research, which explores the role of climate smart agriculture to livelihoods other than food production in maintaining basic wellbeing of climate vulnerable farmers.

A study by Amjath-Babu et al., (2019) connected a resilient income to climate resilience, suggesting policies under the Paris Agreement should focus on the capacity of smallholder farmers to maintain their income under environmental pressures. The importance of financial incentives, crop insurance and social safety nets for income stability is noted. Using quantitative methods, Williams et al., (2020) demonstrated the ability of resilience-enhancing measures such as irrigation and index insurance to dampen income inequality and boost financial security, especially in climate-sensitive areas, while also stressing the need for access to these tools for the most vulnerable groups. Both the studies highlight the role of financial instruments in income resilience but differently though Amjath-Babu et al., (2019) do so as a policy, while Williams et al., (2020) provides empirical evidence. While there are differences

in scope, they both agree to inclusiveness and accessibility. The findings of this current study are strengthened by these insights. This current study's findings emphasize the contribution of climate-smart agricultural practices and policy tools to income stability of vulnerable smallholder populations.

In Vietnam, skill development and value chain integration proved highly beneficial for farmers' income and reducing the shock impact of the market season as presented by Ha et al., (2020). Empowering farmers with technical knowledge and market access was demonstrated to improve the income stability of farmers in the long-term. In Brazil's semi-arid region, integration of rainwater harvesting and agriculture and animal husbandry was found to have a substantial positive impact on food availability and incomes in the country, according to a climate resilience program study by Maia et al., (2021). This dual benefit model enabled households to keep living their lives at the same level even when conditions changed in the environment. Both Ha et al., (2020) and Maia et al., (2021) highlight diversified strategies value chains and dual production systems to ensure incomes. Their focus is on empowerment and diversification in the context of resilience. The views are closely connected with the study's emphasis on the mixed use of natural resource management and market-oriented approaches to enhance income security in agriculture, which is in climate smart agriculture.

A study by Fan et al., (2021) explored food systems and concluded that households with diverse income sources, such as off-farm work and remittances, were more resilient to food systems shocks and price volatility. Likewise, Hussain et al., (2021) emphasized the importance of financial inclusion, including the availability of microcredit and savings, to enhance the financial resilience of households in the rural areas, to enable them to rebuild their livelihoods more rapidly when they face economic shocks. Both Fan et al., (2021) and Hussain et al., (2021) highlight the importance of diversification of livelihoods and financial infrastructure, respectively, but both highlight the importance of decreasing the dependence on one income stream. The findings of the current study examined the potential of climate-smart agricultural practices in creating income security through income diversification and increasing access to financial resources among rural people is consistent with the findings of these studies.

A study by Amoak et al., (2022) called for agroecological transitions as a way towards stable and diversified incomes. Agroecology is shown to improve ecological resilience and to generate various revenue streams on diversifying farm activities and ecosystem services. In studying adaptive strategies in global food systems, Karoliina et al., (2023) found that

enhancing local production and market systems improve smallholders' income stability. A study by Bekuma, (2024) also noted that climate-smart agriculture practices, along with support from institutions and markets, can significantly boost the income security of farmers. All of these authors are united in their view on the need for diverse and local solutions to agroecology and local food systems and institutions in order to achieve income resilience. The studies by Amoak et al., (2022) and Bekuma, (2024) examine market integration and institutional enablers and those of Karoliina et al., (2023) discuss agroecological practices. This study's objective of evaluating climate-smart agricultural practices for both technical and market and institutional solutions towards income security for smallholder farmers is congruent with their complementary insights.

2.3.3 Carbon market access

Carbon market access is about the ability of a person, in this case a smallholder farmer, to have access to a carbon trading system with the carbon credit for one ton of CO₂ removed from the atmosphere. On the agriculture side, this is achieved through climate-smart agriculture, in which carbon sequestration or lessening emission helps farmers achieve climate mitigation while simultaneously generating extra income (Ansari et al., 2021; Tumushabe et al., 2023). Both studies highlight the income diversification and environmental protection advantages of adopting a climate smart agriculture and highlight climate-smart agriculture as a pathway for smallholders to access carbon markets. This viewpoint is similar to that of the current study, which views the practices as being essential for resilience building as they offer alternative sources of income.

A study of Ansari et al., (2021) on carbon budgeting in the east of India and found that when land use change was combined with agroforestry, there was a greater accumulation of carbon and better livelihoods. However, Azadi et al., (2021) challenged the traditional climate-smart agriculture as technocratic and desired a more participatory “vulnerable-smart agriculture”. They stressed that carbon market access should be designed to equitably include marginalized farming populations, warning that otherwise, it risks exacerbating inequalities. Both studies recognize the potential advantages in access to the carbon market, but while Ansari et al., (2021) emphasize environmental and economic benefits, Azadi et al., (2021) highlight social justice and inclusivity. That's where the difference lies: Technical application of the lens versus equity-centered access. These perspectives complement to this study and contribute to a more nuanced understanding of the practical and ethical implications of advocating for climate-smart agriculture to enhance resilience.

According to Bennett et al., (2021), environmental services such as carbon storage, water purification, and biodiversity are important to enhance agricultural landscape's resilience. They stated that with proper management, access to carbon markets could be used to help achieve environmental resilience and economic stability. In the case of Uganda, Tumushabe et al., (2023) found that some of the key challenges impeding access to the carbon market include weak policies and regulations, lack of farmer training, and opaque benefit-sharing mechanisms. They found that institutional factors can cause smallholder farmers to miss out on the benefits of the carbon market. Bennett et al., (2021) however, adopt an ecological perspective, and Tumushabe et al., (2023) place great stress on institutional and policy preparedness. The common ground between the two studies is that they both believe that measures of fostering resilience for climate-smart agriculture depend on more than just implementing the practices; they also believe that supportive policy and institutional measures are necessary for farmers to be equitably engaged.

Specifically, Okyere et al., (2024) analyzed the effect of carbon farming training in Northern Ghana and revealed that training helped to increase farmers' participation in carbon markets, as well as their food security and income and resilience, emphasizing the need for knowledge and training. In the same way, Baffour-Ata et al., (2023) found that the application of mulching, agroforestry, and cover cropping increased the soil fertility, productivity, and carbon sequestration, allowing farmers to receive carbon credits. These studies highlight the need for capacity building and the adoption of specific practices to be able to access carbon markets by smallholders. One places emphasis on training, the other on demonstration of how education and extension services and on-farm interventions can bolster farmer resilience for the uptake of carbon markets, which are similar to objectives of the current study.

2.4 Climate-smart agricultural practices and resilience among smallholder farmers

Smallholder farmers need to be resilient to climate variability and change, which is why climate-smart agriculture is necessary. The farming practices are intended to boost productivity, cut vulnerability and build adaptive capacity, using innovative farming techniques. The key elements are mixed farming, agroforestry and climate-resistant crop varieties.

Mixed farming which involves growing crops and raising animals, offers a diversified source of income and reduces dependence on a single agricultural activity (Baffour-Ata et al., 2023; Makate et al., 2018). This diversification offers protection against production risks and contributes to food security, allowing farmers to continue to make a living in difficult times,

including droughts (Dougill et al., 2021). Crop and livestock integration can help farmers to buffer against climate-induced stresses, to lessen dependency on a single income source.

Agroforestry benefits the soil fertility, water preservation, and generation of supplementary income from timber or non-timber products (Ali et al., 2023; Berhanu et al., 2024). It is a method to reduce production risks, maintain yield and improve soil health, as well as reduce the effects of climate change. Agroforestry helps increase resilience through its capacities to decrease soil erosion, increase soil water holding capacity, and diversify farm production (Phiri et al., 2021). A study by Baffour-Ata et al., (2023) found in Ghana that agroforestry improved farmers' resilience in two ways: by diversifying their income and by providing better environmental services.

Another crucial component of climate-smart agriculture is the development and implementation of climate-smart crop varieties that can withstand climate-related stresses such as drought, heat and disease (Jamil et al., 2021; Zheng et al., 2024). Drought-tolerant or pest-resistant crops allow farmers to ensure more consistent harvests, even in tough conditions. Farmers using climate resilient maize and sorghum reported improved harvests in dry periods, reducing the impact of climate variability on food security and income in Ethiopia (Ali et al., 2023). These varieties help lower the exposure and increase the resilience of smallholders to production risks.

How climate-smart agriculture and resilience are connected is tied to the ability of these interventions to address production risks, enhance income security and develop opportunity in new markets, e.g. carbon trading. Mixed farming and agroforestry, and climate-smart crops, are important for reducing the volatility of production and can cushion the impact of climate change shocks (Berhanu et al., 2024; Makate et al., 2018). The consistent production helps to maintain income stability in order to invest more in other adaptive measures such as irrigation or better farm infrastructure (Saran et al., 2022; Zheng et al., 2024).

Carbon markets can also provide smallholder farmers involved with them (e.g. through agroforestry or reduced tillage) with additional financial resources, that can be dedicated to activities enhancing the farmer's resilience. In Pakistan, Jamil et al., (2021) reported improvements in income and more sustainable practices for farmers involved in carbon credit programmes, which boost the overall resilience. The carbon market is a new opportunity to reinforce agricultural resilience by diversifying incomes and enhancing sustainability through carbon market participation (Zheng et al., 2024).

Climate-smart agriculture is policy congruent with national and regional strategies for climate adaptation and sustainable development. Hellin et al., (2023) discuss the shift from climate-smart to climate-resilient agriculture, incorporating mitigation and adaptation approaches into broader development plans. Hussein, (2024) highlights the importance of government support for climate-smart farming and its role in mitigating the effects of climate change on food security, urging farmers to embrace it for greater climate resilience and productivity.

Social and economic aspect of the climate-smart practices is also key. Saran et al., (2022) demonstrate that interventions focused at women farmers can raise resilience by addressing social and economic barriers to resilience. A good example of this is by locally adapted climate-smart practices for enhancing community participation, decision-making and resource access, as reported by Mensah et al., (2021) in Ghana, where women are largely empowered in these practices. These interventions are designed to foster social justice and environmental sustainability, highlighting the need for a holistic approach that addresses both environmental and socio-economic dimensions of smallholder resilience.

2.6 Summary of the literature

The literature on climate-smart agricultural practices highlights mixed farming, agroforestry, and improved crop varieties as central strategies for enhancing smallholder resilience. Mixed farming is often mentioned as having multiple benefits including generating income diversification, ecological efficiency, and adaptability in resource-limited environments (Bhattacharyya et al., 2020; Gottschalk, 2020). Agroforestry has positive impacts on soil health, biodiversity and carbon sequestration, but adoption is often hindered by insecure land tenure, long gestation periods and other challenges (Musafiri et al., 2022). Crop varieties that are better adapted to climate change, such as drought-tolerant and resistant varieties, provide technological solutions for stabilizing yields, but this is not being adopted universally, with input costs and institutional barriers limiting their use (Diro et al., 2022). These practices are collectively acknowledged as effective practices for building adaptive capacity, although they are differently effective in local contexts and environments. Yet, there is a lack of understanding of the synergistic and context-specific impact these practices have on resilience, specifically how smallholder farmers in rural settings such as Omoro District in the rural districts of Ghana adapt and assimilate these climate smart agricultural practices under institutional, socio-economic and ecological constraints, which this study aims to explore.

Resilience in smallholder farming is not only about coping with shocks, but also the ability to anticipate, absorb and adapt to climatic, market and socio-political disturbances (Fan et al., 2021; Meuwissen et al., 2019). Resilience in practice is managing production risk by diversifying and conserving resources, protecting income by participating in value chain and financial instruments, or, in some cases, taking advantage of carbon markets. Diversifying crops, for example, not only helps to minimize yield variability, but can also offer nutritional and market advantages (Birthal & Hazrana, 2019). In the same way, income stability is strengthened through measures that support farmers' livelihoods in times of stress conditions, including providing insurance, microfinance, and skills training (Ha et al., 2020; Williams et al., 2020). These dimensions, in combination, highlight the ecological, economic and social aspects of resilience, which are, at least in part, dependent on institutional support, rather than on on-farm practices. While there have been many contributions in these areas, there remains an important need to understand the interactions between them, how they can be best adopted and scaled in a way that is effective, and how institutional support should be structured to achieve this. The gap is that the institutional support that can be done to promote these practices in a holistic manner, especially in Omoro District, is not well explored.

Resilience and climate-smart agricultural practices are interlinked because they can both help to lower risk and create income opportunities or spaces to adapt. Mixed farming offers reduced reliance on a single livelihood, and enhances food security during climate shocks (Baker et al., 2023; Gottschalk, 2020). In addition to soil and water conservation, agroforestry also offers farmers a source of income from timber, non-timber products and also qualifies them for carbon credit benefits if these are available (Baffour-Ata et al., 2023). Crop varieties that are more drought-tolerant and withstand pests also increase stability, as do varieties that are climate-smart (Radeny et al., 2022). Yet, research highlights that transformative potential of these practices is achieved through supportive policies, extension services and inclusive market systems (Bekuma, 2024; Tumushabe et al., 2023). Although this knowledge is expanding, the available studies have been general and are specific to countries or regions based and have not provided detailed empirical evidence of the adoption and adaptation of these practices in particular rural contexts like Omoro District.

The study makes a contribution by investigating the context of the relevance, and dynamics of adoption of climate-smart agricultural practices (mixed farming, agroforestry and improved crop varieties) in the smallholder farming systems in Omoro District. It also reviewed the potential impact of these practices to improve resilience within the Climate Victims to Climate

Heroes project. Climate-smart agriculture has the potential to contribute to the resilience of smallholder farmers in resource-constrained regions, and this study sought to fill the gap in knowledge on this topic.

CHAPTER THREE

METHODOLOGY

3.0 Introduction

This chapter discusses the research methodology in detail, including the research design, the study population, sample size and sampling techniques, data collection method and tools, data quality control, ethical consideration, administrative procedures, data analysis approach, limitations and delimitations of the study.

3.1 Research Design

According to Sharma et al., (2023), research design refers to a structured framework which guides the process involved in collecting and analyzing data and interpreting it. It provides a roadmap to put all the elements of the study together and examine the research problem in a coherent way. The research design is the plan for conducting the study, which includes the selection of the participants, instruments to be used for measuring, and the techniques to be employed in the process of analyzing the data.

This study adopted a quasi-experimental research design, which was used to investigate the link between climate-smart agriculture and resilience to climate variability of smallholder farmers in Omoro District. Quasi-experimental design is an empirical method to evaluate the causal effect of a program non-randomly assigned. It is not a fully randomized experiment but is more practical in situations that are not ideal where randomization may be impractical or unethical. In most cases, an experimental or treatment group is being involved in the intervention, while a control or comparison group is not, which makes it necessary to control for possible confounders using statistical controls, matching, or pre- and post-test measurements, as done in the examples above (Aussems et al., 2011; Gopalan et al., 2020; Maciejewski, 2020).

The natural environment of the “From Climate Victims to Climate Heroes” project makes random allocation of participants in this study impossible. The quasi-experimental design enables the project beneficiaries to be compared with the non-beneficiaries to assess causal relationships in the real context.

This study used a quantitative data collection method to come up with measurable data about climate-smart agricultural practices and climate resilience of smallholder farmers. Quantitative

methods are available for numerical analysis, which gives a structured approach to understanding complex phenomena in the social world and to generalizing results (Vivek & Nanthagopan, 2021). This method allows the participants' point of view to be represented and the data to be grounded in their lived experiences.

3.2 The Study Area

The study was carried out in the Omoro District in the Acholi sub region of Northern Uganda, in the sub counties of Koro, Bobi and Lakwana, which forms part of the activities of the project, 'From Climate Victims to Climate Heroes' project implemented by Solidaridad. The study area was chosen due to the escalating climate resilience issue that is confronting the rural farm communities of the district.

Omoro District is located at 02°35'N 32°22'E, and shares boundaries with Gulu District to the north, Pader District to the east, Oyam District to south and Nwoya District to the west. The district is administered by three town councils (Opit, Odek and Lalogi) and 12 sub counties (Bobi, Acet, Lakwana, Moroto, Orapada, Awach, Palaro, Ongako, Abuga, Tochi, Koro and Lamogi). District governance is led by an elected Local Council Five (LCV) Chairperson and political representation at national level is done by directly elected Members of Parliament in Omoro County.

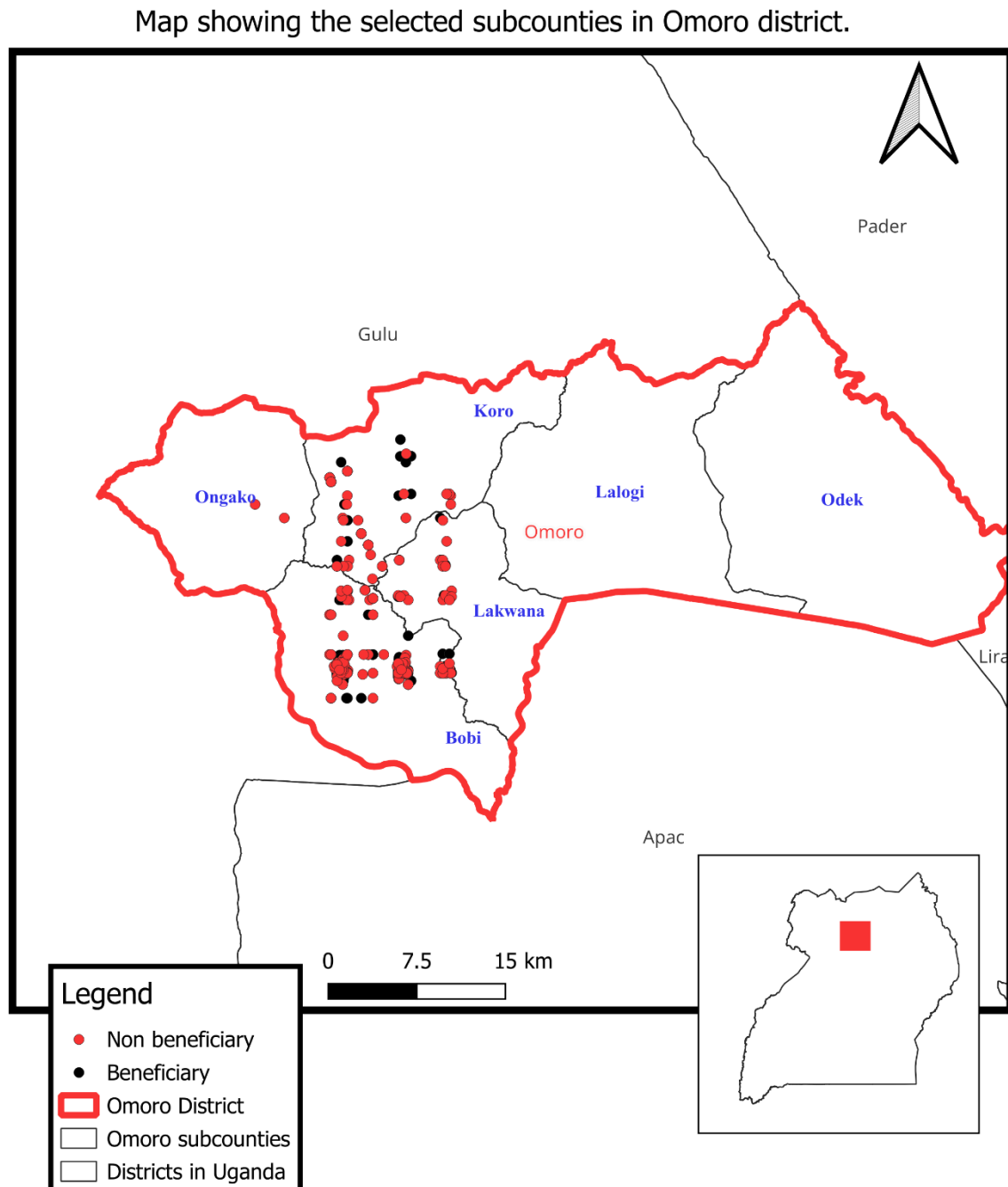
The district has a tropical savannah type of climate with two distinct seasons of dry and wet. The dry season is from November to March and the hottest and driest months are January and February. The average temperatures for the day are between 24°C and 33°C, but can exceed 35°C during periods of extreme heat. The rainy months are likely to be cooler, with temperatures dropping nearer to 20°C.

The rainfall regime in the district is very seasonal ranging from about 800 mm to 1500 mm per year. The main rainy season is from April to October/early November and is generally the heaviest between June and September. The reliance of the district on this one prolonged rain is, therefore, very high in agriculture.

The last few years in Omoro District have seen more and more unpredictable weather patterns, such as frequent droughts and delayed rains that often result in extended dry periods. The impacts of these changes have lowered agricultural productivity, especially of staple food crops like maize, soybeans and green vegetables, which are key to food security and household incomes. Omoro is a largely rural district, which is highly susceptible to variations and shocks

of the environment, making it a suitable area for testing the resilience of the communities and potential adaptation interventions to climate variability under the project.

Figure 2: Map of the study area



Source: Primary Data, 2025 (QGIS)

3.3 Study Population

A study by Willie, (2024) defines the target population as the specific group of people, objects, or events that a researcher intends to study and draw conclusions from. This population

includes all subjects that meet the criteria outlined in the research objectives, and typically a representative sample is selected for practical data collection. Clearly defining the target population ensures that study findings can be widespread to the broader group, enhancing the relevance and applicability of the study.

For this study, the population comprised of 47,275 farming households in Omoro District, as reported by Omoro DLG, (2023). Thus, the total population targeted for this research was 47,275 farming households these included the beneficiaries of the project and the non-beneficiaries.

3.4 Sample Size Determination

The sample size was determined using the Krejcie and Morgan Table, a widely recognized and scientifically validated method for sample size determination, particularly suitable for large populations (Krejcie & Morgan, 1970). Based on this method, a sample size of 381 households forms the respondents who participated in the study. This sample size was drawn from a total population of 47,275 smallholder farmers. This allowed for efficient use of resources during data collection while still maintaining statistical validity. The sample size of 381 respondents was adequate for ensuring reliable and meaningful results in the context of this research. The sample size comprised of 181 beneficiaries and 200 non-beneficiaries.

Sample size classification

Table 1: Classification of the participants

S/N	Category	Sample	Sampling technique
1	Beneficiaries	181	Stratified random sampling
2	Non-beneficiaries	200	Simple random sampling
	Total	381	

Source: Primary Data, 2025

3.5 Sampling techniques

3.5.1 Probability sampling techniques

Probability sampling means sampling techniques are used to ensure that every member in the population has a known and finite chance of being in the sample. The random selection process is used to make sure the sample is representative of the population and that conclusions reached will be more reliable and generalizable (Adekeye & Apeh, 2019; Taherdoost, 2016). Typically, the two sampling methods used include simple random sampling and stratified sampling in

order to reduce bias and ensure that each of the different subgroups in the population is represented.

For this study, probability sampling was utilized to assure that everyone in the population had an equal chance of being selected. This increased the representativeness of the sample, thereby enhancing the accuracy and statistical reliability of the findings and results, and giving the findings a wider representativeness of the population of the smallholder farmers in Omoro District.

3.5.1.1 Stratified random sampling

The use of stratified sampling was helpful as the smallholder farmer beneficiaries were sub-grouped according to their practices. Strata ranged from size of farm, types of crops or geographic zones in the sub-county. These strata were used to group the population and a random sample was taken from each sub population. The number of samples taken did not exceed the number of persons in the group and all the groups were represented. Stratification has been suggested by Taherdoost, (2016) for studies that are likely to have distinct characteristics for each group or subset of groups.

3.5.1.2 Simple random sampling

Both the beneficiary and non-beneficiary smallholder farmers were sampled using simple random sampling for the study. The names of the beneficiary farmers in the selected sub counties of Koro, Bobi and Lakwana were first obtained from the project records and put into a sampling frame. All the farmers on the list were allotted a number and the respondents were selected by random number generation technique. This ensured equal and independent likelihood to be a part of the study sample for all beneficiaries farmers.

Likewise, the non-beneficiary smallholder farmers were also sampled using simple random sampling from the farmer registers from the villages and community lists of households in the same study areas. A number of farmers who did not participate in the project were identified and were numbered, and then they were randomly selected using random number generators, physical randomization methods, etc.

This helps to reduce selection bias and allow every farmer to have equal chance of being selected into the sample (Adekeye & Apeh, 2019). Simple random sampling was especially significant to produce unbiased data regarding the adoption of the climate-smart agricultural practices and level of resilience to climate variability as well as livelihood outcomes of project

beneficiaries and non-beneficiaries. It also increased the study's reliability and generalizability of findings.

3.5.2 Non-Probability Sampling Techniques

Non-probability sampling is a sampling in which not all individuals within the population have a known, and equal, chance of being selected. It's not always done by random choice, and is therefore very useful for exploratory studies or qualitative research. Although this approach is generally more convenient and cost-effective, it also increases the likelihood of selection bias and reduces the generalizability of the results (Stratton, 2023).

Non-probability sampling is appropriate for this study because it allows for the selection of participants who are involved in climate adaptation activities in a purposeful manner. This focused approach has benefits for gaining context-specific and detailed insights, particularly from smallholder farmers who are at the heart of resilience outcomes. When the study goal is to investigate a complex social phenomenon in which depth of information is more important than representativeness of the sample, such techniques are of particular benefit as Rahman, (2023) notes.

3.5.2.1 Purposive sampling

The study area was identified through purposive sampling because of the challenges faced with climate change in the district which directly impact on the agricultural livelihoods. The district was also chosen due with its being one of the areas where the “From Climate Victims to Climate Heroes” project by Solidaridad was being implemented, thus being relevant to the goals of this study. Purposive sampling was also used to identify the beneficiaries of the project.

According to Rahman, (2023) purposive sampling is ideal for selecting participants with the most relevant insights on a topic. For this study it ensured that those with firsthand knowledge of climate-smart agricultural practices gave the depth of information needed, providing rich qualitative data.

3.6 Data collection methods

Survey questionnaire

According to Taherdoost, (2021), questionnaires are the instruments that are designed and structured in a predetermined manner to collect quantitative data from a large number of respondents. This way, it is very efficient in terms of accessing a lot of participants and it can

be statistically analyzed the data gathered. For primary data collection, the study used structured questionnaires for information from smallholder farmers. The approach adopted by Ikart, (2019) is to create a questionnaire that reflects quantitative data and matches the objectives.

3.7 Data collection instruments

Questionnaire

The questionnaires comprised structured questions that sought to gather quantitative information from smallholder farmers on their livelihood outcomes, household adaptation strategies and climate smart agriculture practices. Measurable statistical data as well as detailed views of the respondents were gathered with a blend of closed ended and open-ended questions on the instruments. Both closed ended and open-ended questions proved helpful for quantitative analysis by generating standardized responses from the respondents, and for explaining and elaborating their experiences and perceptions, respectively.

The questionnaires were pretested with a pilot study in a small number of farmers in an area having similar characteristics to the study area, but not included in the sample. The pretest was used to evaluate questions for clarity, relevance, consistency and reliability. The pilot exercise facilitated the identification of language and instructional clarity, repetition in questions, ambiguity and gaps in the instrument. The questionnaires were pre-tested to obtain feedback, which was used to make the necessary changes to improve the validity and reliability of the questionnaires before they were finally administered.

Research assistants were hired and trained prior to the start of fieldwork to improve the quality and consistency of data collection. The training included the aim of the study, ethical issues, interviewing techniques, handing out of questionnaires, interpreting questions, and how to talk to the interviewees. Research assistants were also trained to remain neutral, be confidential, and to ask informed consent and record the answers truthfully. The training sessions were followed by practical demonstrations and mock interviews to get the research assistants familiar with the data collection tools and procedures.

3.8 Reliability and validity

3.8.1 Validity

Validity is the appropriateness and accuracy of a research instrument in measuring the specific concepts or parameters that it is designed to measure. Valid instrument ensures that the data

collected is a true representation of what is being investigated, and increase the credibility of the research results (Bajpai & Bajpai, 2014). The study has ensured validity through writing structured questionnaires, which are closely related to the research objectives. The instruments were pretested for clarity, relevance and effectiveness and also reviewed by content by academic supervisors who are experts in the field before the instruments were used for actual data collection.

3.8.2 Reliability

For quantitative data reliability defined as the consistency of an instrument to produce consistent results in the same conditions and same subjects was discussed. The Cronbach's Alpha Reliability Coefficient test was used to determine the reliability of the types of scales. The reliability coefficient of 0.70 or above is usually acceptable as suggested by Davison & Smith, (2018). A threshold of 70% was used for the study, and results equal to or greater than this were deemed acceptable.

Table 2: Reliability test results (Cronbach's Alpha)

Measure	Value
Average Inter-item Covariance	0.0188
Number of Items in the Scale	68
Scale Reliability Coefficient (Cronbach's Alpha)	0.7334

Source: Primary Data, 2025

The scale reliability coefficient Cronbach's alpha is 0.7334 which is acceptable for a set of items in the questionnaire. In the context of social science research, a Cronbach's Alpha value of > 0.70 is generally regarded as acceptable, indicating that the items were well correlated with each other and measure the same construct in this instance, climate-smart agricultural practices and resilience.

The average inter item covariance value of 0.0188 indicates that there is a relatively low but consistent correlation among the items, as is common in scales consisting of a large number of different items. This further confirms that they are not repetitive, but rather are closely enough related to make a valid scale. The reliability test found that the instrument used in this study was appropriate for measuring the variables intended and can give confidence data that are collected are reliable.

3.9 Data Analysis

This study used descriptive and inferential statistics to analyze the data, based on the three main research objectives of the study. Data was analyzed and processed using the STATA version 15. The goal is to determine the extent of the adoption of climate-smart agricultural practices and determine the level of farmer resilience and the relationship between farmer resilience and adoption.

For the first objective, which involved understanding the extent of adoption of climate-smart agricultural practices, an independent samples t-test was then conducted to assess the level of adoption for the farmers in the treatment group (“From Climate Victims to Climate Heroes” project) and the control group (those not involved in the project). This analysis assisted in identifying if the project has led to a greater uptake of climate-smart practices by smallholder farmers.

In the second objective, assessing the resilience to climate variability of smallholder farmers, an independent samples t-test was then conducted based on several factors including production risk, income security, and access to the carbon market.

Propensity score matching was used to investigate the relationship between the adoption of climate-smart agriculture and resilience to climate variability among smallholder farmers. The project is not randomized but is an active program, which could lead to selection bias. Propensity score matching corrects this by matching farmers from the treatment and control groups who are similar based on the observed characteristics. This helped to make the comparisons between group A and group B more balanced.

The first step in PSM was to estimate the propensity score, which represents the probability that a farmer would be climate smart based on the characteristics they have observed. These scores were determined by probit regression. Let Z be an indicator of the farmer being a beneficiary (1 if they are a beneficiary; 0 if not) and X be a vector of covariates. The propensity score is given as:

$$e(X) = \Pr(Z = 1 | X)$$

This probability was estimated using the probit regression equation:

$$\text{probit}(e(X)) = (\beta_0 + \beta_1 \cdot X_1 + \beta_2 \cdot X_2 + \beta_3 \cdot X_3 + \beta_4 \cdot X_4 + \beta_5 \cdot X_5)$$

Whereby: $X_1 = \text{Age}$

- X_2 – *Sex*
- X_3 – *Marital status*
- X_4 – *Household size*
- X_5 – *Education level*

The propensity score was then expressed as:

$$e(X) = \Pr(Z = 1 | X) = \frac{1}{1 + \exp[-(\beta_0 + \beta_1 \cdot X_1 + \beta_2 \cdot X_2 + \beta_3 \cdot X_3 + \beta_4 \cdot X_4 + \beta_5 \cdot X_5)]}$$

Once the propensity scores were estimated, treated and untreated farmers were matched based on these scores. This ensured that comparisons are made between individuals who are similar in all observed characteristics, except for treatment status. The study used nearest neighbor matching, which pairs each treated farmer with the untreated farmer whose propensity score is closest. Other methods such as radius matching and kernel matching were also applied.

After matching, the study estimated the Average Treatment Effect on the Treated (ATT) to assess the effect of adopting climate-smart agriculture on farmer resilience. The ATT measures the average difference in outcomes between treated and matched control farmers and is defined as: $ATT = E[Y_1 - Y_0 | Z=1]$

Where Y_1 is the outcome if the farmer was part of the project and Y_0 is the hypothetical outcome if the same farmer wasn't part of the project. This estimation focused on three outcome variables production risk, income security, and access to carbon markets. Matching ensured that observed differences in outcomes are less likely to be driven by pre-existing differences between adopters and non-adopters, and more likely to reflect the true effect of the intervention.

The analysis relied on three diagnostic tests which were the key assumptions. Three diagnostic tests were used for the analysis and were the key assumption. First, a graphical approach was applied to verify the common support assumption, which entailed checking for overlapping support for the treated and control groups. Secondly, a t-test was performed to check for significance differences in the matched covariates between the two groups, and no significant difference was found for the balance property. Third, sensitivity analysis (rbounds and mhbounds) was performed to examine the robustness of results to possible unobserved confounding.

3.10 Data Presentation

The data was visually presented through graphs and tables. The visual aids were developed in the form of Stata and excel sheets which presented the numerical data in a clear and concise manner. This approach mixed quantitative analyses to give a summary of the research findings.

3.11 Ethical Considerations

In a study in which the human subject is involved, ethical considerations are of paramount importance. To maintain the highest ethical standards in the research several key steps were taken, these include:

A formal introductory letter from the Faculty of Business and Development Studies was used for approval and authorization. This is for validation of the research and to allow access to the participants, the study would be recognized and supported by the academic institution. A letter from Omoro District was also obtained which gave a permission to the researcher to conduct the research in the area.

An important aspect of the ethical considerations was informed consent. Extensive explanation of the purpose, procedures and potential risks of the study were made to participants. Such transparency is essential to make participants fully aware of their participation. Consent was obtained from each participant before any data gathering started and confirmed their understanding and consent to participate in the study.

Participants' privacy was ensured by maintaining confidentiality and anonymity. All collected data was anonymized and personal data was properly stored in a secure place and could only be accessed by authorized persons. Specific data was redacted from the research report, additional safeguarding of participant confidentiality and protection of the individual's identity.

The researcher stressed the voluntary participation. Participants were told that participation was voluntary, and that withdrawing from the study would result in no adverse consequences. This strategy kept participants' autonomy intact, and made sure that participation is on an informed consent basis.

3.12 Limitations and delimitations of the study

The study was constrained by certain limitations and delimitations, as follows:

Poor transport and network coverage in some areas posed a challenge to reach the respondents and to collect geographic coordinates in these areas. This was overcome by arranging

appointments with respondents before the investigation, which enabled planning, and even hard to reach areas were included in the investigation.

Language barriers were also a constraint as there were sometimes difficulties in engaging with participants. This was done by employing research assistants who were proficient in the local language. This allowed respondents to comfortably express themselves and at the same time reducing the risk of misinterpretation.

Limitation was also the time period as the study took place during a specific time, thus it did not include the seasonal variations of the farming practices. The delimitation was to concentrate data collection on the main agricultural season to ensure that responses were to the current and relevant experiences.

In the same way, the scale of the study and the use of more sophisticated tools was limited by the resources. This was done by taking a representative sample and using cost effective but reliable methods.

Moreover, the study relied on self-reported information, which posed potential risks of recall bias or interpretation bias. The delimitation was to triangulate participants' accounts with direct observation and secondary data as much as possible.

Environmental conditions also presented challenges as often during the rainy seasons, and with other weather events, data collection and respondents' availability was hampered. To cope with this, the research team rescheduled and made some flexible arrangements to suit the farming commitments of the respondents.

CHAPTER FOUR

RESULTS

4.0 Introduction

The chapter presents the result of the study with regards to the three research objectives. It also presents the findings on the model variables. The study examines the level of farmers' climate-smart agricultural practices (CSA) uptake among smallholder farmers in Omoro district, their resilience in the face of climate related challenges, and the linkages between smallholder farmers' uptake of the climate-smart agricultural practices and their resilience in the context of climate related challenges.

4.1 Model variables

The study examined a set of variables considered relevant to understanding the relationships within the model. These variables reflect the demographic, farming and production and income dynamics. There are some variables that are binary, showing whether or not a characteristic or practice is present, and others that are categorical, showing the degree to which, the characteristic or practice has changed. These are the descriptions and measurements for each variable found in table 3 below.

Table 3: Model variables

Variable	Category	Overall		Non-Beneficiaries		Beneficiaries	
		Freq.	Percent	Freq.	Percent	Freq.	Percent
Sex of farmers	Female	104	29.89	68	37.36	36	21.69
	Male	244	70.11	114	62.64	130	78.31
Education level	Never attended school	33	9.48	21	11.54	12	7.23
	Attended school	315	90.52	161	88.46	154	92.77
Marriage status	Not married	87	25	45	24.73	42	25.30
	Married	261	75	137	75.27	124	74.70
Production level	Very low reduction	4	1.15	2	1.10	2	1.20
	Low reduction	42	12.1	38	20.99	4	2.41
	Unchanged	88	25.36	74	40.88	14	8.43
	High increase	204	58.79	64	35.36	140	84.34
	Very high increase	9	2.59	3	1.66	6	3.61
Income level	Very low reduction	3	0.86	3	1.66	0	0.00
	Low reduction	30	8.65	28	15.47	2	1.20
	Unchanged	79	22.77	73	40.33	6	3.61
	High increase	225	64.84	73	40.33	152	91.57
	Very high increase	10	2.88	4	2.21	6	3.61
Carbon market access	No	311	90.67	175	98.87	136	81.93
	Yes	32	9.33	2	1.13	30	18.07
Mixed farming	No	19	5.49	19	10.44	0	0
	Yes	327	94.51	163	89.56	164	100

Agroforestry	No	23	6.61	23	12.64	0	0
	Yes	325	93.39	159	87.36	166	100
Climate-smart crop varieties adoption	No	25	7.25	23	12.85	2	1.20
	Yes	320	92.75	156	87.15	164	98.80
Descriptive	Age	346	40.60(11.80)	181	38.92(12.37)	165	42.44(10.88)
	Household size	349	5.73(2.31)	183	5.79(2.46)	166	5.68(2.14)

Source: Primary Data, 2025

As revealed in the above table 3, there is a clear gender imbalance among farmers, particularly in terms of their participation in the project. The number of female farmers out of all the farmers surveyed is 29.89% while the male farmers are 70.11%. The percentage of female farmers among the non-beneficiaries is also higher at 37.36%, as compared to 62.64% for the male farmers. But, among the beneficiaries, 21.69% are female and 78.31% are male. This implies that the male farmers are getting a much greater benefit from the intervention. Low female participation among the beneficiaries reflects gender-based barriers to access, awareness, eligibility, or other gender based structural constraints to women's inclusion.

The education level of the farmers is relatively high, as 90.52% of the total number of farmers are in school, while 9.48% never attended school. 88.46% of non-beneficiaries and 92.77% of beneficiaries had been attending school when broken down by group. However, 11.54% of non-beneficiaries and 7.23% of beneficiaries had never attended school. This indicates that education could be a potential factor in access to and success in a program, perhaps related to the farmer's capacities to access information, fulfill the program's requirements, or implement new practices.

Marital status is roughly the same for all groups. The overall frequency of farmers being married is 75%, while 25% are not. 75.27% of the non-beneficiaries are married, while 24.73% are unmarried. 74.70% of the beneficiaries are married, 25.30% are not married. These minor differences indicate that marital status does not seem to have an impact on participation in the program.

Differences are greater when considering changes in output. For all farmers, 1.15% had a very low reduction in production, 12.1% had a low production reduction, 25.36% had no production reduction, 58.79% had a high increase in production and 2.59% had a very high increase in production. A dramatic difference is seen if the figures are broken down by group. Only 35.36% of non-beneficiaries indicated a high rise in production and 1.66% indicated a very high rise in production. Forty percent and eight points (40.88%) did not change, and 22.09% of them decreased (20.99% decrease was considered as low, and 1.10% decrease as very low). On the

other hand, 84.34% of beneficiaries reported a high level increase in production, 3.61% reported a very high level increase in production, while 8.43% reported no change in production. Very few beneficiaries experienced a reduction (1.20% very low and 2.41% low). This is clearly showing that there is a positive relationship between the participation in the program and agricultural production.

The same goes for income. Overall, 64.84% of the farmers experienced a high increase in their income, 2.88% experienced a very high increase, 22.77% experienced no changes in their income, 8.65% experienced a low reduction and 0.86% experienced a very low reduction. Within this non-beneficiary group, 40.33% experienced a high increase and 2.21% experienced a very high increase. However, 40.33% saw no change in income, and 17.13% experienced income reductions (15.47% low, 1.66% very low). Of the beneficiaries, the picture was starkly different with 91.57% reporting a very high increase in income, 3.61% a very high increase, and 3.61% no change at all. Only 1.20% of this group were reporting low reduction in their income and none were reporting very low reduction. The findings are very strong in supporting that beneficiaries have significantly higher chances of experiencing a positive income change, which further bolsters the program's economic impact.

The overall access to carbon markets is low, with significant differences between the groups. Of all the farmers, 9.33% reported that they have access to it, and 90.67% did not. Access was negligible at 1.13%, while 98.87% of those without benefits were not involved in access. Within beneficiaries, however, 18.07% (81.93%) said that they had access to it. While the overall figure remains low, beneficiaries are significantly more likely to be approached about carbon market opportunities, which may indicate increased linkages with environmental or climate-smart activities.

In terms of farming practices, all the farmers are widely using mixed farming. Overall 94.51% of farmers reported that they practiced mixed farming while 5.49% did not. The proportion of non-beneficiaries engaged in mixed farming was 89.56% while 10.44% were not. Conversely, all the beneficiaries (100%) said they engaged in mixed farming. This means the program can either be encouraging or attracting farmers already on more diverse and resilient farming systems.

Adoption of agroforestry is also high at 93.39% with 6.61% of all farmers not practicing agroforestry. Of the non-beneficiaries, 87.36% practice agroforestry whereas 12.64% do not. 100% of beneficiaries practice it. This is similar to mixed farming, indicating that agroforestry

can be a necessity or a selection factor, or be a consequence of support offered to a program. The full adoption is a clear sign of the importance of agroforestry for sustainable agriculture interventions by beneficiaries.

The results reveal that the adoption of climate-smart crop varieties is very high. In all, 92.75% of the farmers used these improved varieties while 7.25% did not use them. Of those not receiving benefits, 87.15% have used them, with 12.85% not. Beneficiaries also have higher adoption rates with 98.80% using climate-smart varieties, and 1.20% not using them. This indicates high endorsement or encouragement of these practices, and increased likelihood of adaptive technologies for improving resilience and productivity.

In the complete sample, the mean of farmers' ages is 40.60 years, and the standard deviation (SD) of those ages is 11.80 years. This means that most farmers are in their early 40s, but there is considerable variation many farmers are either younger or older than this average. A standard deviation of almost 12 years implies a large age gap among the farming population, ranging from younger adults (probably 20s) to older adults (possibly 60s). Average Age = 38.92 years, with a standard deviation of 12.37 years, for non-beneficiaries when broken down by group. This suggests that non-beneficiaries tend to be a bit younger, and that there is a broader spread in age within this group some may be quite young, and others older, but with more variation overall. The beneficiaries are, on the contrary, on average considerably older (42.44 years) with a somewhat less standard deviation (10.88 years). This implies that the beneficiaries' age range is narrower, the majority at the age of early 40s. What this means: Farmers who are benefiting from the program are older than those that are not. This may reflect a difference in qualifications or access to the program based on age, perhaps on experience, land ownership or networks, that is, older farmers might be more likely to qualify or access the program. It could be a result of younger farmers' unfamiliarity with the program, or they may be less engaged in formal agricultural activities, or there may be more barriers to their entry. A smaller range of beneficiaries also indicates that the program may be achieving a more targeted or consistent age distribution of beneficiaries.

The average size of a household is 5.73 with a standard deviation of 2.31. This reflects the common household size in rural areas in which family labour plays an important role in farming that ranges from 3 to 8 persons per farm household. The average size of the household does not differ significantly between beneficiaries and non-beneficiaries, with the latter experiencing an average of 5.79. The standard deviation is 2.46 which means there is a greater spread in the

sizes of the households within this group. There can be some non-beneficiary households that are very small, and others that are relatively large. The average size of the beneficiary household is slightly below the average of 5.68, and the standard deviation of 2.14 indicates that most beneficiary households are not that far from average, and have less variation. What this means: No significant difference in household size between the two groups. Households of beneficiaries and non-beneficiaries are of similar size. Based on this, it is suggested that the program may not be related to household size and thus does not necessarily benefit the farmer. It also suggests that most farmers are operating moderately sized farms, whether or not they are included in a program, and perhaps using family labour or the division of labour.

4.2 Adoption of climate-smart agricultural practices among the smallholder farmers

This section presents findings on the level of adoption of climate-smart agriculture amongst smallholder farmers. The analysis focuses on the key practices that include mixed farming, agroforestry and the use of climate-smart crop varieties. These are seen as relevant practices for reducing vulnerability to climate change. The findings indicate the level of adoption by farmers and offer insights into trends and determinants of adoption.

Table 4 The level of adoption of climate-smart agricultural practices among the smallholder farmers

CSA practices	Beneficiaries	Non-beneficiaries	t-statistic
Mixed farming	1.00	0.90	-4.36
Agroforestry	1.00	0.87	-4.89
Climate-smart crop varieties	0.99	0.87	-4.23

Source: Primary Data, 2025

The following table 4 shows that smallholder farmers who have benefited from an intervention have incorporated climate smart agriculture practices more than those who did not benefit from the intervention. Three practices were evaluated: mixed farming, agroforestry, and climate smart varieties of crops.

In the mixed farming practice, all the beneficiaries indicated adoption with a mean of 1. In contrast, the average among non-beneficiaries is about 0.90. The t-statistic is -4.36, which means that this difference is statistically significant. The difference between the group of beneficiaries and the group of non-beneficiaries is statistically significant at the 5% level ($p < 0.05$) when the absolute value of the t-statistic is larger than 1.96. In this case it is clearly true that the result satisfies that condition.

Adoption of agroforestry is also higher among the beneficiaries. All reported using the practice (mean = 1), while the mean for non-beneficiaries is around 0.87. The difference is statistically significant at the same condition with t value = -4.89.

Again for climate smart crop varieties, beneficiaries demonstrate a higher proportion adopting with a mean of ~0.99, versus 0.87 for non-beneficiaries. The t-statistic is -4.23, indicating that the difference between the two is statistically significant.

The findings indicate that the intervention has a strong association with increased uptake of climate-smart agricultural practices. With statistically significant differences in each, beneficiaries are more likely to perform all three practices than are non-beneficiaries. This reinforces the finding that the intervention has contributed to smallholder farmers' adoption of climate-smart agricultural practices.

4.3 Resilience to climate variability of the smallholder farmers

This section presents project findings on the level of resilience to climate variability that is how well smallholder farmers are able to respond to, and bounce back from the effects of climate change. Indicators for measuring resilience include production risk, income levels, and access to carbon market. The analysis offers a general description of the situation of the farmers in coping with challenges and the roots for either strengthening or weakening their resilience.

Table 5: The level of resilience to climate variability of the smallholder farmers

Resilience	Beneficiaries	Non-beneficiaries	t-statistic
Production level	3.87	3.15	-9.48
Income level	3.98	3.26	-10.59
Access to carbon market	0.18	0.01	-5.62

Source: Primary Data, 2025

The results presented in the table 5 above clearly reveal the difference in resilience outcomes between smallholder farmers who benefit from the project and those who do not benefit from the project. These differences are quantified in terms of the following three indicators: production level, income level and access to the carbon market.

The average score of the beneficiaries is 3.87 compared with 3.15 of non-beneficiaries at production level. The t-statistic value is minus 9.48, which means that there is a statistically significant difference - that is, beneficiaries are having higher production levels. This means that the project is helping to make agricultural production more efficient.

The difference is even starker when considering income level. The average income score is 3.98 for beneficiaries and 3.26 for non-beneficiaries. The t statistic value is -10.59, further supporting the result that this difference is statistically significant. This discovery indicates that the project is linked to the increase in income level of smallholder farmers.

Both groups have a lower access to the carbon market, however the difference is still significant. The average access score for beneficiaries is 0.18, whereas it is only 0.01 for non-beneficiaries. This difference is also statistically significant as the t-statistic value is -5.62. While access is generally low, beneficiaries are much more likely to be taking advantage of the opportunity in the carbon market than non-beneficiaries.

Overall, the findings indicate that the intervention is positively correlated to increased production, income and participation in the carbon market among smallholder farmers. The significant differences observed indicate the possible effect of the project on the resilience of the smallholder farmers.

4.4 Participation in the project

4.4.1 Determinants of participation in the project

This section examines the factors that influence smallholder farmers' participation in the "From Climate Victims to Climate Heroes" project. The analysis considers demographic characteristics, socioeconomic conditions, and farming practices that may increase or decrease the likelihood of joining the project. Identifying these determinants helps to understand the profile of participants and provides insights into how future interventions can be better targeted to reach farmers who could benefit most.

Table 6: Determinants of participation in the project

Variable	Coef.	St.Err.	dy/dx	Std.Err.	P>z
Age	0.022	0.007	0.009	0.003	0.001
Sex*	0.39	0.158	0.158	0.061	0.009
Marital status *	-0.118	0.172	-0.052	0.069	0.451
Household size	-0.04	0.033	-0.015	0.013	0.258
Education level*	0.489	0.271	0.187	0.096	0.052
y = Pr(participation) (predict) = .47647599					

* ≈ Significant

Source: Primary Data, 2025

The results in the table 6 indicate that the average probability of a farmer being enrolled in the project is about 47.6% for a farmer with all explanatory variables being at their means. This implies that almost 50% of the farmers in the sample are likely to participate in the program, on average. The marginal effects are the change in this probability as the effecting variables change by a unit, while the others remain constant.

The participation increases with age, and there is a statistically significant effect. The chances of participation go up by 0.9 percentage points per additional year of age. The relationship is very significant with $p=0.001$. The finding indicates that elderly farmers have higher participation probability probably because of their more experience of farming, exposure to the agricultural programs and better network in the farming community.

Sex has an important effect as well. Male are 15.8 % more likely to participate than female. The gender difference in participation is statistically significant ($p = 0.009$), indicating a definite disparity between the sexes. The outcome could indicate structural challenges that prevent women from accessing agricultural programs or decision-making opportunities.

Marital status, however, does not seem to have any significant impact on participation. There is a 5.2% decrease in the odds of participating when married, although this is not significant ($p = 0.451$). So, the involvement of projects does not seem to be heavily related to marital status.

There is also a negative marginal effect of household size; a 1.5 % drop in participation per extra household member. This relationship is not statistically significant, however ($p = 0.258$) suggesting that size of the household is not a major determinant of participation decisions.

Education level has a positive and marginally significant effect. The percentage of farmers who have attended school (18.7%) is 18.7 percentage points higher than the percentage of farmers who have not attended school (12.7%). The p value is 0.052 and this is just above the typical threshold of p value of 0.05. Although not highly significant, this finding indicates that education may have an impact on participation, perhaps due to an improvement in the farmers' awareness or familiarity with the program or its requirements.

The results indicate that age, gender, and perhaps education have significant impacts on participation and that marital status and household size have no significant impacts. Age, gender, education, marital status, and household size were chosen as the covariates in the propensity score matching. These variables were chosen because they were demographic characteristics that were relevant to the study and might influence participation and results, but

not every variable was statistically significant. Their presence allowed for better balance of participants and non-participants, thus enhancing the reliability of the matching procedure. The findings also provide valuable guidance for enhancing the Outreach Strategy and for ensuring greater equity of access to the program.

4.4.2 Effect of involvement in From Climate Victims to Climate Heroes Project on the production level, income level and the carbon market access

This section presents findings the impact of the From Climate Victims to Climate Heroes Project on three outcomes: production level, income level, and access to the carbon market. The assessment contrasts participants and non-participants to see if there is any evidence of better agricultural productivity, household income and potential for carbon trading as a result of participation in the project. The results offer insight into the project's impact and benefits for farmers in terms of their economic and environmental performance.

Table 7: Propensity score matching results on the effect of involvement in “From Climate Victims to Climate Heroes” project on the production level, income level and the carbon market access

Outcome variable	Matching method	Treated	Controls	Difference	S.E.	T-stat
Production level	Nearest neighbor	3.87	3.15	0.71	0.13	5.34
	Radius caliper	3.87	3.14	0.73	0.14	5.37
	Kernel	3.87	3.12	0.74	0.08	9.24
Income level	Nearest neighbor	3.99	3.21	0.77	0.14	5.61
	Radius caliper	3.97	3.21	0.77	0.14	5.47
	Kernel	3.98	3.23	0.74	0.07	10.17
Carbon market access	Nearest neighbor	0.17	0.00	0.17	0.03	5.8
	Radius caliper	0.16	0.00	0.16	0.03	5.56
	Kernel	0.18	0.01	0.18	0.03	5.59

Source: Primary Data, 2025

The results of the propensity score matching analysis in table 7 above show a consistent and statistically significant impact of involvement in the project on production level, income level, and access to the carbon market. Each of these outcome variables is evaluated using three different matching methods: nearest neighbor, radius caliper, and kernel matching. While the exact values vary slightly across methods, the overall pattern remains the same, reinforcing the reliability of the findings.

There has been a definite positive impact of the project on the level of production by smallholder farmers. The average production of beneficiaries (treated group) is 3.87, while the average production of non-beneficiaries (control group) is 3.15 by using the nearest neighbor matching method. This means that beneficiaries generate 0.71 units more output than non-

beneficiaries. The standard error of this difference is 0.13, a measure of the precision of the estimate. The t statistic is 5.34, which is well above the usual value of 1.96, indicating that the difference is statistically significant at the 5% level. A similar result is obtained from a radius caliper matching, with beneficiaries producing 3.87 and 3.14 for controls, a difference of 0.73, but with a standard error of 0.14, and a t statistic of 5.37. Kernel matching gives averages of 3.87 and 3.12 for beneficiaries and non-beneficiaries respectively and it shows a slightly larger difference of 0.74 and a smaller standard error of 0.08, which leads to an even higher t-statistic of 9.24, indicating very high statistical confidence in this estimate. The results are always the same: In all methods, it can be seen that the project increases production by approximately 0.7 units.

For income level, the results indicate a similar situation. Nearest neighbor matching estimates 0.77 units of difference between the earnings of beneficiaries and non-beneficiaries, with an average difference of 3.99 units. The standard error here is 0.14 and the t statistic is 5.61, which is very statistically significant. The radius caliper method gives almost the same difference of 0.77, with a t-statistic of 5.47 with averages of 3.97 and 3.21 for beneficiaries and non-beneficiaries respectively. Averages of 3.98 and 3.23 are obtained for beneficiaries and non-beneficiaries respectively, with a slightly smaller difference of 0.74, although with a much smaller standard error of 0.07, resulting in a very high t-statistic of 10.17 for the kernel matching estimates. That means that the advantage to the beneficiaries is large and calculable precisely. These statistics indicate that the farmers involved in the project earn roughly 75% more than the others.

The results are mixed with respect to the scale effect on access to the carbon market. Nearest neighbor matching results indicate that 17% of the beneficiaries have access to the carbon market (mean of 0.17), and nearly none of the non-beneficiaries have access (mean near zero). This gives the difference 0.17 with a standard error of 0.03, and a t statistic of 5.80, which is highly statistically significant. A very similar effect is estimated with the caliper matching, and gives averages of 0.16 and 0.00 for beneficiaries and non-beneficiaries, respectively, with a difference of 0.16 and a t-statistic of 5.56. The highest difference of 0.18 with t-statistic 5.59 is shown for beneficiaries and non-beneficiaries, with the average of 0.18 and 0.01 respectively. There is a marked difference in the rate of farmers' participation in carbon markets before and after their involvement in the project, suggesting that the project has a high impact on participation in carbon markets.

In the three outcomes, the different values listed are the average gains or changes that farmers experienced in the project compared to those in the non-project group. More specifically, the expected gains for farmers who participated in the project are: on average 0.7 unit of production increase, 0.75 unit increase in income and a 16 to 18 percentage point increase in the likelihood of accessing the carbon market compared to farmers who did not participate in the project. The impacts of these interventions are substantial and stable under various matching strategies, suggesting that climate-smart farming has a positive impact on the resilience of the smallholder farmers.

4.5 Diagnostic tests

This section presents the diagnostic tests performed to assess the robustness and reliability of the propensity score matching results. These diagnostics were important to give confidence that the treatment effect estimates were not being affected by systematic differences between the treated and control groups based on the observable features. First, balance property assumption is checked to determine how well the covariates are balanced after matching. This was followed by a common support graph that visually shows the overlap in propensity scores between the two groups. Finally, a sensitivity analysis was performed to investigate the sensitivity of the estimated treatment effects to the impact of any unobserved factors that might affect treatment assignment and treatment effects.

4.5.1 Balance property assumption

The property of balance was examined before and after matching to determine if the covariate distributions are similar for the treatment and control groups. It is important to balance the groups to ensure that any group differences in outcomes observed can be attributed to the treatment and not to pre-existing group differences. To ensure that the matching process was successful in minimizing selection bias and that the groups were comparable for analysis, the balance property was checked in this research.

Table 8: The balance property assumption

Variable	Before matching			After matching		
	Beneficiary	Non-beneficiary	t-statistic	Beneficiary	Non-beneficiary	t-statistic
Age	42.44	38.78	-2.83	42.44	42.56	-0.09
Sex	0.78	0.63	-3.23	0.78	0.78	0.02
Marital status	0.75	0.75	0.12	0.75	0.78	-0.56
Household side	5.67	5.77	0.40	5.66	5.80	-0.59
Education level	0.93	0.88	-1.37	0.93	0.92	0.15

Source: Primary Data, 2025

Table 8 presents the balance property assumption, which compares the background characteristics of beneficiaries and non-beneficiaries before and after matching. This step was essential in because it tested whether the treated and control groups are sufficiently similar to allow for meaningful comparisons.

Before matching, there were some differences in certain characteristics between the beneficiaries and the non-beneficiaries. However, the average age of the beneficiaries was significantly different, at 42.44 years as compared to 38.78 years for those who were not beneficiaries, giving a t statistic of -2.83 and a significant difference. There was also a clear difference in the proportion of beneficiaries compared with non-beneficiaries by sex, with a higher proportion of males among the beneficiaries (0.78) than among non-beneficiaries (0.63). The t-statistic for the difference is -3.23, which is a significant difference. The findings indicate that there was age and sex bias between the two groups prior to matching.

Other variables reflected less difference prior to matching. There was no difference between the two groups as 0.75 of the farmers were married in both the groups (t-statistic value was 0.12). Household size were averaged to be 5.67 among beneficiaries and 5.77 among non-beneficiaries with no significant imbalance (t-statistic 0.40). Beneficiaries (0.93) had a slightly higher education level than non-beneficiaries (0.88), but this difference was not statistically significant (t-statistic = -1.37). This difference was not statistically significant, but was more toward the threshold than marital status and household size indicating a small imbalance.

After matching, the differences between the groups were largely eliminated. There was little difference between the average age of beneficiaries (42.44) and non-beneficiaries (42.56) and a t-statistic of -0.09 (negligible). Balance was perfect for sex with the same proportion of males in each group (0.78) and a t-statistic of 0.02 showed no difference. Balance was also good for marital status (0.75 and 0.78 for the two groups) and the t statistic was relatively small (-0.56). The same was true of household size, the value of which was also close to each other (5.66 vs. 5.80), but in this case the t value was -0.59. Lastly, education level was very similar after matching (0.93 vs. 0.92) and supported by a t-statistic of 0.15.

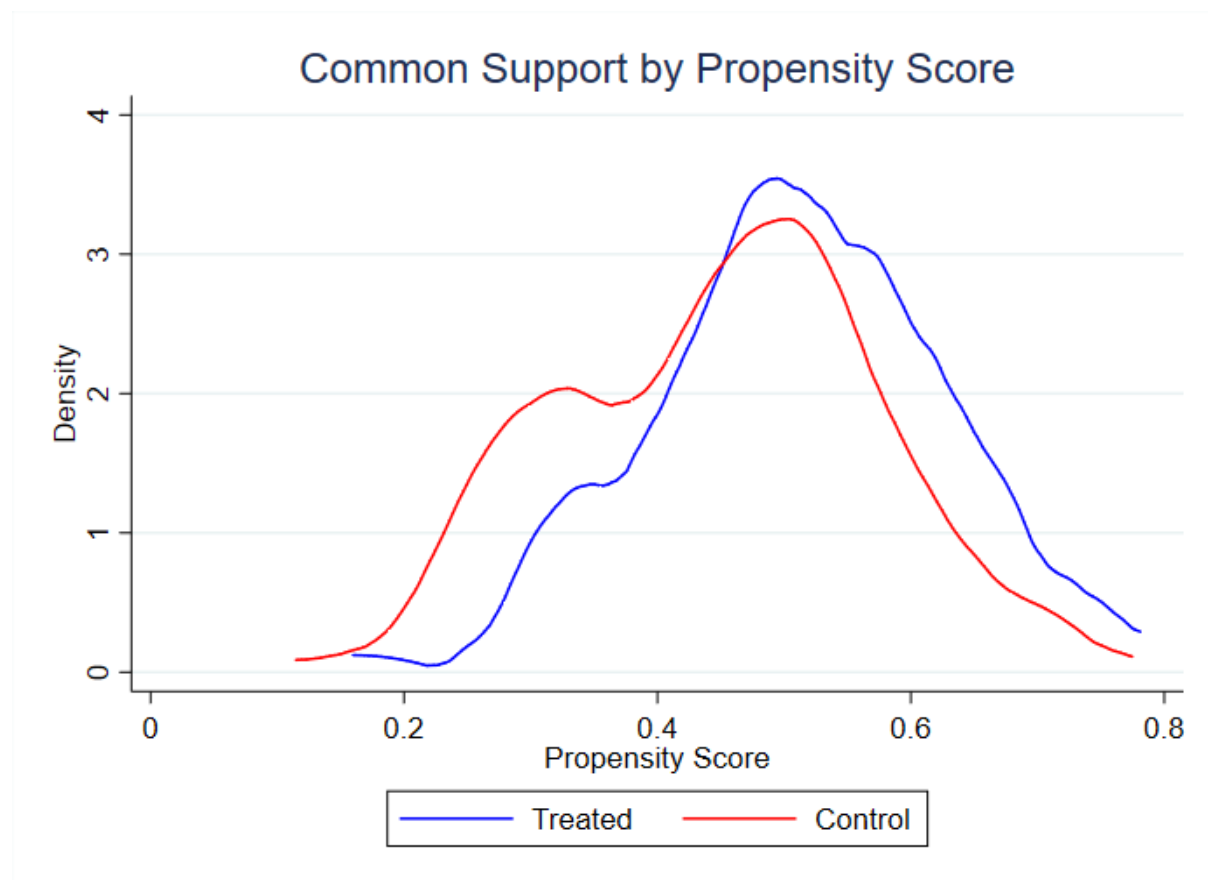
The results illustrate that the observable features of beneficiaries and non-beneficiaries were well matched using propensity score matching. There was no imbalance before matching on age and sex, and some imbalance on education level. All variables after the match, however, showed essentially no differences, supporting the validity of further impact estimates from the match and the balance property assumption.

The rule of thumb is that the difference between groups is statistically significant at the 5% level ($p < 0.05$) if the absolute value of the t-statistic is greater than 1.96. In this instance, all the post-matching t-statistics are well below that. This shows effectiveness of matching process in balancing the covariates between beneficiaries and non-beneficiaries. This allows for a more robust evaluation of the effect of the intervention because the comparison is now between groups that are statistically comparable with respect to background characteristics.

4.5.2 Common support graph

The common support graph presents the common support between the treatment group and the control group. This overlap is important because it guarantees that the control units will be, at least to some degree, similar to the treated units, thus increasing the validity of the matching process. The graph was employed in this study for a visual assessment of whether the common support condition for a comparison of the groups is met, meaning that the groups are based on shared ranges of observed characteristics.

Figure 3: Common support graph



Source: Primary Data, 2025

The distribution of propensity scores for both the treated group (beneficiaries) and the control group (non-beneficiaries) are shown in figure 3. The x-axis is the propensity score that is an estimate of the probability of a farmer being a beneficiary, based on observed characteristics. Y-axis depicts the density (or the number of observations) of each group at various levels of propensity score. The blue line is the treated group and the red line is the control group.

The common support condition is an important requirement in propensity score matching and was assessed with this type of graph. Common support is the set of values of propensity scores for which there are enough observations of both the treated and the control groups. That is, it determines whether, for every person treated, there are similar persons that have not been treated.

There is apparent overlap between the treated and control groups in the middle range of propensity scores, especially across the scores of 0.3 and 0.6 in the graph. This overlap means that there are sufficient numbers of similar individuals in both groups for appropriate matching to be done in this range. But at the lower end (lower than 0.2) the density of the treated group decreases and the control group prevails. Likewise for the higher end (above 0.6), the treated group is larger than the control group.

The overall common support condition was sufficiently met. The area of overlap is appreciable and justifies the matching process. The observations at the extremes very low or very high propensity scores were excluded from the analysis to avoid poor matches and ensure the comparability of groups. The step which is referred to as "trimming" or "restriction to common support region" was a step towards improving the quality of the causal estimates resulting from the matching.

4.5.3 Sensitivity Analysis

Robustness of estimation of treatment effects were tested by doing sensitivity analysis to account for potential unobserved biases. This strategy considers what the findings would be if there were unaccounted-for factors affecting treatment assignment and outcomes. The analysis in this study also enabled it to assess the relevance of the findings under alternative assumptions, giving greater confidence in the reliability of the findings.

Table 9: Sensitivity analysis for production and income level using the rbounds

Variable	Gamma	sig+	sig-	t-hat+	t-hat-	CI+	CI-
Production level	1	0	0	3.5	3.5	3.5	3.5
	1.1	0	0	3.5	3.5	3.5	3.5
	1.2	0	0	3.5	3.5	3.5	3.5
	1.3	0	0	3.5	3.5	3.5	4
	1.4	0	0	3.5	3.5	3.5	4
	1.5	0	0	3.5	3.5	3.5	4
	1.6	0	0	3.5	4	3.5	4
	1.7	0	0	3.5	4	3.5	4
	1.8	0	0	3.5	4	3	4
	1.9	0	0	3.5	4	3	4
	2	0	0	3.5	4	3	4
Income level	1	0	0	3.5	3.5	3.5	4
	1.1	0	0	3.5	3.5	3.5	4
	1.2	0	0	3.5	4	3.5	4
	1.3	0	0	3.5	4	3.5	4
	1.4	0	0	3.5	4	3.5	4
	1.5	0	0	3.5	4	3.5	4
	1.6	0	0	3.5	4	3.5	4
	1.7	0	0	3.5	4	3.5	4
	1.8	0	0	3.5	4	3.5	4
	1.9	0	0	3.5	4	3.5	4
	2	0	0	3.5	4	3.5	4

* gamma - log odds of differential assignment due to unobserved factors

sig+ - upper bound significance level

sig- - lower bound significance level

t-hat+ - upper bound Hodges-Lehmann point estimate

t-hat- - lower bound Hodges-Lehmann point estimate

CI+ - upper bound confidence interval ($\alpha = .95$)

CI- - lower bound confidence interval ($\alpha = .95$)

Source: Primary Data, 2025

Table 9 shows the sensitivity analysis that tests the robustness of the estimated effects of participating in the From Climate Victims to Climate Heroes Project to hidden biases, including the impact of unmeasured factors potentially affecting participation and the effects on participation and outcomes. The important parameter is Gamma (γ): the extent to which the likelihood of being in the treatment group may be influenced by unobserved variables. A higher gamma value means that there is more potential for hidden bias, and a value of 1 means that there is no hidden bias.

The results revealed that the significance levels (sig+ and sig-) do not differ from zero for the level of production from Gamma 1 to Gamma 2. This means that the estimated treatment effect is still statistically significant when the odds of treatment assignment vary by up to 200% depending on the unobserved factors. The Hodges-Lehmann estimates (t-hat+ and t-hat-) are

fairly consistent at 3.5 and 4, respectively, and the confidence intervals are narrow and consistent. This implies that the impact of the climate-smart practices on production level is strong and will not be corrected by moderate hidden biases.

This is the same trend when it comes to income level. The significance levels remain at zero for all values of Gamma up to 2, indicating that the income effect estimated is very robust to unobserved confounding. The point estimates ($t\text{-hat}^+$ and $t\text{-hat}^-$) continue to hover near 3.5 to 4 and are very small, which further bolsters confidence on the positive project participation effect on income. These findings suggest that the observed impacts on production and income would have to be a very large part of the total impact of the unobserved factors.

Table 10: Sensitivity analysis for carbon market access using mhbounds

Mantel-Haenszel (1959) bounds for variable Carbon Market Access

Gamma	Q_mh+	Q_mh-	p_mh+	p_mh-
1	2.68706	2.68706	0.003604	0.003604
1.1	2.55227	2.82655	0.005351	0.002353
1.2	2.43321	2.95812	0.007483	0.001548
1.3	2.32697	3.08278	0.009983	0.001025
1.4	2.23133	3.20137	0.01283	0.000684
1.5	2.14458	3.31456	0.015993	0.000459
1.6	2.06539	3.42291	0.019443	0.00031
1.7	1.99267	3.5269	0.023149	0.00021
1.8	1.92556	3.62692	0.027079	0.000143
1.9	1.86335	3.72333	0.031207	0.000098
2	1.80543	3.81641	0.035503	0.000068

Gamma : odds of differential assignment due to unobserved factors

Q_mh+ : Mantel-Haenszel statistic (assumption: overestimation of treatment effect)

Q_mh- : Mantel-Haenszel statistic (assumption: underestimation of treatment effect)

p_mh+ : significance level (assumption: overestimation of treatment effect)

p_mh- : significance level (assumption: underestimation of treatment effect)

Table 10 shows the bounds for carbon market access with sensitivity analysis for the possible hidden biases. When gamma equals 1, there is convincing evidence of an important effect and the p-value is about 0.0036. The further away the p-values are from 0, the further they are away from 1, the greater the gamma value. In the overestimation scenario the p-values ($p\text{-mh}^+$) increase slowly but stay below 0.05 even at Gamma 2 - when unmeasured confounders double the odds of treatment assignment - demonstrating that the effect is still statistically significant in the extreme case of overestimation. If the underestimation scenario is considered, the results are not as robust: p-values ($p\text{-mh}^-$) rise rapidly and become insignificant at relatively small

Gamma values. This means that the estimated relationship may be reversed by small unobserved confounding, if there is hidden bias.

Overall, the sensitivity analysis reveals robust and stable positive impacts on both production and income due to the project, subject to possible counterbalancing effects. The results are robust and would not be altered by a doubling of the likelihood of treatment assignment due to unobserved factors. This gives confidence that these two outcomes are benefitions that are not explained away by unmeasured confounding. The impact on carbon market access, on the other hand, can be very strong, but is more susceptible to subtle biases. The sensitivity analyses for the carbon market access variables reveal that the estimated effect is substantial at the base level, and remains strong even if the treatment effect is overestimated by a factor of two and the possibility of unmeasured confounders increases the odds of being treated by a factor of two. With underestimation, however, the effect fades rapidly, and is negligible until it becomes relatively high. This indicates that improvements in carbon market access are supported, but are less robust than for production and income and should be viewed with caution. The analysis thus confirms the robustness of the results for production and income, and underscores the importance of careful interpretation of results for carbon market access.

CHAPTER FIVE

DISCUSSION OF THE FINDINGS

5.0 Introduction

The results of a study are discussed in this chapter in the context of literature. The purpose is to explain the results in such a manner that the significance of the results is emphasized, patterns are explained, and links between the empirical results and the research results are made. In this discussion, the focus is specifically on the contribution of climate-smart agriculture towards improving the resilience of smallholder farmers, especially in the context of climate variability and climate change.

The chapter is thematic and presents the major themes of study in the research. It reviews the levels of adoption of CSA practices, the impacts of the interventions on farmer behaviour and performance and links climate-smart agriculture with resilience. The chapter draws comparisons with other studies to identify comparisons, disagreements, and gaps.

5.1 Adoption of climate-smart agricultural practices among the smallholder farmers

The results clearly show that the smallholder farmers who took part in the From Climate Victims to Climate Heroes Project had greater uptake of climate-smart agricultural practices compared to those who did not. The project has seemingly had a significant impact on farmers' capacity and willingness to practice mixed farming, agroforestry, and climate-smart crop varieties, all of which are critical for adaptation and agriculture sustainability. This is in line with the importance of integrated approach towards uptake of climate-smart agriculture which includes inputs, training and awareness, as highlighted by Abhilash et al., (2021). The rate of adoption was almost 100% among beneficiaries, indicating that the project was successful in imparting both knowledge and support, allowing farmers to take meaningful steps towards change. The statistically significant differences between the two groups further reinforce the idea that the adoption of climate-smart agriculture is not a community-level phenomenon, but can be strengthened through targeted interventions, which is also emphasized in Diro et al., (2022) work on how participation in CSA programmes and enabling conditions directly impacts adoption decisions.

Beneficiaries' practices demonstrate effective and scalable practices in the literature. For instance, Baker et al., (2023) note that mixed farming (crop-livestock) is considered practical to improve resource use efficiency and reduce risk. Can help with nutrient recycling and

minimize dependence on outside inputs. This method is especially appropriate in the context of smallholders, as diversification is a widely-adopted solution to climate and market uncertainties.

Another practice that is widespread is agroforestry. It is an integrated planting of trees together with crops or livestock on the same land, and provides several ecosystem services. The literature clearly shows the importance of agroforestry in climate-smart agriculture. A study by Burgess et al., (2022) emphasize its contribution to climate adaptation, particularly as a buffer to extreme weather events and in enhancing soil structure and fertility. Agroforestry is also shown to have a positive effect on smallholder resilience in other African and Asian countries, as seen in the studies conducted in Sri Lanka by Dissanayaka et al., (2023) and in Cameroon by Awazi et al., (2021). In the ongoing project farmers use agroforestry, indicating that they are aware of not only short-term profit, but environmental benefits as well. It's a sign of the learning and mindset that interventions such as these are looking for.

The successful implementation of the project for access to improved inputs and technologies is reflected in the use of climate-smart crop varieties. A study by Radeny et al., (2022) state that these varieties tend to be drought, pest, and climate change resilient, making them suitable to a changing climate that is seeing more precipitation extremes. They can play a crucial role in enhancing productivity and decreasing vulnerability. This higher adoption rate by beneficiaries is probably due to the project's dissemination of these varieties and knowledge about their benefits. It could also imply that access to input is still a significant hurdle for those who do not benefit from the schemes since this is observed in the wider study of Musafiri et al., (2022) in Western Kenya.

The observed trends are similar to those observed in the global and regional reviews. This indicates that the rate at which smallholders adapt to climate-smart agricultural practices is not always uniform and is heavily reliant on socioeconomic and institutional support, such as in Mizik, (2021). Similarly, Acharyya, (2022) points out that information is not enough to drive adoption; capacity building, incentives, and enabling policies are also needed. For this instance, the project seems to have been successful in meeting those needs.

There is a consensus that, as a result of climate-smart agriculture, farmers' roles shift from being at risk to informed and adaptive agents in the literature. According to Mishra et al., (2025) farmer empowerment is highlighted as a prerequisite to achieve sustainable change. The stronger focus on participative learning and demonstration has helped to change the mindset of

the farmers, thus making them not only a victim of climate change, but also a potential contributor to climate resilience.

Overall, the much higher adoption of climate-smart agricultural practices among project beneficiaries is a testament to the effectiveness of the combined knowledge sharing, material support and continued interaction within the integrated intervention. The results align with the existing literature on the benefits of good climate smart agricultural programs in promoting sustainable change among smallholder farmers. The project's results demonstrate the impact that can be realized when small farmers are directly engaged in addressing climate problems.

5.2 Resilience to climate variability of the Smallholder Farmers

The impact of the From Climate Victims to Climate Heroes project has been profound across three key areas: agricultural production, income generation and access to the carbon market, in the resilience of smallholder farmers. These outcomes are the result of direct impact of climate-smart agriculture interventions as well as their broader systems impact on rural livelihoods. The project has seen improvements in beneficiaries, which align with the literature on resilience and climate-smart agriculture, thus supporting both adaptive capacity and transformative resilience.

Production improvements were found to be better for the project beneficiaries compared to the non-beneficiaries, indicating that the production systems are more efficient, productive and responsive to climate variability. This indicates good farm resilience, and is one indicator of it. The results correspond with the conclusions of Aguilar et al., (2022), who noticed that better water use efficiency and diversification of cropping systems are main factors that contribute to smallholder resilience to water scarcity. Mixed cropping, agroforestry, climate-smart seed varieties, and enhanced soil and water management are documented in the literature as effective strategies for boosting productivity under uncertain climatic conditions, and are promoted by the project (Amede et al., 2023; Tadesse & Ahmed, 2023). Diversified cropping systems, especially, lower risk of complete crop losses and multiple production periods. For example, in India, diversified farms are found to be resilient to weather shocks consistently, compared to monocrop farms, as revealed by BIRTHAL & HAZRANA, (2019), while BEKUMA, (2024) finds similar effects in Sub-Saharan Africa. The fact that some project participants are now more productive than before supports the conclusion that the techniques are being implemented and are working in local agroecological settings. Furthermore, better production and less reliance on food imports contributes to greater food security, which are vital factors of long term

resilience. A study by Meuwissen et al., (2019) states in the resilience assessment framework that productivity improvements which result from the sustainable intensification activities are often the first measurable indicators that can be seen at the household level in terms of systemic resilience.

Financial stability is another important aspect of resilience. The data indicates that beneficiaries of the project have much higher incomes than those who are not beneficiaries. This outcome indicates that there is improving smallholder productivity which is leading to a positive economic impact. This is backed by empirical evidence from Maia et al., (2021) which showed that climate resilience programmes that combine sustainable agriculture with market access mechanisms can boost smallholder farmer incomes and their wellbeing in Brazil. Likewise, according to Amoak et al., (2022) agroecological transition in Ghana has increased the income of household by enhancing the quality of Ghana's crops and lowering input costs on farmers. Better income not only brings economic relief in the short term, it also helps a household to cushion and plan for shocks. Financial resilience is an essential part of climate resilience that helps farmers to invest in better technology, diversify sources of income and make emergency savings, as mentioned by Hussain et al., (2021). These are all important coping mechanisms when land is subject to uncertain climate conditions, such as a drought or outbreak of pests. Better market integration may also contribute to improved income outcomes, in many cases. Resilient food systems are defined by farmers being able to access stable market systems, fair input prices, and supply chains even during shocks to the system, such as the COVID-19 pandemic, according to Fan et al., (2021). The current project data do not provide detailed information on marketing channels, but the income differences indicate that project participants might be more competitive in these value chains, which could be related to better farm quality or group marketing.

The addition of the third resilience indicator in the study, access to the carbon market brings a global perspective to the story of local resilience. While comparatively small, the much greater access by beneficiaries suggests the project is bringing smallholder farmers to new opportunities in climate finance. This discovery is timely for the ongoing discussion of the contribution of carbon finance to adaptation by smallholders. Tumushabe et al., (2023) conclude that the carbon market is still in the emergent stage in the majority of Sub-Saharan countries, but their early involvement will be crucial to fostering capacity and making it possible for farmers to profit from these markets once they become fully established. Okyere et al., (2024) also demonstrate that carbon farming training can increase the household income,

food security, and development resilience of Northern Ghana. Carbon markets are especially relevant when integrating smallholders because they connect the local agricultural practices to the global mitigation goals. Inclusion of Agriculture in the Nationally Determined Contributions under Paris Agreement presents a special opportunity for smallholder farmers to not be only the victims of climate action, as Amjath-Babu et al., (2019) explain. As seen in the project, even if access is limited to carbon market schemes, it is a step towards allowing participation in these schemes. Also, carbon finance can offer a long-term, performance-based stream of revenue to boost other elements of resilience. This resonates with the call for moving from reactive to proactive and more economically-integrated climate smart approaches by Azadi et al., (2021) under the umbrella of Vulnerable-Smart Agriculture. Access to carbon markets supports the translation of this transition into mechanisms of compensation for resilience.

The results of this project are not only improvement in individual indicators, but also a systemic improvement in the capacity to become resilient. Beneficiaries are seeing an improvement in production, financial security, and environmental involvement. The three-fold resilience is also reflected in the study by Karoliina et al., (2023), which have identified redundancy, diversity, and adaptability as important factors of food system resilience. The three are all being addressed by the current project: diversified farming systems add redundancy, income provides adaptability, and participation in a carbon market provides long-term stability. It is also key to think of resilience in a systems perspective as mentioned by Ha et al., (2020) as they noted that it is important to consider how livelihood assets, institutions and ecological processes interact. The integrated model that encompasses training, inputs, extension support, and external linkages offered by the project is very similar. Does not view resilience as an endpoint, but as ongoing capacity building. Furthermore, the project aligns with the work of Williams et al., (2020) who highlight the need for equity to be an integral part of resilience strategies. The intervention focuses on vulnerable groups and offers access to new opportunities, thereby contributing to the rebalancing of the distributional impacts of climate adaptation – a critical yet often neglected objective of development work.

The “From Climate Victims to Climate Heroes” project has achieved a definite and measurable contribution to resilience of smallholder farmers. It enhances the productive capacity of agriculture, boosts income, and facilitates access to carbon markets which further bolster the core capacities of households to withstand, adapt to, and recover from climate shock events. The results are reinforced by emerging international research on climate-smart agriculture,

resilience in the rural sector and climate finance. The project's success is evident not just technically, but also because it is in line with the state of the art in global practice, and could be replicated on a larger scale elsewhere in climate sensitive areas.

5.3 Climate-smart agricultural practices and resilience to climate variability of smallholder farmers

Results indicate that climate-smart farming practices significantly correlate with increased resilience among smallholder farmers, especially mixed farming, agroforestry and the cultivation of climate-smart crop varieties. These practices help build food and income security, decrease the climate risks faced by farming families and enable long-term adaptation. Rural farmers that use combinations of these strategies are more likely to be able to cope with unpredictable rainfall, drought and pests. The results also show the potential of new opportunities that arise when adopting CSA, including carbon credit markets, alternative income sources and strengthening adaptive capacity. Importantly, these practices are more effective if underpinned by inclusive policies and outreach to groups typically underrepresented in agricultural decision-making processes, such as women and youth.

The results suggest that inter-crop livestock production systems (mixed farming) contribute to household resilience by diversifying risk over various production activities. Such diversification helps to minimize the risk of livelihood loss if there is a setback in any one segment due to climate change. However, most of the smallholder farmers interviewed that engaged in mixed farming reported reduced income shocks, year-round availability of food and productivity even when rainfall was unreliable. This aligns with the results of Baffour-Ata et al., (2023) which revealed that farmers in Ghana practicing mixed farming were more likely to sustain their food security and income stability in the face of climatic shocks and stresses. Likewise, Makate et al., (2018) found in their Southern African-wide analysis that the use of a package of CSA agricultural practices, such as mixed farming, resulted in higher resilience, especially in marginal areas where climate stress is higher. This is echoed by Dougill et al., (2021) who argue that mixed farming systems are both reactive and proactive, providing immediate protection from shocks and helping farmers to adapt over time through providing greater flexibility. These authors see mixed farming not only as a technique for survival, but as an intentional adaptation technique to lessen dependence on a single resource or market sector. In Zimbabwe's Umguza district, Phiri et al., (2021) confirm these findings that mixed farming was important in mitigating the overall livelihood collapse following long periods of drought.

The literature suggests a clear consensus that mixed farming is not only technically viable, but also is a viable socioeconomically viable option for small farmers. But the level of its promotion is a challenge.

Based on this research, agroforestry is one of the most important climate-smart farming techniques for long-term ecological and economic resilience. Agroforestry technologies like leguminous trees, fruit trees or timber trees improved soil health, reduced runoff and erosion, and provided farmers with a range of food and cash products. In some instances, agroforestry also decreased the degradation of land and prevented erosion especially on sloping fields. This is in line with the results of Ali et al., (2023) in Ethiopia which show that agroforestry contributes to increased productivity and better land use practices and biodiversity to improve household resilience. They report that on-farm agroforestry practices in long drought periods reduced farmers' likelihood of crop failure because of better microclimates and soil moisture retention. Agroforestry practices also acted as a buffer to seasonal food shortages in Ethiopia's drought-prone regions, as it offered alternative income and food sources for households (Berhanu et al., 2024). Across, Ghana, Baffour-Ata et al., (2023) found that agroforestry not only improved household resilience via environmental services but also via market linkages. Similarly, Phiri et al., (2021) report that tree-based systems reduced soil erosion, enhanced infiltration of rainwater, and protected farmers from extreme weather events in southern Africa. There is a clear alignment across these studies and the findings that agroforestry is a key pillar of resilient smallholder agriculture. But there are some discrepancies in the extent of adoption. Berhanu et al., (2024) highlight that institutional support such as extension service and provision of seedlings are a key factor affecting the adoption in Ethiopia. If farmers know the value, but there are no supports in place, uptake is still limited. This emphasises the need to not only encourage the practice of agroforestry, but to make sure the systems are there that will help make agroforestry possible.

The results also demonstrate that the use of climate-resilient varieties like drought-tolerant maize, early maturing sorghum and pest-resistant legumes has a positive effect on yield stability and on minimizing climate-induced yield loss. The farmers who tried the new varieties were pleased with the improved production under unfavorable rainfall conditions, the reduced losses on inputs, and enhanced confidence in production planning in the season. This is supported by the study conducted by Jamil et al., (2021) where the farmers who adopted climate-smart varieties reported enhanced food security, better returns per acre, and generally better outcomes, especially in years of irregular weather conditions in Pakistan. Likewise, Ali

et al., (2023) reported that the yield of the Ethiopian smallholders who grew improved maize and sorghum were significantly higher in dry periods as compared to traditional maize and sorghum varieties. The results are consistent with Zheng et al., (2024), who conducted a meta-analysis to evaluate the effectiveness of climate-smart agricultural practices for yield stability among smallholders, and found that better varieties were among the most promising practices. Hussein, (2024) highlights the need to promote seeds to adapt to climate change as an important component of Ethiopia's national climate adaptation strategy at policy level. This implies that adoption and scaling up will require institutional support and public investments. Improved varieties have consistently been reported to be effective in the literature, and the findings and other studies indicate that access is still a significant problem. Farmers' main concern for not using these seeds was their high cost, limited availability and lack of awareness.

The study shows that climate-smart agricultural practices lead to an increase in income stability, and as a result, farmers have a greater capacity to invest in other climate-resilient strategies, including water harvesting, farm infrastructure, or diversifying livelihoods. This financial stability generates a feedback loop, such that increases in income result in increases in adaptive capacity. This resonates with Saran et al., (2022) who state that sufficient agricultural income helps smallholders invest in longer-term resilience measures, such as implementing risk-reduction technologies. The authors make it a point to stress that climate-smart agri-solutions are not only technical solutions but also economic enabling solutions that will provide farmers with the economic space to plan beyond the immediate need for survival.

The findings also reveal that certain farmers who practiced the CSA have started to participate in carbon credit markets especially in agroforestry. Although the participation is still in its beginning stages, it represents a new opportunity for smallholders to secure economic gains from sustainable land management. Similar stories are reported from Pakistan by Jamil et al., (2021), who highlight the opportunities for smallholders to access carbon credit schemes by embracing climate smart agriculture – such as no-till farming and tree planting – to generate additional income. This has been supported by Zheng et al., (2024) who posited that engaging smallholder farmers with carbon markets can improve farmer resilience and environmental restoration. This has proven that climate smart agriculture practices are especially mixed farming, agroforestry and improved crops are crucial for strengthening the resilience of smallholder. These results are further strengthened by the available literature, which uniformly demonstrates the various advantages of these practices in terms of food security, income stability, and adaptation to climate change. Thus, it is evident that the use of climate-smart

agriculture is most effective when adopted on a combination of technically, economically and institutionally integrated basis. If these elements are connected, then climate-smart agriculture can have a tremendous impact on the vulnerability of smallholder farmers and make them more adaptive.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.0 Introduction

The conclusion and recommendations derived from the main findings of this study on the uptake and impact of climate smart agricultural practices on smallholder farmers' resilience to climate variability are outlined in this chapter.

6.1 Conclusion

The study shows that participation in the “From Climate Victims to Climate Heroes” project has greatly contributed to increased adoption of climate smart agricultural practices among smallholder farmers in Omoro District. Technical results showed higher adoption levels among the beneficiary farmers with respect to their use of climate smart crop varieties, agroforestry and mixed farming compared to non-beneficiaries. The differences in all the practices assessed are statistically significant, suggesting the intervention has had a significant impact on raising awareness, acceptance and implementation of sustainable agricultural practices. In this regard, the project has positively influenced the farmers' capacities to cope with climate variability and environmental risks by adopting climate smart agricultural technologies and practices.

The study also finds that the beneficiaries' farmers are more resilient to climate related shocks and stresses than the non-beneficiary farmers. This is reflected in increased production volumes, higher incomes and a relatively higher access to carbon market opportunities for project participants. There were statistically significant differences in the resilience indicators, indicating that project implementation enhanced farmers' capacity to adjust and adapt to the project, ensuring that their livelihoods are sustainable and resilient even in the face of climatic changes. The concludes that smallholder farming households in vulnerable rural communities can use climate-smart agricultural interventions to increase their adaptive capacity and socio-economic resilience.

The study found a positive and statistically significant impact of participation in the From Climate Victims to Climate Heroes Project on smallholder farmers' production, income, and access to carbon market opportunities. In all matching methods, the propensity score matching results indicated that the beneficiary farmers were more productive, had higher income and better opportunities in carbon markets than the non-beneficiary farmers. The results obtained from the nearest neighbor, radius caliper and kernel matching methods are consistent, further

indicating the robustness and reliability of the project's impact. Therefore, this study finds that by implementing focused interventions, the adoption of climate smart agriculture (CSA) has considerable impact in enhancing the resilience and livelihoods of smallholder farmers. The project has thus successfully enabled farmers to better adapt to climate change and enhance their livelihoods and incomes, as well as improving environmental sustainability.

6.2 Recommendations

6.2.1 To national and local governments

Government should ensure the incorporation of climate-smart agriculture into national and sub-national agricultural development and adaptation strategies. Mixed farming systems, agroforestry models and use of climate resilient seeds should be explicitly promoted by policies. This encompasses integration of climate smart agriculture into rural investment programs, rural climate action plans and extension service delivery. National governments can implement targeted input subsidy schemes to lower the cost of climate smart agriculture inputs like drought-tolerant seeds, agroforestry seedlings and better livestock breeds to boost adoption. In addition, land tenure reforms are critical. Protecting land rights, particularly women's rights, will promote sustainable investments in climate change resilient farming practices such as tree planting and soil conservation.

The government should also be a key stakeholder in establishing the institutional structure to enable smallholders to participate in carbon markets. This involves the facilitation and/or development of farmer aggregation platforms, streamlining monitoring and reporting processes, and farmer engagement with carbon buyers or intermediaries. It is essential to create farmer-friendly, regionally flexible and inclusive carbon finance models in collaboration with national agricultural boards and climate finance units. The investments in rural infrastructure (irrigation, storage facilities, climate information systems) are expected to serve as a complementary measure to climate-smart agriculture adoption and mitigate systemic risks.

6.2.2 Agricultural non-governmental organizations and development agencies

The role of the non-governmental organizations and development organizations in closing the policy-to-practice gap is very critical. They should encourage climate-smart agriculture by ensuring that training programmes are integrated, context specific and focus on the combined use of practices, rather than on individual practices. For instance, training programmes can demonstrate the possibilities of synergies in food production and income arising from mixed farming integrated with agroforestry and use of climate-resilient crops. These programs should

be presented and delivered through participatory approaches such as demonstration farms, farmer field schools and peer learning networks.

Particular emphasis must be placed on the outreach to vulnerable and underserved groups, such as women, youth and remote rural communities. Climate-smart agricultural programmes need to be conceived inclusively, to ensure that these groups have access to resources, information and leadership opportunities. NGOs can also help establish community-based CSE resource centres at the community level, which can house a seed bank, extension materials, tools and climate advice. These centres provide a space for local innovation, exchange, and joint action to improve the sustainability of climate-smart agriculture practices.

6.2.3 To research institutions and universities.

Research institutions need to produce evidence that will guide adaptation of climate-smart agricultural practices to agro-ecological and socio-economic settings. This involves trials of various crop-livestock mixtures, assessing tree species for agroforestry under different climate scenarios and evaluating new seed varieties. Farmers-facilitator collaboration for on-farm trials can improve relevance and uptake of research results. Longitudinal studies need to be undertaken to track the long-term effects of climate-smart agriculture on household resilience, income and ecosystem health also have an urgent need.

In addition to field-level research, universities and think tanks can play a role in designing innovative financial models to link climate-smart agricultural practices to climate finance. This includes consideration of the potential of adapting carbon markets, payments for ecosystem services or risk-sharing mechanisms such as microinsurance to suit smallholder farmers. Institutions also need to be at the forefront of creating resilience measurement systems that facilitate practitioners to monitor the progress of climate-smart agricultural interventions and measure their effects in real time.

6.2.4 To smallholder farmers

The smallscale farmers are key to the success of climate smart agriculture and are encouraged to use a combination of more than one practice, as this will provide the greatest benefit. Farmers should not be dependent on any single technique, but should consider using improved seed varieties, keeping livestock and growing trees in crop fields to diversify production and income. Implementing climate-smart agriculture interventions can assist with food security, minimise the impacts of drought or pests and create new markets.

Farmers are also advised to join or create a farmers group or cooperative. Such facilities improve access to inputs, credit, training and markets, including opportunities to participate in carbon credit schemes. Farmers can share resources and knowledge, and share the risks and gain collective bargaining power. Community trainings, demonstration farms and extension visits will help enhance awareness about new practices and technologies. There is value in farmers' innovations and adaptation strategies, and their experience and knowledge can be a strong motivator for uptake and refinement of practices for climate-smart agriculture.

6.3 Areas for further research

The results identified a number of challenges in the promotion of climate-smart agriculture in smallholder agriculture. While beneficiaries of the intervention are found to be significantly more likely to take up climate-smart practices, the non-beneficiaries are found to lag behind, suggesting that there are barriers to widespread uptake. Overall access to carbon markets is still very low, indicating structural problems related to lack of awareness, and/or financial or institutional barriers. In addition, there is a notable disparity between men and women in project participation, with males more inclined to participate than females, highlighting gender gaps in the accessibility to agricultural programs. Also, younger and less educated farmers are less likely to get involved, suggesting potential non-reachability of vulnerable groups. So further research needs to be conducted in the following areas:

- i. Gender dynamics and participation rates in climate-smart agricultural programs.
- ii. Age and education level and adoption of climate-smart agricultural practices.
- iii. Access to financial and institutional support and engagement of smallholder farmers in carbon markets.
- iv. Awareness and knowledge of climate-smart agriculture and uptake of climate-resilient farming practices.

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APPENDICES

Appendix I: Questionnaire for the respondents

Dear Respondent,

I am **Mukisa Daniel**, a student of Gulu University, pursuing a Master's degree of Monitoring and Evaluation. As part of the academic requirements, I am carrying out a study on ***"Climate smart agricultural practices and resilience of smallholder farmers. A Case of From Climate Victims to Climate Heroes Project in Omoro District"***. I am therefore requesting you to spare some time and fill this questionnaire. The information you give will be treated confidentially and will be anonymously used for purposes of writing the research report, and will not be used for any other purpose.

Thank you for your cooperation.

Please tick (✓) or fill in the blanks where applicable.

Date:

Parish: GPS Coordinates:

Distance from the market: Distance from the road:

SECTION A: DEMOGRAPHIC CHARACTERISTICS

1. Are you the household head?

- i. Yes ☐
- ii. No ☐

1.a) If no, what is your relationship to the household head?

- i. Spouse ☐
- ii. Child ☐
- iii. Relative ☐

2. Age group

- i. 0-14 ☐
- ii. 15-24 ☐
- iii. 25-34 ☐
- iv. 35-44 ☐
- v. 45-54 ☐
- vi. 55-64 ☐
- vii. 65 and Above ☐

3. Age: _____ years

4. Gender:

- i. Male ☐
- ii. Female ☐

5. Marital status:

- i. Single ☐
- ii. Married ☐
- iii. Separated ☐
- iv. Widowed ☐

6. Highest level of education attained:

- i. Never went to school ☐
- ii. Primary ☐
- iii. O-Level ☐
- iv. A-Level ☐
- v. Certificate ☐
- vi. Diploma ☐

- vii. Degree ☐
- viii. Post graduate ☐

7. What is your main occupation?

- i) Farmer ☐
- ii) Teacher ☐
- iii) Medical worker ☐
- iv) Social worker ☐
- v) Others (specify): _____

8. Household size _____

9. Number of the household members under the following categories:

Category		Male	Female
Age group	0-14		
	15-24		
	25-34		
	35-44		
	45-54		
	55-64		
Level of education	Primary		
	O-Level		
	A-Level		
	Certificate		
	Diploma		
	Degree		
	Post graduate		
	Not gone to school		

10. Ownership of assets (please tick the assets you own)

- i. Vehicle ☐
- ii. Motorcycle ☐
- iii. Bicycle ☐
- iv. TV screen ☐
- v. Telephone ☐
- vi. Radio ☐
- vii. Livestock ☐
- viii. Others (specify): _____

11. What is your experience in farming?
_____ years

12. House type

- i. Temporary house ☐
- ii. Semi-permanent ☐
- iii. Permanent ☐

13. Occupancy status

- i. Owner ☐
- ii. Tenant ☐

14. Do you participate in the Climate Heroes Project?

- i) Yes ☐
- ii) No ☐

15. Why did you join the project?

16. What are the benefits of the project?

17. Are you a member of any farmers' group?

- i) Yes ☐
- ii) No ☐

18. If yes, are you involved in any collective activity?

- i. Yes ☐
- ii. No ☐

19. If yes, specify

- i) Savings and Loan ☐
- ii) Collective marketing ☐
- iii) Others (specify): _____

20. What is the land size?

21. What is size of the land under climate-smart agriculture?

22. Do you have access to extension services?

- i) Yes ☐
- ii) No ☐

23.a) If no, why?

23. If yes, what is the main source of the extension services?

- i) Government ☐
- ii) NGOs ☐
- iii) Others (specify):

24. What is the number of visits of extension workers per year?

SECTION B: CLIMATE-SMART AGRICULTURAL PRACTICES

Please tick the most appropriate response or provide the requested information.

Part I: Mixed Farming

No.	Question	Response Options
1	Do you integrate both crop production and livestock rearing on your farm?	1 - Yes ☐ 2 - No ☐
2	If yes, which two main types of crops and livestock do you typically combine?	1 - Crops: _____ 2 - Livestock: _____
3	What level of household income have you experienced as a result of practicing mixed farming?	1 – High reduction ☐ 2 - Low reduction ☐ 3 - None ☐ 4 - Low increase ☐ 5 - High increase ☐
4.	What level of farm production have you experienced due to mixed farming?	1 – High reduction ☐ 2 - Low reduction ☐ 3 - None ☐ 4 - Low increase ☐ 5 - High increase ☐
5.	What level of access to carbon market opportunities have you experienced from practicing mixed farming?	1 – High reduction ☐ 2 - Low reduction ☐ 3 - None ☐ 4 - Low increase ☐ 5 - High increase ☐
6	Do you practice mixed cropping?	1 - Yes ☐ 2 - No ☐

7	What crop combinations do you mostly practice in mixed cropping? (Tick all that apply)	☐ ☐ ☐ ☐ ☐
8	What level of household income have you experienced as a result of practicing mixed cropping?	1 – High reduction ☐ 2 - Low reduction ☐ 3 - None ☐ 4 - Low increase ☐ 5 - High increase ☐
9.	What level of farm production have you experienced due to mixed cropping?	1 – High reduction ☐ 2 - Low reduction ☐ 3 - None ☐ 4 - Low increase ☐ 5 - High increase ☐
10	What level of access to carbon market opportunities have you experienced from practicing mixed cropping?	1 – High reduction ☐ 2 - Low reduction ☐ 3 - None ☐ 4 - Low increase ☐ 5 - High increase ☐

11. What challenges do you face in practicing mixed farming?

Part II: Agroforestry

Please tick the most appropriate response or provide the requested information.

No.	Question	Response Options
i.	Do you grow trees alongside your crops or within livestock areas?	1 - Yes ☐ 2 - No ☐
iii.	What type of trees do you grow under your agroforestry system? (Tick all that apply)	1 - Fruit trees ☐ 2 - Fodder trees ☐ 3 - Timber trees ☐ 4 - Nitrogen-fixing trees ☐ 5 - Medicinal trees ☐ 6 - Other (specify):
iv.	What level of farm production have you experienced as a result of practicing agroforestry?	1 – High reduction ☐ 2 - Low reduction ☐ 3 - None ☐ 4 - Low increase ☐ 5 - High increase ☐

v.	What level of household income have you experienced due to agroforestry practices?	1 – High reduction ☐ 2 - Low reduction ☐ 3 - None ☐ 4 - Low increase ☐ 5 - High increase ☐
vi.	What level of access to carbon market opportunities have you experienced from engaging in agroforestry?	1 – High reduction ☐ 2 - Low reduction ☐ 3 - None ☐ 4 - Low increase ☐ 5 - High increase ☐

vii. What are the challenges of agroforestry?

Part III: Climate-Smart Crop Varieties

Please tick the most appropriate response or provide the requested information.

No.	Question	Response Options
i.	Have you adopted any improved or climate-smart crop varieties in the past three years?	1 - Yes ☐ 2 – No ☐
ii.	If yes, what specific climate-smart crop varieties are you using? (List all applicable)	1 - Crop type(s): _____ 2 - Variety name(s): _____
iii.	What climate-smart traits do the crop varieties you use possess? (Tick all that apply)	1 - Drought tolerance ☐ 2 - Pest resistance ☐ 3 - Short maturity duration ☐ 4 - Heat resistance ☐ 5 - High yield ☐ 6 - Disease resistance ☐ 7 - None ☐
iv.	What level of farm production have you experienced from using climate-smart crop varieties?	1 – High reduction ☐ 2 - Low reduction ☐ 3 - None ☐ 4 - Low increase ☐ 5 - High increase ☐
v.	What level of household income have you experienced as a result of using climate-smart crop varieties?	1 – High reduction ☐ 2 - Low reduction ☐ 3 - None ☐ 4 - Low increase ☐ 5 - High increase ☐

vi.	What level of access to carbon market opportunities have you experienced from adopting climate-smart crop varieties?	1 – High reduction ☐ 2 - Low reduction ☐ 3 - None ☐ 4 - Low increase ☐ 5 - High increase ☐
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vii. What challenges do you face in adopting climate-smart crop varieties?

SECTION C: RESILIENCE

Instruction: Please tick the most appropriate response or provide the requested information where applicable.

Climate Risk

No.	Question	Response Options
1	What level of rainfall did you experience the last two seasons?	1 - Very low rainfall ☐ 2 - Low rainfall ☐ 3 - Normal rainfall ☐ 4 - High rainfall ☐ 5 - Very high rainfall ☐
2	If very low, was there drought?	1 - Yes ☐ 2 - No ☐
3	If very high, was there floods?	1 - Yes ☐ 2 - No ☐

Part I: Production Risk

No.	Question	Response Options
1	Have you experienced crop loss in the past 3 years due to the following? (<i>Multiple responses possible</i>)	1 - Drought ☐ 2 - Excess rainfall/flooding ☐ 3 - Other (specify): _____
2	What is the main factor affecting production?	_____
3	How has the rainfall pattern affected your crop yield?	1 – High reduction ☐ 2 - Low reduction ☐ 3 - None ☐ 4 - Low increase ☐ 5 - High increase ☐

4	What is your current level of agricultural production?	1 - Very low reduction ☐ 2 - Low reduction ☐ 3 - Unchanged ☐ 4 - High increase ☐ 5 - Very high increase ☐
5	If very low, was there drought?	i. Yes ☐ ii. No ☐
6	If very high rainfall, was there drought?	i. Yes ☐ ii. No ☐
7	What is your actual yield per season (in kg or bags)?	_____
8	Do you experience variation in the level of production across seasons?	1 - Yes ☐ 2 - No ☐
9	Which type of weather event do you prefer for optimal production?	1 - Very low rainfall ☐ 2 - Low rainfall ☐ 3 - Normal rainfall ☐ 4 - High rainfall ☐ 5 - Very high rainfall ☐

10. What are the challenges to production?

Part II: Income Security

No.	Question	Response Options
1	What is your current level of income from agriculture?	1 - Very low reduction ☐ 2 - Low reduction ☐ 3 - Unchanged ☐ 4 - High increase ☐ 5 - Very high increase ☐
2	Has your agricultural income been affected by climate change?	1 - Yes ☐ 2 - No ☐
3	Which climatic condition has most affected your income?	1 - Drought ☐ 2 - Floods ☐ 3 - Erratic rainfall ☐ 4 - Heatwaves ☐ 5 - Other: _____
4	What is the level of prices of agricultural produce?	1 - Very low ☐ 2 - Low ☐ 3 - Normal ☐ 4 - High ☐ 5 - Very high ☐

5	How has the rainfall pattern affected your agricultural income?	1 – High reduction ☐ 2 - Low reduction ☐ 3 - None ☐ 4 - Small increase ☐ 5 - High increase ☐
6	How has rainfall affected the prices for agricultural products?	1 - Significantly increased prices ☐ 2 - Slightly increased prices ☐ 3 - No effect on prices ☐ 4 - Slightly decreased prices ☐ 5 - Significantly decreased prices ☐

7. What are the challenges to income security?

Part III: Carbon Market Access

No.	Question	Response Options
1	Have you heard of carbon credits or carbon trading?	1 - Yes ☐ 2 – No ☐
2	If yes, how did you learn about it? <i>(Tick all that apply)</i>	1 - Extension agents ☐ 2 - NGO ☐ 3 - Media ☐ 4 - Farmer group ☐ 5 - Other: _____
3	Do you currently have access to the carbon market?	1 – Yes ☐ 2 – No ☐
4	If no, what opportunities have you missed due to lack of access to the carbon market?	1 - Financial incentives ☐ 2 - Climate-smart training ☐ 3 - Input subsidies ☐ 4 - Group membership ☐ 5 - Other: _____
5	What is your level of participation in the carbon market?	1 - Certified ☐ 2 - Registered ☐ 3 - Not registered ☐
6	What are the benefits you have gained from accessing carbon credits?	1 - Extra income ☐ 2 - Training opportunities ☐ 3 - Access to inputs ☐ 4 - Improved soil health ☐ 5 - Other: _____

7. What are the challenges to carbon market access?

Thank you for your precious time

Appendix II: Introductory letter

GULU
P.O. Box 166
Gulu, Uganda



UNIVERSITY

Tel: 0471-42923
Fax: 256-471-42094

OFFICE OF THE DEAN FACULTY OF BUSINESS AND DEVELOPMENT STUDIES

Date: 14th May 2025

TO WHOM IT MAY CONCERN

RE: MUKISA DANIEL

REG. NO. 23/U/0439/MME/PS

The above named person is a final year student pursuing Masters of Monitoring and Evaluation (MME) Degree of Gulu University.

In partial fulfillment of the requirements for the award of the Degree, he is carrying out a research on the topic: **Climate-Smart Agricultural Practices and Resilience of Smallholder Farmers: A Case of From Climate Victims to Climate Heroes Project in Omoro District.**

Due consideration accorded to him shall be highly appreciated.

Yours Faithfully,

[Handwritten signature] 14/05/2025



Dr. Olanya David Ross (Ph.D)
Vice Chairperson - Higher Degrees Committee
Faculty of Business and Development Studies
Tel: 0773-170-448
Email: d.olanya@gu.ac.ug

Appendix III: Permission letter from Omoro District

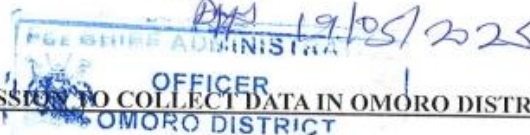


Mukisa Daniel
Gulu University
P. O. Box 166, Gulu – Uganda
danielmukisa623@gmail.com
0761819482 / 0759615916
18th May 2025

The Chief Administrative Officer
Omoro District Local Government
P.O. Box 252, Gulu, Uganda

*Permission Granted
Act in touch with the
Sub center where you intend
to collect data*

Dear Sir/Madam,



RE: REQUEST FOR PERMISSION TO COLLECT DATA IN OMORO DISTRICT

I am a student at Gulu University pursuing a Master of Monitoring and Evaluation. As part of the requirements for my degree, I am conducting a research study titled "Climate-smart agricultural practices and resilience of smallholder farmers: A case of From Climate Victims to Climate Heroes Project in Omoro District."

The purpose of this study is to assess how climate-smart agricultural practices are influencing the resilience of smallholder farmers, both those participating in the From Climate Victims to Climate Heroes Project and those who are not. The findings will contribute to academic knowledge and may also offer practical insights for improving agricultural adaptation strategies in the district.

I am therefore kindly requesting your permission to collect data within Omoro District. The study will involve interviews and questionnaires administered to selected smallholder farmers and key stakeholders. All information collected will be used strictly for academic purposes and handled with confidentiality and respect for ethical research standards.

I will be grateful for your support and look forward to your positive response.

Yours sincerely,

A handwritten signature in blue ink, appearing to read "Mukisa Daniel".

Mukisa Daniel