FINANCING MECHANISMS FOR AGRO-CLIMATIC ADVISORY SERVICES AND IMPACT ON PRODUCTIVITY AND INCOME OF SMALLHOLDER GRAIN FARMERS IN NORTHERN GHANA:

A GENDERED ANALYSIS

BY

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THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF DOCTOR OF PHILOSOPHY DEGREE IN AGRIBUSINESS

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DECLARATION

I, Maureen Erekua Odoi, do hereby declare that except for the references cited, which have been duly acknowledged, this work "**FINANCING MECHANISMS FOR AGRO-CLIMATIC ADVISORY SERVICES AND IMPACT ON PRODUCTIVITY AND INCOME OF SMALLHOLDER GRAIN FARMERS IN NORTHERN GHANA: A GENDERED ANALYSIS** " is the result of my own research. It has never been presented either in whole or in part for any other degree of this University or elsewhere

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DEDICATION

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ABSTRACT

This study explores gender-responsive financing mechanisms for Agro-Climatic Advisory Services (ACAS) and their impact on productivity and income among smallholder grain farmers in Northern Ghana. The research addresses four primary issues: (1) the nature of financing mechanisms and their effects on ACAS accessibility, (2) factors influencing ACAS access among male and female farmers, (3) determinants of ACAS adoption by gender, and (4) ACAS's impact on productivity and income. Guided by random utility theory and gender-intersectionality theory, and employing a mixed-methods research design, the study combines quantitative and qualitative approaches for the analysis. Data were collected from 730 smallholder farmers across the Northern and Savannah regions of Ghana using semi-structured questionnaires, interviews, and focus group discussions. Analytical techniques included econometric modeling and descriptive analysis to evaluate factors influencing access, adoption, and outcomes of ACAS. The findings reveal significant disparities in financing mechanisms supporting ACAS. Sources such as grants, loans, and Village Savings and Loan Associations (VSLAs) were identified, with grants being more accessible to male farmers and younger females benefiting more from VSLAs. The study highlights the pivotal role of public-private partnerships in ensuring sustainable ACAS financing. However, systemic barriers limit equitable access, with women and youth disproportionately affected. Key determinants of access include education level, farm size, membership in farmer organizations, and gender. Female farmers face additional constraints due to time poverty, cultural norms, and limited mobility, underscoring the need for gender-sensitive interventions. Regarding ACAS adoption, results show that factors such as trust in information sources, ease of access, and alignment of advisory content with local farming practices significantly influence uptake. Female farmers demonstrated lower adoption rates due to limited financial resources and restricted access to information networks. However, targeted interventions addressing these barriers increased adoption rates, with notable gender-specific impacts. The study finds that adoption of ACAS significantly improved productivity, with Integrated Pest Management (IPM) ACAS achieving the highest gains. Female adopters of IPM recorded an increase of 314.69 kg/hectare in productivity, compared to 283.81 kg/hectare for male adopters. Similarly, Water Management Irrigation (WMI) and Crop Planning Weather Forecast (CPWF) services yielded productivity increases of 309.68 kg/hectare for females and 273.48 kg/hectare for males. The benefits of ACAS adoption were more pronounced among adult farmers, who leveraged greater experience and access to resources. Impacts on income were similarly pronounced. Female adopters of IPM ACAS experienced an income increase of GHS 3866.83 per hectare, while their male counterparts gained GHS 3166.54 per hectare. WMI adopters reported income gains of GHS 3701.41 for females and GHS 1906.96 for males among youth, reflecting the gendered distribution of benefits. CPWF services demonstrated income gains of GHS 3019.55 per hectare for adult females and GHS 2147.84 per hectare for adult males. These results underscore the transformative potential of ACAS in enhancing economic resilience but also highlight persistent gender disparities. In conclusion, the study underscores the transformative potential of ACAS in improving productivity and income among smallholder farmers while highlighting the critical need for gender-responsive financing mechanisms. Addressing disparities in access and adoption requires promoting inclusive policies, expanding education and training, strengthening financial support systems, and fostering public-private collaborations. Policy recommendations include integrating ACAS into national agricultural programs, providing targeted subsidies for marginalized groups, and enhancing the institutional capacity to deliver gender-sensitive services. These measures are vital for maximizing the benefits of ACAS and achieving sustainable agricultural development in Northern Ghana.

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LIST OF ACRONYMS

FM	Financing Mechanisms
GDP	Gross Domestic Product
MoFA	Ministry of Food and Agriculture
GAWU	Ghana Agricultural Workers Union
CPI	Climate Policy Initiative
OECD	The Organization for Economic Cooperation and Development
SHGF	Small-holder Grain Farmers
CSA	Climate Smart Agriculture
CIS	Climate Information Services
AICCRA	Accelerating the Impact of CGIAR Climate Research for Africa
FAO	The Food and Agriculture Organization
AFI	Alliance for Financial Inclusion
SSPiNG	The Sustainable Soybean Production in Northern Ghana
TASAI	The African Seed Access Index
SRID	Statistical Research and Information Directorate
PFJ	Planting for Food and Jobs
WFP	World Food Program
IFAD	The International Fund for Agricultural Development

CCAFS	Climate Change, Agriculture and Food Security
WEAI	Women's Empowerment in Agriculture Index
PPPs	Public-Private Partnerships
SDGs	Sustainable Development Goals
TIFs	Tax Increment Financing
PES	Payments for Ecosystem Services
MERESE	Mechanism for Ecosystem Services
PIATA	Partnership for Inclusive Agricultural Transformation in Africa
IFC	International Finance Corporation
VSLA	Village Savings and Loans Association
K-REP	Kenyan Rural Enterprise Programme
ACAS	Agro-climatic Advisory Services
GCF	Green Climate Fund
GEF	Global Environment Facility
NDBs	National Development Banks
SLF	Sustainable Livelihoods Framework
GAPs	Good Agronomic Practices
NAP	National Agricultural Policy

CHAPTER ONE

INTRODUCTION

1.1 Background

Around 95% of the world's farms are of small sizes operating on less than five hectares of land; together they represent about 20% of the global farmland (World Bank Group, 2018 & Hannah Ritchie, 2021). According to the World Bank (2023), the regions with the highest concentration of small farms include South Asia and Sub-Saharan Africa where agriculture accounts for about 15% of the gross domestic product (GDP). Small-scale farmers are estimated to provide up to 80% of the food produced in Asia and Sub-Saharan Africa (Lowder *et al.*, 2014; Fan & Rue, 2020). The World Bank reports that 52% of the jobs in low-income countries of Sub-Saharan Africa and 40% of employment in South Asia are in the agricultural sector (World Bank, 2021).

Several studies in sub-Saharan Africa attest to the role and importance of agriculture in employment, livelihood, and the overall economy (for example, refer to Yegbemey & Egah, 2021). In Ghana, small farms account for over 90% of agricultural production and incomes for rural communities (Feed the Future, 2020). Agriculture, particularly smallholder tropical agriculture, which produces 30-34% of the world's food supply on 28-31% of the total agricultural land, is more vulnerable to climate impacts than any other sector (van der Ploeg et al., 2019).

About 33% of the Ghanaian working population depends on agriculture for employment and income (Ghana Statistical Service, 2021). Ghana's agriculture is largely of the rain-fed type. Given the expected increase in average temperatures in the future, Agriculture is likely to be severely hit by climate change (Anuga *et al.*, 2019). The overall economy of Ghana is also highly vulnerable to climate variability due to the climate vulnerabilities of its key sectors such as energy, health, energy, infrastructure, transportation and water resources UNFCCC, 2024; World Bank, 2024; IPCC, 2022).

Global climate finance nearly doubled from USD 653 billion in 2019/2020 to USD 1.3 trillion in 2021/2022, driven mainly by mitigation investments in renewable energy and transport, with green bonds expanding support for agriculture, forestry, and land-use sectors (CPI, 2023). The agricultural sector which is one of the biggest sources of greenhouse gas emissions receives disproportionately little (i.e. less than 4%) of the total mitigation and dual benefits finance (Global Landscape of Climate Finance, 2023). This indicates that not much financing is reaching those in need and specifically targeting small-scale producers, their associated value chains. International Climate Finance providers have been working towards making finance more accessible to the poorest people and communities. Research studies on climate finance for small-scale agriculture are few. These studies also tend to focus on climate change with less emphasis on climate finance for agriculture (refer to CPI, 2023; Mungai *et al*., 2021; Nkiaka *et al*., 2019; Making Climate Finance Work in Agriculture, 2016). The study conducted by (Djido *et al*., 2021) is an important exception with its particular focus on climate-based finance for smallholder agriculture.

, financing mechanisms often involve a combination of public funding, private sector contributions, and innovative financial models like blended finance (Schmidt-Traub, 2015; Convergence, 2018; OECD, 2019). However, there are several challenges involved in sustaining long-term investments and aligning funding with the needs of smallholders rather than profit-driven priorities (Convergence, 2018; World Bank, 2018; Kassam *et al*., 2016). In Africa, the exclusion of smallholder farmers, particularly women, from formal financial systems remains a critical issue (FAO, 2017; Njuki *et al*., 2016; Kaur *et al*., 2020). Informal sources of financing such as Village Savings and Loan Associations (VSLAs) are often the primary means of finance for these farmers due to their limited access to formal institutions (Kaur *et al*., 2020; AfDB, 2020; Njuki *et al*., 2016). In Ghana, particularly in the northern regions, financing remains concentrated in urban centers, with rural areas facing significant challenges in accessing both formal and informal funding sources (MOFA, 2019; Hansen *et al*., 2019; Njuki *et al*., 2016). Government initiatives like "Planting for Food and Jobs" have made some strides, but resource allocation and integration of informal Financing Mechanisms with formal institutions remain problematic (MOFA, 2019; AfDB, 2020; Kassam *et al*., 2016). FM for ACAS often neglect gender-specific needs, leaving women and young smallholder farmers marginalized (FAO, 2017; Doss *et al*., 2020; Njuki *et al*., 2016). Women, in particular, face barriers and high hurdles in accessing these services due to systemic biases and limited funding, which hinder their ability to benefit from climate-smart agriculture (Doss *et al*., 2020; FAO, 2017; Hansen *et al*., 2019). Additionally, young farmers frequently encounter difficulties in securing financing for ACAS, exacerbating their vulnerability and limiting their growth potential (FAO, 2017; Njuki *et al*., 2016; World Bank, 2018; Kaur *et al*., 2020; Schmidt-Traub, 2015).

Initiatives like the CGIAR's Research Program on Climate Change, Agriculture, and Food Security (CCAFS) have made progress globally, yet there is often a significant disconnect between technological advancements and the practical needs of smallholder farmers (OECD, 2019; World Bank, 2018; FAO, 2017). In Africa, ACAS are often disjointed and are not aligned with local farming practices (Njuki *et al*., 2016; Kaur *et al*., 2020; Hansen *et al*., 2019). Programmes such as the Africa Climate Change Resilience Alliance (ACCRA) and Esoko have made notable contributions towards ACAS availability but have struggled to reach scale due to cultural and infrastructural barriers (FAO, 2017; MOFA, 2019; Njuki *et al*., 2016). In Ghana, services such as Accelerated Impacts for Climate Change and Research in Africa (AICCRA) and Esoko provide valuable information to farmers; however, their integration with local agricultural extension systems is weak, and many farmers continue to rely on informal advice networks such as other farmers and friends (MOFA, 2019; Hansen *et al*., 2019; Kaur *et al*., 2020). Women and young farmers often face additional barriers and high hurdles in accessing these ACAS due to socio-cultural constraints and limited outreach efforts (Doss *et al*., 2020; Njuki *et al*., 2016; FAO, 2017).

Smallholder grain farmers are a critical component of the global food system, particularly in developing regions like Africa. These farmers typically operate on small plots of land and face significant challenges, including limited access to markets, technology, and financing, which are further exacerbated by climate change (World Bank, 2018; FAO, 2017; Njuki *et al*., 2016). Smallholder farmers in Africa are often marginalized by agricultural policies that favor large-scale agribusiness, leaving them vulnerable to economic and climatic shocks (Kassam *et al*., 2016; AfDB, 2020; Njuki *et al*., 2016).

In Northern Ghana, smallholder grain farmers face acute challenges, including low productivity, poor access to markets, and vulnerability to climate shocks (MOFA, 2019; Hansen *et al*., 2019; Kaur *et al*., 2020). Women in these regions often endure the impact of these challenges due to traditional norms that limit their access to resources and decision-making power (FAO, 2017; Njuki *et al*., 2016; AfDB, 2020). While government programmes have aimed to support these farmers, their impact has been inadequate due to uneven resource distribution and reliance on traditional, non-climate-resilient farming methods (MOFA, 2019; AfDB, 2020; FAO, 2017).

Gender analysis is crucial in understanding the disparities in access to resources, decision-making, and opportunities in agriculture. Efforts to address these disparities have been made, but its progress remains slow, and gender inequalities continue to hinder agricultural development (FAO, 2017; Njuki *et al*., 2016; AfDB, 2020). Although NGOs and community-based organizations are working to address these issues, their efforts are often constrained by a lack of resources and government support (AfDB, 2020; MOFA, 2019; Njuki *et al*., 2016).

Internationally, unresolved issues in FM include sustaining long-term investments and creating incentives for private sector involvement in climate adaptation strategies (Convergence, 2018; OECD, 2019; World Bank, 2018). The accessibility and relevance of ACAS, particularly digital platforms, also remain a challenge for smallholder farmers (FAO, 2017; OECD, 2019; World Bank, 2018). For smallholder grain farmers, the global food system's reliance on large-scale agribusiness often marginalizes these farmers, limiting their market access and financial support (Kassam *et al*., 2016; FAO, 2017; World Bank, 2018). Additionally, gender disparities in agriculture continue to restrict women's access to resources and decision-making opportunities (Njuki *et al*., 2016; FAO, 2017; Doss *et al*., 2020).

In the African region, FM are heavily reliant on informal sources, with formal financial institutions reluctant to provide credit to smallholders (Kaur *et al*., 2020; AfDB, 2020; Njuki *et al*., 2016). ACAS face challenges in aligning with local farming practices, and formal services often fail to reach scale (FAO, 2017; Njuki *et al*., 2016; Hansen *et al*., 2019). Smallholder grain farmers in Africa are further marginalized by policies that prioritize large-scale farming, and gender inequalities are exacerbated by cultural norms and legal barriers that prevent women from fully participating in agriculture (Njuki *et al*., 2016; AfDB, 2020; Kapari *et al*., 2023).

Within the local Ghana economy, financing for ACAS is concentrated in urban areas, with rural regions like Northern Ghana facing significant challenges in accessing both formal and informal funding (MOFA, 2019; Kaur *et al*., 2020; Hansen *et al*., 2019). ACAS like AICCRA and Esoko are making strides but struggle with integration into local extension systems (MOFA, 2019; Hansen *et al*., 2019; Njuki *et al*., 2016). Smallholder grain farmers in Northern Ghana continue to face low productivity and market access issues, while women farmers are further disadvantaged by patriarchal norms and limited access to resources (MOFA, 2019; AfDB, 2020; FAO, 2017).

Previous research has highlighted the complementary nature of CSA and CIS, suggesting that access to CIS can lead to increased adoption of appropriate CSA practices (Alidu *et al*., 2022). However, the delivery of these services to smallholder farmers in Northern Ghana remains fragmented, with various barriers hindering their effective utilization (Baffour-Ata *et al*., 2022). While some initiatives like Esoko's *banbƆ* model and AICCRA's training workshops have explored bundling CSA practices and CIS, these efforts have been limited in scope and geographic reach (Kagabo and Ouedraogo, 2022). The "banbo" model, for instance, is available in some parts of Northern Ghana but has yet to be widely adopted and tailored to the specific needs of smallholder grain farmers (specifically maize and soyabean famers) in all parts of Northern Ghana.

To address this gap, this study introduces the term "Agro-Climatic Advisory Services (ACAS)" which refers to bundled services that combine Climate Information Services (CIS) and Climate Smart Agriculture (CSA) practices and technologies and provide tailored information specifically for smallholder grain farmers to manage climate risks and build resilience in Northern Ghana.

Climate Information Services (CIS) refer to the transformation of climate data into customized products such as seasonal forecasts, early warning systems, and climate advisories that provide farmers with information to guide decision-making (Tall *et al*., 2018; Yegbemey and Egah, 2021). Climate Smart Agriculture (CSA) practices consist of adaptation and mitigation practices and technologies that sustainably increase productivity, enhance resilience, and reduce/remove greenhouse gases (Zougmoré *et al*., 2018).

The introduction of the term "Agro-Climatic Advisory Services" in the study is motivated by the need to address the fragmented delivery of CSA practices and CIS to smallholder grain farmers in Northern Ghana, considering their specific agricultural advisories, climatic conditions, and socio-economic contexts. By bundling these services and tailoring them to the needs of this target group, farmers can receive context-specific climate information along with the corresponding CSA advisories, enabling them to make informed decisions and adopt appropriate climate-resilient strategies. This integrated approach has the potential to enhance agricultural productivity, improve resilience, and contribute to the increase in income and improvement in the wellbeing of small holder grain farmers in the face of climate variability, with a particular focus on the unique challenges faced by smallholder grain farmers in Northern Ghana.

Furthermore, the study incorporates a gendered analysis to understand the specific challenges, needs, and opportunities related to the adoption and financing of ACAS among male and female smallholder grain farmers in Northern Ghana. This analysis informs the development of tailored FM that address gender-specific barriers and promote equitable access to these bundled services. Financial inclusion barriers for smallholder grain farmers operate at both micro and macro levels. At the micro level, on the demand side, smallholder farmers often lack the assets or collateral needed to obtain formal credit from banks and financial institutions (Murphy & Savoy, 2022; Teye and Quarshie, 2021; Anang and Asante, 2020; World Bank, 2019; FAO 2019). Many smallholder farmers have limited financial literacy and capacity to navigate the formal banking system (Antwi-Agyei *et al*., 2021; AFI, 2018). High transaction costs associated with small loans makes lending unviable for financial institutions (Iddrisu *et al*., 2023; Anang and Asante, 2020).

On the supply-side, financial institutions consider agriculture lending as risky due to weather dependencies (Murphy & Savoy, 2022; AFI, 2018). There is difficulty in verifying the creditworthiness of small-scale farmers due to lack of financial records (Teye and Quarshie, 2021). Rural areas often lack financial access points. Limited infrastructure increases transaction costs for lenders (Murphy & Savoy, 2022). At the macro level, on the demand-side, underdevelopment of the broader rural financial system limits product options for farmers (Khan *et al*., 2024). There is a lack of national framework for agricultural credit provision to smallholders (Balana *et al*., 2022). Prior experiences with failed government programs or unscrupulous lenders have eroded smallholder farmers' trust in formal institutions (Donkoh *et al*., 2019).

On the supply-side, high inflation and interest rates discourage commercial banks from lending to the agriculture sector (Iddrisu *et al*., 2023). Lack of structured markets and warehouses for agricultural produce also discourages lending (Adekunle *et al*., 2020).

1.2 Problem Statement of the Study

Climate variability is a serious threat to grain production and income of small holder farmers in Northern Ghana despite their critical role in ensuring food security and sustaining rural livelihoods. Rising temperatures, variable precipitation, and water scarcity are reducing crop yields for smallholder maize and soybean farmers in Northern Ghana (Klutse *et al*., 2020; Baffour-Ata *et al*., 2021). To adapt and build resilience, smallholder farmers need access to productivity-enhancing ACAS (Antwi-Agyei *et al*., 2015; Nyantaki-Frimpong, 2015; Sutcliffe, 2016).

Smallholder farmers face significant challenges in accessing and adopting ACAS. These services, which bundle CIS and CSA practices, have the potential to enhance the resilience of smallholder farmers to climate variability impacts and improve their productivity and incomes (File and Nhamo, 2023; Alidu *et al*., 2022; Baffour-Ata *et al*., 2022). However, the fragmented delivery of

CIS and CSA services, coupled with the lack of tailored FM, hinders their widespread adoption among smallholder grain farmers in Northern Ghana.

While initiatives like Esoko's "banbƆ" model and AICCRA's training workshops have made efforts to bundle CSA practices and CIS, their reach and impact have been limited, particularly in addressing the specific needs of smallholder grain farmers in Northern Ghana (Kagabo and Ouedraogo, 2022). The lack of ACAS tailored to the unique agricultural practices, climatic conditions, and socio-economic contexts of these farmers presents a significant barrier to their ability to manage climate risks and build resilience. Moreover, the existing FM for agricultural services often fail to address the gender-specific constraints faced by women smallholder farmers in Northern Ghana (Ugwu, 2019; Kinkingninhoun-Mêdagbé *et al*., 2008).

Discriminatory cultural norms, limited access to credit and financial services, low decision-making power, and time poverty restrict women's ability to adopt climate-smart technologies (Antwi-Agyei *et al*., 2021; Tovennor *et al*., 2019). This gender disparity not only perpetuates inequalities but also undermines the overall resilience and productivity of smallholder farming communities in the region. Addressing this problem requires a comprehensive understanding of the FM suitable for delivering ACAS to smallholder grain farmers in Northern Ghana, with a particular emphasis on gender-specific barriers and opportunities. Identifying and implementing tailored FM that promote access and adoption of ACAS is crucial for enhancing the resilience and livelihoods of smallholder grain farmers, particularly women, in the face of climate variability.

This study seeks to address this overall question: what are the appropriate financing mechanisms for enhancing access to ACAS for smallholder male and female grain farmers in Northern Ghana? The specific research questions are as follows:

i. What is the nature of the financing mechanisms for ACAS among male and female smallholder grain farmers in Northern Ghana?

ii. What are the factors that influence the degree and level of access to ACAS by male and female smallholder grain farmers in Northern Ghana?

iii. What are the factors that influence the choice of ACAS by male and female smallholder grain farmers in Northern Ghana?

iv. What is the impact of ACAS on the productivity and incomes of male and female smallholder grain farmers in Northern Ghana?

1.3 Objectives of the Study

The major objective of this study is to examine financing mechanisms which improves access to ACAS for smallholder male and female grain farmers in Northern Ghana. The specific objectives of this study are as follows:

1. Describe the nature of the financing mechanisms for ACAS among male and female smallholder grain farmers in Northern Ghana.
2. To measure the extent of access to ACAS by male and female smallholder grain farmers in Northern Ghana.
3. Identify factors influencing the choice of ACAS by male and female smallholder grain farmers in Northern Ghana.
4. Analyse the impact of ACAS on the productivity and incomes of male and female smallholder grain farmers in Northern Ghana.

1.4 Relevance of the Study

This is supported by studies showing that smallholder farmers contribute the majority of staple crop production in Northern Ghana and are central to rural household food security and income generation (FAO, 2019; MoFA, 2021).In the past five years, they have contributed significantly to national food security and the local economy, with agriculture employing about 80% of rural households (Gyasi *et al*., 2019; Antwi-Agyei *et al*., 2020). Despite their importance, these farmers are highly vulnerable to climate variability, which threatens grain yields and household incomes. Climatic challenges such as erratic rainfall, rising temperatures, and water scarcity (Klutse *et al*., 2020; Baffour-Ata *et al*., 2021) have exacerbated their situation.

This study focuses on the nature of the FM necessary to effectively support ACAS for these farmers. Understanding these mechanisms is critical because access to finance directly influences the ability of farmers to adopt climate-smart practices, by examining how financing mechanisms (FM) influence access to climate information services (CIS) and climate-smart agriculture (CSA) technologies, this study identifies which financial approaches most effectively support smallholder farmers. The findings can inform policymakers, financial institutions, and development agencies on designing targeted, gender-sensitive, and scalable financing strategies that enhance productivity, strengthen climate resilience, and promote sustainable agricultural development in Northern Ghana.Gaps in the current financing structures need to be addressed. For example, although initiatives like Esoko's *banbƆ* model and AICCRA's training programs have made strides, they lack adequate financing to expand coverage and address the specific needs of smallholder grain farmers (Kagabo and Ouedraogo, 2022). Service providers struggle to scale up and reach marginalized farmers, particularly women, due to fragmented delivery of services, lack of credit access, and limited institutional support (Tovennor *et al*., 2019).

Moreover, gender disparities in accessing financing and agro-climatic services are a critical barrier. Women smallholder farmers face discriminatory norms, reduced access to credit, and time poverty, which restrict their ability to adopt climate-smart technologies (Ugwu, 2019;

Kinkingninhoun-Mêdagbé *et al*., 2018). These challenges result in uneven outcomes, limiting both agricultural productivity and household resilience.

The study thus aims to address these service gaps by examining the types of FM that would enhance access to ACAS among smallholder grain farmers. Specifically, it will explore the effects, choices, and access to these services, focusing on gender-specific constraints. By identifying financing solutions tailored to the needs of smallholder farmers, particularly women, this research can help improve climate resilience, productivity, and livelihoods in the region.

Furthermore, this research aligns with global efforts to achieve United Nations Sustainable Development Goals, particularly SDG 2 (Zero Hunger), SDG 5 (Gender Equality), and SDG 13 (Climate Action). Specifically, the study examines how FM impact smallholder grain farmers' access to ACAS, fostering improved grain productivity, income, and resilience to climate variability. Additionally, it explores the gendered effects of these mechanisms, contributing to gender equality in agricultural decision-making and resource allocation. This research is timely and relevant, addressing the intersection of climate adaptation, sustainable agricultural development, and gender equality in Northern Ghana.

Additionally, this research aligns with Ghana's Food and Agricultural Sector Development Policy (FASDEP II) by focusing on key areas of its strategic goals. Specifically, the study examines the nature of FM and their effect on ACAS, which supports FASDEP II's objective of improving access to agricultural technology and enhancing technology adoption. By measuring the extent of access and identifying factors influencing this access, the research contributes to FASDEP II's emphasis on ensuring gender equity in the provision of agricultural resources and services.

Furthermore, the study identifies factors influencing the choice of ACAS and estimates their effect on productivity and income, directly addressing FASDEP II's goals of promoting sustainable agricultural development and increasing productivity. By generating insights into tailored FM and gender-responsive approaches, this research provides valuable information for policymakers, development organizations, and stakeholders. It informs the design and implementation of effective strategies to build resilience, foster inclusive growth, and advance sustainable agricultural development in Northern Ghana.

Additionally, this research also aligns with the focus of Ghana's Food and agricultural Sector Development Policy (FASDEP II's) focus on improving access to agricultural ACAS, including technology dissemination. By examining the FM that support ACAS, the study contributes to FASDEP II's goal of enhancing technology adoption, especially in the context of climate change.

1.5 Organisation of the Thesis Report

This research report is structured into five chapters. Chapter One introduces the study, providing background information, problem statement, objectives, justification, and organization. Chapter Two reviews relevant literature on grain production, agricultural financing, ACAS, and gender analysis in agricultural development.

Chapter Three outlines the methodology, including data sources, theoretical and conceptual frameworks, and methods of data analysis. Chapter Four presents the results and discussions, covering socioeconomic profiles, factors influencing access and adoption of ACAS, and their impact on productivity and income. Finally, Chapter Five concludes the report with key findings and recommendations.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

In this chapter, the relevant theoretical and empirical literature on the study is presented. First, a description of grain production in Northern Ghana is provided. Next, agricultural financing in developing countries, ACAS and its FM, are described. The gender-specific challenges faced in accessing financial and ACAS are also discussed. Then, sections on empirical studies that support the specific objectives of the study are reviewed. The penultimate section of the chapter is devoted to the summary of reviewed literature and the research gaps identified. The final section of the chapter is devoted to a discussion of gender theories of development which underpin the theoretical framework of the entire study.

2.2 Grain Production in Northern Ghana

Maize, rice, and legumes, like soybeans and cowpeas, are Ghana's principal cereal and grain crops. These grains and legumes were the subject of a 2022 study by The African Seed Access Index (TASAI) to evaluate the composition and financial performance of Ghana's official seed system due to their significance for the food and nutritional security of the country. For the majority of Ghana's rural populace, these grains constitute essential staple foods as well as important sources of work and revenue. About 66% of Ghana's arable land is devoted to these four crops combined (SRID/MOFA 2021; FAOSTA). These crops are also included among the six food crops that have been chosen for Planting for Food and Jobs (PFJ), a government subsidy program (MoFA 2017).

The Upper West, Upper East, Northeast, Northern and the Savannah regions make up what is generally referred to as Northern Ghana (Ghana Local Government Service, 2025). Approximately four million smallholder farmers reside in these five regions, contributing approximately 80% of the country's food crop production (WFP, 2019). Ghana's main crop for food security and most significant grain crop is maize. Since the late 16th Century, maize has been grown in Ghana; it used to be a major food crop in the southern region of the nation (Abbeam *et al*., 2017).

The majority of rural households in Ghana's five (of six) agro-ecological zones—the coastal savannah, high rainforest zone, semi-deciduous rainforest, forest savannah, and guinea savannah—produce maize, which is a staple food that is crucial to the country (Amanor-Boadu, 2012). Maize makes up between 50 and 60 per cent of Ghana's total cereal production. In 2020, the production of maize occupied 1.2 million hectares of land (SRID/MOFA 2021). However, the average yield of maize in Northern Ghana is just one tonne per hectare, which is less than half of Ghana's national average, and only about 18% of the yields in high-productivity regions such as the Ashanti region (SRID/MOFA 2021).

Recently, portions of the Northern region have seen an increase in the production of rice in interior valleys that get regular rainfall. Nevertheless, because smallholding households mostly employ native varieties, without the application of mineral fertilizers or pesticides, the average paddy yield is still just two tonnes per hectare (SRID/MOFA 2021). The next major cereals farmed in Northern Ghana are millet and sorghum. Average yields are 1.5 and 1.7 tons per hectare, respectively, which are again much less than their average potential yields of 2.0 tons per hectare each, despite being more robust to dry growing conditions (MoFA, 2011).

Soybean is another important grain that is grown in northern Ghana. Due to its many applications, this highly nutritious leguminous crop is frequently described to as the "miraculous" crop (Abdul–

Rashid *et al*., 2016). It appears in a variety of forms, occasionally as tiny grains with a black or creamy color (Chianu *et al*., 2009). According to Plahar (2006), soybeans are a nutritional storehouse because they have higher concentrations of vital minerals, vitamins, fatty acids, and high levels of protein. According to Greenberg and Hartung (1998), the crop has 40% protein. However, only 2% of this protein is eaten by humans in the form of food products, and the remaining 98% is fed to livestock like pigs and poultry as processed soybean meal (Goldsmith, 2008). According to Plahar (2006), the crop has the potential to advance Ghana's economy in three important areas: agriculture, health, and industry. However, like other grains, soybean yields in Northern Ghana are low, ranging from 2.00 to 2.13 MT/ha, falling short of the crop's potential yield of 3.00 MT/ha (SRID/MOFA 2021).

2.3 Maize and Soybean production in Northern Ghana

2.3.1 Maize Production in Northern Ghana.

Maize is the most widely grown staple cereal crop across Ghana's northern savannah agro-ecological zone. Nearly every smallholding farmer cultivates some maize, predominantly for subsistence use (Abdulai & Huffman, 2014). However, the average yield of maize in the Northern area is just one ton per hectare, which is less than half of Ghana's national average (nearly 60% below the national average) and only 18% of the yields in high-productivity regions such as the Ashanti region (SRID/MOFA 2021).

The main causes of this poor productivity include excessive reliance on rain-fed agriculture and a restricted use of fertilizers that could increase output. The adoption of improved maize varieties is hampered by the fact that most smallholder farmers are subsistence farmers and have limited access to high-quality seeds, fertilizers, extension assistance and financing (Issahaku & Abdulai, 2019). Furthermore, northern cropland-carrying capacities are constrained by small farm sizes, land fragmentation, and low soil fertility (Drechsel and Keraita, 2014). Maize production is also challenged by shifting climate patterns characterized by significant rainfall fluctuation, flooding, and sporadic droughts. Household food insecurity is sustained by a lack of irrigation infrastructure and a lack of off-farm income opportunities to cushion environmental shocks (Kuwornu *et al.*, 2013). Limited access to credit disincentivizes farmers from investing in productivity boosting inputs which require significant upfront costs. Lack of lucrative markets for surplus maize gives little incentive for intensification too (Al-Hassan & Diao, 2007). This combination of agronomic, economic and institutional constraints keeps maize yields in Northern Ghana far below attainable levels (MoFA, 2021). However, some studies have shown average yields across the five northern regions could potentially double or even triple by addressing key limitations around irrigation infrastructure, agricultural credit, improved seeds and fertilizers accessibility, climate-smart agronomic training of farmers, and land tenure security improvements (for example, refer to the work of Akramov & Malek, 2012).

2.3.2 Soybean Production in Northern Ghana

Soybean is a relatively new non-staple income crop that is gaining appeal in Ghana's five northern regions, primarily for animal feed (Martin and Goldsmith, 2020). Soyabean growing has grown from over 85,000 hectares in 2012 to more than 126,000 hectares in 2021, especially in the Northern and Upper West regions (MoFA, 2021)

This growth aims to substitute soybean imports, meet rising local food and industrial demand, and provide an additional cash crop option for smallholders. However, like other grains, average soybean yields in northern Ghana are considerably below their potential values.

2.4 Agro-climatic Advisory Services (ACAS)

Climate variability threatens agricultural productivity while population growth necessitates increased crop yields, highlighting the value of ACAS to empower farmers with critical weather and climate information as well as techniques and technologies. Existing literature suggests that providing farmers with localized, timely, and actionable advisories boosts productivity as compared to no advisories or generic weather forecasts (Mittal, 2016). The content and communication channels for agro-advisories significantly impact farmer use and outcomes as well (Lobo *et al*., 2017). While traditional mass media like radio broadens reach, ICT-enabled personalized advisories show the most promise for relevance and behaviour change. For instance, an SMS campaign providing Indian farmers with hyperlocal advisories three times per week increased yields by 14% compared to just a 3.6% (**Aker, 2020)** and increase from traditional mass media (Cole & Fernando, 2021). Furthermore, pairing SMS-based advisories with in-person demonstration plots addressing climate resilience practices also outperformed other information-only campaigns targeting smallholders (Carr & Onzere, 2017).

However, gaps remain around service sustainability and equity of access specifically regarding gender divides. The digital gender divide has several underlying factors, such as barriers to access, cost, education (or lack thereof), and lack of technology proficiency. It also stems from ingrained prejudices and sociocultural norms that promote gender-based digital exclusion (OECD, 2018d; OECD, 2015a; Hilbert, 2011; Cooper, 2006; Korupp & Szydlik, 2005). In general, women tend to have less access to ACAS. Additionally, public sector funding primarily supports most services currently, raising questions about effective public-private partnership models for financial viability long-term (Tall *et al*., 2014).

Even though initiatives, like Esoko's banbↃ model and AICCRA's training workshops have explored bundling CSA practices and CIS, there is a gap in literature when it comes to ACAS as these efforts have been limited in scope and geographical reach (Kagabo & Ouedraogo, 2022).

2.5 Climate-Smart Agriculture (CSA)

Climate-smart agriculture (CSA) has emerged in recent years as an integrated approach to managing landscapes for increased productivity, enhanced resilience, and reduced greenhouse gas emissions (FAO, 2013). The concept of CSA was introduced in 2010 through a joint programme launched by the Food and Agriculture Organization (FAO) and the World Bank to integrate the complex challenges posed by climate change into agricultural development planning (Sam *et al*., 2021). This is built upon related ideas such as sustainable agriculture and sustainable intensification that had gained traction in prior decades (Pretty *et al*., 2011; Garnett *et al*., 2013). While increased productivity alone was gaining attention for meeting global food security needs, CSA emphasized productivity gains must align with building resilience and mitigating climate impacts through reduced emissions (Campbell *et al*., 2014). Three interconnected pillars: productivity, adaptation, and mitigation; thus form the conceptual framework underpinning CSA (FAO, 2013). CSA aims to address tradeoffs between these pillars through integrated solutions tailored to local contexts. This requires coordinated planning from farm to landscape scales based on specific agricultural systems, climates, and socioeconomic conditions (Aggarwal *et al*., 2018). The flexibility built into CSA means implementation varies greatly, from agro ecological practices to sustainable intensification using advanced technologies (Sinclair, 2017). Despite flexibility in implementation, CSA alignment with the key pillars of productivity, adaptation, and mitigation represents core principles. A growing body of empirical evidence demonstrates CSA’s ability to address these pillars across diverse agricultural systems and climates jointly.

Regarding productivity, evidence shows that properly implemented CSA practices, such as cover crops, crop rotations, and integrated soil fertility management, can increase yields over the long term by enhancing soil health and water retention while reducing reliance on external inputs (Baffour-Ata *et al*., 2023; Mugwe & Otieno, 2021; Matteoli *et al*., 2021). Practices tailored to local ecology, soils, and farmer needs and knowledge are most effective for sustained productivity increases. Increasing resilience to climate change is also crucial for long-term productivity. Here practices such as crop and livelihood diversification, use of resilient crop varieties, and water management align production systems better with climate variability and change (Lipper *et al*., 2014). Agroforestry integrating trees into crop and livestock systems plays an important adaptation role through microclimate regulation, soil conservation, and diversified income sources (Mbow *et al*., 2014). Diversification and integration act as risk mitigation and adaptation strategies buffering farmers against climate shocks that may devastate single, simplified systems. Regarding climate change mitigation, evidence clearly shows that many CSA practices reduce greenhouse gas emissions, enhance carbon storage in soils and biomass, and avoid fossil fuel emissions (Richards *et al*., 2015). Practices like conservation agriculture, agroforestry, and integrated crop-livestock systems have significant mitigation potential that increases over time as soil carbon builds up (Aggarwal *et al*., 2018). Tradeoffs can exist between productivity and mitigation goals, however, as higher yields often rely partly on increased synthetic fertilizer use which boosts emissions (Lamb *et al*., 2016).

While empirical evidence demonstrates CSA's potential for jointly addressing productivity, adaptation, and mitigation goals, some critical perspectives should be considered. Testing many CSA practices at scale over long periods poses challenges, making the evidence base incomplete (Taylor, 2018). How practices combine in integrated systems tailored to different contexts also requires further study to determine synergies and tradeoffs. There are also concerns that without shifts in larger socioeconomic and policy environments, the productivity and climate resilience of smallholder farmers may not improve under CSA (Taylor, 2018). Overall assessments show CSA holds promise as an integrated approach but needs much wider implementation and testing focused on long-term evidence across diverse agricultural systems (Campbell *et al*., 2014; Aggarwal *et al*., 2018). Realizing climate-smart agriculture will likely require supporting policies and institutional environments aligned to the approach (Lipper *et al*., 2014). Adequate FM that provides incentives for the adoption of integrated practices and access to relevant technologies and information are also critical needs (FAO, 2013). Research gaps remain in understanding these systemic barriers and requisite changes.

To conclude, climate-smart agriculture has rapidly gained traction as an integrated approach to address the interlinked challenges of productivity and climate variability impacts on agricultural systems. Core principles aligned with increasing productivity, enhancing resilience, and reducing emissions provide guidance for tailored implementation across diverse contexts. A growing evidence base demonstrates CSA's ability to jointly address these multiple objectives through practices fine-tuned to local contexts. Critical perspectives should continue to be integrated into research on long-term, widespread CSA adoption and enabling policies and institutions. Overall CSA shows promise but requires much greater implementation, testing, and supportive systemic changes before potential impacts can be fully realized.

2.5.1 Climate Information Services (CIS)

As climate variability and extreme weather events pose growing risks for agricultural production globally, climate information services have emerged as a vital means of supporting climate-informed management practices. A predominant theme is the need for agricultural climate information services that provide actionable advisories and projections tailored to localized conditions and timescales relevant to farm management. Findings from several continents indicate that due to spatial heterogeneity in climate impacts, farmers desire location-specific seasonal forecasts, drought early warning data, and agro-climatic projections to support farm-level decision-making (Rao *et al*., 2019; Manjula & Rengalakshmi, 2015; Masinde *et al*., 2012). Customizing climate information via participatory processes to match regionally specific cropping systems, landscapes, and farmer needs enhances salience and uptake (Dorward *et al*., 2015; Nyamwanza *et al*., 2017). Highlighting synergies with Indigenous forecasting methods also shows promise for improving credibility and adoption (Chisadza *et al*., 2015; Kalanda-Joshua *et al*., 2011). However, barriers to communicating uncertainties persist and probabilistic information poses interpretation challenges that inhibit use (Masinde *et al*., 2012; Rao *et al*., 2019).

Studies trace recent initiatives across Ghana testing diverse models for communicating climate information to farming communities. Approaches include traditional print and radio broadcasting as well as digital methods like mobile phone messaging services and climate-smart advisory platforms (Antwi-Agyei *et al*., 2021; Hansen *et al*., 2019). Findings affirm that credibly sourced, localized advisories on imminent weather and hourly to seasonal forecasts can aid planning for planting, fertilizer application, and harvest timing at farm scale (Laube *et al*., 2012; Masinde, 2015). A prevailing research priority entails collaborative development processes that engage farmer feedback to tailor climate services to distinct agricultural decision contexts, land use constraints, and information needs. Nyadzi *et al*. (2019) demonstrate that incorporating farmers' indigenous weather indicators and knowledge to design locally relevant advisory content improves trust and uptake. Findings likewise highlight the promise of participatory communication to translate probabilistic climate data into easy-to-understand risk messaging through community engagement forums (Masinde, 2015). However, Ouedraogo *et al*. (2018) reveal uneven capacity gains across pilot interventions, signaling that sustained outreach remains necessary to reinforce skills for interpreting and applying climate information.

In assessing tradeoffs among delivery formats, Antwi-Agyei *et al*. (2021) find interactive voice services achieve greater satisfaction and engagement than text advisories, while Sarku *et al*. (2022) document usability challenges for an online climate information platform. Roudier *et al*. (2014) argue SMS and voice-based services enable timely delivery during critical decision windows even across dispersion and infrastructure barriers. Yet Nyadzi *et al*. (2022) caution that overemphasizing technology risks marginalizing vulnerable groups lacking digital access or skills. Instead, findings advocate bundled, multi-channel communication drawing upon interpersonal, traditional media, and digital pathways tailored to localized needs and capacities (Carr & Owusu-Daaku, 2016). Beyond climate science input alone, research signals that sustained mainstreaming in agricultural planning and operations requires 'impact-based forecasting' fused with actionable recommendations alongside institutional coordination (Masinde, 2015). However, gaps persist between producing salient climate insights and facilitating systemic organizational change to enable uptake (Antwi-Agyei *et al*., 2021). Nyadzi *et al*., (2019) argue that in the absence of long-term resource allocations for ongoing engagement, to reinforce capacities, and incent implementation, climate information use will likely remain ad-hoc in nature. Despite surging experimentation to advance climate services nationally, a critical research gap involves sparse evidence documenting how information aids adaptation decision-making or outcomes over time. Assessments overwhelmingly focus on adoption indicators rather than long-term changes in practices or resilience (Antwi-Agyei *et al*., 2021). Exceptions such as tracing such pathways remain isolated to few commodities, locales or interventions (Roudier *et al*., 2014). The application of mixed methods research work to discern links between information access, use, land-use choices, and indicators of household welfare and sustainability is useful (Nyadzi *et al*., 2022).

2.5.2 Role and Importance of ACAS in Agricultural Development

Access to Agricultural Climate Advisory Services (ACAS) has become increasingly essential for strengthening climate resilience and supporting agricultural development, especially as climate variability continues to intensify globally. ACAS provides farmers with timely and localized climate and weather information such as seasonal forecasts, early warnings, and agronomic advisories which enhances decision-making and reduces uncertainty in farming operations (Buontempo et al., 2020; Blair et al., 2020).

The rising frequency of extreme climate events continues to threaten smallholder farmers, who often lack irrigation, insurance, and access to formal credit. ACAS plays a crucial role in helping farmers anticipate climate risks and adopt preparedness strategies that improve yield stability and reduce climate-induced crop losses (Carter et al., 2021; Nyadzi et al., 2020). Through improved access to climate information, farmers are better equipped to choose suitable crop varieties, adjust planting dates, and adopt appropriate soil and water conservation practices that enhance resilience.

In addition, ACAS supports the advancement of climate-smart agriculture (CSA) by enabling farmers to integrate adaptation and productivity-enhancing practices. Evidence shows that farmers who regularly receive climate advisories are more likely to adopt innovative practices such as drought-tolerant seeds, integrated pest management, and efficient irrigation technologies (Jha et al., 2020; WMO, 2020). These interventions promote higher productivity while helping farmers cope with climate-induced challenges.

ACAS also contributes to policy development and agricultural planning by enabling governments and development agencies to design data-driven programs that strengthen national climate adaptation strategies. Research indicates that well-structured climate advisory systems improve early warning dissemination, support risk management frameworks, and enhance the effectiveness of climate finance investments in agriculture (Totin et al., 2021; Tall et al., 2020).

2.5.3 Communication and Use of Climate Information

Studies stress the role of ACAS in alerting farmers to imminent weather hazards and extremes through location-specific advisories, allowing protective decisions like harvesting or moving livestock in anticipation of events (Ramaraj *et. al*., 2023; Radeny *et al*., 2019; Manjula and Rengalakshmi, 2015). Short-term advisories on daily to weekly timescales inform tactical responses, while seasonal forecasts assist planning for the timing of operations, input decisions, or crop variety selections aligned with climate outlooks (Madhuri, 2023; Ofoegbu and New, 2022; Friedman *et al*., 2022; Kumar *et al*., 2020). However, communication barriers around scientific uncertainties and probabilistic information pose challenges to use (Kause *et al*., 2021; van der Bles, 2019; Schneider, 2016). Participatory design and dissemination methods that translate forecasts into understandable messaging show promise for broader adoption (Chaudhuri and Kendall, 2020; Gbangou *et. al*., 2020; Dorward *et al*., 2015)

2.5.4 Informing Climate-Smart Farm Management

Research documents the potential for ACAS to aid the incorporation of climate information in farm-level decision-making processes around land preparation, crop choices, planting dates, fertilizer applications, irrigation scheduling, and more based on weather data and climate projections (Sarku *et al*., 2022; Dogbey, 2021; Partey *et al*., 2018). Advisories allow the alignment of practices with forthcoming conditions to optimize production. However, uneven access persists across socio-economic barriers while gaps remain around facilitating sustained services integration within planning workflows and reinforcing user capabilities over time through institutional support (Rengalakshmi and Manjula, 2018; Dorward *et al*., 2015).

2.5.5 Shaping an Enabling Policy Environment

Research also emphasizes the role of ACAS in shaping an enabling policy environment that supports climate-smart agriculture. By generating reliable climatic datasets, ACAS enables governments to conduct risk mapping, which helps direct agricultural technology targeting and prioritize adaptation investments (Jain et al., 2020). Seasonal and long-range climate predictions further guide policy planning, allowing ministries to anticipate future conditions and align research and development strategies accordingly (Bank for International Settlements, 2020).

ACAS also plays an institutional role by informing the design of weather-indexed insurance **schemes**, which expand farmer access to credit and compensation while reducing government expenditure on disaster relief (Dalhaus & Finger, 2020). Through these functions, ACAS contributes to a policy landscape that incentivizes risk-aware production, promotes resilience, and improves resource allocation. However, realizing this enabling environment requires **strong coordination** between meteorological agencies, research institutions, and extension systems, in addition to sustained funding to ensure continuity and scaling of services (Hurlbert & Pittman, 2020)

2.5.6 Gaps around Impact Assessments

A considerable research gap involves limited evidence verifying if ACAS lead to improved climate-risk management, adaptation outcomes or long-term resilience. Available assessments emphasize technology access more than shifts in practices, land use choices, productivity or welfare over time (Carr & Onzere, 2017). Robust evaluation requires multi-disciplinary methods tracing complex pathways from information use to agricultural sustainability indicators, developed through participatory processes (Hansen *et al*., 2019; Nyadzi *et al*., 2022). Addressing this evidence gap around influence remains critical for guiding effectiveness improvements.

To conclude, ACAS constitutes an invaluable means of alerting farmers to risks, guiding informed farm management under uncertainty, and enabling policies that incentivize resilient, sustainable agricultural systems. Yet strengthening inclusiveness, sustained use, and coordination alongside impact assessments remain imperative priorities for advancing climate-smart agriculture through actionable advisories globally.

2.5.7 Challenges Faced in Disseminating Agro-Climatic Information to Smallholder Farmers

The dissemination of accurate and timely agro-climatic information, including weather forecasts, early warning systems, and climate resilient advisories, can be invaluable for smallholder farmers to plan agricultural activities and manage climate-related risks effectively (Pienaah *et. al*., 2023; Dogbey, 2021; FAO, 2019; Rengalakshmi & Manjula, 2018). However, many studies highlight the significant challenges in getting relevant agro-climatic information and services to vulnerable smallholder populations in developing countries (Hansen *et al*., 2019; Knox *et al*., 2020; Nyasimi *et al*., 2017). A predominant challenge emphasized across literature is the “technology-centric” orientation of many agro-climatic information dissemination efforts, which focus overwhelmingly on introducing modern ICTs from a top-down approach without adequate understanding of end-users' contexts (Knox *et al*., 2020; Rengalakshmi & Manjula, 2018). This condenses into three main disconnects: literacy divide, resource divide, and content relevance divide.

Firstly, the literacy divide refers to mismatches between the education levels, language diversity, and technological literacy amongst smallholder farmers versus the modes used for information dissemination-whether radio, print media, SMS services, smartphone applications or automated voice messages (Hansen *et al*., 2019; Rengalakshmi & Manjula, 2018). Secondly, the resource divide encompasses barriers like lack of infrastructure in remote rural areas, market failures restricting farmers' access to mobile devices/internet, high costs of ICT services, inadequate electrical and network connectivity, and inability of resource-poor farmers to physically access advisory offices (Knox *et al*., 2020; Nyasimi *et al*., 2017). Lastly, the content relevance divide represents gaps in provisioning of locally contextual, gender-sensitive information in understandable formats about crops, livestock varieties, languages, weather variability, indigenous forecasting knowledge, and baseline climate scenarios prevalent in the target smallholder communities (Hansen *et al*., 2019; Rengalakshmi & Manjula, 2018). While illiteracy, poverty and remoteness amongst marginal smallholder farmer groups are positioning the literacy, resource and relevance divides, the core driver underpinning these divides seems to be a lack of participatory processes and ground-level embeddedness while designing agricultural advisory content and platforms (Nyasimi *et al*., 2017).

2.6 Financing Mechanism for ACAS in Developing Countries

Agriculture serves as a fundamental pillar of economies in developing countries, providing essential sustenance, livelihoods, and economic stability for a significant portion of the population. However, financing for agricultural production and ACAS remains a subject of national interest and challenge. Agricultural financing refers to the mobilization of public and private resources, including equity, loans, and grants, to promote the development of the agricultural sector and improve social welfare (Schreiner & Yaron, 2001). This financing envelope includes contributions from both government funds and non-governmental organizations (NGOs) through matching grants, which aim to foster community and sector development, income equality, and local empowerment using services related to weather forecasting, early warning systems, and climate risk assessments, are crucial components of modern agricultural systems. These services enhance agricultural production, resilience, and food security by providing farmers with timely and accurate information. Yet, the sustainable provision of these services is heavily reliant on efficient and diversified FM. Traditionally, national meteorological and hydrological services (NMHSs) have relied on public funds to support their infrastructure and activities. However, limited government budgets and conflicting priorities have often led to underfunding, resulting in operational constraints and restricted service delivery (Wakweya, 2023). Additionally, international development organizations, including the World Bank, UN agencies, and bilateral donors, have played a critical role in financing ACAS through project-based funding, technology transfer, and capacity-building initiatives (Neufeldt *et al*., 2023). Despite their contributions, the short-term nature of these projects and the uncertainties of external funding pose challenges to the long-term sustainability of ACAS.

To overcome these challenges, there is growing recognition of the need to explore innovative financing strategies that engage the private sector, diversify funding sources, and align financial incentives with high-quality service delivery (GCA, 2022). Given the enormous investment needs, estimated to be in the trillions of dollars annually (IPCC, 2022), traditional financing methods alone are insufficient. The exploration of new financial tools that can mobilize resources from a broad range of stakeholders, including the private sector, is crucial for ensuring the scalability and sustainability of both agricultural production and ACAS in developing countries.

Agricultural financing remains crucial for unlocking the productivity potential in developing country agriculture systems, where over 500 million small-holder farmer households with under two-hectare landholdings produce about 30-35 per cent of global food output (IFAD, 2019). However, just about 10 per cent of total bank lending in these economies is directed towards the agriculture sector with smallholders getting a minuscule 1.7 per cent share (Dalberg, 2012), making access to finance a major challenge for smallholder farmers in most developing countries. The problem often is seen in terms of limited access to production credit to buy and use farm inputs, adopt agricultural technology, as well as pay for non-family farm labour and other farm maintenance costs (Feder *et al*., 1990; Feder and Umali, 1993; Onumah and Meijernk, 2012; Abate *et al*., 2016; Khandker and Koolwal, 2016).

On the demand side, remoteness from bank branch networks, lack of collateral assets, high transaction costs of small loans, irregular cash flows, financial illiteracy of farmers, and absence of credit records exclude small farmers from formal credit access (Balana *et al*., 2022). Information gaps also hinder service providers in securing adequate financial resources, as financial institutions struggle to accurately assess the creditworthiness and financing needs of these providers operating in diverse agricultural contexts (Binswanger-Mkhize, 2012). The risk of defaults due to external factors such as weather variations and pest outbreaks also discourages private lenders from investing in service providers. Furthermore, politically motivated loan write-off schemes can undermine the overall repayment culture, affecting the willingness of financial institutions to extend credit to service providers (Duong & Izumida, 2002). Politically motivated loan schemes are linked to the adverse selection information market failure problem whereby the ability to pay of consumers of loans is not seriously factored into loans supply decisions. On the supply side, there is limited availability of alternative credit sources in local areas, unavailability of financial products that suit the needs of smallholders, or high costs of borrowing (Balanaa et. al., 2022).

2.6.1 Innovative FM

Innovative FM for ACAS has emerged as a significant approach that cater for the needs of male and female smallholder farmers, particularly in developing countries (Ruben *et al*., 2019; Gouett *et al*., 2023). A wide range of financial mechanisms exist, like the blended finance, public-private investment, and payment for ecosystem. The blended finance, which combines concessional public funds with commercial private investment, can be used to scale up investment for climate adaptation in agriculture, with innovative financial instruments like social bonds potentially used to support climate adaptation co-benefits in the agriculture sector (Clark *et al*., 2018; Convergence, 2019). The public-private partnerships are known for their long-term relationship between government and private partners for providing a public asset or climate-smart services in which the private party bears significant risk and management responsibility; remuneration is linked to performance (PPP Knowledge Lab, 2017).

The World Bank (2016) recognized climate finance as a catalyst to accelerate climate-smart investments in the agriculture sector which can help unlock additional sources of capital, strengthen the links between financial institutions and farmers, and build the capacity of both lenders and borrowers. The demand-driven agricultural ACAS require innovative FM that empower farmers and their organizations to take greater responsibility and negotiate the services they want, as demonstrated by the Village Savings and Loan Association (VSLA) in Ghana and

Local Innovation Support Fund (LISF) in Burkina Faso (Amponsah *et al*. 2023, Triomphe *et al*., 2013.)

According to Garbero & Songsermsawas (2021), financial service providers (FSPs) can capitalize on digital solutions to help grow their agriculture portfolios and make informed lending decisions that account for agroclimatic risk, providing climate risk analytics, value chain management, financial analytics, and other services to support FSPs in assessing and managing climate risks in their agricultural lending.

2.6.2 Impact of Access to Finance on Farm Productivity and Income.

Effective ACAS can significantly enhance farmers' decision-making regarding input use, crop selection, and risk management strategies, leading to increased productivity. The aim is to empower farmers with the information they need to optimise their agricultural practices, ultimately improving their output and economic resilience in the face of climate-related challenges. This is crucial because understanding the link between ACAS and productivity can inform the development of tailored strategies that maximize the benefits of these services for smallholder farmers, ensuring that they remain competitive and sustainable in the long term (Hussain *et al*., 2021).

Access to finance is critical for improving farm performance, productivity, income, and, ultimately, farmer well-being since it allows farmers to purchase inputs and technologies. Small-scale farmers typically need agricultural finance to survive, while large-scale farmers use it to diversify their income streams (Das *et al*., 2009). Similarly, Ngeno (2018) and Solano and Rooks (2018) addressed both credit availability and socioeconomic factors in improving farm household well-being. There is evidence in the literature to support the favorable impact of access to financing on agricultural productivity, income, and farmer well-being (Awotide *et al*., 2015; Ogundeji *et al*., 2018; Fowowe, 2020; Haryanto *et al*., 2023; Siaw *et al*., 2023). In 2013, Girabi and Mwakaje found that, in comparison to those who did not get credit from microfinance institutions, agricultural productivity was higher for those who did.

Farmers in emerging economies are typically hampered by low incomes and limited resources because they are unable to provide collateral for bank loans (Conning and Udry, 2007). The goal of a 2020 study by Amanullah *et al*. was to ascertain how credit restrictions affected the welfare of wheat growers in Pakistan. The study's findings demonstrated that credit limitations had a detrimental effect on farmers' income and well-being. Finance limitations, whether internal or external, are essential to the efficient operation of farm productivity. Farm production is greatly impacted by the interaction of internal and external financial factors, and many farms require external financing due to inadequate cash flow (Li *et al*., 2018). Due to widespread credit limits and inadequate financial infrastructures, emerging countries exhibit a delayed growth process (Skott and Gomez-Ramírez, 2018).

2.6.3 Innovative Financial Products Tailored to Women Farmers

For smallholder farmers, especially women, financial exclusion is a problem that hinders economic growth and productivity (Fletschner & Kenney, 2014). Nonetheless, novel financial instruments designed exclusively for female farmers exhibit the potential to mitigate capital limitations. Targeting rural women explicitly with market-priced microfinance has raised income and long-term investment (Banerjee *et al*., 2015). Furthermore, women's economic and social empowerment results from combining microcredit with agricultural training (Kim *et al*., 2009). More recently, by tying payouts to meteorological occurrences, index-based agricultural insurance products assist female smallholders in managing climate risks (Akter *et al*., 2016). Moreover, advancements in digital financial services such as digital credit scoring and mobile money assist in removing obstacles that prevent women from obtaining loans (Holloway *et al.*, 2017).

Research on the effects of insurance and loans on female smallholders highlights the necessity of combining financial services with relevant non-financial offerings, such as financial literacy instruction (Lusardi & Mitchell, 2014). Financial literacy is a critical factor in determining loan payback and savings behaviour, according to microfinance studies. This emphasizes the need for financial literacy while providing women farmers with innovative financial solutions (Drexler *et al*., 2014). Research on agricultural insurance also suggests that to assist farmers in using index insurance products efficiently, they should receive financial literacy training (Cole *et al*., 2012). While many studies focus on insurance and credit products for female farmers, advances in payments and savings also support women's economic empowerment and agricultural growth. Research indicates that mobile money services, by enabling consumer payments and assisting in overcoming mobility constraints, contribute to increased financial inclusion, risk mitigation through simpler remittances, and enterprise growth for women (Suri & Jack, 2016). Similar potential exists for digital savings, but further study is needed to determine their effectiveness and the best layout for female farmers (Demirguc-Kunt *et al*., 2018).

New financial products that promote women farmers' involvement and results include digital financial services, specially crafted micro insurance products, loans that come with training, and more (Buvinić & O'Donnell, 2019). However, research is inadequate in the appraisal of more recent digital financial innovations designed specifically for women smallholders and the best way to bundle with non-financial services. To promote positive change, evidence can guide the creation of products as well as the supportive legislative frameworks.

2.6.4 Funding Climate Change Programmes

Climate change poses an existential threat, and substantial funding is required to avoid the worst impacts. However, current climate finance flows are insufficient. Global climate finance nearly doubled over the past decade, totalling $4.8 trillion from 2011-2020 (Naran *et al*., 2022). Yet this only represents a 7% compound annual growth rate, below the estimated 21% required by 2030. While liquidity exists, barriers impede the deployment of the estimated $4.3 trillion in annual climate finance required (Naran *et al*., 2022; Muller & Sensini, 2021). New opportunities are arising across sectors in Africa as the industrial mix extends beyond extractives (EY, 2020). Over 90% of African GDP is represented in Nationally Determined Contributions (NDC) totalling $2.8 trillion in estimated implementation costs from 2020-2030 (EY, 2020). However, limited funding access challenges NDC implementation in countries, like Ghana. Ghana's NDC activities rely predominantly on the Green Climate Fund, with only 28% of the $22.6 billion total from domestic revenue (Ghana INDCs, 2015). Ghana has initiated an environmental fiscal reform program to establish the Ghana Green Fund and enable ministries and agencies to access bilateral and multilateral climate funding without Ministry of Finance approval (Ghana INDC, 2015).

Regional funding access gaps are significant, with Sub-Saharan Africa facing an 82% gap between potential demand and supply (Muller & Sensini, 2021). In the agricultural sector, smallholder farmers rely heavily on informal financing from family, moneylenders and NGOs (Boachie & Gyimah, 2018; Donkoh *et al*., 2019). Credit acquired from formal institutions are sometimes used for non-agricultural purposes (Denkyirah *et al*., 2016). Studies are needed on effective agricultural FM aligned with gender and development goals (Antwi-Adjei *et al*., 2021). CIS and CSA can help farmers manage climate risks, but access to financial mechanisms to use CIS and CSA remains limited, particularly for women (Diouf *et al*., 2019; Djido *et al*., 2021; Yegbemey & Egah, 2021). CSA adoption facilitates sustainable productivity gains (Djido *et al*., 2021).

In Africa, tailored CIS enables climate-optimized decision-making on planting, fertilization, pest management and more (Balaji & Craufurd, 2011; Muema, 2018). However, research shows lower CIS access among women farmers, underscoring the need for gender-sensitive CIS design and dissemination via farmer organizations (Diouf *et al*., 2019). Substantial increases in climate finance are imperative but are constrained by deployment barriers (FAO, 2018). Smallholder farmers lack adequate access to formal financing and climate information to support sustainable and climate-resilient productivity gains

2.7 Gender Analysis in Agricultural Development

Gender issues in agriculture have gained significant attention in recent years, as research has highlighted the critical role women play in agricultural production, food security, and rural development. Several studies have explored the gendered division of labour in agricultural contexts. Doss (2017) found that women often bear a disproportionate burden of unpaid labour, including tasks related to crop production, livestock management, and household responsibilities. Quisumbing *et al*. (2014) noted that while women contribute significantly to agricultural labour, they often have limited access to productive resources, such as land, credit, and extension services. Issues of access to resources and decision-making power within households have been a central theme in gender analysis literature. Peterman *et al*. (2014) examined the impact of women's bargaining power on agricultural productivity, finding that increasing women's control over resources can lead to improved household welfare and child nutrition outcomes. Meinzen-Dick *et al*. (2019) explored the gendered dimensions of land tenure systems and highlighted the importance of securing women's land rights for inclusive agricultural development.

The adoption of agricultural technologies and access to extension services have also been examined through a gender lens. Ragasa (2012) found that gender norms and intra-household dynamics can influence women's participation in agricultural extension programs. Theis *et al*. (2018) explored the gendered impacts of climate-smart agriculture technologies, emphasizing the need for gender-responsive technology design and dissemination strategies. Gender transformative approaches in agricultural development aim to challenge and reshape gender norms, power relations, and inequalities to promote equitable access to resources, opportunities, and decision-making for women and men. Recent literature has emphasized the importance of gender-responsive approaches in agricultural development. Hillenbrand *et al*. (2015) advocated for interventions that challenge traditional gender norms and power dynamics; Njuki *et al*. (2016) highlighted the potential of collective action and women's empowerment groups in promoting gender equity.

Researchers have also explored methodological issues in conducting gender analysis in agricultural contexts. Doss and Kieran (2014) discussed the challenges of measuring women's empowerment and proposed a multidimensional approach. Alkire *et al*. (2013) developed the Women's Empowerment in Agriculture Index (WEAI) as a tool for quantifying empowerment and gender parity in agricultural households. There are diverse ranges of issues in recent gender analysis research in agriculture development, including gender roles, access to resources, technology adoption, gender-responsive approaches, and methodological considerations.

2.7.1 Gender Roles in Agriculture: Insights from Northern Ghana

Gender roles refer to the socially constructed norms and expectations that dictate and/or influence the behaviours, responsibilities, and opportunities considered appropriate for men and women within a particular society (Lambrecht *et al*., 2018). These roles are often shaped by cultural, economic, and historical factors, leading to a division of labor based on perceived physical differences and social norms (Njuki *et al*., 2016). In agriculture, a typology of gender roles typically includes productive roles (such as crop cultivation and livestock management), reproductive roles (such as childcare and household maintenance), and community roles (such as leadership and participation in local organizations) (Mosso *et al*., 2022).

The five northern regions of Ghana provide a unique context for examining gender roles in agricultural production and rural livelihoods. Several studies have documented the distinct roles and responsibilities of men and women in agricultural production in Northern Ghana.. Men perform specific "male tasks," while women perform specific "female tasks." (Alstad, 2018). Mensah and Fosu-Mensah (2020) found that women's roles have expanded into labour-intensive farming tasks traditionally performed by men, in addition to their domestic/reproductive responsibilities but still have limited control over productive resources and decision-making compared to men.

Ayaaba (2022) found that even though other farm activities were dominated by both genders, there was a clear difference in some activities and responsibilities that are gendered. He stated that in terms of farm activities, men dominated in ploughing, weeding, and chemical and pest management, while women dominated in only one activity: cooking for farm labor. He also found that farms managed by women were more productive than farms managed by males however his results also showed that farms dominated by male labour recorded higher yields than farms dominated by female labour. Wahaga (2018) also found that even though women contribute up to a total of 56 hours a week on farm labour, their contributions are unpaid because they work on family farmlands and do not control farm produce.

Access to productive resources, such as land, credit, and agricultural inputs, has been a critical issue in the gender analysis of agriculture in Northern Ghana. Azumah *et al*. (2022) indicated that patriarchy restricted female farmers when it comes to access to farmland. Bogweh *et al*. (2023) stated that tenure security for women is held back by social and cultural norms which often undermine their livelihoods. Married women are often not recognized as part of the lineage, thereby limiting their access to and use of land (Yaro, 2010). Customary tenure is common in Africa, where land is inherited or held by a clan lineage though individuals have use rights to pieces of land that they farm (Nadasen, 2012).

Thus the physical ability of women to farm pieces of land could reduce their overall use rights to land in the communal setting. Bogweh *et al* (2023) also stated that secure land ownership among women also depends on socio-demographic and economic characteristics, including marital status (married, divorced, or widowed), women's position in households and communities, age, sex, marriage types, education, economic status, and social capital and networks; the works of Nnoko-Mewanu (2016) and Doss and Meinzen-Dick (2020) agreed with this statement. Ankrah *et al.* (2020) explored the differential access to productive agricultural resources and found that access to resources such as land, agricultural credit, agricultural extension services and information remained gendered, highlighting the need for gender-responsive policies and interventions.

Do women have a say in decision-making? The dynamics of intra-household decision-making processes have been explored in various studies from Northern Ghana. Kaunza *et al.* (2022) aimed to understand the involvement of women in critical household decision-making areas in polygamous homes in rural northern Ghana and found that the male household head has the critical decision-making role regarding food production, consumption, and resource control at the compound (multiple households) level however women's participation in decision-making is gradually increasing; even though women are more in charge of basic daily necessities like food production, consumption, and control of resources on the household/ family level.

The importance of understanding gender roles and inequalities within the broader cultural and socio-economic contexts cannot be overlooked. Alo *et al* (2022) discussed the complex nature of male-female relationships and how power dynamics and disparities between men and women manifest within the gendered perceptions of women in Northern Ghana. They stated that gender relationships in Northern Ghana were subjective and skewed in favour of men, giving them more privileges. Factors like male lineage hierarchies, gendered division of labor, and unequal power distribution between women and men compel women into a subordinate socio-political class in both personal and civic spheres. This unequal power dynamic leads to women's overreliance on men to attain social and political status as well as economic survival (Alo *et al.*, 2022).

Alo *et al*. (2022) study suggests that there are deep-rooted patriarchal norms and structures in Northern Ghanaian society that reinforce gender inequalities. Women face disadvantages and lack equal opportunities compared to men across various domains - social, political, and economic. Researchers have also examined the potential of gender-responsive interventions in addressing gender inequalities in agriculture in Northern Ghana. Fischer *et al.* (2023) highlighted the importance of incorporating gender-responsive interventions alongside technical agricultural interventions to effectively address gender inequalities in agriculture, specifically in the context of Northern Ghana. To promote gender equity, they argued that underlying inequitable gender norms need to be explicitly targeted and transformed, in addition to technical agriculture interventions; simply adding gender components to technical packages is insufficient if the technical components themselves are not redesigned with a gender equity lens.

2.7.2 Impact of Gender Disparities on Agricultural Productivity

Gender disparities in access to productive resources, decision-making power, and economic opportunities have significant implications for agricultural productivity and rural development. Research has shown a notable gender gap in agricultural productivity, where female-managed farms often experience lower productivity compared to male-managed farms. For instance, Kilic *et al*. (2015) found a gender productivity gap of 23% to 25% in some Sub-Saharan African countries, even after accounting for individual, household, and plot-level factors. Similarly, Oseni *et al*. (2015) reported that differences in resource endowments and input use intensity contribute to this gap in Nigeria. However, recent studies have challenged this view. Ayaaba (2022) found that farms managed by women were, in fact, more productive than those managed by men. This contradicts earlier findings and highlights the need for a nuanced understanding of gender dynamics in agricultural productivity.

A critical factor influencing these productivity disparities is the differential access to productive resources such as land, labour, credit, and agricultural inputs. Gender inequalities in land access and tenure security, as documented by Azumah *et al*. (2022), Bogweh *et al*. (2023), Yaro (2010), Nadasen (2012), Nnoko-Mewanu (2016), and Doss & Meinzen-Dick (2020), underscore systemic barriers women face. Patriarchal norms, customary inheritance systems, and socio-cultural factors like marital status, household position, age, education, and economic status intersect to limit women's land ownership and use.

Moreover, access to agricultural ACAS, including agro-climatic information and smart agricultural practices, plays a crucial role in enhancing productivity. Disparities in access to these services further exacerbate gender gaps. Women often face challenges in obtaining essential ACAS, which are vital for improving agricultural practices and productivity. This systemic exclusion undermines their ability to adopt innovative practices that could potentially enhance yields and overall farm productivity (Ankrah *et al*., 2020).

Addressing these gender disparities in access to both productive resources and ACAS is essential for bridging the productivity gap. By focusing on enhancing access to ACAS for women, this study aims to contribute to closing the gender productivity gap and supporting more equitable and sustainable agricultural development

Gender disparities in the adoption of improved agricultural technologies and innovations have also been explored concerning productivity. Sam and Sathyan (2021) highlighted how entrenched gender disparities and inequalities act as major barriers preventing women, especially in developing regions, from accessing and adopting productivity-enhancing agricultural technologies and innovations on par with men. The study identified three main areas where gender inequalities exist regarding technological interventions:

- Technologies that increase agricultural productivity
- Labor-saving and transport technologies – and
- Information and communication technologies

Gezimu *et al*. (2019) explored disparities in the adoption of improved maize varieties in Dawuro Zone, Ethiopia. While the study did not find significant evidence of gender differences in the rate and intensity of adoption when considering the gender of the household head or primary decision-maker alone, it did reveal important nuances related to joint decision-making dynamics. The findings indicated that the intensity of adoption (how much of the improved variety was planted) varied among male decision-makers, female decision-makers, and joint decision-makers. However, this effect diminished when accounting for other factors. Female-headed households, where decisions were made jointly by men and women, had a lower intensity of adoption compared to male-headed households with joint decision-making. Gezimu *et al*. (2019) concluded that while overt gender disparities were not always evident, joint decision-making dynamics and economic factors interact to influence adoption intensities, especially for female-headed households.

These insights are crucial for understanding the role of gender dynamics in the context of your study on ACAS. Gender differences in decision-making and adoption can significantly impact how ACAS are received and implemented by different households. Highlighting these dynamics helps justify the need to design ACAS that considers gender-based preferences, joint decision-making processes, and socio-economic constraints. By tailoring ACAS to address these factors, it becomes possible to enhance the effectiveness and reach of ACAS, ensuring that both male and female farmers benefit equitably from the information and support provided.

Another nationally representative study from Malawi revealed gender differences in adoption patterns across specific technologies like intercropping, crop rotation, and improved seed varieties (Tufa *et al*., 2022). Notably, it found that female-managed plots were 14.6-23.1% less productive than male-managed plots. This gender productivity gap was attributed more to underlying structural disadvantages faced by women (23.1%) than differences in resource endowments (8.2% advantage for women). These findings highlight that in addition to increasing access to productive assets for female farmers, policies must address broader systemic constraints inhibiting their ability to efficiently translate resources into higher productivity (Tufa *et al*., 2022).

The gender division of labour and time allocation patterns within households have also been identified as potential determinants of the productivity gap. Palacios-Lopez *et al*. (2017) analyzed data from six countries and found that women's time burdens, particularly in domestic work and childcare, constrained their ability to allocate labour to agricultural production, leading to lower productivity. Arora (2015) highlighted the need for labour-saving technologies and interventions that reduce women's time poverty. Recent studies have also explored the relationship between women's empowerment, decision-making power, and agricultural productivity. Diiro *et al*. (2018) found that women's empowerment in agriculture, measured using the Women's Empowerment in Agriculture Index (WEAI) was positively associated with higher productivity in Kenya. To address the gender productivity gap, researchers have emphasized the need for policy interventions and gender-responsive approaches. There is the need for policy interventions and gender-responsive approaches to address the gender productivity gap. Several researchers have emphasized this need; Quisumbing *et al*. (2014) advocated for interventions that address the underlying causes of gender disparities, such as reforming discriminatory laws and promoting gender-responsive approaches in agricultural development programs. O'Sullivan *et al.* (2014) highlighted the potential of collective action and women's empowerment groups in enhancing productivity and sustainable agricultural practices.

2.7.3 Gender-Specific Needs in Accessing and Utilising Agricultural Advisory Services

Agricultural advisory services play a pivotal role in disseminating knowledge, information, and best practices to farmers. However, numerous studies have highlighted the gender disparities in accessing these services. Peterman *et al*. (2014) found that in many developing countries, women farmers are less likely to receive visits from extension agents or attend training sessions, primarily due to socio-cultural norms, mobility constraints, and gender biases within extension systems. Research by Mbo'o-Tchouawou and Colverson (2014) emphasised the need for gender-sensitive extension approaches that account for women's distinct roles, responsibilities, and constraints in agriculture. They recommended the employment of extension agents, the incorporation of women's perspectives in the design and delivery of services, and the provision of childcare facilities during training sessions.

Access to financing is essential not only for women farmers but also for service providers who deliver ACAS. studies emphasize that gender disparities in accessing these services affect both the supply and uptake of climate-related advisories. Recent research shows that service providers often lack sufficient funding to extend gender-sensitive ACAS, which limits their ability to cater to the diverse needs of both male and female farmers (Alvi *et al*., 2021; Partey *et al*., 2020; Antwi-Agyei *et al*., 2021; Agyekum *et al*., 2022). While the literature has traditionally emphasized supply-side constraints like interest rates and collateral requirements as barriers to women's access to finance, recent research has shed light on the critical role of demand-side factors rooted in behavioural gender differences. Evidence from credit markets across 47 African countries suggests women entrepreneurs tend to self-select out of applying for loans due to low perceived creditworthiness, discouraged by their own belief that applications would be denied despite actual creditworthiness (Morsy, 2020). This phenomenon persists even when controlling for institutional barriers, complexity of procedures, and discrimination by lenders, underscoring that differing risk perceptions, financial literacy levels, and financial behaviors between men and women drive women's lower demand for credit (Morsy, 2020).

Corroborating studies find that while women bear liability for microcredit programs, they often lack control over how loan proceeds are invested by male partners, subverting potential benefits and exacerbating intra-household gender tensions (Naz and Doneys, 2022). The financial control exercised by men undermines positive social externalities anticipated from enhancing women's agency and adaptive capacities through credit access (Naz and Doneys, 2022). Together, these findings reveal how the nexus of gender dynamics, power relations, and self-perceptions impede women from truly accessing and benefitting from financial resources. Addressing these demand-side constraints through interventions like tailored financial literacy programmes and product innovations is thus crucial to realize equitable financial inclusion and its associated economic impacts in Africa. Bhatia *et al*. (2019) highlighted the importance of integrating financial literacy training and support services into agricultural finance programs, as this can empower women farmers to make informed decisions and effectively utilize financial resources.

Recent literature has emphasized the importance of intersectional approaches that consider the intersections of gender with other social identities and contexts (Okali, 2012; Tavenner & Crane, 2018). For instance, Yadav and Lal (2018) found that the specific needs and challenges faced by women farmers vary across different agroecological zones, socio-economic statuses, and cultural contexts. Moreover, Njuki *et al*. (2016) advocated for context-specific interventions that recognize the heterogeneity of women's experiences and address the unique constraints and opportunities within specific agricultural value chains and production systems.

2.7.4 Gender Differences in Access to Financial Services for Farmers

Gender dynamics also play a critical role in the ability of service providers to secure financing for delivering ACAS to smallholder farmers.

Although women make up more than 43% of the agricultural workforce worldwide, there are stark gender disparities in developing nations when it comes to female farmers' access to bank and microfinance institutions' loan, savings, and insurance products (FAO 2019; Jost *et al*., 2016). Demirguc-Kunt *et al*. (2013) discovered an estimated seven percentage point's difference between the number of formal credits taken by male and female farmers in a multi-country study on Asia and Africa. In addition to having lower rates of approval and application, women received loans with sizes that were about 50% less than those of men for the identical income baselines (Agier & Szafarz, 2013). Indicators of financial inclusion such as having bank accounts, using digital payments, having crop or livestock insurance, and the distance between locations such as bank branches were found to exhibit gender disparities (Singh & Asante, 2016). Gender disparities in capabilities, including income, education, and formal employment, can account for gender inequities in financial inclusion (Aterido *et al*., 2013; Ndoya & Tsala, 2021). Research indicates that men are more likely than women to have access to education, which may help to partly explain the differences between the sexes' use of and access to financial services (Aterido *et al*., 2013; Kara *et al*., 2021; Ndoya & Tsala, 2021; Sharif *et al*., 2022). Education is directly related to financial literacy (Ozili, 2020).

Intersectional limitations pertaining to literacy, legal rights, mobility, land ownership patterns, and ingrained institutional prejudices are the cause of this unequal access (Fletschner & Kenney, 2014). These factors can affect their leverage as collateral assets. Reduced average output and agricultural revenues that suppressed women's creditworthiness were also caused by a lack of access to market links, extension services, and production inputs (Croppenstedt *et al*., 2013). Microfinance indicated that female payback rates were on par with or even higher than male repayment rates; nevertheless, mainstreaming was impeded by inadequate documentation of independent financial flows (D'Espallier *et al*, 2011).

2.8 Effectiveness of Different FM for Gender-inclusive Agricultural Development

Gender inequality continues to limit women’s access to resources, opportunities, and decision-making in agriculture. This section reviews the effectiveness of various financing mechanisms (FM) in promoting gender-inclusive agricultural development, highlighting how each mechanism enables or constrains women’s participation and benefits in agriculture.

Blended Finance: Blended finance strategically combines philanthropic and development funds with private investment to support sustainable development objectives. Evidence suggests that it can effectively reduce gender gaps in agriculture. For example, USAID's "INVEST Close Up" programme and AfDB's Affirmative Finance Action for Women in Africa (AFAWA) have successfully increased women entrepreneurs' access to capital, enabling them to participate more fully in agricultural value chains (Attridge & Engen, 2019; USAID, 2021; AfDB, 2022). These initiatives demonstrate that blended finance can directly improve women's financial inclusion and decision-making in agriculture.

Public-Private Partnerships (PPPs): PPPs enhance women farmers' access to markets, technology, and capacity-building. Initiatives like the Partnership for Inclusive Agricultural Transformation in Africa (PIATA) have shown that PPPs can effectively increase women's involvement in agricultural value chains and decision-making, though the extent of impact often depends on the design and inclusiveness of the partnership (AGRA, 2021).

Innovative Insurance and Risk Transfer Mechanisms: Women farmers are often more vulnerable to agricultural risks due to limited safety nets. Programs like index-based insurance and the R4 Rural Resilience Initiative have effectively improved women's resilience by reducing risk exposure and enabling greater investment in productive activities (Greatrex et al., 2015; WFP & Oxfam America, 2018). Their effectiveness, however, depends on awareness, affordability, and accessibility for female farmers.

Stormwater Markets and Tax Increment Financing: While these mechanisms primarily target environmental issues, they may indirectly support women farmers by promoting sustainable, climate-resilient practices. Their effectiveness for gender inclusion is less established, but they offer potential pathways for integrating women into climate-smart agriculture initiatives (Valderrama et al., 2013; Merriman, 2021).

Green Bonds and Climate-Resilient Bonds: These instruments finance climate-smart initiatives that can improve women's adaptive capacity. Evidence from the International Finance Corporation shows that green bonds have supported projects enhancing women's participation in agriculture and environmental management, indicating moderate effectiveness in promoting gender equality (Shislov et al., 2016; IFC, 2021).

Payment for Ecosystem Services (PES): PES programs can provide women with additional income and promote sustainable practices. While men have historically captured cash-crop benefits, successful programs, such as women-managed tree nurseries supported by Ecotrust and Taking Root, show that gender-sensitive design can enhance women's participation and income generation (Engel et al., 2008; IIED, 2015).

Crowdfunding and Community-Based Financing: Crowdfunding platforms and community financing have shown strong potential in supporting women-led agricultural initiatives. Female participation and success rates are higher compared to other funding mechanisms, although outcomes are influenced by local social norms and the range of accessible funding options (Serwaah, 2021).

2.9 Gender-Sensitive Design in Agricultural Finance and ACAS

Incorporating gender considerations into agricultural finance and ACAS is essential to ensure equitable access and participation for both men and women in smallholder farming. Women often face barriers such as mobility restrictions, discriminatory laws, lack of collateral, and sociocultural norms that limit their use of financial services and extension programs (Peterman et al., 2014;

Buvinić & O'Donnell, 2019; Fletschner & Kenney, 2014). Designing services with gender sensitivity involves tailoring delivery mechanisms, products, and advisory services to meet the distinct needs, preferences, and challenges of different gender groups, thereby empowering women to engage fully in agricultural decision-making and productivity-enhancing initiatives.

Evidence from Ghana shows effective gender-sensitive approaches. Adatuu et al. (2021) evaluated the Village Savings and Loans Association (VSLA) model in the Upper East Region and found that mobilizing funds locally improved women's access to credit, raised household incomes, and strengthened women's participation in household decision-making. However, gaps in capacity-building opportunities were noted, suggesting the need for integrated training to enhance benefits. Similarly, digital financial services, including agent banking and mobile money, have demonstrated potential in overcoming mobility constraints and promoting women's financial inclusion (Buvinić & O'Donnell, 2019).

For ACAS, gender-sensitive designs are crucial for enabling women to adapt to climate variability. Studies in West Africa show that climate services often fail to account for women's specific information needs, preferred communication channels, and local sociocultural realities (Tall et al., 2014; Huyer, 2016). Initiatives such as the Gender-Smart Agriculture approach developed by CGIAR, CCAFS provide strategies and monitoring frameworks for gender-responsive climate-smart agriculture, enhancing women's access to resources and agency in climate adaptation (Huyer & Chanana, 2021). Incorporating these gender-sensitive designs, agricultural finance and ACAS can more effectively empower women, improve equitable access, and enhance resilience and productivity in smallholder farming communities.

2.10 Empirical Studies on FM, ACAS and Farmer Productivity and Income

While exploring innovative financing models for ACAS, it is valuable to examine case studies from similar regions or contexts. These real-world examples can provide insights into the practical implementation, challenges, and lessons learned from various financing approaches. This approach focuses on examining scientific evidence and data-driven findings that link FM for ACAS to factors such as gender dynamics, socioeconomic contexts, and service delivery models. By grounding the discussion in empirical research, we aim to draw upon validated relationships and outcomes that can inform a deeper understanding of the challenges, opportunities, and potential impacts of financing models for delivering ACAS to smallholder farmers. This evidence-based approach ensures that the conclusions and recommendations are well-founded on scientific insights relevant to the study's objectives. A description of some successful case studies and models is provided in the next section of this report.

2.10.1 Project 1: Index-Based Livestock Insurance in Northern Kenya

In a pilot experiment carried out by Mude *et al*. (2012), farmer cooperatives in Northern Kenya provided index-based livestock insurance. The objective of this technique was to mitigate the hazards linked to livestock mortality caused by drought and foster financial stability in pastoralist communities. The insurance payouts were predicated on satellite-derived vegetation data, which functioned as a stand-in for fodder availability, and the premiums were substantially subsidised. Using this community-based approach, the pilot project showed the possibility of risk-sharing and financial sustainability. It also brought attention to the necessity of building capacity and implementing efficient communication techniques.

2.10.2 Project 2: Public-Private Partnership in Climate Services in Northern Ghana

A noteworthy case study on expanding climate information services to farmers in Northern Ghana was carried out by Partey *et al*. (2019). A trial project in the Lawra and Jirapa areas provided 1,000 farmers with climate information services (CIS) using mobile phones between 2011 and 2017. The Ghana Meteorological Agency, the CCAFS programme, and the for-profit ICT business, Esoko collaborated to accomplish this project. A public-private partnership (PPP) business model was created in 2017 to increase the distribution of CIS since it was recognised that farmers could make better decisions about planting, fertilising, irrigating, and harvesting with the assistance of CIS. The PPP unites governmental agricultural institutions that offer training, commercial organisations that provide meteorological data, and cell operator Vodafone, which charges farmers a $0.2 monthly membership fee to access market and CIS data. This creative multi-stakeholder strategy, which is strategically connected to the government's "Planting for Food and Jobs" project, has already touched over 300,000 farmers in only two years, with 21% of them being women. This PPP case study shows how climate services may be mainstreamed into development programmes and sustainably supported, with set roles, monitoring, and the potential to scale throughout Ghana.

2.10.3 Project 3: Blending Grants, Community Equity, And Microfinance Loans For Water Access In Kenya.

According to Atieno *et al*. (2021), a blended finance scheme was put into place between 2013 and 2018 to finance water projects. This scheme combined microfinance loans from the Kenyan Rural Enterprise Programme (K-Rep) Bank, grants and output-based subsidies from the World Bank, and investments from the local community equity. With the help of World Bank funding, K-Rep Bank was able to lend money to eligible community organisations, potentially covering the operating and maintenance expenses of the water project. Furthermore, grant finance's technical support made it easier to create bankable loan applications.

This case study revealed several important insights. First and foremost, K-Rep Bank, the private finance partner, was convinced of the project's feasibility by the reporting requirements imposed by the World Bank's concessional capital. This proof was crucial in getting them to agree to participate. Second, technical support turned out to be a crucial enabler, helping with project planning and funding initiatives alike. Ultimately, the project's success depended on choosing the right private funding partner with the necessary expertise. Because K-Rep Bank had already participated in similar financing arrangements, they were a perfect partner, demonstrating how important it is to partner with organisations that have experience and knowledge of blended finance models. These lessons highlight the value of concessional capital in de-risking investments, access to technical support, and strategic private sector partnerships in effectively structuring and implementing blended finance initiatives.

2.10.4 Blending Concessional Loans with Private Equity for Climate-Smart Agriculture in Nepal.

The Prakriti Resource Centre described a project that was carried out between 2013 and 2019 that involved combining equity investments from local private equity fund Business Oxygen and a concessional loan from the IFC to enable agribusiness firms to invest in climate-resilient farming practices. In addition, government subsidies on imported commodities and 5% bank interest rate refunds on agricultural loans were advantageous to the investors. Several important lessons for encouraging private investment in traditionally hazardous industries like agriculture are highlighted in this case study. First off, the supply of concessional, catalytic financing can be a key factor in promoting private sector involvement in these risky, niche areas that have historically discouraged investment.

Secondly, it is imperative to involve local investors and domestic banks wherever possible, since they have an unmatched comprehension of the local market dynamics and potential investors. Their knowledge and proximity are extremely helpful in efficiently enabling the flow of private capital. Thirdly, it becomes clear that government assistance is a critical facilitator, both in terms of permitting foreign investment into locally significant and strategically vital industries and in creating a transparent risk climate that gives private investors the assurance and clarity they need. Through tackling risk perceptions, securing local knowledge, and selectively allocating concessional money, this multifaceted strategy can open new avenues for private investment in industries that have traditionally faced financing challenges.

2.10.5 Blended Finance for Agriculture: Exploring the Constraints and Possibilities of Combining Financial Instruments for Sustainable Transitions

Havemann *et al*. (2020) sought to bridge the substantial financial gap impeding the shift to sustainable agriculture systems a critical step towards accomplishing the Sustainable Development Goals (SDGs). The researchers observed that public and private funders are separated by the existing configurations of the financial markets, which makes it difficult to raise the additional funds needed for more sustainable agriculture production systems.

To mobilise extra private capital, Havemann *et al*. (2020) suggested blended finance as a crucial approach. This involves using concessionary development-oriented funding. To guarantee the efficient and effective use of the small pool of concessionary funds, the authors stressed the need to have a common understanding of the responsibilities and constraints of public and private donors. The paper described the high-level funding gap for sustainable agriculture, the general landscape of agricultural finance, and the concept and potential roles of blended finance in this context. It introduced the conditions under which different FM can contribute to addressing barriers related to sustainable agriculture investments. The main finding highlighted that multiple funding modalities must be utilized to achieve meaningful agricultural investment levels, encouraging greater exploration of various blended financing structures to increase SDG-related agriculture investments.

2.10.6 Gender and Access to Agro-Climatic Advisory Services

Gender plays a critical role in shaping access to and utilization of ACAS. In agricultural contexts, deeply rooted social norms, roles, and responsibilities often result in women farmers being more vulnerable to the impacts of climate change compared to men (FAO and World Bank, 2017; Ngigi *et al*., 2017). Studies consistently show that gender dynamics significantly influence how men and women access and apply climate information, with women facing more pronounced barriers. Research by Partey *et al*. (2020) highlights that women farmers have more limited access to ACAS than men, constraining their ability to mitigate and adapt to climate risks. For instance, female farmers often do not receive timely weather and climate information, which limits their capacity to manage climate-related challenges effectively (Partey *et al*., 2020).

Furthermore, recent evidence from Alvi *et al*. (2021) indicates that gender disparities were exacerbated during the COVID-19 pandemic, as lockdowns made it even more difficult for women to access timely climate information, negatively affecting their agricultural productivity. Gendered differences are also evident in household dynamics. A study by CCAFS (2017) in Vietnam found that less than 40% of farmers share weather forecasts and agricultural advice with their spouses, with men more likely to share information with their wives than vice versa. Cultural norms, time poverty, and women's domestic responsibilities also limit their participation in training sessions and meetings where critical climate information is disseminated (Tall *et al*., 2014).

The complexity of gender relations extends beyond comparisons of male-headed and female-headed households. Ngigi *et al*. (2017) argue that there is a need to understand the differing perceptions of climate risks between husbands and wives within the same household. Their findings revealed that adaptation strategies are closely linked to gendered roles and responsibilities, social norms, and access to resources. Women, for example, are more likely to adopt crop-related strategies, while men focus on livestock and agroforestry (Ngigi *et al*., 2017). This gender-specific demand for climate information is further supported by studies in Senegal, where women primarily seek information on the onset of the rainy season and prefer receiving advisories via radio (Diouf *et al*., 2019). Ngigi and Muabge (2022) showed that men tend to have greater access to early warning systems, while women prioritize weather forecasts that support household food security.

Despite some progress, women continue to face numerous barriers to accessing and utilizing ACAS. Their limited access to resources such as land, credit, agricultural inputs, and extension services restricts their ability to implement adaptive strategies (Doss, 2017). Additionally, lower literacy levels among women can impede their ability to interpret advisories (Muema *et al*., 2018). Bridging these gender gaps in resources and capabilities is essential for strengthening women's climate resilience. Moving forward, closing the gender gap requires more than just technological interventions; it demands transformative approaches that enhance women's skills, resources, and decision-making power, alongside the provision of tailored, gender-responsive climate information. It also requires the expansion of infrastructure especially to remote areas where female-headed households have significant presence.

The rise in technological advancements in agriculture has favoured men, with women being excluded from extension services that provide modern farming technologies and techniques. Anaglo *et al*. (2014) showed that women in rural settings in Ghana have less access to extension programmes, which are vital for enhancing productivity and resilience in agriculture. These study focuses on the importance of incorporating gender-sensitive techniques in extension services to ensure women can seemingly equally benefit from agricultural innovations that improves farm yields and income security.

The study done by Akpatsu *et al*. (2023) held light on how multiple social challenges such as marital status, age, ethnicity, intersect with gender to further hamper access to agricultural services. Specifically, younger women are at a greater handicap due to limited networks, inadequate social capital, and less experiences in steering bureaucratic systems for land acquisition or accessing training. These challenges call for more targeted interventions that consider intersectional gender differences in assisting with agricultural services.

A recent study by Tyagi *et al*. (2023) pinpointed the demand and supply-side factors such as perceptions, financial regulatory frameworks, and low levels of financial literacy serves as barrier women encounter, particularly those rural agricultural settings. Women often lack collateral, mostly due to restricted land ownership, which escalate further limiting their ability to invest or venture in modern agricultural technologies or scale their farming activities.

2.10.7 Securing Climate Finance through National Development Banks

Griffith-Jones *et al.* (2020) in an Overseas Development Institute (ODI) report examined the unique role national development banks (NDBs) can play in supporting the transition to a low-carbon, climate-resilient economy and mobilizing private finance for investment in LCCR infrastructure, as well as the prerequisites for NDBs realizing this potential. Key findings were that NDBs have a dual role as public financiers and private finance mobilizers, acting as financiers, mobilizers, intermediaries, policy influencers, and pipeline developers. However, good governance, clear green mandates, sufficient capitalization, access to local capital markets, and international support are crucial prerequisites. While international institutions recognize NDBs' importance, engagement varies, with some providing valuable assistance like governance improvements, concessional climate finance access, and capacity building. Direct access to climate funds can help NDBs develop green portfolios and leverage private capital, but access processes are burdensome. The research highlights NDBs' vital role and provides policy recommendations for governments, NDBs and the international community to fully unleash NDBs' potential in financing the LCCR transition.

2.10.8 Gender Theories of Development

Most of the empirical studies on female empowerment related to the access and use of FM and ACAS indicate the general marginalization and exclusion of women. Hence, theories are needed to help us understand the persistence of the empirical evidence of women marginalization and exclusion as related to FM and ACAS. Gender theories provide general theoretical framework to analyse women's marginalization and exclusion and are discussed in this section as the first component of the theoretical framework of this research study. The other parts of the theoretical framework of this study is reported in the beginning of the next chapter, Chapter 3.

Gender theories of development are generally situated in the body of political economy of development literature (Saros, 2019). Gender theories view femininity and masculinity as human-constructed features which have persistent impacts on the lives of men and women. They analyse human behaviour patterns within the divides of feminine and masculine contexts, perceptions and realities (Feldman, 2001). There are various types of gender theories documented in the literature. The major theories include (1) patriarchy theory, (2) feminist theory, (3) standpoint theory and (4) intersectional theory.

Patriarchy theory suggests that the roles and positions of people in society depend substantially on their sex status. These roles are crucially linked to access to property rights, positions of power and income-earning ability. Given the physical strength of males, many human societies have tended to place leadership roles for men on the account of their physical ability to manage events involving physical danger and large movements of resources and assets during conflicts (Twum & Asante, 2020). This leadership role of men had been conditioned during the early stages of human evolution in Eastern Africa when men played a bigger role in the defence of the family and the larger group.

The theory of feminism emphasizes conflict as a fundamental driver of societal inequalities between men and women, asserting that male dominance is structurally embedded in institutions and social norms (Pertermann & Karena, 2023; PhiloNotes, 2024). Feminists argue that women's historically lower status is not biologically determined but socially constructed, challenging patriarchal systems that limit women's access to power, property, and economic resources (Gupta, Madabushi, & Gupta, 2023). Unlike patriarchy theory, which often rationalizes male leadership based on physical strength or reproductive roles, feminist theory views social stratification as a result of ongoing power struggles rooted in institutionalized gender norms (Mocombe, 2022; MDPI, 2024).

The standpoint gender theory was developed by Smith (1987, 1997). This theory argues that the daily experiences of women in different roles such as housewives, mothers and workers define their real statuses in society. The struggles of women in juggling various roles and tasks in modern societies may not be fully appreciated by elites due to lack of appreciation and ignorance of women at the bottom of the social ladder. A common critique of gender theory is that they tend to neglect the interactions of the sex of the person with other social stratifications. This led to the development of the intersectional gender theory.

The intersectional gender theory considers the several identities of women based on their age group, income class, religious affiliations, race, sex preferences, tribe and experiences from their childhood and geographical origins as influencing their statuses and positions in society (Robinson, 2018). This theory basically disputes the overarching tendency of feminists to place the sex of the person at the central core of the discourse of the analysis of marginalization and social exclusion which has gender aspects. Given that marginalization and social exclusion are not only influenced by the sex of the person alone, but the intersectional gender theory is also used as a driving tool of this study. Following the work of Adjei-Annan (2023), the groups of farmers to consider in analysis of marginalization and social exclusion could include women, people with disabilities, followers of traditional African religions, older people and members of small tribes.

CHAPTER THREE

METHODOLOGY OF THE STUDY

3.1 Introduction

This chapter outlines the research methodology used to examine FM available for ACAS through a gender-responsive lens among grain farmers in Northern Ghana. Firstly, Theoretical Framework of the study is presented, covering various theories that guide the analysis, such as random utility theory, Gender and intersectionality theories. Secondly, the Conceptual Framework of the Study is outlined, connecting these theories to the study's objectives, providing a structured approach to analysing FM and their effects on ACAS usage. Thirdly, the methods of data analysis are discussed, focusing on how the study describes the nature of FM and their effects, the extent of access to ACAS, factors influencing service choice, and the impact on productivity and income using models like Tobit regression and Inverse Probability of Treatment Weighting with Regression Adjustment (IPTWRA).

Fourthly, the chapter explains the method of data collection, detailing the sources of data, instruments used, sampling procedures, sample size determination, and the study area's geographic focus. Lastly, the Scope and Limitations of the study are addressed.

3.2 Theoretical Framework

This study employs an integrated political economy theoretical framework that draws upon key concepts from relevant theories to analyse FM and ACAS for smallholder grain farmers in Northern Ghana from a gendered perspective. This integrated approach ensures that the theoretical framework aligns with the study's objectives, providing a basis for analysing the relationship between FM, access to ACAS, choice behaviours, and their impacts on agricultural outcomes.

An analysis from a gendered perspective recognizes that a decision maker, such as a farmer in Northern Ghana, is faced with constraints which are not only related to livelihood capital assets but also those related to his/her marginalization and social exclusion. The core of the theoretical framework used for the study is anchored on the Random Utility Theory. the core neoclassical economic theory of choice, is used to analyse farmers' choice behaviours with regards to FM and ACAS adoption.

To understand the gender dynamics in accessing and utilizing ACAS, the framework integrates Gender Intersectionality Theory, which emphasises the role of gender in shaping access to resources and services. These theories highlight how intersecting social factors like gender, socioeconomic status, and cultural norms influence the choices available to farmers and ultimately their decision-making and outcomes.

3.2.1 Random Utility Theory

The Random Utility Theory serves as a theoretical lens for examining an individual farmer's' decision-making regarding ACAS given the available resources and constraints facing him/her. The Random Utility Theory originates from econometric analysis of discrete choices and assumes that consumers are quasi-rational decision-makers seeking to maximize utility (Manski, 1977; McFadden, 1984). According to the Random Utility Theory, when consumers are presented with various choices, they select the alternative that maximizes their expected utility (Samuelson, 1938; Houthakker, 1950). The Random Utility Theory is represented mathematically as:

$$U_a > U_b \quad \text{iff} \quad E(U_a) > E(U_b) \qquad (3.1)$$

The indirect utility gained from a particular choice is not directly observable or measurable hence, the theory treats the indirect utility as a random variable. The indirect utility function can be expressed as follows in 3.2.

$$U_{i_n} = V_{i_n} + \varepsilon_{i_n} \quad (3.2)$$

Where U_{i_n} is the indirect utility, a person obtains from choice i; V_{i_n} is the systematic, observable component of indirect utility; and ε_{i_n} is the random, unobservable component of utility. The probability that a consumer will choose option i among a set of J discrete alternatives is given as:

$$P(i) = Prob(U_{i_n} > U_{j_n}) \ for\ all\ j \neq i \quad (3.3)$$

This implies that the alternative with the highest indirect utility will be selected.

In the study, the application of the Random Utility Theory involved modelling a small holder grain farmers' decision to use (choose) a particular agro-climatic advisory service among available options as a discrete choice. Small holder grain farmers were assumed to be rational hence select the agro-climatic advisory service that maximized their expected utility based on preferences, available information, and perceived benefits and limitations of each service. The Random Utility Theory has been extensively used in studying technology adoption decisions in agriculture (Adesina & Zinnah, 1993; Ghadim & Pannell, 1999). It provides a robust framework for modelling smallholder grain farmers' choices when it comes to ACAS as a function of the utility derived from each service. Overall, the Random Utility Theory formed an appropriate theoretical basis, aligned with the study objectives, for examining how smallholder grain farmers choose between different ACAS and the establishment of factors influencing ACAS adoption.

3.2.2 Gender Transformative Approach

The Gender Transformative Approach (GTA) guides this study by offering a way to understand how gender inequalities are produced and sustained within farming households and community institutions. Rather than viewing limited access to ACAS as an issue of resources alone, the GTA draws attention to the social norms, expectations, and power relations that influence how women and men engage with agricultural information. This perspective helps the study move beyond surface-level explanations to consider how everyday interactions, decision-making roles, and institutional practices shape farmers' opportunities.

Within this study, the GTA provides a framework for interpreting why women may be less involved in climate information services and how these patterns are reinforced by broader social structures. It also informs the kinds of changes the study considers necessary for promoting equitable access. By using this approach, the analysis highlights the importance of strengthening women's voice and agency, encouraging supportive roles for men, and recognising institutional responsibilities in addressing gender disparities. In this way, the GTA helps the study focus on the deeper transformations needed to ensure that both women and men can benefit equally from ACAS.

3.2.3 Gender and Intersectionality Theory

Access to climate information and agricultural advisory services is not uniform across populations thus, it is mediated by social roles, economic capacity, and power relations that are often structured along gendered lines. Gender theory provides the lens through which these differences can be examined. It explores how socially constructed roles, norms, and expectations define men's and women's access to and control over productive resources, information, and decision-making processes. In agriculture, gender roles often influence how farmers engage with extension services, financial institutions, and technologies, ultimately shaping their productivity and resilience.

While gender theory demonstrates the differences between men and women, Intersectionality Theory by Crenshaw (1989, 1991) extends this analysis by examining how multiple social identities such as gender, class, age, education, and geographical location intersect to produce unique experiences of privilege or marginalization. Intersectionality thus provides a nuanced framework for understanding how overlapping social categories interact to shape individuals' opportunities, constraints, and responses within specific socio-economic and institutional settings.

In the Northern Ghana, this theoretical approach helps uncover how factors such as gender**,** financial capacity, education, and access to infrastructure collectively influence farmers' access to Agro-climatic Advisory Services (ACAS) and Financing Mechanisms (FM). Rural women, for instance, often face multiple layers of exclusion thus, limited access to credit, restricted mobility, and reduced exposure to formal advisory systems, resulting in a heavier dependence on informal information networks. Men, on the other hand, are more likely to access formal ACAS and credit systems, benefitting from greater mobility, asset ownership, and institutional linkages (Farnworth et al., 2017; Njuki et al., 2016; Kristjanson et al., 2017).

Integrating gender and intersectionality theory in this study therefore allows a deeper exploration of the determinants of access, usage, and outcomes of ACAS among smallholder farmers. It acknowledges that gender alone cannot explain disparities in access; rather, it is the intersection of gender with other social and economic identities that shapes how different farmers engage with and benefit from ACAS. For example, a female farmer with higher education or financial capital may navigate these systems differently from one with limited resources, even though both are women.

Furthermore, the theoretical perspective supports the study's analytical focus on how intersectional disadvantages influence productivity and income outcomes. As Peterman et al. (2014) demonstrate, unequal access to agricultural information and inputs translates directly into gender gaps in yield and income. Thus, applying intersectionality in this study helps to identify how the combined effects of gender, class, and access to financial and technological resources determine farmers' capacity to adapt to climatic risks.

For the main research question, the framework supports an understanding of why financing mechanisms for ACAS may benefit men and women differently. It allows the study to examine how overlapping identities shape who receives information, who is able to pay for or adopt services, and who benefits from them. This perspective ensures that the analysis does not treat farmers as a uniform group but acknowledges the multiple layers of advantage or disadvantage that influence access.

In relation to the specific objectives, the framework is applied in the following ways:

1. Describing financing mechanisms: The framework helps identify how gender and intersecting social positions influence farmers' ability to participate in or benefit from different financing arrangements. It guides the analysis of whether these mechanisms reinforce or reduce existing inequalities.

2. Measuring access to ACAS: Intersectionality informs the assessment of access by highlighting differences not only between men and women but also within these groups. It helps explain variations in access linked to social norms, household roles, education levels, and resource control.

3. Identifying factors influencing the choice of ACAS: The framework is used to interpret how intersecting identities shape preferences and decisions. It helps capture how gender roles, time burdens, mobility constraints, or financial control influence the type of climate services farmers choose or can use.

4. Analysing the impact of ACAS: Intersectionality guides the examination of how the benefits of ACAS such as improved productivity or increased incomes are distributed. It allows the study to explain why men and women may experience different outcomes even when they have access to similar services, due to differences in resource ownership, decision-making power, and social expectations.

3.3 Conceptual Framework of Study

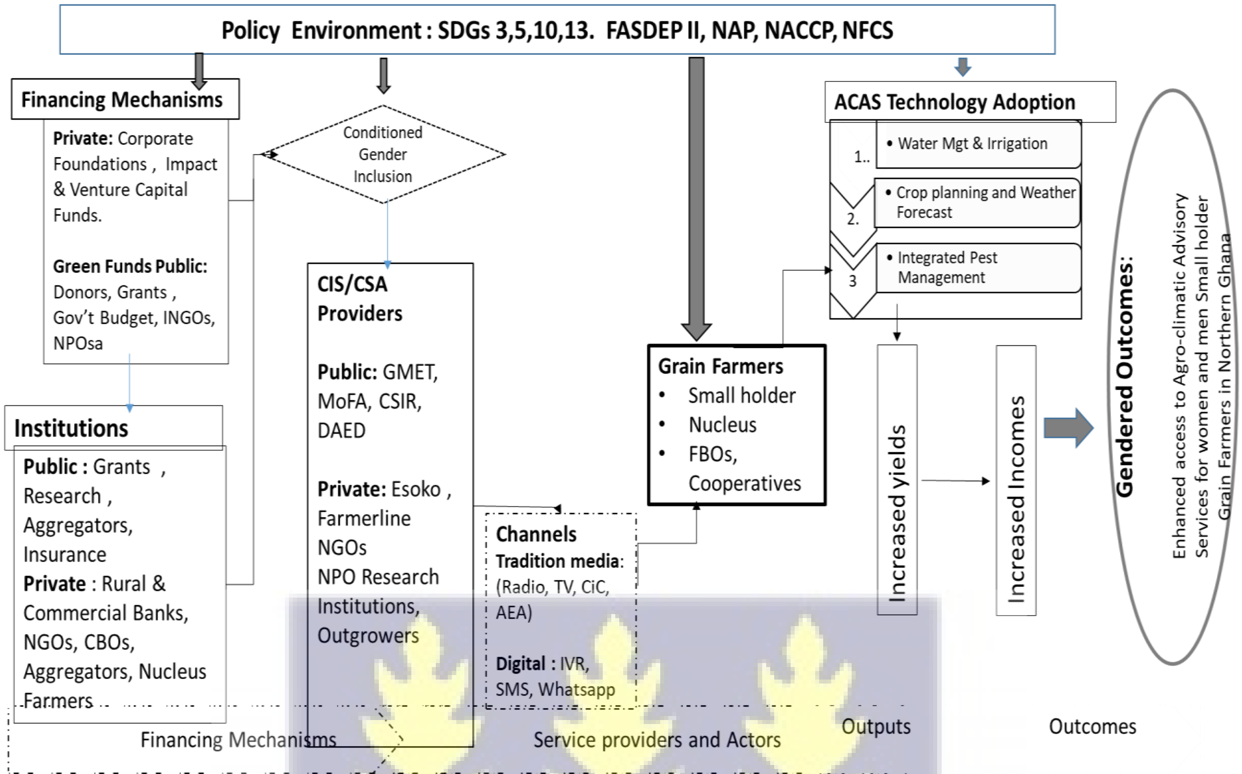
A conceptual framework is the bridge between the theoretical framework and the methods and procedures employed for the study. The conceptual framework is presented in Figure 3.1; it is organized into four key inter-related components. These are FM, services, stakeholders, and outcomes. FM encompasses the methods by which funds are procured, managed, and distributed for specific purposes, exhibiting diverse forms within various sectors. This includes engagement with international institutions such as the World Bank, IMF, and UNDP, as well as corporate green finances, venture capital funds, insurance, impact investors, partners, and governmental funding. Subsequently, these financial resources are channelled to formal financiers, ranging from rural and commercial banks, GIRSAL, and contract farmers to processors, NGOs, farmer-based organizations, civil society organizations (CSOs). and aggregators. Additionally, informal FM involving village savings and loan associations (VSLAs), family and friends contribute to mobilizing funds to support farming activities.

The mobilized funds from these financiers are directed towards supporting ACAS, emphasizing the consideration of gender and social inclusivity in the services targeted for funding. ACAS encompasses climate information services (CIS), covering factors such as temperature, rainfall, and wind, alongside climate-smart agriculture (CSA) practices, including market information, improved seed, good agronomic practices (GAPs), mechanization services, soil management, and water management.

The availability of these information services and advisory support is then disseminated to smallholder farmers being the main stakeholders. As these farmers successfully implement these recommendations, short-term improvements in agricultural yields are anticipated, consequently leading to enhanced household income.

In the long run, sustained utilization of these services is expected to contribute to improved access to ACAS for grain farmers in Northern Ghana. Furthermore, the influence of national policies, such as the National Agricultural Policy (NAP), FASDEP II, NACCP, and NFCS, is pivotal in shaping the dynamics within this framework. These policies impact the availability and allocation of funds, influence the behaviours of formal and informal financiers, and shape the implementation and accessibility of ACAS.

Figure 1.1: Conceptual framework of the study



3.4 Methods of Data Analysis

This section describes the systematic approach employed to organize, interpret, and derive conclusions from the data collected. In this section, the methods, techniques, and tools utilized to analyze the dataset are comprehensively detailed. From statistical procedures to qualitative coding frameworks, each method was strategically chosen and applied to address the research objectives effectively. This subsection elaborates on the rationale behind method selection, ensuring transparency in the analytical process and laying the foundation for the robustness and credibility of the study's findings.

3.4.1 Hypotheses of the Study

Guided by the theoretical framework, the study formulated the following hypotheses to examine the influence of gender on access to financing mechanisms, utilization of agro-climatic advisory services, and the resultant productivity and income outcomes among smallholder farmers in Northern Ghana.

Hypothesis 1: Gender and Access to Agro-climatic Advisory Services (ACAS)

- **H_{01}:** There is no significant difference between male and female smallholder farmers in access to agro-climatic advisory services.
- H_{11}: There is a significant difference between male and female smallholder farmers in access to agro-climatic advisory services.

Hypothesis 2: Gender and Access to Financing Mechanisms (FM)

- H_{02}: There is no significant association between gender and access to agricultural financing mechanisms.
- H_{12}: There is a significant association between gender and access to agricultural financing mechanisms.

Hypothesis 3: Gender, ACAS Utilization, and Productivity Outcomes

- H_{03}: Utilization of agro-climatic advisory services has no significant effect on farm productivity, regardless of gender.
- H_{13}: Utilization of agro-climatic advisory services has a significant effect on farm productivity, and this effect differs by gender.

Hypothesis 4: Gender, Financing Mechanisms, and Income Outcomes

- **H_{04}:** Access to financing mechanisms has **no significant impact** on household income, irrespective of gender.
- **H_{14}:** Access to financing mechanisms has a **significant impact** on household income, and this impact varies by gender.

Hypothesis 5: Combined Effect of Gender, Financing Mechanisms, and ACAS on Productivity

- **H_{05}:** The combined effects of gender, financing mechanisms, and access to ACAS do **not** significantly influence agricultural productivity among smallholder farmers.
- **H_{15}:** The combined effects of gender, financing mechanisms, and access to ACAS significantly influence agricultural productivity among smallholder farmers.

3.4.2 Describing the nature of Financial Mechanism

The first objective of the study was to describe the nature and categories of financing mechanisms (FM) available to support smallholder grain farmers to access ACAS. To achieve this, key informal interviews were conducted with farmers to understand how financing for ACAS is obtained, its main purposes, and whether it is gender inclusive. Additionally, focus group discussions were held with relevant stakeholders to explore how these financing mechanisms operate in practice and how they reach farmers. The qualitative data from interviews and focus groups were analysed using content analysis, where responses were compiled and coded according to key indicators. Frequencies of mentions for each indicator were calculated to provide a descriptive overview of the FM and their characteristics. Furthermore, farmers were asked about the number of ACAS services they received annually, linked to the specific financing mechanisms used to sponsor these services. This quantitative measure allowed the study to connect the availability and type of finance with the actual receipt of ACAS.

3.4.3 Extent and Factors Influencing Level of Access to ACAS

Extent analysis: The objective two which sought to identify key factors influencing the extent of access to ACAs was addressed using the Tobit Model equation 3.10

The extent of smallholder farmers' access to ACAS was measured using descriptive statistical analysis that's the number of times received ACAS per year. Descriptive statistics were calculated to measure the breadth of access, including the percentage of smallholder grain farmers that are aware of different types of ACAS and the percentage who had received different types of advisories and the percentage that use the different types of ACAS. Descriptive statistics were also usedto measure the depth of access, including the frequency distribution of how often smallholder grain farmers received the ACAS and the mean number of times farmers accessed advisories in the past season. Inferential statistics was used to compare access across different channels. This analysis provided insights into the breadth and depth of farmers' access to various ACAS across different channels.

Access analysis:

The determinants of access to ACAS were analysed using a Tobit regression model. The Tobit model is appropriate when the outcome variable is censored at zero and takes on continuous non-negative values (McDonald and Moffitt, 1980). The outcome variable here is the extent of access, measured through a normalized index of the number of services used, frequency of access, and diversity of channels. The index ranges from 0 to 10 but is censored at 0 for non-users.

The Tobit model estimated the effects of independent variables X on the latent uncensored outcome variable y*:

$$y* = X\beta + \varepsilon \qquad 3.10$$

Where y* is only observed for values greater than 0. The parameters β reflect the influence of covariates X on the uncensored y*. Independent variables will include farmer demographics, assets, information sources, institutional factors, and geographical variables. Separate models will estimate determinants for male and female farmers. This quantitative analysis will assess the current state of smallholder farmers' agro-climatic service level of access and identify socioeconomic, institutional, and spatial factors influencing gendered differences in access.

Diagnostic test

To ensure the robustness of the Tobit model used in this study, several diagnostic tests were conducted. Multicollinearity among independent variables was assessed using the Variance Inflation Factor (VIF). Heteroscedasticity was evaluated using the Breusch-Pagan test, and robust standard errors were applied to correct for any detected variance inconsistencies. Model specification was assessed using the linktest, which indicated no specification errors. Finally, the proportion of censored observations was examined to confirm the appropriateness of the Tobit model for analyzing ACAS adoption and its determinants.

3.4.4 Identifying ACAS Adoption Factors and Estimating the Impact of ACAS on Productivity and Income

Factors influencing the adoption of ACAS, the study bundled CSA practices by Accelerating Impacts of CGIAR Climate Research for Africa (AICCRA) PROJECT Ghana Cluster for their baseline study and climate information from Ghana Meteorological Agency (GMeT) and purposively selected three of five ACAS approved by project for grain production (maize and soya bean). The study therefore presents the three ACAS as;

1. **Water management and Irrigation Scheduling Service**: Using weather and soil data to optimize irrigation scheduling and improve water use efficiency.
2. **Crop Planning and Weather Forecasting Service:** Providing weather forecasts and climate data to farmers and help farmers make informed decisions about crop selection, planting, and management.
3. **Integrated Pest Management (IPM) Advisory Service:** Combines pest monitoring and weather data to provide sustainable pest management recommendations to farmers.

with regards to impact of ACAS adoption on productivity and income, a multivalued treatment approach using Inverse Probability Weighting with Regression Adjustment (IPWRA) was employed. This method is suitable for evaluating causal effects in observational studies, as it combines a selection model with an outcome model, providing doubly robust estimates.

The selection model estimated the probability of a farmer adopting each type of ACAS (Water Management Irrigation (WMI), Crop Planning Weather Forecast (CPWF), and Integrated Pest Management (IPM)) based on observed socio-economic and farm-specific characteristics. These included age, gender, education level, household size, farming experience, and farm size. The estimated probabilities were used to create inverse probability weights, ensuring that the distribution of covariates was balanced across adoption categories and reducing selection bias.

The outcome model analysed the effects of ACAS adoption on productivity (kg/acre) and income (GHS/hectare), controlling for the same covariates used in the selection model. This combination allowed for an unbiased estimation of the Average Treatment Effect (ATE) and Average Treatment on the Treated (ATT), while accounting for potential confounding factors.

Empirical Model Specification

1. **Selection Equation (Multinomial Logit Model):** The selection equation models the choice of ACAS (m) as a function of observed characteristics (X) and instruments (Z). It can be specified as a multinomial logit model:

   $P(m = j \mid X, Z) = F(X'\beta\_j + Z'\gamma\_j) \ \ for\, j = 1, 2, \ldots, J$ 3.5

   Here, $F(.)$ is the cumulative distribution function (logistic for logit, normal for probit), β_j and γ_j are the parameter vectors to be estimated, and one category (e.g., $j = 0$) is chosen as the base category for identification.

2. **Outcome Equation (IPTW-RA Model):** In the context of conducting an impact evaluation analysis using the Inverse Probability of Treatment Weighting with Regression Adjustment (IPTW-RA) model, the outcome equation for modeling ACAS can be reformulated as follows:

   The outcome equation for the ACAS (y) is modeled as a function of observed characteristics (X) and the chosen ACAS (m). This framework assumes a multivalued treatment setting where the impact of the ACAS on y is evaluated by combining inverse probability weighting and regression adjustment.

The model can be specified as:

$$y = \sum_{m} I(M - m) \left[\frac{y_i}{P\,(M = m/X)} - \right] + \beta_m\,(X)$$

Where:

- *I(M=m)* is an indicator function that equals 1 if the observed ACAS is m and 0 otherwise.

- P(M=m | X) represents the estimated probability of choosing ACAS m given the observed characteristics X (propensity score).
- $\beta_m\ (X)$ represents the estimated coefficients for the conditional outcome model, which varies with the ACAS choice m.

This specification leverages the IPTW to reweight the data to create a pseudo-population where the treatment assignment is independent of X, and the regression adjustment ($\beta_m\ (X)$) ensures precision in the outcome estimation across different ACAS

In this combined model:

- Level 1: The inverse probability weights adjust for selection bias by balancing the distribution of observed covariates across different ACAS
- Level 2: The regression adjustment corrects any residual confounding by modeling the outcome within each ACAS.

This approach thus ensures an unbiased and robust estimation of the effect of each ACAS outcomes, accounting for observed characteristics

Diagnostic checks for the IPWRA

To ensure the validity of the Inverse Probability of Treatment Weighting with Regression Adjustment (IPTW-RA) model, it was necessary to confirm that the distribution of covariates was balanced across different ACAS treatment groups and that sufficient overlap existed between treated and control units.

Balance Check:

The balance of observed covariates across ACAS groups was assessed using standardized mean differences (SMDs) before and after weighting. An SMD of less than 0.1 was considered indicative of good balance. After applying the IPTW weights, all covariates showed substantial improvement in balance, demonstrating that the reweighting successfully reduced systematic differences between groups and minimized potential confounding.

Overlap Assessment: Overlap between treatment groups was assessed using propensity score distributions and visualized with overlap plots. These plots display the density of propensity scores for each ACAS category, confirming that for each level of observed characteristics, there were sufficient observations in both treated and control groups. Adequate overlap ensures that the treatment effect is estimated within the common support region, enhancing the credibility of causal inferences. Together, the balance and overlap assessments confirmed that the IPTW-RA model assumptions were satisfied, providing confidence in the robustness and validity of the estimated effects of ACAS adoption on productivity and income.

Table 1.1: Variable Descriptions and A Priori Expectations

Variable	Description	Measurement	A priori expectations
Dependent variables			
Frequency of access	Number of times ACAS were received per year	Continuous	
Water management and irrigation scheduling service		Treatment indicator is nominal multivalued dependent variable that picks the value 1 = If the farmer adopts only WM&I ; 2 = if farmer adopts only CPFW; 3 if farmer adopts only IAS ; and 0 if farmer adopts non	
Crop planning weather forecast service			
IPM			
advisory service			
Independent variables			
Farm size	Size of farm	Continuous	+/-
Age	Number of years of smallholder grain farmer	Continuous	-
Experience	Number of years in farming	Continuous	+
Land tenure	Landholding status of smallholder grain farmer	Categorical (1= Family land, 2=Owned land, 3=Rented land, 4=Sharecropped, 5=Temporary offer for cropping)	+/-
Perceived effectiveness	The usefulness of the advisories	Binary (1=yes, 0=No)	+
Availability	Availability of the advisories	Binary (1=Yes, 0=No)	+
Education	Farmers' educational status	Binary (1=Educated, 0=Not educated)	+/-
Gender	Gender of smallholder farmer	Binary (1=Male,0=Female)	+/-
Trust in the Source of information	Trust in the source of information on advisories	Binary (1=Yes, 0=No)	+
FBO Membership	The farmer is part of an FBO	Binary (1=Yes, 0=No)	+
Access to finance	Farmers having access to finance	Binary (1=Yes,0=No)	+
Access to AEAs	Farmers having access to agricultural extension agents	Binary (1=Yes, 0=No)	+

3.5 Research Design

The study adopted a cross-sectional mixed-methods design, combining quantitative and qualitative techniques to gain a comprehensive understanding of access to ACAS and financing mechanisms among smallholder grain farmers. Cross-sectional studies capture data at a single point in time, enabling examination of relationships between variables without manipulating the study environment (Creswell & Plano Clark, 2018). Quantitative data were collected through structured surveys, allowing for statistical analysis and generalization of findings (Bryman, 2016). Complementing this, qualitative methods including interviews and focus group discussions provided in-depth insights into participants' perspectives and lived experiences (Guest, Namey, & Mitchell, 2017).

The mixed-methods approach facilitated triangulation, enhancing the validity and reliability of the findings by integrating numerical data with narrative evidence (Tashakkori & Teddlie, 2019). This combination enabled a holistic investigation, balancing the breadth of quantitative analysis with the depth of qualitative content analysis to comprehensively address the research questions.

3.6 Type of Data, and Method of Data Collection

Along with observation, the study used both primary and secondary data. Secondary data from publications and project technical reports that were published were sourced to complement data collection. Primary data involved the use of semi-structured questionnaires and checklists and established an experimental model – treatment and control groups to conduct in-depth interviews with farmers and support institutions. A structured guide and a questionnaire were designed with a combination of both open and closed-ended questions to be used to collect primary data. The instruments received ethical clearance from the committee of the University of Ghana, Legon.

The survey instrument was pre-tested for validation and improvement. Expert opinions (Elites) were also sourced to validate data collection. Instruments used: Questionnaires (farmers). Interview guide for (Is). For household respondents, the study purposively targeted male, female, and youth groups to ensure respondents were able to provide relevant information without any cultural constraints. As part of the initial preparations, a team undertook an exploratory survey of the study areas and selected crop actors to guide the survey design and tools, select and sensitize relevant stakeholders about the proposed research for buy-in and validate interest.

The data collection procedure surveyed 730 selected crop farmers and value chain actors across the study ecological zones through in-person interviewing techniques. Quantitative and qualitative data collection were carried out using Kobo collect software. The study used secondary data and sources such as archival records, and documentation. Focus group discussions with stakeholders in the study area were also used. Other secondary data, academic literature, theories and adaptation of conceptual frameworks, institutional reports, grey literature, and stakeholder reports were used.

3.7 Data Collection Tools and Procedures

The data collection tools employed in this study included semi-structured questionnaires, interview guides, focus group discussion (FGD) guide, observation checklists. These tools were designed to capture both quantitative and qualitative data aligned with the study's objectives.

1. **Semi-Structured Questionnaires**: The quantitative data was collected through a structured household survey using semi-structured questionnaires. These questionnaires were designed based on key variables identified from the conceptual framework related to innovative agricultural financing and gender-responsive approaches. The questionnaire covered sections on the demographic characteristics of the respondents, their access to

ACAS, FM, productivity, and income levels. The use of semi-structured questions allowed for standardized data collection while giving respondents the opportunity to elaborate on specific issues where necessary.

2. **Interview Guides**: For the qualitative data, interview guides were used to conduct key informant interviews with stakeholders. The interview guides included open-ended questions, enabling the interviewees to express their insights on FM and ACAS. Key informant interviews were conducted with representatives from financial institutions, service providers, cooperatives, and policymakers, focusing on their role in facilitating access to finance and ACAS for grain farmers. This approach allowed for the collection of in-depth qualitative data.

3. **Focus Group Discussions (FGDs)**: FGDs were a critical tool in collecting qualitative data from the smallholder grain farmers. Initially, 730 farmers were selected from the Northern and Savannah Regions. From this group, 150 farmers were purposively chosen from six project districts: Saboba, Kumbungu, East Gonja, Yendi, Gushegu, and Kpanshegu, with 25 farmers selected from each community. The FGDs were segmented into male-only, female-only, and youth groups to facilitate manageable and productive discussions and capture diverse perspectives. Given that female farmers often face significant challenges in accessing financial resources and services (Kirsten, 2007), the sample was designed to include a higher proportion of women. This approach allowed for an in-depth examination of whether the impact of the studied interventions differed by gender. FGDs allowed for interaction among participants, encouraging the expression of community-level insights and experiences. This method facilitated the exploration of gender-specific issues, especially related to women's access to financial services.

4. **Observation Checklists**: Observation checklists were used to complement the data collected through questionnaires and interviews. Researchers used the checklists to record relevant environmental and socio-economic conditions within the farming communities, including observations on farming practices, infrastructure, and access to financial services. This tool ensured that non-verbal data and contextual information were systematically recorded.

3.8 Data Processing and Method of Analysis

After the focus group discussions (FGDs) were completed, the conversations were transcribed from a recorder to standardized forms verbatim to capture the full range of responses from participants and identify key themes and patterns. This step was crucial to ensure that no information was lost or misrepresented during the analysis phase. Identification codes were assigned to each male, female and youth groups according to their respective regions and districts. The transcriptions were then subjected to a meticulous cleaning process, during which they were reviewed for accuracy and completeness. Errors or inconsistencies in the transcriptions were corrected by comparing them with the original audio recordings. Microsoft Excel was used during the cleaning process to systematically organize and verify the data. Excel's functionalities, such as filtering, sorting, and formula-based checking, facilitated the identification of any discrepancies in the data. This process enhanced the overall reliability and quality of the dataset, ensuring its accuracy for subsequent analysis. Once the data had been processed, it was organized and prepared for analysis using two key software tools: NVivo and Microsoft Excel.

The analysis of data in this study followed a structured and methodologically rigorous approach tailored to the specific objectives outlined in the research. For the first objective, which sought to describe the nature of financing mechanisms and categorize them, a combination of descriptive statistical techniques and qualitative content analysis was employed. Descriptive statistics were used to summarize and present key characteristics of the financing mechanisms, while qualitative content analysis provided deeper insights into the contextual and thematic patterns associated with the financing mechanisms. This dual approach ensured a comprehensive understanding of the financing mechanisms under consideration.

The second part of the first objective, which aimed to assess the effect of financing mechanisms on the level of access to Agro-climatic Advisory Services (ACAS), was analyzed using a Tobit regression model. The Tobit model, as specified in Equation 3.10, was chosen to account for the censored nature of the dependent variable, ensuring robust estimation of the relationship between financing mechanisms and access to ACAS.

The second objective sought to identify the key factors influencing the extent of access to ACAS among smallholder grain farmers. Similar to the second part of objective one, the Tobit regression model specified under Equation 3.10 was utilized. This model facilitated the identification of critical determinants influencing the intensity of access to ACAS, providing empirical evidence on the factors that drive variability in access levels.

The third objective focused on determining the factors influencing the adoption of ACAS by smallholder farmers. For this analysis, a multinomial regression model was employed. This model was particularly suited to capture the multinomial nature of the adoption decision, allowing for the examination of various categories of adoption behaviour and their associated influencing factors.

Finally, the fourth objective, which sought to estimate the impact of ACAS adoption on productivity and income, was addressed using the Inverse Probability of Treatment Weighting with Regression Adjustment (IPTW-RA) approach under a doubly robust nominal multivalued treatment effect analysis framework. This advanced methodological approach was employed to mitigate potential biases arising from confounding factors, thereby ensuring accurate and credible estimates of the causal effects of ACAS adoption on productivity and income.

Each analytical technique was rigorously implemented to align with the study's overarching objectives and to ensure the validity and reliability of the findings. The choice of methods was informed by theoretical underpinnings, the nature of the data, and the specific research questions addressed.

The combination of quantitative and qualitative data allowed for the triangulation of findings. By comparing results from the different data sources, the study was able to cross-validate the results and provide a more comprehensive understanding of the FM available for ACAS in Northern Ghana. The mixed methods approach ensured that the findings were well-rounded, capturing both statistical trends and in-depth insights from the experiences of farmers and key stakeholders. The integration of tools such as Kobo Collect, Nvivo, and Microsoft Excel, along with the application of advanced statistical models, ensured methodological rigor in the research process. These tools enabled the study to provide accurate, reliable, and comprehensive insights into innovative gender-sensitive FM for ACAS in Northern Ghana's grain sector.

3.9 Sampling Procedure and Sample Size Determination

A multistage sampling procedure was employed to select smallholder grain farmers for this study, focusing on the Northern and Savannah regions of Ghana. These regions were selected due to their significance as "hot spots" for grain production, particularly maize and soybeans, which are used both as cash crops and in animal feed and food production (Osman, 2023). The study's target population consisted of 289,109 grain farmers in Northern Ghana (MoFA, 2022), with a sample size of 730 smallholder farmers derived from power calculations and projects under the International Institute of Tropical Agriculture (IITA) and Accelerating Impact of CGIAR Climate Research for Africa (AICCRA) Ghana baseline survey. The smallholder farmers were randomly selected from a list compiled through these projects, namely AICCRA and SSPiNG.

Stage 1: Regional Selection

The first stage of sampling involved the purposive selection of two Northern regions: The Savannah Region and the Northern Region. These regions were chosen due to their importance in grain production and the presence of ongoing agricultural projects such as the International Institute of Tropical Agriculture (IITA) Ghana and the Ghana Commercial Agriculture Project (GCAP). The selection of these regions allowed the study to leverage existing relationships and agricultural data, ensuring access to relevant stakeholders and grain farmers.

Stage 2: District Selection

Within these two regions, six districts were purposively selected based on the active presence of IITA Ghana and GCAP initiatives. The selected districts were:

- Savannah Region: West Gonja District (Salaga)

- Northern Region: Saboba District (Saboba), Guishegu District (Guishegu), and Yendi District (Yendi)

These districts were considered appropriate study locations, as they provided access to a diverse range of grain farmers who were involved in previous projects related to agricultural development and climate research.

Stage 3: Community and Farmer Selection

In each of the six districts, farming communities were identified as the next sampling unit. Within each community, a list of grain farmers (specifically maize and soybean farmers) was compiled. Farmers were then randomly selected from this list to ensure a representative sample. The total sample size for the study was initially set at 706 farmers, determined using power calculations based on cereal productivity data collected by IITA in 2022. These calculations, which aimed for a significance level of 5% and a power of 80%, suggested a sample size of 353 farmers per group (treatment and control), yielding 706 participants. However, the study opted to oversample by 10% to account for potential non-responses, resulting in a final sample size of 730 farmers.

Stage 4: Sample Allocation

The final sample of 730 farmers was distributed equally across the two regions:

- **Northern Region**: 365 farmers were selected from three farming communities, with 122 farmers drawn randomly from each community.
- **Savannah Region**: 365 farmers were selected from two farming communities, with 183 farmers randomly selected from each community.

The final sample of 730 smallholder farmers was distributed equally across the two regions (Northern and Savannah) to ensure regional balance and gender representation. Within each selected community, respondents were proportionally drawn to reflect the actual gender composition of farmers, maintaining the study's gendered analytical focus on access and utilization of ACAS. The sampling logic ensured that both men and women were adequately represented based on their relative presence in farming activities. A stratified random sampling approach was adopted: farmers were first stratified by gender and then randomly selected within each stratum.

The sample was divided into treatment and control groups, with 345 farmers in the treatment group and 385 farmers in the control group. This allocation ensured sufficient data for comparing the effects of ACAS on grain production. The use of systematic sampling within each community helped maintain randomness while ensuring that farmers from different parts of the community were proportionally represented.

Power Calculations

The sample size was determined using power calculations based on cereal productivity data provided by IITA in 2022. The study utilized baseline data from the AICCRA project to assess the impact of ACAS on grain farmers' productivity and income. According to this data, the average cereal productivity for ACAS users was 107.51 kg/ha with a standard deviation of 114.82, while non-users had an average productivity of 87.42 kg/ha with a standard deviation of 98.91. These calculations established the need for a sample size of 353 per group (706 total) to achieve an 80% power and a 5% significance level. To ensure robustness, the sample size was increased by 10%, resulting in the final selection of 730 farmers.

Table 3.2: Sample Size Distribution across Two Regions

Region	District	Communities	Specific Commodity	Number of respondents
Northern Region (365)	Saboba District	Saboba	Maize and Soya bean	122
	Guishegu	Guishegu	Maize and Soya bean	122
	Yendi District	Yendi	Maize and Soya bean	122
Savanna Region (365)	West Gonja District	Supuni	Maize and Soya bean	183
		Busunu	Maize and Soya bean	183

Source: Survey data (2023)

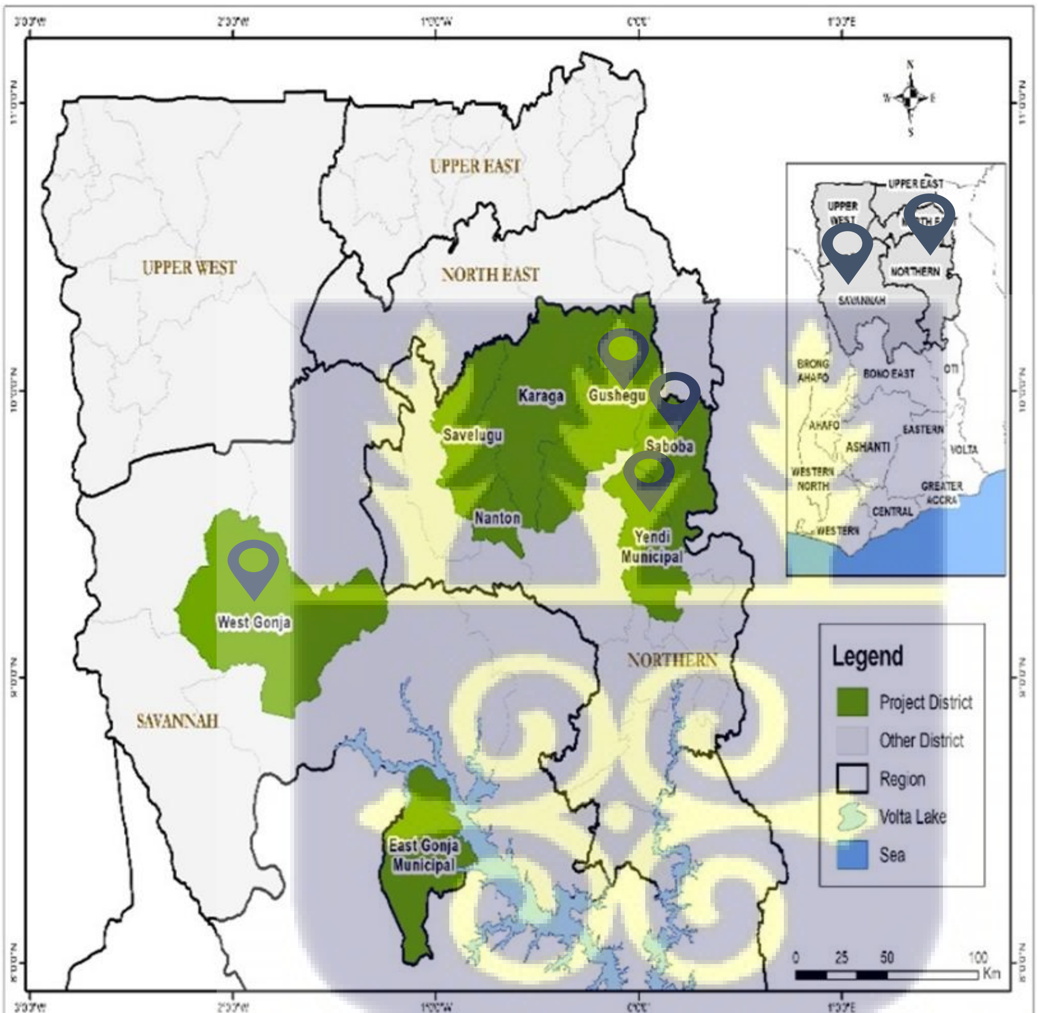
3.9.1 The Study area

Ghana is generally divided into three zones from north to south: savanna, forest, and coastal ecological zones based on the nature of rainfall and vegetation (Bessah et. al., 2022). The study was conducted across northern Ghana, spanning the Upper West, Upper East, North East, Savannah, and Northern regions. These five regions encompassed the savanna climatic zone of Ghana (Bessah et. al., 2022). The study focused on Northern Ghana because it is noted in literature as a "hot spot" and suitable and sensitive to grain production (Osman, 2023).

Most households in Northern Ghana are grain farmers but as project sites of IITA Ghana and GCAP, the systematic sampling technique was employed to purposively select the Northern and Savannah regions from the larger pool of options, including Northern, Northeast, Savannah, Upper East, and Upper West regions.

This method involved organizing these regions systematically, arranging them alphabetically from Northern to Upper West. By implementing a predetermined interval within this ordered list, specifically selecting every second region, the aim was to systematically pinpoint the Northern and Savannah regions. This systematic approach ensured a fair and structured selection process, reducing biases and resulting in a sample that aptly aligned with the research objectives. These chosen regions served as pivotal focal points for in-depth analysis, enriching the broader context of the study with heightened credibility and reliability.

Figure 3.2 Map of Study Area



Source: Geography Department (2023)

3.9.2 Crop selection

In selecting the crops, the study employed a purposive method (grains sensitive to climate - soy and maize) based on the IITA/AICCRA/Ssping Project. An exploratory study was conducted using a focus group discussion to validate the gaps identified in the literature and the need for the study. The research targeted the two regions of the IITA Project areas in Ghana. The research was carried out in five communities across the two regions, where youth and women-led crop farmers and groups were identified, and activities and relationships of actors were specifically targeted as Grain Farmer's production. These crops are major crops produced and processed by youth and women due to roles played in the production process (Lihoussou and Limbourg, 2022; Ayaaba, 2022; Ayela *et al*., 2019).

3.10 Scope and Limitations

This studies scope encompasses the analysis of various FM, their gendered aspects, and their effects on ACAS, particularly for small-holder grain (maize and soybean) farmers. However, the study faced significant limitations. Additionally, the geographical focus on northern Ghana and the specificity to grain farmers may limit the generalizability of findings to other regions or farming systems. These limitations should be considered when interpreting the results and conclusions of this study, and future research may benefit from addressing these constraints, particularly by allowing more time for data collection and enhancing stakeholder engagement.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the empirical findings related to FM and access to ACAS for smallholder grain farmers in Northern Ghana, with a focus on gender dimensions. Section 4.2 defines variables and discusses socioeconomic profiles of respondents. The analysis is structured around four objectives: 1) describing the nature of FM and their impact on the access to ACAS, 2) measuring ACAS access levels and their influencing factors, 3) establishing the factors influencing choice of specific ACAS, and 4) estimating the impact of ACAS on productivity and income for male and female farmers. The findings of the study are critically discussed within the broader literature, highlighting theoretical and practical implications for enhancing gender-responsive access to financing and ACAS in the Northern and Savannah regions.

4.2 Background of Respondents

The background of respondents describes the socio-economic features of smallholder grain farmers interviewed. The personal characteristics include age, gender, education, marital status, access to finance, and source of finance. Household characteristics include household size. The farm characteristics include farm size, years of farming experience, and ownership of farmland.

4.2.1 Personal and Household Characteristics of Respondents

A summary of farmer-specific and farms pecific have been presented in Table 4.1. It includes information on their age, household size, land size, farmer experience and number of times information is being received.

Table 2.1: Selected Farmer-Specific and Farm-Specific Factors

Variable	Female	Male	Youths	Adults	Pooled
Age (Yrs.)					
Mean	39.78	43.58	28.69	54.00	41.69
Std. Deviation	13.65	14.06	3.63	7.48	13.98
Minimum	21	19	19	36	19
Maximum	68	68	35	68	68
Household Size (Numbers)					
Mean	4.77	4.91	3.98	5.65	4.84
Std. Deviation	2.05	2.11	1.77	2.03	2.08
Minimum	1	1	1	1	1
Maximum	10	10	10	10	10
Landsize (Acres)					
Mean	2.54	3.16	2.81	2.89	2.85
Std. Deviation	1.20	1.94	1.50	1.77	1.64
Minimum	0.5	0.5	0.5	0.5	0.5
Maximum	6	10	9	10	10
Farming Experience (Yrs.)					
Mean	10.73	12.46	5.97	16.93	11.60
Std. Deviation	9.16	9.88	3.19	10.49	9.56
Minimum	1	1	1	1	1
Maximum	41	45	22	45	45
No. of Times Information Was Received					
Mean	75.79	71.39	74.03	73.14	73.57
Std. Deviation	103.35	96.53	100.49	99.53	99.93
Minimum	0	0	0	0	0
Maximum	560	560	560	560	560

Source: Field Survey (2024)

The results reveal a noticeable variation in age distribution across the different groups. The average age of female farmers is 39.78 years, while male farmers are relatively older, with an average age of 43.58 years. This difference in average age aligns with findings from previous studies. For instance, JICA (2013) reports gendered patterns in agricultural labour participation, noting that men often remain engaged in farming for longer periods or enter the sector later due to sociocultural expectations and labour market dynamics. This supports the disparity observed in the current study.. More striking is the age disparity between youths and adults. Youths, defined in this context, have an average age of 28.69 years, while adults have a significantly higher mean age of 54 years. The clear age difference between the two groups aligns with earlier studies. FAO & World Bank (2017) also report a similar generational divide in farming, where older adults tend to represent the more experienced farming population. This mirrors the pattern observed in the present study.. The pooled mean age of 41.69 years suggests that the sample is relatively middle-aged, with a wide distribution spanning from younger to older farmers, as the maximum age recorded is 68 years.

This diversity in age is important for assessing productivity, technology adoption, and access to agricultural information, as different age groups tend to exhibit varying capacities and constraints. Similar observations were made by Ngigi et al. (2017), who found that age differences significantly shape farmers' decision-making and uptake of innovations.

Household size is another important factor with implications for labour availability and the economic sustainability of farming households. Female-headed households have an average size of 4.77 members, slightly smaller than the male-headed households, which have an average of 4.91 members. While the difference is marginal, it may indicate differences in household structures, particularly the presence of more children or dependents in male-headed households, which could affect resource allocation and labor dynamics on the farm. A more pronounced difference is seen when comparing youths and adults. Youths have smaller households on average (3.98 members), while adults maintain significantly larger ones (5.65 members). This pattern aligns with life-cycle dynamics, where younger farmers typically have fewer dependents, whereas older adults tend to support extended families. Similar household-size differences across age groups have been reported in earlier studies, such as Aidoo et al. (2018), which also found that older farming households are generally larger due to accumulated family responsibilities.The pooled data indicate an average household size of 4.84 members, with a maximum household size of 10. The larger households, particularly among adults, could imply greater availability of family labor for farming activities, but also higher consumption demands, which could influence decisions related to farm management and resource allocation.

The data on land size reveal gender and age-related disparities in farm ownership and management. Male farmers manage larger farms on average, with a mean landholding of 3.16 acres, compared to females who manage an average of 2.54 acres. This disparity may reflect gendered access to land, with men traditionally having greater access to land due to patriarchal inheritance systems or social norms that favour male ownership. These findings align with the findings of Doss (2017), who reported that men typically have greater access to land due to patriarchal inheritance systems and social norms that favour male ownership.. Youths and adults exhibit more comparable land sizes, with youths managing an average of 2.81 acres and adults slightly higher at 2.89 acres.

The small difference between these groups may suggest that land access is less influenced by age than by gender. The pooled sample shows an average farm size of 2.85 acres, with the maximum farm size being 10 acres, indicating considerable variation in landholdings across the sample. Larger landholdings are often associated with greater agricultural productivity, assuming other factors such as access to inputs and labour. These findings align with FAO (2011), which reported that larger landholdings are generally associated with higher agricultural productivity, assuming other factors such as access to inputs and labour remain constant.. However, These findings align with the World Bank (2012), which indicated that smaller farm sizes, especially among female farmers, can constrain their ability to scale production and adopt modern technologies, highlighting the need for equitable land distribution policies.Farming experience, a critical determinant of agricultural efficiency and productivity, shows notable differences across gender and age categories. Male farmers, on average, have 12.46 years of farming experience, significantly higher than their female counterparts, who have 10.73 years of experience. This gap may be reflective of historical trends where men are more likely to be long-term participants in farming, while women may have less consistent participation due to household responsibilities or limited access to agricultural resources. Youths, as expected, have much less experience (5.97 years) compared to adults, who have an average of 16.93 years of farming experience.

The disparity in experience between youths and adults is substantial, highlighting the importance of targeted agricultural interventions for younger farmers who may lack the experience necessary to navigate farming challenges effectively. These findings align with Anaglo et al. (2014), who observed that younger farmers often have less farming experience, indicating the need for targeted agricultural interventions to support them in overcoming challenges and improving productivity. The pooled farming experience is 11.60 years, with a maximum of 45 years, indicating that while the sample includes many experienced farmers, a significant proportion of the population is less experienced, particularly among the youth.

The frequency of information received by farmers serves as a proxy for their access to extension services and agricultural knowledge through ACAS, which are crucial for improving farm productivity and adopting new technologies. Female farmers, on average, received ACAS information 75.79 times, slightly more than male farmers, who received information 71.39 times. This may suggest that access to information about ACAS are becoming more gender-inclusive, or that women are more engaged in seeking out information. Interestingly, the average frequency of information received by youths (74.03 times) is comparable to that of adults (73.14 times), indicating that both age groups have relatively similar access to information. The pooled sample shows an average of 73.57 instances of information dissemination, though a high standard deviation suggests variability in how information is distributed among the population. These findings align with Ragasa et al. (2013), who noted that variations in farmers' access to information are influenced by location, social networks, and available support, all of which shape how agricultural knowledge is shared and utilized.

The summary statistics provided valuable insights into the demographic and operational characteristics of farmers across gender and age groups. Gender disparities are evident in land size and farming experience, while age differences are more pronounced in terms of farming experience and household size. Access to information appears to be relatively equitable across groups, though further analysis is required to understand the drivers of variability. These findings indicate the need for targeted agricultural policies that address the specific challenges faced by different demographic groups, particularly in improving access to land, resources, and agricultural knowledge. Figure 4.1 provides a description of the distribution gender of respondents.

Figure 4.1: Gender Distribution of Respondents (%)

Source: Field Survey (2024)

The gender distribution of respondents, disaggregated by age group, presents notable insights into the participation dynamics of male and female farmers in Northern Ghana. Among adults, males dominate the sample, constituting 60.33% of the respondents, while females account for 42.27%. This gender imbalance suggests that men are more likely to engage in farming activities or are more visible in agricultural surveys, possibly due to sociocultural norms that favor male participation in formal agricultural endeavours. This gender disparity persists among youth respondents, with 57.73% being male and only 39.67% female. The higher male representation among both adults and youths may reflect underlying gender biases in access to ACAS, financial mechanisms, or agricultural resources in the region.

However, when the data is pooled across all respondents, the gender distribution exhibits near parity, with males representing 50.41% and females 49.59%. This suggests that, at the aggregate level, there is a near-equal participation rate between genders, despite the observed disparities within individual age cohorts. The overall gender balance in the sample may indicate that, while men dominate specific age groups, women's involvement in smallholder grain farming remains substantial. This finding underscores the importance of a gender-sensitive analysis in assessing the FM for ACAS, particularly in ensuring that both male and female farmers have equitable access to critical agricultural resources.

4.2.2 Household Characteristics Including Access to Finance

Table 4.2 presents the distribution of household and farm-specific characteristics by gender and age groups (adults and youths). The characteristics analysed include marital status, educational level, access to finance, and sources of finance. The table provides a breakdown of these variables to identify the unique patterns among adults and youths, males and females. The findings help in understanding how social and economic factors, such as education and access to finance, influence the livelihoods of smallholder farmers across different demographic segments.

Table 3.2: Marital Status, Educational Level and Sources of Finances of Farmers

	Adults		Youths		Pooled	
	Female	Male	Female	Male	Female	Male
Marital Status						
Married	83.01	77.48	78.95	67.81	80.66	73.64
Separated/Divorced	2.61	3.60	3.83	2.74	3.31	3.26
Single	3.92	8.11	4.78	19.86	4.42	12.77
Widowed	10.46	10.81	12.44	9.59	11.60	10.33
Education Level						
No Formal Education	61.44	40.09	55.02	49.32	57.73	43.75
Primary Education	11.11	12.16	20.57	25.34	16.57	17.39
JHS	22.22	35.14	11.48	9.59	16.02	25.00
Secondary Education	4.58	9.91	11.96	15.75	8.84	12.23
Tertiary	0.65	2.70	0.96	0.00	0.83	1.63
Access to Finance						
Access	35.95	54.05	28.23	60.27	31.49	56.52
No Access	64.05	45.95	71.77	39.73	68.51	43.48
Main Sources of Finance						
Bank	21.82	18.33	5.08	26.14	13.16	21.63
Microfinance	14.55	15.83	11.86	22.73	13.16	18.75
Money Lender	9.09	14.17	15.25	6.82	12.28	11.06
VSLA	30.91	18.33	37.29	14.77	34.21	16.83
Family and Friends	23.64	33.33	30.51	29.55	27.19	31.73

Source: Field Survey (2024)

The results revealed that the majority of respondents, particularly among adults, are married. As indicated in Table 4.2, 83.01% of adult females and 77.48% of adult males reported being married. For youths, however, the proportion of married individuals is lower, with 78.95% of females and 67.81% of males being married. The relatively high percentage of married individuals among the adult population reflects the social structure in rural communities, where marriage is often tied to responsibilities such as farming and household management.

On the other hand, the percentage of single individuals is notably higher among youths, with 19.64% of males and 12.77% of females reporting being single. This aligns with societal norms where younger individuals are less likely to be married compared to their older counterparts.

Regarding educational attainment, Table 4.2 shows that a significant portion of the population has no formal education, particularly among adult females (61.44%) and adult males (40.09%). Among the youth, the percentage of individuals without formal education is lower, at 55.02% for females and 49.32% for males. This trend highlights the generational gap in educational opportunities, with youths having relatively better access to education than adults. However, despite improvements in educational attainment among the youth, the majority still have only primary or junior high school education. The percentage of individuals with secondary or tertiary education remains quite low across all demographic groups, which may impact access to better farming technologies and ACAS.

4.2.3 Access to finance and financing mechanism for ACAS

Access to finance remains a critical factor for smallholder farmers. The data indicate that female farmers, both adults and youths, have slightly better access to finance compared to their male counterparts. Specifically, 35.95% of adult females and 28.23% of female youths have access to finance, compared to 34.05% of adult males and 23.09% of male youths.

As shown in Table 4.2, the primary sources of finance for the respondents include microfinance institutions, money lenders, village savings and loan associations (VSLA), and family and friends. Money lenders and microfinance institutions are the most common sources of finance across all demographic groups, with family and friends playing a significant role as well, particularly among adults.

4.3 The Nature of FM and its Effects on ACAS

Based on the content analysis of qualitative data, it is ascertained that the FM supporting ACAS for smallholder farmers in Northern Ghana are diverse and vary based on the type of institution, their source of funding, and the needs of the agricultural community. These mechanisms include grants, corporate sponsorships, government funding, revenue from services, multilateral funding, private foundations, loans from commercial banks, Village Savings and Loan Associations (VSLA), subscription fees, and international donors. These findings are in line with AGRA's risk-sharing value chain finance model, which reports that smallholder farmer finance often includes input loans, government and multilateral funding, and contributions from actors such as off-takers, aggregators, and traders (AGRA, 2020). Table 4.3 is a summary of the financing mechanisms for ACAS ascertained from the qualitative field research. These funding mechanisms play a crucial role in ensuring the effective delivery and are discussed below.

Table 4.3 Financing Mechanisms for ACAS

Financing Mechanism	Nature of Financing Mechanism
Grants	Non-repayable funds provided by governments, international organizations, private foundations, or NGOs to support specific projects or initiatives, such as climate resilience and agricultural development. These funds are usually aimed at research, innovation, and capacity building.
Corporate Sponsorships	Financial or in-kind support from private companies to fund projects or services in exchange for brand visibility or alignment with corporate social responsibility (CSR) goals. This funding often supports climate-smart initiatives and sustainable agricultural practices.
Revenue from Services	Income generated from charging fees for services provided, such as weather forecasting, market advisory, or pest management. This model creates a sustainable financial flow directly from users or subscribers, promoting long-term service delivery.
Government Funding	Financial resources provided by national or local governments to support agricultural programs, research, and ACAS. These funds often aim to promote food security, climate resilience, and sustainable farming practices.

Multilateral Funding	Financial support from multiple countries or international organizations through joint initiatives or programs. This funding often targets large-scale projects aimed at climate adaptation and agricultural development, such as regional climate resilience plans.
Private Foundations	Funds provided by philanthropic organizations to support research, innovation, and the implementation of climate-smart agricultural practices. This funding typically promotes sustainable solutions and capacity-building efforts in the agricultural sector.

Source: Compiled by author from Institutional Reports and Agro-Climatic Advisory Service Providers.

1. **Grants**: Many organizations, particularly research institutions and NGOs, rely on grants provided by governments, international bodies, and development agencies. For example, institutions like the International Institute of Tropical Agriculture (IITA) and CABI Africa depend on these funds to finance climate-smart agricultural research, pest management strategies, and extension services. Grants allow these institutions to offer free or subsidized services to smallholder farmers, making essential information and training more accessible. This finding is in line with the Global Agriculture and Food Security Program (GAFSP, 2023), which reports that grants enable institutions to provide free or subsidized services, improving smallholder farmers' access to essential information and training.

2. **Corporate Sponsorships**: Corporate sponsorships come from agribusinesses or companies that invest in climate-smart agriculture initiatives. Institutions such as Sinapi Aba Trust, Esoko and Farmerline rely on corporate partnerships to fund their climate information platforms, which provide services such as market data and weather forecasts.

This financing model allows organizations to develop scalable technologies that can serve large farming communities, though it may sometimes prioritize regions with more developed markets. This finding is in line with OECD (2020), which notes that such financing models enable organizations to develop scalable technologies for large farming communities, focusing on areas with more developed markets

3. **Government Funding**: Agencies like the Ministry of Food and Agriculture (MOFA) and the Ghana Meteorological Agency (GMet) are supported by national government budgets. Government funding is essential for maintaining public ACAS like weather forecasting and agricultural extension. These funds are used to implement national climate policies, develop early warning systems, and conduct public agricultural training programs. This findings are in agreement with OECD (2020), which reports that public climate adaptation funds are often directed toward national climate policies, early warning systems, and public agricultural training programs.

4. **Revenue from Services**: Some institutions, like Sinapi Aba Trust, AgriBiz Ghana and Farmerline, generate revenue by charging fees for bundled services such as market advisory, soil health information, and climate adaptation advice. This model ensures sustainability but can limit access to poorer smallholder farmers who may be unable to afford regular payments. This finding is consistent Aboagye et al. (2021), which found that fee-based services by institutions support sustainability but can restrict access for poorer smallholder farmers.

5. **Multilateral Funding**: Organizations like the West African Regional Action Plan (WARAP) and International Institute of Tropical Agriculture (IITA) rely on funding from multilateral donors such as the World Bank and the African Development Bank. This type

of funding focuses on regional resilience-building initiatives and large-scale projects aimed at improving access to climate ACAS across multiple countries. It facilitates the implementation of joint projects to tackle climate adaptation challenges that cut across national borders. These findings are in line with AGRA (2020), which emphasizes that multilateral funding supports regional resilience initiatives and large-scale projects that improve access to climate ACAS across multiple countries.

6. **Private Foundations**: Private philanthropic foundations, such as those supporting ICRISAT and CABI Africa, play a critical role in financing climate-smart agriculture initiatives. These foundations prioritize long-term sustainability and fund innovative research and development projects that address climate change's impact on smallholder farming. The results align with UNEP (2021), which highlights that climate adaptation funds are often allocated to national climate policies, early warning systems, and public agricultural training programs.

7. **Loans from Commercial Banks**: Commercial banks such as the Agricultural Development Bank (ADB), Stanbic Bank, ABSA Bank, and Ecobank provide climate finance products like green loans. These loans support farmers who seek to invest in climate-smart technologies and practices, enabling them to adopt more resilient farming methods. However, the stringent collateral requirements of commercial banks limit access for many smallholder farmers. The findings are consistent with Kosec et al. (2017), which notes that commercial banks, provide loans that enable farmers to adopt climate-smart technologies, though collateral requirements limit access for many smallholder farmers.

8. **Village Savings and Loan Associations (VSLA)**: VSLAs operate as informal community-based financial systems where farmers pool their savings and lend money to each other.

These associations are crucial for rural farmers who lack access to formal banking services. VSLAs provide farmers with the financial flexibility to invest in climate-smart inputs and adopt ACAS. These findings align with Khavhagali et al. (2020), reporting that VSLAs serve as informal community-based financial systems, allowing rural farmers to pool resources and invest in climate-smart inputs.

9. **Subscription Fees**: Some service providers, such as Farmerline, have adopted a subscription-based model where farmers pay a recurring fee to access weather forecasts, market prices, and climate-smart agricultural advice. Subscription fees ensure steady revenue streams but may exclude low-income farmers, limiting their ability to benefit from critical ACAS. The finding agrees with Mhlanga et al. (2019), highlighting that subscription-based models, offer stable revenue for service providers but may exclude low-income farmers from critical climate advisory services.

10. **International Donors**: International donors like the United States Agency for International Development (USAID), the International Fund for Agricultural Development (IFAD), and the United Nations Development Programme (UNDP) provide substantial funding for climate resilience programs of governments. These funds are typically channeled into projects aimed at building local capacity for climate adaptation and offering comprehensive ACAS to smallholder farmers. These findings align with FAORAP (2018), indicating that donors like USAID, IFAD, and UNDP support climate adaptation programs to improve ACAS access for smallholder farmers.

4.3.1 Contribution of Financing Mechanism on ACAS

The diverse FM available to support ACAS play a crucial role in determining the quality, accessibility, and sustainability of these services for smallholder grain farmers in Northern Ghana. These mechanisms range from grants and corporate sponsorships to loans from commercial banks and informal savings schemes like Village Savings and Loan Associations (VSLAs). Each type of financing has its distinct effect on ACAS, influencing not only the level of support farmers receive but also the long-term viability of these services.

Grants, which are typically provided by international donors, government agencies, and multilateral organizations, have a particularly significant impact on ACAS. These funds allow research institutions, non-governmental organizations (NGOs), and government agencies to offer critical ACAS, often at no cost or at heavily subsidized rates. Institutions like the International Institute of Tropical Agriculture (IITA) and initiatives such as the Ghana Agricultural Technology Transfer Project (GATTP) have benefited immensely from grants, enabling them to reach farmers even in remote regions with improved technologies through demonstrations. The result is improved access to vital climate information, including weather forecasts, pest control methods, and climate-resilient farming techniques. However, the reliance on grants poses a sustainability challenge. Once the funding cycles end, service providers may struggle to maintain operations, leading to interruptions in the ACAS that farmers rely on. For example, projects funded through the International Fund for Agricultural Development (IFAD) have brought significant short-term gains, but sustaining these services beyond the life of the grant remains an ongoing challenge for many institutions (IFAD, 2019).

Corporate sponsorships also play a role in financing ACAS, particularly in supporting digital platforms and tech-based solutions like Esoko and Farmerline. These platforms provide smallholder farmers with access to market prices, weather forecasts, and climate-smart agricultural advice via mobile phones and other technologies. Corporate backing has enabled these organizations to expand their reach and develop scalable solutions for smallholder farmers. The integration of private-sector funding has helped to professionalize the delivery of ACAS, making it more innovative and responsive to market needs. However, the commercial nature of corporate sponsorships often means that services are tailored to areas with stronger market potential, which can leave out more marginalized farming communities that are further away from developed infrastructure (Ochieng *et al*., 2021). The farmers most in need of these services may not always be the primary beneficiaries of such financing.

Government funding, on the other hand, is vital for the provision of public agricultural extension services. Ministries like the Ministry of Food and Agriculture (MOFA) and the Ghana Meteorological Agency (GMet) rely heavily on national budgets to deliver climate information and extension services to smallholder farmers. This support is critical for maintaining essential services, such as early warning systems for weather events, which are crucial for climate adaptation. However, the scope of government funding is often limited by budget constraints and competing priorities, resulting in inconsistent service delivery. As a result, the availability and reliability of government-supported ACAS can fluctuate, especially in rural regions like Northern Ghana where infrastructure is weaker (Bawakyillenuo *et al*., 2022).

Beyond institutional grants and government funding, commercial loans provided by banks such as the Agricultural Development Bank (ADB), Stanbic Bank, and Ecobank offer another avenue for financing ACAS-related activities. These banks provide green loans and other financial products that enable farmers to invest in climate-smart technologies, such as improved irrigation systems, drought-resistant seeds, and better storage facilities. However, the stringent collateral requirements and high-interest rates associated with these loans create barriers for many smallholder farmers. Access to formal finance from commercial banks remains limited for grain farmers, particularly those in remote areas without sufficient collateral. The result is that only a small fraction of farmers can benefit from these financing options, limiting the overall reach and impact of such mechanisms on ACAS uptake (Alhassan *et al*., 2020).

Village Savings and Loan Associations (VSLAs) serve as an alternative, informal financing mechanism that has proven highly effective in supporting climate-smart agricultural practices. VSLAs are community-based savings groups that allow members to pool their savings and provide each other with small loans. This grassroots financing model has been especially successful in rural parts of Northern Ghana where access to formal banking services is limited. Through VSLAs, smallholder farmers can obtain the funds necessary to adopt new technologies, purchase inputs, or pay for ACAS-related services. The communal nature of VSLAs fosters a sense of collective responsibility and encourages the sharing of climate-related information within farming communities. As a result, VSLAs have had a direct and positive impact on increasing access to climate ACAS, particularly among the most vulnerable farmers (Anderson *et al*., 2019).

Additionally, subscription fees are increasingly being used by private companies to finance the delivery of ACAS. Companies like Farmerline charge farmers a small recurring fee in exchange for access to market prices, climate data, and other relevant agricultural information. While this model provides a sustainable source of revenue for service providers, it can exclude poorer farmers who are unable to afford regular payments. In some cases, the reliance on subscription fees may create disparities in access to critical climate information, with wealthier farmers benefiting more from such services than their lower-income counterparts (Ochieng *et al*., 2021).

Finally, international donors play a crucial role in financing large-scale projects that aim to improve climate resilience in Northern Ghana. Donors such as the United States Agency for International Development (USAID) and the World Bank have invested in programs designed to increase farmers' capacity to adapt to climate change. These programs often include the provision of ACAS, the promotion of climate-smart technologies, and the strengthening of agricultural value chains. International donor support has facilitated the delivery of high-quality ACAS, ensuring that farmers receive timely and relevant climate information. However, similar to grant funding, donor dependence can create long-term sustainability challenges. Once the donor funding ends, the continuity of ACAS delivery becomes uncertain, which may undermine the resilience-building efforts that were initially achieved (World Bank, 2020).

Table 4.4 provides a detailed characterization of the institutions involved in the financing and provision of ACAS for smallholder grain farmers in Northern Ghana, underscoring the multiplicity of sectors engaged in addressing agricultural resilience and climate adaptation. The survey data was collected from a diverse pool of 19 institutions, encompassing commercial banks, research organizations, non-governmental organizations (NGOs), private companies, government agencies, and informal sources. Each of these entities plays a distinctive role in the ecosystem of support for ACAS, bringing varied resources, expertise, and FM that collectively drive agricultural adaptation efforts in the region.

Table 4.4: Summary of Institution Types

Institution Type	Number of Institution Type
Commercial Banks	4

Research Institutions (NPO)	3
NGOs	4
Private Companies (ICS)	2
Government	4
Informal Sources (VSLA)	2
Total	19

Source: Compiled by Author

A notable component of the surveyed institutions are the four commercial banks, which embody the formal financial sector's contribution to agricultural financing. These banks are positioned as primary sources of structured lending, providing loans and credit facilities to farmers. However, the commercial banks' requirement for collateral and their general preference for lending to well-established farmers or agribusinesses may limit the accessibility of their services for smallholder farmers. As a result, while commercial banks represent an essential aspect of agricultural finance, their reach may be constrained to a specific demographic—typically those who possess the assets or creditworthiness that commercial banks deem necessary for loan approvals. The role of these formal financial entities in agricultural financing is therefore crucial, albeit somewhat selective, often favouring farmers who have established financial histories or access to valuable assets.

Three research institutions, classified within the scope of this study as non-profit organizations (NPOs), contribute another layer to the ACAS support system. These organizations are primarily research-driven, dedicated to generating data, conducting analysis, and informing agricultural policies based on empirical evidence. Their role is vital in enhancing the scientific basis of agricultural practices, supporting data-informed decision-making processes, and advancing adaptive strategies for climate resilience. Funded largely through grants and donor investments, research institutions work to bridge gaps in knowledge and provide actionable insights into the effectiveness of ACAS interventions. These entities serve as critical sources of information, offering research outputs that guide policymakers and practitioners in designing, implementing, and refining climate adaptation measures within the agricultural sector.

NGOs are another significant stakeholder group, represented by four entities in this study. NGOs typically operate as mission-driven organizations, often reliant on external funding and international partnerships to deliver on their mandates. Within the ACAS framework, NGOs focus on directly engaging with farming communities, disseminating information, and facilitating access to resources that empower farmers to adopt climate-resilient practices. These organizations are particularly active in community capacity-building and advocacy, which are instrumental in strengthening farmers' adaptive capacities. Through targeted interventions, NGOs frequently address barriers faced by marginalized groups, such as women and youth, in accessing ACAS. Their role in community-level engagement and the provision of direct support services underscores their unique position in reaching underserved populations within the agricultural sector.

Private companies, categorized in this study as integrated corporate stakeholders (ICS), are represented by two firms. These companies engage in ACAS provision either through formal partnerships or as part of their corporate social responsibility (CSR) initiatives. For these private-sector actors, involvement in ACAS may be woven into their broader business models, often in the form of technological solutions, data analytics, or logistical support that complements the needs of climate-smart agriculture. Private companies can introduce innovative tools and systems, enhancing farmers' access to timely and actionable climate-related data. By leveraging advanced technology and market-driven approaches, these entities play a valuable role in the ACAS landscape, particularly in providing scalable and cost-effective solutions to agricultural challenges.

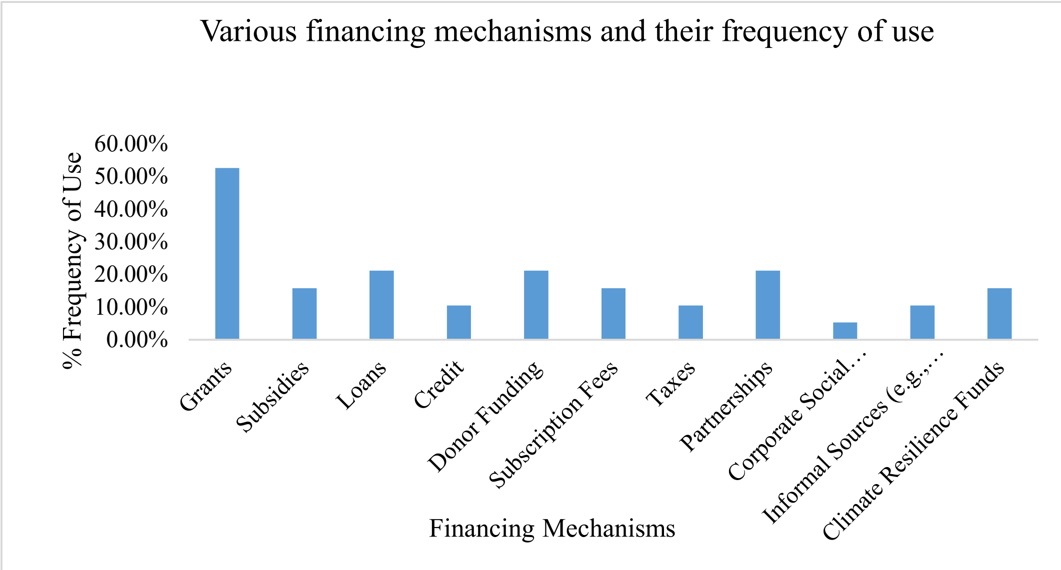
Government institutions, also numbering four, stand out as foundational actors in the ACAS ecosystem. These agencies are pivotal for policy formulation, the allocation of subsidies, and the development of public infrastructure to support agricultural adaptation. Government involvement in ACAS is crucial, as it shapes the regulatory environment and provides essential public goods that foster sector-wide resilience to climate change. Through the provision of direct funding, technical assistance, and infrastructure development, governmental institutions facilitate a conducive environment for agricultural innovation and resource distribution. They play a central role in scaling ACAS services and ensuring that these services are accessible to smallholder farmers across socio-economic and demographic lines.

Finally, informal sources—represented in this study by Village Savings and Loan Associations (VSLAs) - comprise two of the surveyed institutions. VSLAs embody a community-based approach to financial inclusion, offering savings and micro-lending options to rural populations, particularly in areas where access to formal banking services remains limited. These associations are essential for smallholder farmers who may lack the collateral or financial history required by commercial banks. VSLAs provide a flexible and community-driven financing model, supporting farmers' short-term financial needs and offering a lifeline to those operating at the margins of the formal financial sector. Through the aggregation of community resources, VSLAs enhance access to credit for smallholder farmers, enabling them to make timely investments in agricultural inputs or climate-smart practices.

Collectively, the data from these 19 institutions highlight the diverse and multi-sectoral approach required to facilitate effective climate adaptation in agriculture. Each type of institution—whether formal or informal, private or public—contributes a unique set of resources, expertise, and operational frameworks that support the financing and implementation of ACAS for smallholder grain farmers in Northern Ghana. This broad spectrum of stakeholders demonstrates the complexity and the collaborative nature of the ACAS ecosystem, wherein financial, technical, and community-driven efforts converge to address the pressing challenge of climate change adaptation within the agricultural sector.

Figure 4.2 provides a comprehensive illustration of the range and frequency of FM employed by institutions to support ACAS for smallholder grain farmers in Northern Ghana. This analysis is based on primary data collected from 19 institutions, including commercial banks, research institutions, NGOs, private companies, government agencies, and informal sources, using surveys and interviews. Secondary data was gathered from institutional reports and publicly available information on official websites. The graph captures the relative reliance on different funding methods, including grants, subsidies, loans, credit, donor funding, subscription fees, taxes, partnerships, corporate social responsibility (CSR) funds, informal community sources, and climate resilience funds. The findings provide valuable insights into the prevalence, accessibility, and sustainability of these financing approaches within the ACAS landscape in Ghana.

Figure 4.2: Various financial mechanisms and their frequency of use



Grants emerged as the predominant financing mechanism in ACAS, accounting for approximately 58% of the total financing methods employed by surveyed institutions. The high frequency of grant usage reflects the reliance on external funding sources, particularly for NGOs, research institutions, and government entities. For instance, current research demonstrates that grants remain the primary funding strategy for public service-oriented entities engaged in climate adaptation and resilience-building initiatives (Kwarteng & Aheto, 2023). Grants are typically non-repayable and designed to support projects without placing a financial burden on end-users, such as smallholder farmers, who might otherwise struggle to afford essential services. This funding model aligns with the general tendency in developing regions to depend heavily on international donors and development partners, particularly in agricultural adaptation (Gyamfi *et al*., 2021). However, reliance on grants may raise concerns about sustainability, as these funds are often finite and subject to changes in donor priorities or economic conditions (Opoku, 2022). In the case of ACAS, where climate resilience requires long-term investment, grant-dependent models may pose risks if alternative FM are not concurrently developed to ensure continuity of services.

The second most common financing method, loans, represents 16% of the total. Loans are primarily offered by commercial banks, reflecting the role of formal financial institutions in agricultural financing, particularly for higher-income farmers or agribusinesses with established credit histories. While loans can stimulate investment in ACAS by enabling farmers to access necessary ACAS, this approach may be inaccessible for smallholder farmers, who frequently lack the collateral or financial stability required for loan eligibility. Current studies on agricultural financing corroborate this finding, indicating that commercial banks generally cater to relatively affluent clients, leaving a substantial portion of smallholder farmers underserved (Atta & Mensah, 2022). Moreover, reliance on loans as a financing mechanism for climate adaptation poses additional challenges for smallholder farmers in Ghana, where limited financial literacy and unpredictable climate conditions increase the financial risks associated with loan repayment (Obeng *et al*., 2023). This issue suggests a need for innovative financial products, such as climate risk insurance or blended finance approaches, to increase loan accessibility for marginalized farmers (Baafi & Osei, 2021).

Subsidies, accounting for 11% of total FM, underscore the role of government intervention in making ACAS affordable and accessible to smallholder farmers. Subsidies typically reduce the financial burden on farmers, allowing them to receive services at reduced costs, which is essential in regions where agriculture remains the primary source of livelihood but where economic constraints inhibit farmers' ability to invest in climate adaptation (Nyarko, 2023). The role of subsidies in promoting agricultural adaptation is well-supported in recent literature, as government subsidies help bridge financing gaps that are often unaddressed by the private sector (Agyei, 2023). Nevertheless, while subsidies effectively promote ACAS accessibility, challenges remain regarding their sustainability, as government budgets for agricultural support fluctuate based on economic and political priorities. Moreover, budget limitations can restrict the reach and impact of subsidies, highlighting a critical need for resource optimization and targeted subsidy distribution to maximize benefits for the most vulnerable farming groups (Akoto & Owusu, 2022).

The partnership model, comprising 11% of FM, primarily involves collaborative efforts between private companies, NGOs, and government entities. These partnerships leverage the unique strengths of each partner to broaden ACAS access and enhance service quality. Research emphasizes the effectiveness of public-private partnerships (PPPs) in pooling resources, such as technology and expertise, which are essential for providing sophisticated ACAS to smallholder farmers (Acheampong & Agyemang, 2023). Private-sector engagement through corporate social responsibility (CSR) initiatives or technology partnerships is particularly valuable in regions where resource constraints inhibit ACAS provision. However, the reliance on partnerships requires careful coordination to avoid conflicts of interest and ensure that the collective goals of climate adaptation and farmer support remain central to the collaboration (Nyamekye, 2024).

Donor funding represents 5% of the FM observed, indicating a selective yet impactful role in ACAS support. Donor funding is typically allocated through international aid agencies, channelled mainly to NGOs and research institutions, and is often project-specific with predetermined objectives. Although donor funding facilitates the development of innovative ACAS initiatives and pilot projects, it may be inherently limited due to stringent donor requirements, short funding cycles, and potential alignment challenges between donor objectives and local needs (Boateng *et al*., 2023). As demonstrated in recent studies, while donor funding is valuable for pioneering projects, over-reliance on this funding mechanism may undermine project sustainability once donor priorities shift or funding cycles end (Mensah & Tetteh, 2022).

In summary, the distribution of FM employed by institutions supporting ACAS for smallholder grain farmers in Northern Ghana reflects a multi-faceted approach that combines grants, loans, subsidies, partnerships, and donor funding. While each financing model offers distinct advantages, they also present limitations that necessitate a strategic approach to ensure ACAS sustainability and accessibility. Grants and donor funding remain critical but risk dependency issues; loans offer growth potential but limit accessibility for low-income farmers; and subsidies promote affordability yet face sustainability challenges. The findings underscore the importance of diversified, adaptable financing strategies tailored to the unique needs of smallholder farmers.

The remaining financing mechanisms - taxes, subscription fees, corporate social responsibility (CSR) funds, informal sources, and climate resilience funds—account for a smaller share of funding for ACAS in Northern Ghana. Each of these mechanisms represents different approaches to addressing funding gaps in ACAS, but they also reveal certain challenges related to accessibility, equity, and sustainability in the context of smallholder farmers.

Taxes, which account for 5% of the total financing, are primarily used by government institutions to fund public ACAS programs. This mechanism reflects a system of resource redistribution aimed at supporting agricultural development. As such, taxes are an essential source of financing, particularly in regions where the government plays a significant role in public service delivery (UNDP, 2020). However, taxes may not be sufficient on their own, given the substantial budget constraints faced by many governments, particularly in low-income countries like Ghana. Furthermore, the effectiveness of tax-based funding mechanisms depends on the efficiency and accountability of public institutions in delivering services to farmers.

Subscription fees, also accounting for 5%, are used by a few private companies that offer ACAS on a fee-for-service basis. This financing model may contribute to long-term sustainability by ensuring the continuous provision of services. However, it is inherently exclusionary, as it requires farmers to have the financial means to pay for these services, which limits its applicability to low-income or resource-constrained farmers. Similar findings have been noted in studies by Thapa & Poudel (2021), who argue that while subscription models can ensure the ongoing availability of services, they also risk deepening inequality in access to agricultural knowledge and technology. Thus, the reliance on subscription fees may exacerbate disparities between wealthier and poorer farmers, especially in rural areas where financial inclusion is low.

Corporate social responsibility (CSR) funds, also accounting for 5%, are occasionally used by private companies to support ACAS programs, often as part of broader corporate sustainability initiatives. These funds can provide valuable resources for community-focused projects, particularly those aimed at improving farmers' resilience to climate change. However, CSR funding is typically sporadic and often limited to specific geographic regions or types of interventions (Osei & Hossain, 2019). As such, CSR funds are unlikely to be a consistent or reliable source of long-term financing for ACAS, although they can play a complementary role when targeted strategically.

Informal sources and climate resilience funds, each also contributing 5%, represent important but less formal mechanisms of financing. Informal sources, such as community savings groups, provide a vital means for rural farmers to access financial resources, especially when formal financial institutions are either inaccessible or untrustworthy (Osei & Hossain, 2019). These sources are often more flexible and accessible to smallholder farmers who may not have collateral or formal credit histories. However, the reliance on informal mechanisms may limit the scalability of ACAS programs, as they are often constrained by the resources available within the community.

Climate resilience funds, derived from international climate finance initiatives, also play a role in supporting ACAS, albeit to a lesser extent. These funds are typically targeted at building climate resilience in vulnerable communities and may complement existing funding sources for ACAS (UNDP, 2020). While climate resilience funds are increasingly available through global climate finance mechanisms, their application to ACAS specifically may be limited by narrow eligibility criteria or by the specific types of projects they support.

The diversity of FM for ACAS reflects the complex landscape of agricultural financing in Northern Ghana. Grants, subsidies, and loans represent the most common funding mechanisms, with a significant role played by public and private sector actors. However, the limited use of subscription fees and loans suggests that there are barriers to accessibility, particularly for low-income farmers. Moreover, the role of informal sources and CSR funds highlights the importance of community-driven and corporate-driven financing in bridging gaps where formal mechanisms fall short. As argued by Thapa & Poudel (2021), a balanced, multi-stakeholder approach will be essential to ensure equitable and sustainable access to ACAS for all farmers, particularly in rural areas with high poverty rates.

4.4 Factors Influencing Access to ACAS for Male and Female Smallholder Grain Farmers

4.4.1 Distribution of Awareness, Access and Sources of ACAS

Table 4.5 highlights the distribution of awareness, access, and sources of ACAS by age and gender groups. Understanding these factors is crucial for promoting sustainable agricultural practices, as ACAS provide farmers with essential information to adapt to climate change and improve productivity. A higher percentage of adult females (70.59%) and youths (65.49%) are aware of ACAS compared to their male counterparts, where 64.86% of adult males and 65.07% of male youth report awareness. This finding is noteworthy, as awareness is a critical first step in ensuring that farmers can access the services they need.

However, a considerable proportion of respondents remain unaware of these services. Specifically, 35.14% of adult males and 34.93% of male youths are unaware of ACAS. The relatively high percentage of individuals without awareness highlights the need for targeted outreach programs to enhance the sensitising and dissemination of information about these ACAS and the potential impact it will have on their livelihoods through the existing channels, while complementing with other informal channels.

Despite the moderate levels of awareness, actual access to ACAS remains relatively low across all groups, as depicted in Table 4.3. 45.1% of adult females and 41.63% of female youths have accessed the ACAS, while the percentage for adult males and male youths stands at 34.23% and 43.15%, respectively. The low access rates suggest that even though some farmers are aware of these services, barriers such as cost, availability, or lack of trust may prevent them from utilizing the services. Further research is necessary to explore these barriers and recommend appropriate interventions.

Table 4.5: Awareness, Access and Sources of ACAS by Age and Gender Groups

	Adults		Youths		Pooled	
	Female	Male	Female	Male	Female	Male
Aware of ACAS						
Aware	70.59	64.86	64.59	65.07	67.13	64.95
No Awareness	29.41	35.14	35.41	34.93	32.87	35.05
Access to ACAS						
Access	45.1	34.23	41.63	43.15	43.09	37.77
No Access	54.9	65.77	58.37	56.85	56.91	62.23
Level of Access to the ACAS						
Very Low Access	55.34	17.11	20.67	12.5	34.78	15.42
Low Access	21.36	32.24	35.33	4.55	29.64	22.08
Medium Access	16.5	14.47	16.00	13.64	16.21	14.17
High Access	2.91	25.66	17.33	39.77	11.46	30.83
Very High Access	3.88	10.53	10.67	29.55	7.91	17.5
Sources of Information on ACAS						
Extension Agents	1.96	18.92	5.74	16.44	4.14	17.93
Community Information Center (CIC)	15.69	12.61	7.66	4.11	11.05	9.24
Radio	18.3	38.74	28.23	28.08	24.03	34.51
Television	10.46	13.96	14.83	10.96	12.98	12.77
Other Farmers	48.37	15.77	25.84	17.12	35.36	16.30
Social media	5.23	0.00	17.70	23.29	12.43	9.24

Source: Field Survey (2024)

Figure 4.3 highlights that females generally have higher access to ACAS compared to males and youth across most districts, with notable exceptions where overall access levels are relatively low.

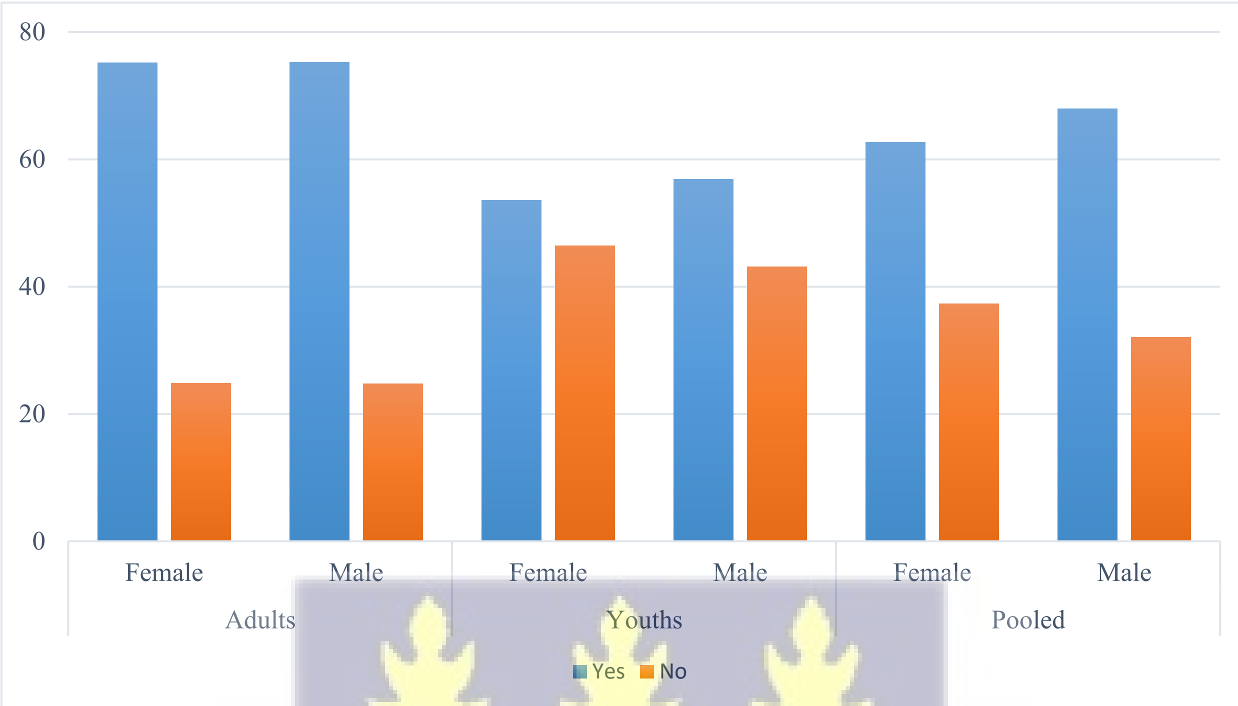


Figure 4.3: Use of ACAS by Age and Gender Groups (%)

4.4.2 Access to ACAS by Various Districts

Access to ACAS originating in various districts is illustrated in Figure 4.4. The results of the analysis of data from various focus group discussions (FGDs) involving farmers identified various FM utilized by smallholder grain farmers, including Village Savings and Loan Associations (VSLAs), support from NGOs and private companies, cooperative savings (susu), and inputs from private organizations. The results indicate that Village Savings and Loan Associations (VSLAs) emerged as the most widely used financing mechanism across all districts. This is likely due to their accessibility and community-based nature. VSLAs provide a platform for farmers to pool savings and access loans, which are crucial for purchasing inputs and investing in productivity-enhancing technologies. Studies have shown that VSLAs significantly improve financial inclusion and economic resilience among rural populations (Allen & Staehle, 2021).

Support from NGOs and private companies also played a significant role in providing both financial assistance and ACAS. These organizations often offer tailored support that addresses specific needs of the farmers, enhancing their capacity to manage climatic risks. According to Lamboll *et al*. (2020), NGO interventions can improve agricultural productivity and sustainability by providing essential resources and knowledge.

Additionally, cooperative savings (susu), a traditional form of savings and credit, were prevalent, particularly among older farmers who prefer familiar financial systems. Cooperative saving schemes have been recognized for their effectiveness in promoting savings and providing credit in rural areas (Aryeetey & Udry, 2020).

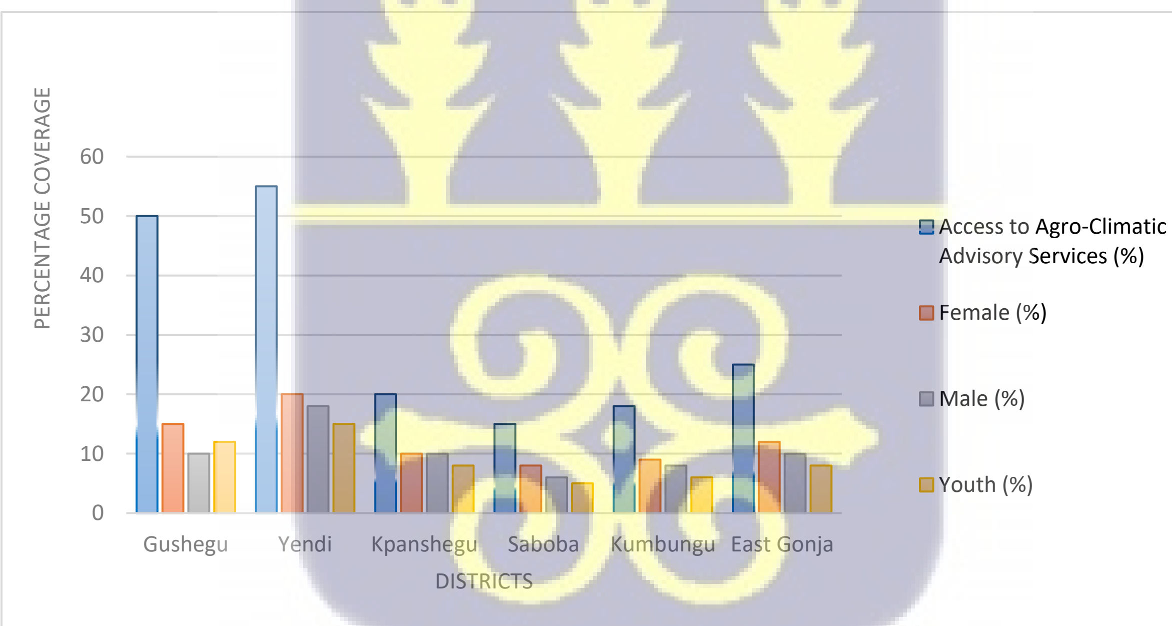


Figure 4.4: Access to ACAS by Various Districts

4.4.3 Frequency of Access to ACAS

Figure 4.5 illustrates the frequency of access to ACAS among respondents. The results indicate that 38% of respondents' access these services daily, reflecting a strong need for real-time updates to support immediate agricultural decision-making. Weekly access accounts for 30%, suggesting regular use of ACAS for short-term planning. Monthly access is reported by 29% of respondents, likely aligning with seasonal activities or long-term agricultural strategies. Only 3% of respondents access ACAS annually, indicating that this frequency is the least utilized, possibly due to its limited relevance for day-to-day or seasonal farming operations. These findings highlight the importance of providing ACAS in a manner that supports frequent updates, catering to the needs of farmers who rely on timely information for optimizing their farming practices.

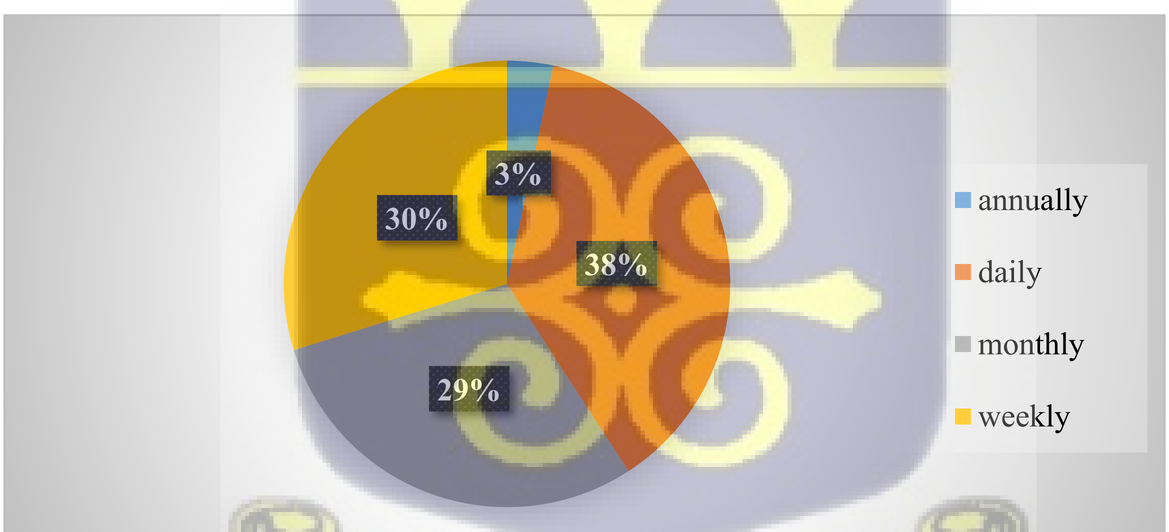


Figure 4.5: Frequency of Access to ACAS

4.4.4 Level of Access to ACAS for Youth by Gender

To quantify the level of access to ACAS, this study employed a quantification range based on the number of times ACAS are received per month according to the work of Hartman *et al*. (2018). The quantification levels were as follows:

- 1 – 2 times per month in cropping season = very low
- 3 – 4 times per month in cropping season = low
- 5 – 7 times per month in cropping season = medium
- 8 – 10 times per month in cropping season = high
- Above 10 times per month in cropping season = very high (Hartman *et al*., 2018)

Figure 4.6 shows that 65% of youth male small holder grain farmers reported to have very low access to ACAS compared to 35% of youth female small holder grain farmers. This is followed by 76% of youth male small holder grain farmers reporting to have low levels of access to ACAS as compared to 24% of youth female small holder grain farmers. 66.7% of youth male small holder grain farmers reported having a medium level of access to agro-climatic advisory service compared to 33.3% of female small holder grain farmers. Surprisingly on the high level of access front, the findings show that 63.6% of youth female smallholder grain farmers reported having high levels of access to agro-climatic advisory service compared to 36.4% of youth male small holder grain farmers while 58.8% youth female small holder grain farmers reported to have very high levels of access compared to 41.2% of youth male small holder grain farmers. The finding shows that youth female smallholder grain farmers tend to have better access to ACAS compared to their male counterparts. This could potentially be due to various factors, such as targeted extension services, different information-seeking behaviors, or gender-specific barriers to accessing ACAS. The findings agree with the work of Muema *et al*. (2018).

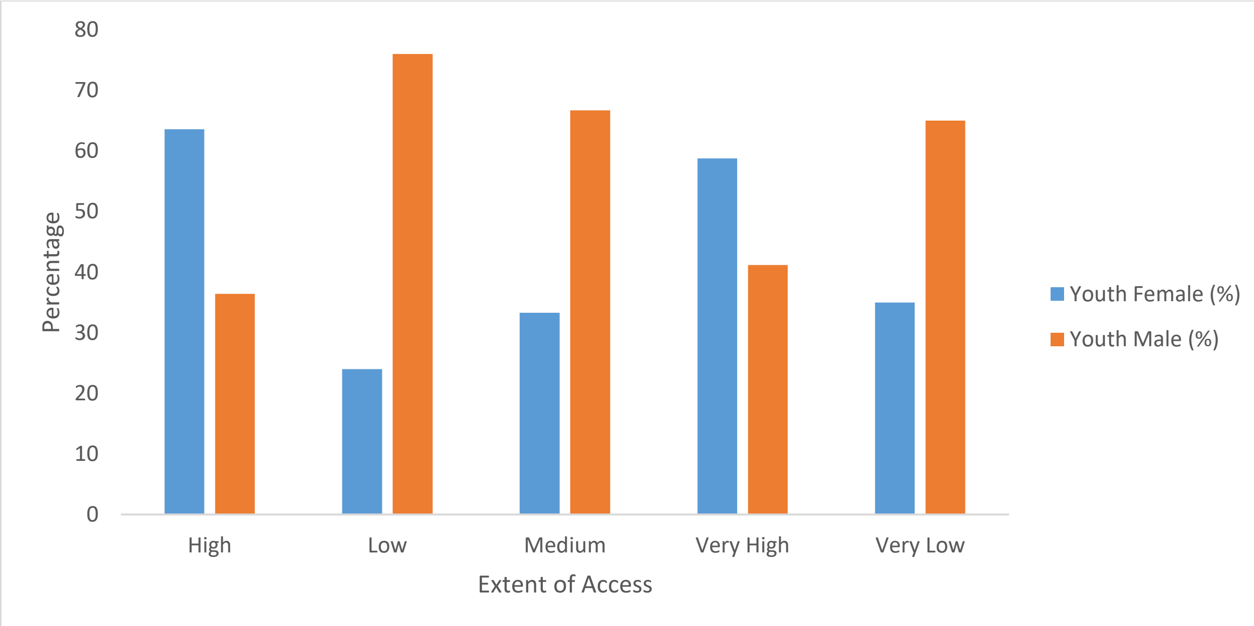


Figure 4.6: Level of Access to ACAS for Youth by Gender

4.4.5 Factors Influencing Level of Access to ACAS received

The factors influencing the level of access to agro-climatic advisory service was determined using a Tobit regression model. Table 4.6 presents a comprehensive regression analysis exploring the determinants influencing the level of access to ACAS among smallholder grain farmers in Northern Ghana, differentiated by gender. This analysis encompasses an extensive array of socio-economic and demographic variables and their effects on ACAS.

Diagnostic Checks for Tobit

For the Tobit model analysing the factors influencing the level of ACAS received, multicollinearity was assessed using the Variance Inflation Factor (VIF), with all independent variables below 5, indicating no serious multicollinearity. The Breusch-Pagan test for heteroskedasticity yielded $\chi^2(12) = 11.47$, $p = 0.50$, showing no evidence of heteroskedasticity. The link test confirmed correct model specification (hat² coefficient $p = 0.71$). Residuals were approximately normally distributed (Shapiro-Wilk $W = 0.98$, $p = 0.15$)

Table 4.6: Factors Influencing Level of Access to ACAS by Gender

	Female		Male		Pooled	
	Coeficient	Std. Error	Coeficient	Std. Error	Coeficient	Std. Error
Age (Yrs.)	0.0042	0.0344	0.0556***	0.0197	0.0469***	0.0175
Marital Status (RC = Single)						
Maried	2.1455**	0.8240	0.3964	0.3644	0.6688*	0.3594
Separated/Divorced	5.9454***	1.6872	4.6018***	1.0330	3.9483***	0.8658
Widowed	1.9308*	1.0389	0.2902	0.4804	0.6665	0.4657
Education (RC = No Formal Education)						
Primary Education	1.9117***	0.6453	1.7052***	0.3615	0.9917***	0.3160
Junior High School (JHS) Education	0.6553	0.6170	-0.0557	0.3330	-0.7857***	0.2822
Secondary Education	1.9796**	0.7532	0.6371	0.4156	0.4385	0.3688
Tertiary Education	0.0507	1.5356	1.0651	0.9542	0.0743	0.8705
Household Size	0.1778	0.1064	-0.1305*	0.0676	0.0035	0.0552
Age Group (RC = Adults)						
Youths	-3.6553***	1.0010	0.9656	0.6089	-0.2303	0.4957
Main Occupation (RC = Non-Farming)						
Farming	0.6787	0.4640	0.2875	0.3150	0.4110	0.2809
Years of Farming	-0.0456*	0.0268	-0.0066	0.0145	-0.002	0.0132
Land Size	0.0546	0.1674	0.113*	0.0651	0.0848	0.0636
Land Ownership (RC = Owned)						
Communal Ownership	1.1811	0.7295	1.3387**	0.5374	1.5717***	0.438
Family Land	0.2115	0.5481	0.5558*	0.3122	0.8019***	0.2888
Rent	-1.5950	1.4921	1.2381*	0.6561	0.1875	0.6601
Temporary Offer for Cropping	-1.9466**	0.7817	0.355	0.4592	0.0389	0.4141
Sharecropping	-1.3914**	0.6594	1.4177***	0.4082	0.9326**	0.3613
FBO Membership (RC = No Membership)						
Membership	-1.8434***	0.3827	0.4133*	0.2407	-0.1244	0.2136
Main Sources of Finance (RC = Bank)						
Microfinance	3.6820***	0.9494	0.0618	0.4182	0.3324	0.3886
Money Lender	1.4434*	0.7792	0.4906	0.4453	0.3729	0.4063
VSLA	1.1846*	0.6893	1.5370***	0.4195	0.9211***	0.3511
Family and Friends	2.6552***	0.7391	0.2064	0.3709	0.4046	0.3353
Awareness of Services (RC = No Awareness)						
Awareness	-1.4114**	0.5494	0.4699	0.3638	-0.2672	0.3083
Access to Services (RC = No Access)						
Access	0.5266	0.4165	-0.5428*	0.2972	-0.0119	0.2493
Main Sources of Information (RC = AEA)						
Community Information Center (CIC)	0.3453	0.7924	1.1780**	0.5472	1.3872***	0.4551
Radio	1.4523*	0.7339	0.0541	0.3563	0.8733**	0.3385
Television (TV)	0.2228	0.8442	-0.5310	0.4536	-0.2017	0.43
Fellow Farmers	1.1371	0.7058	0.7732*	0.4466	1.8606***	0.3552
Social Media	-0.7724	0.7876	0.1131	0.4871	0.5923	0.4135
Perceived Usefulness (RC = No Usefulness)						
Useful	1.7615***	0.5685	-0.9365**	0.3717	-0.0236	0.3044
Very Useful	1.2547**	0.5951	0.1155	0.3701	0.1861	0.3172
Constant	0.2099	2.1834	-2.2309	1.2345	-2.0445	1.1030
No. of Observations	362		368		730	
Uncensored	298		304		620	
Left-censored	45		45		59	
Right-censored	19		19		51	
LR Chi-squared (32)	283.27		141.64		173.13	
P-value	0.000		0.000		0.000	
Pseudo R-squared	0.5002		0.4501		0.415	
Log Likelihood	-1272.4317		-636.2158		-1067.5179	

Source: Field Survey (2024)

* $p < 0.10$; ** $p < 0.05$; *** $p < 0.001$

The result reveals a statistically significant positive relationship between age and the level of access to ACAS for male farmers, with a coefficient of 0.0556 ($p < 0.001$). This finding underscores the notion that older male farmers possess a higher likelihood of utilizing ACAS, a trend likely attributable to their accrued farming experience and enhanced social capital. This aligns with the assertions of Aryal *et al*. (2021), who found that older farmers often leverage their experience to better engage with agricultural ACAS, thus improving their access to vital resources.

Nonetheless, the pooled data suggests an overall positive coefficient of 0.0469 ($p < 0.001$), reinforcing the premise that, generally, older farmers are more inclined to access ACAS. This pattern is echoed in the literature, with several studies indicating that age facilitates a more profound understanding of agricultural practices, enabling older individuals to effectively utilize ACAS (Abdul-Rahaman & Abdulai, 2020; Mudege *et al*., 2020). The apparent gender disparity in age-related access to ACAS underscores the need for gender-sensitive policies that enhance women's engagement with ACAS, particularly among younger farmers who may lack the same level of social capital and experience as their male counterparts.

The results show that marital status significantly influences level of access to ACAS among female farmers in Northern Ghana. Specifically, married female farmers exhibit a coefficient of 2.1455 ($p < 0.05$), while separated or divorced female farmers show a markedly higher coefficient of 5.9445 ($p < 0.001$). Widowed female farmers also demonstrate increased access, albeit at a coefficient of 1.9308 ($p < 0.10$), compared to their single counterparts. This finding suggests that marital status may enhance the level of accessing ACAS, particularly for women, potentially due to the financial and social networks associated with marriage or the need for resource independence postseparation. In contrast, marital status does not appear to be a significant determinant for male farmers regarding ACAS access level.

Interestingly, the pooled analysis reinforces the prominence of marital status across genders, revealing that separated or divorced farmers have a coefficient of 3.9438 ($p < 0.001$), indicating that individuals in these categories are substantially more inclined to seek out ACAS. This trend aligns with Ng'endo *et al*. (2020), who posited that separated or divorced individuals, particularly women, may exhibit heightened financial independence and proactive behaviour in resource-seeking, which is critical for sustaining their livelihoods. Such findings are supported by the work of Owusu (2022), which emphasized that marital status can significantly affect access to agricultural resources and services, with divorced and widowed farmers being more likely to engage in resource-seeking behaviour due to changing economic circumstances. The insights gleaned from this analysis highlight the necessity for gender-responsive policy frameworks that acknowledge and address the distinct needs of women farmers, particularly those navigating the challenges of marital transitions.

The result further reveals a significant effect of education level on level of access to ACAS (ACAS) among smallholder farmers in Northern Ghana, with notable differences between genders. Specifically, female farmers with primary education demonstrate a positive and significant coefficient of 1.9117 ($p < 0.01$), while their male counterparts show a coefficient of 1.7052 ($p < 0.01$). These findings underscore the critical role that even basic education plays in empowering farmers to comprehend and effectively utilize agro-climatic information, which is essential for informed decision-making in agricultural practices. The pooled analysis further corroborates this, revealing a coefficient of 0.9917 ($p < 0.05$), reinforcing the notion that educational attainment is a key determinant in accessing ACAS. A study by Abdul-Rahaman and Abdulai (2018) supports these findings, highlighting that educated farmers are better positioned to recognize the value of ACAS, thereby actively seeking out these services to enhance their productivity and sustainability.

Furthermore, a study by Osei *et al*. (2023) posits that education enhances farmers' cognitive skills, enabling them to interpret complex agricultural data and apply this knowledge in practice. This trend is especially pertinent in the context of climate change, where access to timely and accurate agro-climatic information is paramount for adapting agricultural practices. Therefore, investing in educational initiatives, particularly at the primary level, could be instrumental in bridging the knowledge gap among farmers, fostering greater access to ACAS, and ultimately enhancing food security in the region.

The findings indicate that youth status has a significantly detrimental effect on the level of access to ACAS for female farmers, as evidenced by a coefficient of -3.6553 ($p < 0.01$). This suggests that young female farmers are markedly less likely to access these essential services compared to their older counterparts. In contrast, the result reveals that the youth status of male farmers yields a positive, albeit non-significant, effect on the level of access to ACAS. This disparity highlights the gendered dimensions of agricultural support services, wherein young women face greater challenges in obtaining necessary resources for agricultural advancement.

The lower level of access to ACAS among young female farmers may be attributed to several factors, including limited financial resources, lack of social capital, and entrenched gender norms that restrict their engagement in agricultural advisory networks. Mudege *et al*. (2017) underscore these barriers, noting that young women in agriculture frequently encounter obstacles that inhibit their ability to access critical ACAS, thereby exacerbating their vulnerability in a competitive agricultural environment. Furthermore, a study by Quisumbing *et al.* (2021) emphasizes the importance of integrating gender-sensitive approaches in the design and implementation of agricultural support services, arguing that targeted interventions could help mitigate these barriers for young female farmers.

The pooled data analysis indicates no significant effect of youth status on access to ACAS overall, suggesting that the challenges faced by young female farmers may not be universally applicable across genders. These insights stress the necessity of developing tailored strategies that enhance access to ACAS for vulnerable demographics, particularly young women, who play a crucial role in agricultural sustainability and food security.

The findings indicate that the mere occupation of farming does not significantly affect level of access to ACAS for either gender, suggesting that other underlying factors may be more pivotal in determining the level of access. Notably, while the number of years spent in farming has a small but statistically significant negative effect on the level of access for female farmers (coefficient = -0.0456, $p < 0.10$), this raises critical questions about the relationship between experience and openness to new ACAS. This phenomenon may reflect deeply ingrained traditional practices among seasoned female farmers, which can inhibit their willingness to adopt innovative advisory frameworks (Kansiime *et al*., 2021). A study by Davis *et al*. (2020) supports this assertion, noting that experienced female farmers often remain tethered to conventional practices, thereby missing opportunities for technological advancement and improved productivity. Furthermore, the findings align with the work of Mwesigye *et al*. (2023), who emphasize that entrenched gender norms significantly shape the attitudes and behaviours of women in agriculture, often leading to resistance to external advice. Therefore, it is imperative to understand the sociocultural context that shapes the engagement of female farmers with ACAS. Such insights could inform the design of more inclusive and effective ACAS that are sensitive to the needs and experiences of women in agriculture.

The result reveals that while land size has a small positive but non-significant effect on the level of access to ACAS across both male and female farmers, the type of land ownership plays a crucial role in determining the level of access to these ACAS. Specifically, male farmers who own communal land exhibit significantly higher level of access to ACAS (coefficient = 1.3387, $p < 0.05$), underscoring the potential benefits of collective land ownership arrangements in facilitating resource sharing and collaboration among farmers. Conversely, female farmers face considerable barriers related to insecure land tenure. For instance, those with temporary cropping agreements show a negative effect on access (coefficient = -1.9466, $p < 0.10$), while female sharecroppers also experience diminished access to ACAS (coefficient = -1.3914, $p < 0.05$). Interestingly, sharecropping appears to benefit male farmers, who see an increase in level of access (coefficient = 1.4177, $p < 0.10$). This divergence highlights the gendered dimensions of land tenure and access to agricultural services, as insecure land arrangements for women may deter investments in new technologies and services (Mwesigye & Matsumoto, 2022). A work by Akinola *et al.* (2021) corroborates these findings, illustrating that women's lack of secure land rights is often linked to reduced level of access to credit and ACAS, which are critical for enhancing agricultural productivity. This scenario indicates an urgent need for policies that reinforce land tenure security for female farmers, thereby fostering their engagement with innovative agricultural practices and ACAS.

The results indicate a significant negative relationship between membership in farmer-based organizations (FBOs) and level of access to ACAS for female farmers, with a coefficient of -1.8434 ($p < 0.10$). This finding raises concerns about the effectiveness of FBOs in supporting female agricultural practitioners, suggesting that these organizations may not be adequately reaching or benefiting women in the same way they do their male counterparts. This aligns with the work of Arslan *et al*. (2020), who found that women often encounter systemic barriers to full participation in agricultural organizations, which ultimately constrains their access to essential resources and services.

The pooled analysis further supports this notion, as the overall effect of FBO membership is not statistically significant for either gender. Such findings underscore the need for a critical evaluation of the operational frameworks of FBOs to enhance their inclusivity and effectiveness. A study conducted by Huyer *et al*. (2021) highlights that women's participation in agricultural cooperatives is frequently impeded by socio-cultural norms and lack of access to information, which can hinder their ability to voice their needs within these organizations. Additionally, Rahman *et al*. (2022) emphasize the importance of tailoring organizational strategies to accommodate the unique challenges faced by female farmers, such as limited time due to household responsibilities and reduced mobility. Given the significant barriers female farmers face, it is crucial for policymakers and stakeholders to redesign FBOs to be more gender-sensitive, ensuring that women not only gain access to ACAS but also have their voices heard in organizational decision-making processes. Addressing these disparities is essential for achieving equitable agricultural development and enhancing the overall productivity of smallholder farmers in northern Ghana.

The findings also reveal a significant positive relationship between microfinance and level of access to ACAS for female farmers, with a coefficient of 3.6820 ($p < 0.01$). This strong effect indicates that microfinance serves as a critical enabler for women, allowing them to invest in and access essential agricultural services. Conversely, the effect of microfinance on male farmers is statistically insignificant, suggesting a gendered disparity in the utility derived from such financial instruments. This finding corroborates research by Mudombi *et al*. (2021), who emphasize that women benefit disproportionately from microfinance initiatives, as these programs often provide them with the necessary capital to adopt innovative agricultural practices and technologies. Moreover, access to Village Savings and Loan Associations (VSLAs) is shown to positively influence access to ACAS for both genders. The coefficients of 1.1846 ($p < 0.10$) for female farmers and 1.5370 ($p < 0.05$) for male farmers indicate that VSLAs play a significant role in improving the availability of agricultural ACAS.

The pooled analysis further underscores this finding, with a pooled coefficient of 0.9211 ($p < 0.01$) signifying the overall importance of VSLAs in enhancing access to ACAS. This aligns with the work of Kinyua *et al*. (2022), which highlights that such associations not only provide financial resources but also serve as platforms for knowledge sharing and community support, particularly for women who may face additional barriers to information access. The evidence indicates that microfinance and VSLAs are pivotal in bridging the gender gap in access to agricultural ACAS. However, it is essential for policymakers to ensure that these financial mechanisms are designed to cater specifically to the needs of female farmers, enhancing their financial literacy and capacity to utilize these services effectively. As agricultural economies evolve, understanding the nuanced ways in which gender influences access to financial and ACAS will be crucial for developing inclusive strategies that bolster the productivity and resilience of smallholder farmers.

The findings reveal a significant negative correlation between awareness of ACAS and level of access for female farmers, with a coefficient of -1.4114 ($p < 0.05$). This suggests that mere awareness does not guarantee access, particularly for women. The barriers faced by female farmers may stem from entrenched social and cultural norms that restrict their mobility and decision-making authority. As indicated by Farnworth *et al*. (2019), these constraints can significantly hinder women's ability to translate awareness into action, thereby limiting their engagement with available agricultural services. In contrast, the lack of a significant relationship between awareness and access for male farmers implies that once they are informed about ACAS, they are more empowered to utilize these services effectively. This disparity underscores the need to address the gender-specific barriers that impede women's access to agricultural resources. Supporting this observation, a study by Tambo & Abdoulaye (2022) highlights that gender roles significantly influence how farmers engage with agricultural services. The authors argue that women often navigate complex social dynamics that affect their agency, making it critical to design interventions that not only inform but also empower female farmers to act on that information.

Additionally, the literature indicates that targeted awareness campaigns, coupled with capacity-building initiatives, can foster greater engagement from women in the agricultural sector (Ogunleye *et al*., 2021). Therefore, addressing these social and cultural barriers is essential for enhancing female farmers' level of access to ACAS. Future policies must aim to create an enabling environment that empowers women, ensuring that awareness translates into meaningful engagement with agricultural ACAS. This approach will not only benefit female farmers but also contribute to the overall sustainability of the agricultural sector in Northern Ghana.

The analysis of access to information sources, particularly the Community Information Center (CIC), radio, and peer interactions, reveals significant gender disparities in their influence on the level of access to ACAS. For male farmers, the utilization of radio as an information source has a positive and significant effect on ACAS access level, with a coefficient of 1.1780 ($p < 0.05$). This finding suggests that male farmers are effectively leveraging radio as a communication medium to enhance their agricultural knowledge and resource access. Conversely, the effect of radio on female farmers' access to ACAS is not significant, highlighting a critical gap in information dissemination that necessitates a gender-sensitive approach to communication strategies. Kebede *et al*. (2022) emphasize that men and women often have distinct preferences for accessing agricultural information, necessitating tailored communication channels that consider these differences. The lack of significant impact from radio on female farmers' level of access to ACAS could be attributed to various factors, including cultural norms that restrict women's mobility and their engagement with certain information platforms.

Moreover, findings from a study by Fadimu *et al*. (2023) underscore that female farmers may rely more heavily on personal networks and face-to-face interactions, which are often overlooked in traditional media-focused information campaigns. Thus, the observed gender disparities in the level of access to ACAS through various information sources underscore the urgent need for policymakers and practitioners to develop targeted communication strategies that address these differences. By integrating diverse information delivery methods—such as community workshops, social gatherings, and localized content in media—stakeholders can enhance female farmers' level of access to crucial agricultural services. Such strategies will not only improve the reach of ACAS but also contribute to empowering women in the agricultural sector, ultimately leading to enhanced productivity and food security in northern Ghana.

In conclusion, the findings of this analysis highlight significant gender disparities in the determinants of level of access to ACAS among smallholder farmers. For female farmers, critical factors influencing level of access include marital status, educational attainment, youth status, microfinance opportunities, and the nature of land tenure arrangements. Each of these elements underscores the unique challenges that female farmers face in their pursuit of agricultural ACAS. For instance, marital status can impact decision-making power within households, while education serves as a vital pathway to acquiring knowledge about available resources and technologies. Furthermore, the access to microfinance is crucial for enabling female farmers to invest in necessary agricultural inputs and technologies, thereby enhancing their productivity (Mwesigye & Matsumoto, 2022).

Conversely, the result reveals that for male farmers, age, communal land ownership, and access to information sources, such as radio and peer interactions, are paramount determinants of ACAS access level. These findings emphasize the importance of context-specific interventions that acknowledge the distinct needs of male farmers. As such, policy initiatives aimed at enhancing ACAS accessibility must adopt a gender-responsive framework, addressing the specific barriers that female farmers encounter. For instance, increasing female participation in farmer-based organizations (FBOs) and ensuring their access to secure land tenure arrangements are critical for empowering women in agriculture (Arslan *et al*., 2020). Moreover, there is an urgent need to enhance youth engagement in the agricultural sector, particularly for young female farmers. Tailored interventions, such as mentorship programs and targeted outreach, can foster a supportive environment for this demographic, ensuring that they have equitable access to ACAS. By integrating gender-responsive strategies into policy frameworks, stakeholders can create a more inclusive agricultural landscape, ultimately contributing to improved food security and economic resilience in Northern Ghana.

4.5 Gendered analysis of factors influencing the adoption of ACAS

To capture the gender element of this study, the data analysis further dives into analysis based on each gender group. To analyse the factors influencing the adoption of ACAS for both male and female, the study analysed individual group separately

4.5.1 Factors Influencing Male Farmers' Adoption of ACAS

Table 4.7 presents the marginal effects estimates of factors influencing male farmers' decisions to adopt ACAS: Water Management Irrigation (WMI), Crop Planning Weather Forecast (CPWF), and Integrated Pest Management ACAS (IAS).

Table 4.7: Marginal Effects Estimates of Factors Influencing Males Adoption of ACAS

	(1) WMI	(2) CPWF	(3) IAS
Age of Farmer (Yrs.)	0.0033*	0.0001	−0.0038**
	(-0.0019)	(-0.0019)	(-0.0017)
Farmer is Married	0.0315	−0.0998***	−0.0028
	(-0.0267)	(-0.0277)	(-0.0235)
Farmer has Formal Education	0.0119	0.0593***	−0.0463**
	(-0.0233)	(-0.0227)	(-0.0211)
Number of People in the HH	0.0187***	0.0064	−0.0152***
	(-0.006)	(-0.0061)	(-0.0055)
Farmer is a Youth	0.1160**	0.0327	−0.0896*
	(-0.0547)	(-0.0533)	(-0.048)
Farming as a Major Occupation	−0.0463	−0.0094	−0.0147
	(-0.0285)	(-0.0282)	(-0.0263)
Farming Experience (in Years)	−0.0015	0.0048***	−0.0020
	(-0.0014)	(-0.0013)	(-0.0013)
Size of Farm (acres)	−0.0006	−0.0129**	0.0021
	(-0.0062)	(-0.006)	(-0.0051)
Respondent Owns Farmland	0.0185	−0.0302	0.0193
	(-0.0271)	(-0.027)	(-0.0236)
Farmer is a Member of FBO	0.0078	0.0116	0.0167
	(-0.0233)	(-0.0227)	(-0.0206)
Awareness of Agro-climatic Advisory Services	0.1079**	−0.0684	0.1025***
	(-0.0456)	(-0.0466)	(-0.0397)
Access to Agro-climatic Advisory Services	−0.0922***	0.1197***	−0.1540***
	(-0.0304)	(-0.0327)	(-0.028)
Information from Community Information Center	−0.0978***	0.0585*	−0.0199
	(-0.0328)	(-0.0322)	(-0.0311)
Information from Radio	0.1867***	0.0545*	−0.1109***
	(-0.0323)	(-0.0326)	(-0.0273)
Information from TV	0.0246	−0.1224***	0.0251
	(-0.0309)	(-0.0331)	(-0.03)
Information from Other Farmers	−0.1664***	0.0015	0.1304***
	(-0.03)	(-0.0312)	(-0.0317)
Information from NGO	−0.0119	−0.1080***	0.0721**
	(-0.0299)	(-0.031)	(-0.0305)
Information from FBO	0.1070***	−0.0794**	−0.0413
	(-0.0323)	(-0.0338)	(-0.031)
Perceived Usefulness of Information	−0.0142	0.0220*	−0.0326***
	(-0.0115)	(-0.0118)	(-0.0103)

Standard errors in parentheses
WMI denotes Water Management Irrigation
CPWF denotes Crop Planning Weather Forcasts
IAS denotes IPM Advisory Services
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

The adoption of ACAS by smallholder farmers is shaped by multiple socio-economic factors that significantly influence their decision-making processes. In the case of male farmers in Northern Ghana, key factors such as age, marital status, formal education, household size, etc. including key farm-specific and institutional factors have varying impacts on the likelihood of adopting Water Management Irrigation (WMI), Crop Planning Weather Forecast (CPWF), and Integrated Pest Management ACAS (IAS).

Age plays a critical role in shaping farmers' decisions to adopt innovative agricultural practices. The findings reveal that older male farmers are more inclined to adopt WMI, which aligns with broader trends in agricultural development where experienced farmers tend to prioritize the adoption of water management techniques that directly impact crop productivity and mitigate the risks associated with water scarcity. This finding is consistent with earlier research by Khan *et al*. (2021), which emphasizes that older farmers may be more risk-averse but are also keen to adopt practices with immediate and tangible benefits, such as irrigation systems that ensure consistent water supply for crop cultivation. Conversely, younger farmers are more likely to adopt IAS, indicating a generational divide in the types of ACAS that are perceived as valuable. Younger farmers are typically more open to adopting innovative pest management practices due to their greater willingness to experiment with new technologies and techniques (Oladele, 2022). This observation is supported by studies on technology adoption, where younger farmers are often more agile and responsive to emerging agricultural innovations (Adu-Gyamfi & Adzobu, 2020). IAS, which involves integrating ecological pest control measures, is often seen as a modern and sustainable approach to farming, making it more appealing to younger, forward-thinking farmers. However, age has an insignificant impact on the adoption of CPWF, suggesting that weather forecasting services are not necessarily seen as age-specific tools.. Farmers of all age groups may struggle to incorporate weather forecasting into their farming practices due to constraints related to accessibility, timeliness, or the perceived complexity of interpreting weather data.

Marital status emerges as another socio-economic factor influencing the adoption of ACAS, with mixed results across the different services. Married farmers are less likely to adopt CPWF, a finding that aligns with the notion that married individuals, often bearing greater household responsibilities, tend to be more risk-averse and cautious in adopting new and less tangible ACAS (Ahmed & Melesse, 2023). The time and financial constraints that come with managing larger families may lead to a preference for more immediate, low-risk interventions that directly affect farm productivity, as opposed to tools like weather forecasts, which may not offer immediate or visible benefits. In contrast, while marriage has a positive but insignificant effect on WMI and IAS adoption These findings point to the need for targeted interventions that take into account the household dynamics and time constraints of married farmers, ensuring that ACAS are designed and delivered in ways that accommodate their unique challenges.

Education is one of the most significant determinants of agro-climatic advisory service adoption, particularly in relation to CPWF and IAS. Farmers with formal education are more likely to adopt these services, as education equips them with the necessary skills to understand, interpret, and apply complex advisory tools (Mohammed *et al*., 2021). Educated farmers are better positioned to appreciate the long-term benefits of climate-smart agriculture, including the predictive power of weather forecasts and the ecological advantages of integrated pest management. The positive impact of education on CPWF adoption reflects the need for a certain level of literacy and cognitive ability to process weather data and apply it to crop planning. In areas where climate variability is a constant threat to agricultural productivity, farmers with formal education may be more attuned to the advantages of using weather forecasts to optimize planting and harvesting schedules

(Amanuel & Amede, 2022). Similarly, the adoption of IAS, which requires a nuanced understanding of biological pest control methods and the broader ecosystem, is more prevalent among educated farmers. The ability to understand pest cycles, crop health, and ecological balance may be limited among farmers without formal education, further reinforcing the role of education in driving the adoption of such sophisticated services. However, education does not appear to have a significant effect on the adoption of WMI. This could be because water management techniques, unlike weather forecasting or pest management, may be more intuitive and require less formal education to implement. For instance, the installation and maintenance of irrigation systems often rely more on practical experience than on theoretical knowledge, making WMI accessible even to farmers with lower levels of formal education (Kassie *et al.*, 2022). This finding suggests that while education enhances the adoption of more complex ACAS, certain practical interventions, such as water management, may not be as dependent on educational attainment.

The size of a farmer's household significantly influences the adoption of WMI, but has no significant impact on the adoption of CPWF or IAS. Larger households are more likely to adopt WMI, possibly due to the availability of a greater labor force that can be mobilized to manage labour-intensive irrigation systems. As noted by Kassie *et al.* (2022), households with more members often have more hands available to carry out water management tasks, making irrigation systems more feasible to adopt and maintain. Water management, especially in smallholder farming systems, requires constant attention and labor, and larger households may be better equipped to meet these demands. The lack of significant relationships between household size and the adoption of CPWF and IAS could reflect the less labour-intensive nature of these services. Weather forecasting and pest management are ACAS that do not necessarily demand additional labour; rather, they require decision-making and the application of knowledge. As such, household size is less relevant to their adoption, as these services are more about optimizing existing practices than increasing labour inputs.

Being a youth has shown mixed results across different ACAS. While youthfulness has a positive relationship with the adoption of IAS, it remains insignificant for WMI and CPWF. This could be attributed to younger farmers' greater familiarity with modern agricultural technologies and a higher tolerance for risk, making them more inclined to adopt innovative practices such as pest management (Olorunfemi *et al.,* 2021). Young farmers may possess a stronger propensity to engage with practices that have direct, observable impacts on their yield, such as pest control, which can be implemented more immediately than water management or weather forecasting, which require longer-term planning and are more complex in nature. This aligns with the work of Gutu *et al*. (2022), who argue that younger farmers are more likely to adopt labour-saving and output-enhancing technologies. In contrast, the insignificant relationship between youth and WMI or CPWF adoption may indicate that these services require a deeper understanding of long-term climatic patterns, something that older experienced farmers might find it easier to appreciate.

Interestingly, whether farming is a farmer's major occupation does not significantly affect the adoption of any of the three ACAS examined. This finding contrasts with earlier studies, such as Nnadi *et al*. (2022), which suggest that full-time farmers might be more inclined to adopt agricultural innovations due to their direct dependence on agriculture for livelihood. The lack of significant impact in this case may imply that farmers who engage in other occupations alongside farming are still motivated to adopt ACAS based on other factors, such as profitability or the need to mitigate risks. It may also suggest that the marginal utility of these services does not vary substantially between part-time and full-time farmers in Northern Ghana, especially given that most smallholder farmers often engage in diversified livelihood strategies as a risk management mechanism (Ahmed *et al*., 2023).

The results indicate that farming experience has a positive effect on the adoption of CPWF, but not on WMI or IAS. Experienced farmers likely have a more nuanced understanding of how weather patterns affect crop cycles over time and may appreciate the long-term benefits of accurate climate forecasting (Amadu *et al*., 2023). This is consistent with studies by Danso-Abbeam and Baiyegunhi (2020), which argue that experienced farmers are more capable of interpreting complex information like weather forecasts, making them more willing to incorporate it into their decision-making processes. Conversely, the lack of significant impact of farming experience on WMI and IAS adoption may suggest that these services require specific technical knowledge or resources that experienced farmers may not necessarily have or prioritize, especially if they have developed alternative methods to address water management or pest issues.

Farm size plays an important role in determining whether farmers adopt IAS, but not WMI or CPWF. Smaller farms are more likely to adopt pest management services, which could be due to the high potential for damage from pests on smaller plots (Vanlauwe *et al*., 2023). This finding is consistent with studies by Agula *et al*. (2021), which argue that smallholder farmers tend to be more risk-averse and are therefore more likely to adopt practices that directly mitigate risks, such as pest infestations. The insignificant effect of farm size on WMI and CPWF adoption may indicate that these services are not necessarily scaled according to farm size but rather according to the broader needs of the farmer, regardless of the acreage being cultivated. This highlights the importance of understanding farm size dynamics in relation to the specific challenges farmers face, particularly in the adoption of pest management strategies.

The analysis reveals that land ownership has no significant impact on the adoption of WMI, CPWF, or IAS. This contradicts previous findings by Ndiritu and Kassie (2020), who argue that land tenure security is a critical factor in the adoption of long-term technologies. One possible explanation is that in Northern Ghana, land tenure systems are often informal, with communal or family ownership structures, which may reduce the perceived need for individual investment in long-term agricultural technologies. Farmers may feel secure enough in their land use rights, even without formal ownership, to adopt new technologies based on immediate need rather than long-term land tenure considerations.

Membership in FBOs has a positive effect on the adoption of WMI but not on CPWF or IAS. This highlights the role of social capital and collective action in facilitating the adoption of water management technologies. FBOs often provide access to shared knowledge and resources, which can reduce the costs and risks associated with adopting new technologies (Mwaura *et al*., 2022). FBOs may also provide training and demonstration plots that expose farmers to new irrigation techniques, making it easier for them to adopt WMI. The lack of significant impact on CPWF and IAS adoption suggests that these services may require more individualized decision-making processes, where collective action through FBOs is less relevant. This underscores the importance of targeting ACAS to different farmer groups based on the type of technology and the nature of its implementation.

Awareness of ACAS plays a critical role in the adoption of both WMI and CPWF, but has no significant effect on IAS. This finding is consistent with Ozor *et al*. (2023), who argue that awareness is a prerequisite for the adoption of complex agricultural technologies. Farmers who are aware of the existence and potential benefits of WMI and CPWF are more likely to incorporate these services into their agricultural practices, as they are better informed about how these services can mitigate risks related to water shortages and weather unpredictability. The insignificant effect on IAS may suggest that awareness alone is not sufficient to drive adoption of pest management practices, which might require additional technical knowledge or resources. This highlights the need for targeted extension services that not only raise awareness but also provide practical support for the adoption of pest management technologies.

In the context of ACAS, access to such services plays a crucial role in shaping the adoption behaviour of smallholder grain farmers. The findings suggest that access to ACAS significantly influences the likelihood of adopting various types of agro-climatic services, including Weather Monitoring Information (WMI), Climate Prediction for Weather Forecasting (CPWF), and Integrated Agricultural Services (IAS). The importance of access to timely and reliable ACAS cannot be overstated, as it enhances farmers' ability to make informed decisions that directly affect their productivity and resilience against climatic risks. This observation aligns with recent literature, which underscores the significance of providing farmers with the necessary tools and information to improve agricultural output and adaptive capacity in response to climatic variability (Mutenje *et al*., 2021).

While access to ACAS promotes the adoption of agro-climatic services, the role of local information dissemination platforms, such as community information centres, appears to be insignificant. This might indicate a gap in the trustworthiness or efficiency of these centres in delivering essential agricultural information. Maro *et al*. (2020) suggest that this could be attributed to the irregular operation of these centres, along with a general lack of trust among farmers in the information disseminated through such channels. Given the increasing digitization of agriculture, it may be that farmers are shifting towards more technologically advanced means of receiving information, thereby diminishing the relevance of traditional community information centres. This calls for a review of the role of community-based dissemination systems in promoting ACAS and whether their structure and operation require modernization to improve their efficacy.

The role of mass media in disseminating ACAS is another aspect that emerged from the findings. Specifically, radio remains a vital source of agricultural information for farmers, particularly for services like WMI and IAS. This is consistent with Asante *et al*. (2022), who highlighted the widespread access to and trust in radio as a primary medium for farmers in rural and remote areas. Radio provides an affordable and accessible platform for disseminating critical agricultural information, particularly in regions where other forms of mass media, such as television or internet services, may not be readily available or affordable. In contrast, the findings show that television does not significantly influence the adoption of agro-climatic services, echoing the findings of Agyeman *et al*. (2022), who argue that television may be more influential in urban contexts but less so in rural areas where radio remains the dominant medium.

Peer influence, which manifests through information sharing among farmers, emerges as a strong determinant of agro-climatic service adoption across all three categories of services: WMI, CPWF, and IAS. Farmers are highly likely to adopt new technologies and practices when they observe their peers benefiting from such innovations, as has been consistently demonstrated in the literature (Ogutu & Qaim, 2021). This peer effect plays a critical role in the dissemination of agricultural knowledge, especially in rural areas where formal extension services may be limited. It reinforces the importance of community-based approaches to agricultural ACAS, where farmer-to-farmer knowledge transfer can significantly enhance the overall adoption of innovative practices. Such peer-led dissemination mechanisms can act as complementary or alternative platforms for knowledge sharing, particularly in contexts where formal institutional support is inadequate.

In addition to peer influence, Farmer-Based Organizations (FBOs) continue to play a pivotal role in promoting agro-climatic services, particularly in relation to water management (WMI). FBOs, as collective groups of farmers, provide an important platform for the dissemination of information and for promoting the adoption of sustainable agricultural practices. These organizations facilitate collective learning, knowledge exchange, and provide access to shared resources (Faye & Sarr, 2021). However, it is noteworthy that FBOs do not appear to have a significant influence on the adoption of CPWF and IAS, which may be due to the specific focus of FBOs on water management and irrigation-related services. This suggests that FBOs may need to expand their scope to include a broader range of agro-climatic services in order to better serve the needs of smallholder farmers.

The findings reveal a mixed influence of Non-Governmental Organizations (NGOs) on agro-climatic service adoption. While NGO information positively influences the adoption of IAS, it has a negative effect on CPWF. This could reflect the varying focus of NGOs on different aspects of agricultural ACAS. Some NGOs may prioritize pest management over climate prediction services, given the immediate and visible effects of pest outbreaks on farm productivity. Fowler and Ottow (2022) argue that NGOs often focus on immediate agricultural challenges, such as pest infestations, which may explain the positive influence on IAS adoption. However, the negative effect on CPWF adoption suggests that NGO efforts might not align with long-term weather forecasting services, potentially due to resource constraints or differing programmatic priorities.

The perceived usefulness of information also plays a critical role in shaping farmers' adoption behaviour. The findings show that while perceived usefulness has a positive effect on the adoption of CPWF, it has a negative effect on WMI and IAS. This indicates that farmers are more likely to adopt climate prediction services when they find the information useful for long-term planning and decision-making (Hodgson *et al*., 2022). However, for services such as WMI and IAS, farmers may question the relevance or applicability of the information provided, particularly if they do not see immediate benefits or if the information is perceived as too technical or difficult to implement. This highlights the need for ACAS to be tailored to the specific needs and capacities of smallholder farmers, ensuring that the information provided is not only timely but also practical and actionable.

The findings of this analysis underscore the complex interplay of socio-demographic and information-related factors that shape the adoption of ACAS among male smallholder farmers. Key determinants such as age, level of education, household size, sources of information, and peer influence significantly impact the adoption decision-making process. However, the magnitude and direction of these effects are not uniform across different types of ACAS, pointing to the need for tailored, context-specific interventions. Future research and policy interventions should prioritize these nuanced determinants to enhance the uptake of climate-smart agricultural services, ensuring that they are both accessible and relevant to the unique needs of male farmers. Moreover, these findings highlight the necessity of integrating FM that cater to these factors, which could further incentivize widespread adoption and increase the resilience of smallholder farming systems in Northern Ghana.

4.5.2 Factors Influencing Female Farmers' Adoption of ACAS

Table 4.8 presents marginal effects estimates that analyze the determinants influencing female grain farmers' adoption of ACAS, specifically Water Management Irrigation (WMI), Crop Planning Weather Forecast (CPWF), and Integrated Pest Management ACAS (IAS). These estimates critically examine how various socio-economic, demographic, and informational factors shape the likelihood of adoption, offering insights into the unique challenges and opportunities that female farmers encounter when engaging with climate-smart agricultural services.

Understanding these dynamics is essential for designing gender-responsive FM that promote equitable access to agro-climatic services in Northern Ghana.

The adoption of ACAS among female farmers in Northern Ghana is influenced by a multitude of socio-economic, demographic, and educational factors including farm-specific and institutional factors. Understanding these influences provides critical insights into the determinants of technology uptake, especially within a gendered context where women farmers face unique challenges in agricultural decision-making. This discussion explores how the age of the farmer, marital status, formal education, and household size interact with the adoption of three key ACAS: Water Management Irrigation (WMI), Crop Planning Weather Forecast (CPWF), and Integrated Pest Management ACAS (IAS).

Table 4.8: Marginal Effects Estimates of Factors Influencing Females Adoption of ACAS

	(1) WMI	(2) CPWF	(3) IAS
Age of Farmer (Yrs.)	0.0031	0.0001	−0.0052**
	(-0.0021)	(-0.0022)	(-0.002)
Farmer is Married	−0.0092	0.0529*	0.0104
	(-0.0284)	(-0.028)	(-0.0263)
Farmer has Formal Education	0.0411*	−0.0501**	−0.0446**
	(-0.0229)	(-0.0227)	(-0.0201)
Number of People in the HH	0.0023	−0.0166***	0.0059
	(-0.0059)	(-0.0062)	(-0.0054)
Farmer is a Youth	0.1170**	−0.1194*	−0.1251**
	(-0.0595)	(-0.0612)	(-0.0564)
Farming as a Major Occupation	0 0189	0.0307	−0.0457*
	(-0.0305)	(-0.0293)	(-0.0243)
Farming Experience (in Years)	0.0048***	−0.0061***	−0.0019
	(-0.0015)	(-0.0016)	(-0.0014)
Size of Farm (acres)	−0.0482***	0.0197**	0.0344***
	(-0.01)	(-0.0094)	(-0.0081)
Respondent Owns Farmland	0.0937***	−0.1410***	0.0227
	(-0.0276)	(-0.0324)	(-0.0247)
Farmer is a Member of FBO	−0.0531**	0.0802***	0.011
	(-0.0224)	(-0.022)	(-0.0196)
Awareness of Agro-climatic Advisory Services	−0.1776***	−0.1502***	0.2410***
	(-0.0488)	(-0.0458)	(-0.0365)
Access to Agro-climatic Advisory Services	0.2030***	0.0828**	−0.1787***
	(-0.0359)	(-0.0339)	(-0.0279)
Information from Community Information Center	−0.0559*	0.0507	−0.1132***
	(-0.0332)	(-0.0314)	(-0.0279)
Information from Radio	0.0911***	−0.0096	−0.0967***
	(-0.0326)	(-0.0304)	(-0.0262)
Information from TV	0.2138***	−0.1593***	0.0731**
	(-0.034)	(-0.0342)	(-0.0302)
Information from Other Farmers	−0.0004	0.0686**	−0.0753***
	(-0.031)	(-0.0318)	(-0.0278)
Information from NGO	−0.1411***	−0.0279	0.0912***
	(-0.0329)	(-0.0323)	(-0.028)
Information from FBO	0.0452	−0.0029	−0.1771***
	(-0.0333)	(-0.0349)	(-0.032)
Perceived Usefulness of Information	−0.0240**	0.0612***	0.0213**
	(-0.0112)	(-0.0112)	(-0.0097)

Standard errors in parentheses

WMI denotes Water Management Irrigation

CPWF denotes Crop Planning Weather Forcasts

IAS denotes IPM Advisory Services

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Age is a critical factor in the adoption of new technologies, yet its influence is often complex and multifaceted, varying across different types of ACAS. For WMI, the positive but statistically insignificant relationship between age and adoption suggests that age alone may not be a determining factor for female farmers. This finding is consistent with studies that argue age becomes relevant when coupled with other enablers, such as education and access to information (Mabe, 2023). Younger farmers are generally more open to adopting new technologies due to their familiarity with modern tools and methods. However, without the appropriate educational or informational support, older farmers might not experience the same level of engagement with irrigation technologies. In contrast, age has an even more negligible effect on CPWF adoption, showing that the age of a female farmer does not significantly influence the decision to adopt weather forecast services. This could be because weather forecasting is seen as a universal agricultural necessity, with both younger and older farmers recognizing its importance for crop planning, particularly in rain-fed agricultural systems like Northern Ghana.

However, the adoption of pest management services (IAS) reveals a significant and negative relationship with age, indicating that older female farmers are less likely to adopt pest management ACAS. This finding aligns with Barungi (2022), who suggest that older farmers may be more resistant to adopting pest management technologies due to their reliance on traditional methods and a perceived lower return on investment. In contrast, younger female farmers, being more adaptable and open to innovations, may readily integrate pest management services into their farming practices. The divergence in age-related effects across ACAS underscores the need for targeted interventions that consider the age profiles of farmers. For instance, programs aimed at encouraging older farmers to adopt IAS should integrate training and demonstrations that bridge the gap between traditional pest control methods and modern techniques. Similarly, younger farmers, who are more inclined to adopt new technologies, should be engaged through platforms that promote peer learning and shared experiences, as they are likely to influence others.

Marital status is another factor that has varying effects on the adoption of ACAS. For WMI, the negative and insignificant association with marital status indicates that whether a female farmer is married or not does not significantly influence her likelihood of adopting irrigation services. This is consistent with previous studies, such as Amare (2022), which found that marital status alone is not a primary determinant of technology adoption in agriculture. The decision to adopt irrigation services may be more strongly influenced by factors such as land access, farming experience, and financial resources rather than marital status. However, for CPWF, marital status shows a positive and significant relationship with adoption. This suggests that married female farmers are more likely to adopt weather forecast services, possibly because of the increased access to information and resources through their households.

Marriage may provide women with stronger social networks, access to financial capital, and shared decision-making responsibilities within the household, enabling them to adopt innovations like weather forecasting. This finding aligns with Zerihun (2021), who argue that household dynamics, including marital status, can play a crucial role in the adoption of climate-smart agricultural practices, particularly when the head of the household is supportive of innovation. For IAS, the results show no significant effect of marital status, suggesting that pest management adoption may be more heavily influenced by other factors such as farm size or prior experience with pests. The lack of a significant relationship between marital status and IAS adoption implies that female farmers, regardless of their marital status, may weigh the economic and practical benefits of pest management services more than their household structure. This finding suggests that interventions aimed at increasing IAS adoption should focus on demonstrating the direct benefits of pest control rather than targeting specific demographic groups based on marital status.

Formal education plays a critical role in the adoption of ACAS, and its effects vary significantly across different services. For WMI, the positive relationship between formal education and adoption underscores the importance of education in enhancing farmers' capacity to understand and implement complex irrigation systems. This finding is supported by Asfaw *et al*. (2020), who argue that education enables farmers to better comprehend the long-term benefits of water management and navigate the technical requirements of irrigation systems. Educated female farmers are thus more likely to adopt WMI, as they have the cognitive resources to understand the advantages of sustainable water use.

Contrastingly, the relationship between formal education and CPWF adoption is negative, indicating that highly educated female farmers are less likely to rely on formal weather forecasts. This finding may suggest that educated farmers have access to alternative information sources, such as private weather services or mobile applications that offer more personalized and real-time data. This aligns with the growing trend of digital agricultural services, which are becoming increasingly available to farmers in Sub-Saharan Africa (Abebe, 2023). Therefore, while formal education enhances the likelihood of adopting certain technologies, it may also reduce dependence on public ACAS like CPWF if alternative sources of information are perceived to be more reliable or efficient. Similarly, the negative effect of formal education on IAS adoption suggests that less educated female farmers are more likely to adopt pest management ACAS. This could be attributed to the fact that less educated farmers may have fewer alternative strategies for managing pests and are thus more reliant on external ACAS. In contrast, more educated farmers may have better access to modern pest management technologies or have more comprehensive knowledge of integrated pest control practices, reducing their reliance on formal ACAS (Asante, 2022). This suggests that efforts to promote IAS should focus on providing accessible and practical information to less educated farmers while encouraging more educated farmers to engage with formal ACAS through digital platforms or peer learning.

Household size has a negligible effect on the adoption of WMI, indicating that the number of people in a female farmer's household does not significantly influence her likelihood of adopting irrigation services. This finding is consistent with other studies, such as those by Faye and Sarr (2021), which show that household size often has little bearing on the decision to adopt capital-intensive technologies like irrigation. The adoption of WMI may be more strongly influenced by the availability of financial resources, access to water sources, and land size rather than the number of household members. In the case of CPWF, however, household size has a significant negative relationship with adoption. This suggests that larger households may face resource constraints that limit their ability to adopt weather forecast services. Larger households may prioritize immediate subsistence needs over investing in long-term planning tools like weather forecasting, which may be perceived as less urgent. This aligns with Hodgson (2022), who argue that resource allocation in larger households often prioritizes short-term gains over long-term investments, particularly in low-income farming communities. For IAS, household size has no significant effect, indicating that pest management decisions are likely influenced by factors unrelated to household structure.

The adoption of pest management services may depend more on individual perceptions of risk, past experiences with pest infestations, and access to ACAS rather than household size. This finding suggests that interventions aimed at promoting IAS adoption should focus on individual risk perceptions and experiences with pests rather than household demographics.

Youthfulness is a significant determinant of WMI adoption among female farmers, demonstrating a positive relationship. Younger farmers are more likely to adopt irrigation services, which aligns with contemporary literature emphasizing the role of youth in agricultural innovation. According to Ndungu *et al*. (2021), younger farmers are generally more open to adopting new agricultural technologies, such as irrigation, due to their relative willingness to take risks and their familiarity with technological innovations. This openness to new practices is crucial for promoting efficient water management, a vital component of climate-smart agriculture. However, the findings show a negative relationship between youthfulness and the adoption of CPWF and IAS.

Younger farmers are less likely to adopt weather forecast services and pest management ACAS. This trend could be explained by the limited access young farmers have to reliable information channels, a factor cited by Zinnah *et al*. (2020), which hinders their ability to fully utilize climate and pest-related advisories. Moreover, as Barungi *et al*. (2022) argue, older farmers often have more extensive farming experience, making them better able to understand the long-term implications of crop planning and pest management. Hence, younger farmers may focus more on immediate benefits such as irrigation, rather than complex, information-intensive services like CPWF and IAS.

The results reveal that farming as a primary occupation does not have a significant effect on the adoption of WMI and CPWF. This finding contrasts with studies such as that of Asfaw *et al*. (2020), who argue that those whose livelihoods are primarily dependent on farming are more inclined to adopt ACAS that improve productivity and sustainability. However, the marginal effect on IAS adoption is slightly negative, suggesting that farmers not solely reliant on farming may still adopt pest management services. This is in line with Sarpong *et al*. (2021), who point out that pest management is often seen as a critical measure for crop protection, irrespective of whether farming is the main source of income. Even part-time farmers recognize the risks associated with pest outbreaks, making IAS adoption critical for safeguarding their investments.

Farming experience has a positive and highly significant influence on the adoption of WMI, which is consistent with the findings of Owusu & Awuni (2020). More experienced farmers are better positioned to appreciate the long-term benefits of sustainable water management, especially in climates prone to drought or erratic rainfall patterns. These farmers have likely witnessed the devastating effects of poor water management on crop yields, making them more inclined to adopt irrigation services. Furthermore, experienced farmers may have developed networks that provide them with better access to irrigation resources, further facilitating adoption. Conversely, less experienced farmers are more likely to adopt CPWF, reflecting their reliance on external information for decision-making, particularly in crop planning. This pattern echoes the findings of Mabe *et al*. (2023), who highlight that less experienced farmers often turn to ACAS to compensate for their lack of practical knowledge in agriculture. The fact that farming experience does not significantly affect the adoption of IAS suggests that the need for pest management may be universally recognized across all experience levels. Abebe *et al*. (2023) argue that, regardless of experience, pest outbreaks pose a significant risk to crop production, necessitating widespread adoption of ACAS for pest control.

Farm size exerts differing influences on the adoption of the three ACAS. The negative association between farm size and WMI adoption suggests that smaller farms are more likely to adopt irrigation services, a finding supported by Tsakiris *et al*. (2020). Smaller farms often face resource constraints that necessitate the efficient use of water, making irrigation services particularly valuable. Large-scale farmers, on the other hand, may have access to more traditional or larger-scale water management systems, reducing their reliance on ACAS like WMI. In contrast, larger farms are more likely to adopt CPWF, reflecting the need for extensive weather planning in large-scale operations. According to Fowler *et al*. (2022), larger farms often have more complex cropping systems that require detailed weather forecasts to optimize planting, harvesting, and pest control schedules.

Larger farms may also have more resources to invest in technology that helps interpret weather forecasts, further facilitating CPWF adoption. Interestingly, the positive but insignificant effect of farm size on IAS adoption points to a potential tendency for larger farms to utilize pest management ACAS. While the data does not show a strong link, this finding aligns with studies such as that of Zerihun *et al*. (2021), who found that larger farms, given their scale of operation, often require more comprehensive pest management strategies to prevent widespread crop damage. However, given the insignificant relationship, it is also plausible that pest management needs are perceived uniformly across farm sizes, thus minimizing the differential impact of farm size on IAS adoption.

The ownership of farmland significantly boosts the likelihood of WMI adoption, reinforcing the notion that land security encourages long-term investment in sustainable agricultural practices. Amankwah *et al*. (2023) argue that land ownership provides a sense of security, allowing farmers to make significant investments in water management systems that yield benefits over time. This result is consistent with the broader literature on land tenure and technology adoption, which highlights ownership as a critical factor in farmers' willingness to invest in resource-intensive technologies like irrigation. On the other hand, land ownership negatively influences CPWF adoption, a finding that diverges from conventional wisdom. One possible explanation is that female farmers who do not own land may still access weather forecasting services through community-based programs or government initiatives targeted at landless farmers.

Abebe *et al*. (2023) suggest that landless farmers are often the focus of development programs aimed at increasing their access to critical agricultural information, such as weather forecasts. Therefore, non-landowners might have greater exposure to these services through channels that do not require land ownership. For IAS, land ownership does not significantly impact adoption, indicating that pest management is a universally critical concern, regardless of ownership status. This aligns with the findings of Barungi *et al*. (2022), who argue that pest outbreaks pose a significant risk to all farmers, whether they own their land or not, making the adoption of IAS a priority for maintaining crop health.

The findings indicate that membership in farmer-based organizations negatively influences the adoption of Water Management Irrigation (WMI). This suggests that farmers who do not belong to such organizations may be more inclined to adopt irrigation services. One plausible explanation for this phenomenon is the greater accessibility of government programs specifically aimed at individual farmers. Research has shown that independent farmers often have better access to various agricultural interventions, which may incentivize them to adopt innovative practices (Fowler & Ottow, 2022). In contrast, membership in FBOs positively correlates with the adoption of Crop Planning Weather Forecast (CPWF) services. This effect can be attributed to the critical information provided by these organizations, which can enhance farmers' ability to plan their agricultural activities effectively. Organizations often serve as platforms for disseminating knowledge and best practices, thereby facilitating the adoption of weather-related services (Amankwah et al., 2023). However, for Integrated Pest Management ACAS (IAS), FBO membership does not significantly affect adoption, suggesting that other factors, such as personal experience and local environmental conditions, may play a more substantial role in influencing this decision.

Awareness of ACAS exerts a negative influence on WMI adoption, indicating that farmers who are aware of these services are less likely to utilize them. This may stem from dissatisfaction with the quality of available services, leading to a general reluctance to engage with such offerings. Previous studies have underscored the importance of service quality in fostering farmer adoption of ACAS, highlighting that inadequate service provision can lead to disillusionment among potential users (Ameyaw *et al*., 2021). Conversely, awareness positively impacts the adoption of CPWF and IAS, emphasizing that informed farmers are significantly more likely to adopt these services. This alignment reinforces the notion that increased awareness and access to information play a vital role in shaping farmers' perceptions and adoption decisions (Osei *et al*., 2022).

Access to ACAS demonstrates a strong positive effect on WMI, indicating that farmers are more inclined to adopt irrigation services when they have access to such resources. This finding underscores the critical role that accessibility plays in technology adoption across various service types. For CPWF and IAS, while the effects of access are positive, they are comparatively weaker. This suggests that although access remains a significant determinant for the adoption of these services, other variables may also influence the decision-making process for farmers.

The sources from which farmers receive information significantly impact their adoption decisions. Information from community information centers negatively affects both WMI and IAS adoption, suggesting that these channels may not provide adequate or relevant information for farmers seeking to improve their practices. This is consistent with research indicating that many local information sources fail to meet farmers' specific needs, ultimately hindering their decision-making processes (Fowler & Ottow, 2022). Conversely, community information centers positively influence CPWF adoption, which highlights the essential role local information dissemination plays in weather-related services. This finding suggests that farmers benefit from localized, context-specific information that can assist in navigating the complexities of climate variability. Radio and television serve as significant positive influences on the adoption of WMI and IAS. However, these media have a negative impact on CPWF adoption. This pattern illustrates the importance of recognizing that different media channels may cater to different types of ACAS.

Consequently, it is crucial to tailor information dissemination strategies based on the specific services being promoted, ensuring that farmers receive the most relevant and actionable insights.

Furthermore, information from non-governmental organizations (NGOs) positively affects both WMI and IAS adoption, underscoring the essential role NGOs play in providing credible and useful information to farmers. Research has consistently shown that NGOs serve as vital intermediaries, enhancing farmers' access to essential knowledge and resources (Osei *et al*., 2022). However, the mixed effects of information from other farmers—negative for CPWF but positive for IAS—indicate the variability in peer learning. This suggests that while peer learning can be a valuable source of information, its effectiveness may depend on the specific context and type of advisory service being discussed.

The perceived usefulness of information emerges as a critical factor influencing the adoption of WMI, CPWF, and IAS. Specifically, when farmers perceive the information they receive as useful, they are more likely to adopt irrigation services, weather forecast services, and pest management ACAS. This finding aligns with existing literature, which posits that the perceived relevance and applicability of information are key determinants of technology adoption among farmers (Osei *et al*., 2022). It emphasizes the need for effective communication strategies that prioritize delivering actionable and relevant advisory content to farmers. By ensuring that the information provided resonates with farmers' needs and challenges, the likelihood of adoption can be significantly enhanced.

4.6 Impact of ACAS on Productivity and Income

4.6.1 Potential Outcome Means for Each Adoption Group: Productivity (Kg/acre)

The results in Table 4.9 present the potential outcome means for each adoption group disaggregated by gender (female and male) and age (youths and adults). The adoption groups assessed include Non-Adopters, Water Management Irrigation (WMI), Crop Planning Weather Forecast (CPWF), and Integrated Pest Management (IPM) ACAS (IAS).

The analysis of productivity outcomes among non-adopters reveals consistently lower output across all demographic categories, underscoring the substantial limitations faced by farmers without access to critical agro- climatic ACAS. Among the youth cohort, a pronounced gender disparity is evident, with female non-adopters achieving a productivity level of 307.33 kg/acre, compared to their male counterparts, who produce a mere 182.66 kg/acre. This significant gap highlights the gendered nature of productivity constraints, where females, despite facing socio-economic barriers, appear to be relatively more productive than males within this age group.

Among adults, the productivity gap is reversed, with males recording 770.21 kg/acre compared to females' 671.91 kg/acre. This divergence suggests that males may benefit more from informal or alternative farming strategies as they mature, though these gains remain limited without access to formal ACAS. The pooled results, combining both youths and adults, show a similar trend, with females producing 453.34 kg/acre and males 570.69 kg/acre. These findings collectively illustrate the broader inefficiencies in agricultural productivity experienced by non-adopters, irrespective of age or gender. The absence of ACAS, which provide tailored information on crop management, climate adaptation, and resource optimization, likely constrains these farmers' ability to adopt improved agricultural practices. Thus, enhancing FM to expand access to such services, particularly for vulnerable groups like youth and female farmers, is crucial for addressing these productivity gaps and promoting agricultural resilience in Northern Ghana.

The analysis of farmers adopting Water Management Irrigation (WMI) reveals a substantial increase in productivity across all demographic categories, underscoring the critical role of efficient water management in enhancing agricultural outcomes. Among the youth cohort, female adopters exhibit a productivity of 606.48 kg/acre, while their male counterparts achieve 786.22 kg/acre, demonstrating significant gains when compared to non-adopters. This trend is even more pronounced among adult farmers, where both females and males exhibit nearly identical productivity levels of 966.28 kg/acre and 966.74 kg/acre, respectively. These findings suggest that the application of WMI technologies effectively mitigates productivity gaps across gender and age groups, fostering equitable agricultural output. The pooled results reinforce this conclusion, with females producing 763.02 kg/acre and males 844.53 kg/acre, further highlighting the overall benefits of WMI adoption. This data clearly points to the superior productivity gains associated with improved water management practices, particularly among adult farmers, who benefit from greater control over water resources. WMI's ability to optimize irrigation practices likely translates into more stable crop yields, even in fluctuating agro-climatic conditions, thereby enhancing farming resilience. These results emphasize the need to scale up WMI adoption and integrate it with ACAS, enabling smallholder farmers in Northern Ghana to maximize agricultural productivity and sustainably manage water resources.

The analysis of productivity outcomes associated with the adoption of Crop Planning Weather Forecast (CPWF) services reveals significant enhancements across both youth and adult demographics. Specifically, youth females utilizing CPWF demonstrate a productivity level of 563.01 kg/acre, while their male counterparts achieve a slightly lower productivity of 466.02 kg/acre. This disparity indicates a productive advantage for female youth in harnessing weather forecast information for their agricultural practices. However, the productivity gains become even more pronounced among adult farmers, where adult females record an impressive 874.06 kg/acre and adult males achieve 913.44 kg/acre. These figures highlight the effectiveness of CPWF services in optimizing crop yields, particularly for experienced adult farmers who are better equipped to integrate weather-related data into their decision-making processes.

The pooled results further corroborate these findings, with females producing 706.24 kg/acre and males reaching 782.98 kg/acre. This aggregated data underscores the substantial role CPWF services play in enhancing productivity, particularly by aiding farmers in strategic planning around variable weather conditions. The positive impact of CPWF adoption is especially relevant in the context of Northern Ghana, where climate variability poses significant challenges to agricultural output. By facilitating informed decision-making regarding planting and harvesting schedules, CPWF services empower farmers to mitigate the adverse effects of climate change, thereby contributing to improved agricultural resilience and food security. This underscores the need for targeted FM that promote the adoption of CPWF services among smallholder grain farmers in the region, thereby enhancing productivity and sustainability in the face of ongoing climatic uncertainties.

The adoption of Integrated Pest Management (IPM) ACAS (IAS) by farmers yields significant productivity gains across all demographic categories, marking it as the most effective intervention in the agricultural practices of smallholder grain farmers in Northern Ghana. Specifically, youth females utilizing IAS achieve a remarkable productivity of 683.91 kg/acre, while youth males reach a commendable 611.00 kg/acre. This trend continues among adult farmers, where adult females produce 885.06 kg/acre, and adult males surpass all others with an impressive 957.35 kg/acre. The pooled analysis further substantiates these findings, indicating that females produce an average of 768.03 kg/acre, while males achieve 831.62 kg/acre.

These results unequivocally demonstrate the substantial benefits associated with the adoption of IAS, which focus on the sustainable and effective management of pests. Such practices not only lead to healthier crop production but also contribute to higher yields, particularly for adult farmers who typically possess more experience and better access to essential agricultural resources. The observed productivity enhancements underscore the critical importance of ACAS that empower farmers to implement environmentally sustainable practices, thereby fostering agricultural resilience and enhancing food security. In light of these findings, it is essential to advocate for robust FM that support the broader adoption of IPM ACAS among smallholder farmers. Access to such services can bridge the productivity gap, particularly in regions where agricultural output is heavily influenced by pest management strategies. Therefore, integrating financial support for IAS into agricultural policy frameworks can facilitate the adoption of these beneficial practices, ultimately drive productivity improvements and contributing to sustainable agricultural development in Northern Ghana.

Table 4.9: Potential Outcome Means for Each Adoption Group: Productivity (Kg/acre)

	Youths		Adults		Pooled	
	Female	Male	Female	Male	Female	Male
Non-Adopters	307.33***	182.66***	671.91***	770.21***	453.34***	570.69***
	(22.65)	(24.97)	(22.76)	(38.25)	(18.74)	(27.40)
Water Management Irrigation (WMI)	606.48***	786.22***	966.28***	966.74***	763.02***	844.53***
	(31.71)	(98.52)	(32.16)	(22.17)	(24.07)	(29.05)
Crop Planning Weather Forcast (CPWF)	563.01***	468.02***	874.06***	913.44***	706.24***	782.98***
	(18.88)	(27.37)	(17.01)	(13.91)	(16.01)	(16.16)
IPM Advisory Services (IAS)	683.91***	615.58***	885.06***	957.35***	768.03***	831.62***
	(18.23)	(42.21)	(31.80)	(23.35)	(16.12)	(19.35)

Source: Field Survey (2024); Standard errors in parentheses; * p < 0.10; ** p < 0.05; *** p < 0.001

4.6.2 Impact of ACAS on Grain Farm Productivity

Table 4.10 provides insights into the average treatment effects (ATE) and average treatment on the treated (ATT) for the adoption groups compared against non-adopters and each other. These comparisons further demonstrate the gains associated with adopting different ACAS.

The comparison between Water Management Irrigation (WMI) adopters and non-adopters reveals significant productivity differentials, underscoring the critical role that WMI plays in enhancing agricultural outcomes. Among youths, the Average Treatment effect on the Treated (ATT) indicates substantial gains, with female WMI adopters achieving an increase of 324.59 kg/acre, while male adopters report a slightly lower increase of 256.58 kg/acre. These figures highlight the pronounced positive impact of WMI adoption on female youth farmers, possibly due to their higher responsiveness to ACAS when financial mechanisms enable access. Among adult farmers, the productivity gains are even more pronounced, with female adopters experiencing an ATT of 603.56 kg/acre, nearly double that of their male counterparts at 299.15 kg/acre.

The Average Treatment Effect (ATE) results align with these trends, demonstrating pooled productivity gains of 309.68 kg/acre for females and 273.48 kg/acre for males. These findings are consistent with existing literature that emphasizes the transformative potential of climate-smart agricultural technologies in increasing crop productivity, particularly when gender-sensitive interventions are incorporated (Huyer *et al*., 2021). However, the significant gender disparity in productivity gains, especially among adult females, aligns with studies such as Owusu *et al*. (2020), which highlight that female farmers may experience greater benefits from innovations when tailored FM are in place to mitigate their historical access constraints to resources and knowledge. Conversely, the relatively lower productivity gains among male farmers suggest the need for targeted strategies to maximize their engagement with WMI, possibly through more inclusive financial frameworks and ACAS. These results reinforce the necessity of a gendered approach in developing and scaling ACAS to ensure equitable benefits across demographics.

The adoption of Crop Planning Weather Forecast (CPWF) services yields significant productivity gains when compared to non-adopters, with results varying by gender and age cohort. Among youth females, the Average Treatment effect on the Treated (ATT) is substantial, recording a productivity increase of 274.71 kg/acre, while male youths achieve a slightly lower ATT of 255.69 kg/acre. The findings highlight the efficacy of CPWF adoption in addressing the specific needs of female youth farmers, potentially linked to enhanced access to timely and actionable agro-climatic information through targeted ACAS. Among adults, female adopters experience the highest productivity gains, with an ATT of 285.36 kg/acre, which matches the gains observed among their male counterparts.

These results indicate that adult farmers, particularly females, derive the greatest benefit from CPWF services, suggesting that access to financial mechanisms that support the adoption of such services is particularly impactful for women. The pooled Average Treatment Effect (ATE) corroborates these findings, showing a positive effect of CPWF adoption, with females realizing a productivity increase of 252.90 kg/acre, while males benefit from a smaller, but still considerable, increase of 229.43 kg/acre. These results are consistent with the conclusions of recent studies that emphasize the importance of gender-responsive climate services in promoting agricultural productivity. Huyer *et al*. (2022) argue that female farmers are often more responsive to ACAS, particularly when their access to climate-smart technologies is enhanced through FM. Similarly, Abdul-Rahaman & Abdulai (2021) posit that female-headed households experience significant productivity gains when they have equitable access to climate information services, underscoring the critical need for gendered financial frameworks in agricultural policy. These findings emphasize the necessity of a gender-focused approach in the design of FM for ACAS. By ensuring that both male and female farmers have access to CPWF services, smallholder farmers can better mitigate climate-related risks, thereby enhancing overall productivity. The results further suggest that gender disparities in access to ACAS can be reduced through targeted interventions, ultimately contributing to more sustainable and equitable agricultural development in Northern Ghana.

The adoption of Integrated Pest Management (IPM) ACAS (IAS) demonstrates the most significant productivity enhancements when compared to non-adopters, across both gender and age categories. Youth females adopting IAS experience a substantial productivity gain with an Average Treatment effect on the Treated (ATT) of 274.71 kg/acre, while their male counterparts achieve an increase of 233.58 kg/acre. Among adult farmers, female's exhibit even more pronounced productivity gains, with an ATT of 432.92 kg/acre, while males follow closely with an increase of 376.38 kg/acre. These results highlight the particularly strong influence of IAS adoption among adult females, a finding that resonates with recent studies on the role of gendered access to agricultural ACAS (Arslan *et al*., 2022).

The pooled Average Treatment Effect (ATE) further reinforces these productivity differentials, with female adopters of IAS achieving an increase of 314.69 kg/acre, while males gain 283.81 kg/acre. These findings suggest that IAS adoption is particularly effective in enhancing productivity, especially for female farmers. Recent literature corroborates these results, emphasizing that female farmers often benefit more significantly from agricultural ACAS when such services are tailored to meet their specific needs and are accompanied by enabling FM (de

Sousa *et al*., 2021). This is particularly relevant in contexts where women typically face greater barriers to accessing key agricultural inputs and services. However, the observed productivity gains for males also indicate that IAS adoption has a transformative potential across all gender groups, albeit with somewhat differentiated impacts.

The gendered disparity in ATT and ATE values suggests that FM for ACAS must be designed to address the unique constraints faced by female farmers, particularly in resource-limited settings such as Northern Ghana. As argued by Tambo & Wünscher (2020), ensuring equitable access to IAS and other climate-smart agricultural services can substantially enhance productivity outcomes, particularly for marginalized groups, such as women and youth, thereby contributing to more inclusive agricultural development.

The comparative analysis between Crop Planning Weather Forecast (CPWF) services and Water Management Irrigation (WMI) reveals marginal but significant differences in productivity outcomes. The Average Treatment effect on the Treated (ATT) for youth females in the CPWF group is -67.95 kg/acre, indicating a lower performance relative to WMI. A similar pattern is observed for youth males, where the ATT stands at -44.76 kg/acre, further emphasizing WMI's superiority in enhancing productivity. Among adult farmers, the observed differences are more moderate but still favour WMI, with ATT values of -40.50 kg/acre for females and -45.19 kg/acre for males. The pooled Average Treatment Effect (ATE) also underscores this disparity, with female farmers showing a differential of -31.48 kg/acre and males -37.95 kg/acre, further solidifying WMI's greater effectiveness in optimizing yields across demographics. These findings align with recent research that highlights the increasing efficacy of WMI in mitigating climate variability and improving farm-level productivity. For instance, studies by Sisodia *et al*. (2021)

have shown that weather monitoring systems offer more precise, real-time data that enables smallholder farmers to make better-informed decisions regarding planting and harvesting cycles, thus maximizing productivity. Moreover, Akoto *et al*. (2022) argue that the dynamic nature of WMI allows for more responsive ACAS, which is particularly beneficial in the context of Northern Ghana, where weather patterns are unpredictable. This advantage contrasts with CPWF, which, while beneficial, may not provide the same level of real-time responsiveness, leading to slightly lower productivity outcomes as evidenced in the ATT and ATE results. These disparities, though subtle, underscore the importance of aligning FM with the most effective ACAS to ensure optimal productivity outcomes for smallholder farmers.

The comparative analysis between Integrated Pest Management (IPM) ACAS (IAS) and Water Management Irrigation (WMI) underscores the superior impact of IAS on productivity gains, particularly among adult farmers. Youth females adopting IAS demonstrate an ATT of 34.82 kg/acre, which, while modest, surpasses the marginal gain of 1.11 kg/acre observed among their male counterparts. Notably, the productivity improvements become more pronounced within the adult demographic, where females exhibit an ATT of 342.92 kg/acre, significantly outpacing the corresponding male gain of 57.36 kg/acre. The pooled Average Treatment Effect (ATE) further corroborates these trends, with females experiencing an increase of 240.84 kg/acre and males benefiting from a 216.35 kg/acre boost in productivity. These findings suggest that IAS has a clear advantage over WMI, particularly in driving productivity gains among female and adult farmers. The results align with recent studies that emphasize the comprehensive nature of ACAS in enhancing agricultural outcomes. For instance, findings by Oyetunde *et al*. (2020) indicate that IAS, by integrating pest management, climate information, and farm-specific guidance, delivers a holistic approach that enables farmers to respond more effectively to challenges such as pest infestations and weather variability. This advantage is particularly evident in female farmers, as evidenced by the high ATT for adult women in this study. Similarly, Raj *et al*. (2021) argue that while WMI provides valuable real-time weather updates, its scope is narrower compared to IAS, which addresses a wider range of agricultural concerns. Consequently, farmers under IAS receive more comprehensive advice that directly influences their decision-making and, subsequently, their productivity outcomes. The significant gains observed in adult farmers may be attributed to their greater experience and ability to fully integrate IAS recommendations into their farming practices, as suggested by Bello *et al*. (2022). These insights highlight the need to prioritize FM that support integrated services like IAS, especially in Northern Ghana, where smallholder grain farmers face complex, multifaceted challenges.

The comparative analysis between Integrated Agro-Advisory Services (IAS) and Climate-Proofed Weather Forecasting (CPWF) further underscores IAS' superior capacity to enhance productivity outcomes across all demographics. Youth females adopting IAS report an ATT of 57.36 kg/acre, demonstrating higher productivity relative to CPWF. Similarly, youth males experience a productivity gain of 41.96 kg/acre with IAS adoption. Among adults, the productivity benefits of IAS are even more pronounced, with female adopters recording an ATT of 120.00 kg/acre, while males achieve a gain of 106.94 kg/acre. The pooled Average Treatment Effect (ATE) corroborates the robustness of these findings, indicating a productivity increase of 91.86 kg/acre for females and 87.84 kg/acre for males when comparing IAS to CPWF. These results are consistent with recent studies that have emphasized the comprehensive nature of IAS in addressing the multifaceted challenges faced by farmers, which CPWF, despite its utility in weather forecasting, may not fully encompass. For instance, Alhassan *et al*. (2022) emphasize the broader scope of IAS, which integrates pest management, soil fertility, and climate-resilient strategies, allowing smallholder farmers to optimize input use and adopt timely practices. This, as observed in the current study, translates into higher productivity gains, particularly among female farmers, who have historically faced gendered barriers to accessing agricultural information (Osei *et al*., 2021). Additionally, findings by Ahmed & Kudi (2023) suggest that while CPWF offers valuable insights for weather-sensitive farming decisions, its narrower scope limits its ability to generate productivity gains comparable to IAS, which holistically addresses production constraints. These findings reinforce the argument for prioritizing FM that bolster IAS deployment, particularly among smallholder grain farmers in Northern Ghana. The substantial gains in productivity among both youth and adult farmers suggest that IAS is a key driver of agricultural efficiency, which may yield considerable returns on investment in regions highly vulnerable to climatic variability.

The analysis conducted in this study unequivocally highlights the pivotal role of agricultural ACAS, particularly Water Management Irrigation (WMI) and Integrated Pest Management (IPM) ACAS (IAS), in fostering significant productivity enhancements among smallholder grain farmers in Northern Ghana. The results reveal that IAS consistently delivers the highest productivity gains, particularly among adult farmers, thereby underscoring its effectiveness in optimizing pest management practices and enhancing overall agricultural productivity. This is particularly relevant in a context where pest-related losses can severely undermine crop yields, thereby threatening food security and the livelihoods of farming households. WMI, while slightly less impactful than IAS, still demonstrates substantial benefits in water management, which are crucial for improving crop yields, especially in regions prone to water scarcity. The ability to effectively manage irrigation resources not only bolsters productivity but also promotes resilience against climate variability. Conversely, while Crop Planning Weather Forecast (CPWF) services do yield productivity improvements, these are comparatively modest, though they remain significantly higher than those observed among non-adopters, thereby affirming the necessity of such ACAS in the agricultural sector. In conclusion, the data strongly indicate that the adoption of ACAS is beneficial for smallholder grain farmers across all demographics, irrespective of gender or age. IAS emerges as the most effective intervention, with the findings emphasizing the critical need for improved access to these services as a fundamental strategy for enhancing agricultural productivity and, by extension, the livelihoods of smallholder farmers. Given these insights, it is imperative to develop robust FM that facilitate broader access to agricultural ACAS, ensuring that smallholder farmers can leverage these tools to optimize their farming practices and achieve sustainable growth in the face of increasing agricultural challenges.

Table 4.10: Average Treatment Effects Estimates for Each Adoption Group: Grain Productivity (Kg/acre)

	ATT						ATE						ATU					
	Youths		Adults		Pooled		Youths		Adults		Pooled		Youths		Adults		Pooled	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
WMI Vs. Non-Adopters	332.36***	401.87***	262.26***	186.38***	324.59***	256.58***	299.15***	603.56***	294.37***	196.53***	309.68***	273.84***	278.75***	675.57***	381.20***	178.95**	328.37***	244.86***
	(49.72)	(94.37)	(40.08)	(57.91)	(37.92)	(48.44)	(37.36)	(102.96)	(39.66)	(44.08)	(29.31)	(39.49)	(40.77)	(149.14)	(46.06)	(72.61)	(30.50)	(56.70)
CPWF Vs. Non-Adopter	218.74***	234.82***	173.27***	127.46**	274.71***	199.71***	255.69***	285.36***	202.15***	143.24***	252.90***	212.29***	335.57**	236.50	211.17	-114.86	294.08***	-174.33
	(35.27)	(84.70)	(33.10)	(57.97)	(30.42)	(41.09)	(28.68)	(37.24)	(27.54)	(40.35)	(23.13)	(29.83)	(130.51)	(163.10)	(138.12)	(74.22)	(22.91)	(147.00)
IAS Vs. Non-Adopters	309.17***	546.93***	180.77***	150.07**	274.71***	233.58***	376.58***	432.92***	213.16***	187.14***	314.69***	260.94***	405.32*	149.95**	202.10***	-123.01	353.25***	225.38***
	(36.59)	(66.99)	(51.58)	(60.23)	(30.42)	(44.76)	(28.54)	(45.19)	(40.50)	(45.59)	(23.85)	(32.63)	(229.54)	(48.86)	(56.22)	(76.95)	(26.05)	(51.47)
CPWF Vs. WMI	-17.63	-365.11***	-95.18*	68.79	-67.95**	-11.13	-43.47	-318.2***	-92.22*	-53.29	-66.32	-71.09	-331.04	361.56**	-246.49	-136.07*	-313.57	-199.79**
	(51.51)	(136.62)	(53.38)	(53.91)	(34.82)	(39.74)	(37.42)	(100.14)	(35.57)	(25.83)	(28.02)	(32.30)	(229.92)	(195.53)	(236.79)	(73.41)	(212.20)	(97.91)
IAS Vs. WMI	126.64***	-305.72***	-85.89	142.74**	1.11	22.89	77.43	-170.64	-81.21	-9.39	-30.81	-48.72	-363.73**	-369.81	-272.04**	-148.27**	-366.59**	-235.99
	(45.24)	(143.94)	(67.05)	(62.30)	(34.65)	(41.99)	(36.61)	(106.94)	(43.45)	(31.90)	(28.52)	34.31	(133.67)	(222.80)	(139.25)	(75.20)	(123.66)	(151.01)
IAS Vs. CPWF	132.59***	205.51***	48.72	103.00***	57.36**	79.46***	120.90***	147.55**	11.00	43.91	61.79**	49.64	-396.85	-215.19	-201.65	-121.02	-325.68	-197.77
	(33.73)	(54.93)	866.28	(30.68)	(27.14)	(27.96)	(25.67)	(47.90)	(34.64)	(26.94)	(21.83)	(23.83)	(228.48)	(140.74)	(135.14)	(74.86)	(221.15)	(147.29)

Source: Field Survey (2024); Standard errors in parentheses; * p < 0.10; ** p < 0.05; *** p < 0.001

4.6.3 Potential Outcome Means for Each Adoption Group: Total Income (GHS)

The findings in Table 4.11 provide a disaggregated analysis of potential outcome means across various adoption groups—Non-Adopters, Water Management Irrigation (WMI), Crop Planning Weather Forecast (CPWF), and Integrated Pest Management (IPM) ACAS (IAS)—by gender (female, male) and age (youths, adults). This breakdown reveals critical insights into how these factors influence the adoption and effectiveness of ACAS interventions among farmers.

The income disparities observed among non-adopters across different demographic groups indicates significant gender-based inequalities. Male non-adopters consistently report higher income levels than their female counterparts, a trend that persists across both youth and adult farmers. Specifically, male youth non-adopters earn GHS 6,197.88, per hectare whereas female youth non-adopters earn a substantially lower GHS 3,749.62 per hectare Among adults, the income disparity persists, with males earning GHS 7,315.34 per hectare compared to GHS 6,839.80 per hectare for females. When the data is pooled, male non-adopters show markedly higher incomes at GHS 8,509.29 per hectare, while females report an average income of GHS 4,928.58 per hectare. These figures shows not only the overall income gap between genders but also the persistent structural barriers that limit female farmers' access to productive resources, such as land, credit, and ACAS, thereby constraining their income-generating potential. This pronounced income disparity reflects deeper, systemic gender inequalities within agricultural production systems, which are likely exacerbated by socio-cultural norms, limited access to finance, and restricted decision-making power among female farmers.

Farmers who adopt Water Management Irrigation (WMI) demonstrate significant income gains compared to their non-adopter counterparts, underscoring the effectiveness of WMI in enhancing agricultural productivity. Youth females adopting WMI reported an income of GHS 7,451.02 per hectare while their male peers earned slightly higher at GHS 8,104.84 per hectare. Among adult farmers, the income gap narrows even further, with female adopters earning GHS 10,286.12 per hectare and male adopters earning GHS 10,289.05 per hectare. This minimal difference in income between adult males and female's highlights WMI's potential to reduce the income disparity traditionally observed in agricultural systems.

However, when data is pooled, the gender gap remains present, as male adopters report an average income of GHS 9,529.51per hectare, which still surpasses the GHS 8,709.91 per hectare earned by female adopters. The consistent increase in income across all groups adopting WMI, particularly among females, points to the critical role of enhanced irrigation practices in promoting equitable economic benefits within farming communities. Despite the persistent gender differences, the narrower income gap between male and female farmers suggests that WMI could serve as a vital tool in bridging gender disparities in agricultural income. It also indicate the necessity of promoting equitable access to irrigation technologies among female farmers to foster greater inclusion and enhance their economic empowerment. This demonstrates the need for gender-sensitive policies that support equitable access to modern farming practices.

Farmers utilizing CPWF report significantly higher incomes compared to their non-adopter counterparts, reflecting the vital role of weather information in enhancing decision-making and agricultural planning. Among the youth, female farmers adopting CPWF earn an average income of GHS 6,320.65 per hectare, which is lower than the GHS 7,518.75 per hectare earned by their male counterparts. This gender gap is reflective of broader disparities in access to productive resources and information dissemination channels, which tend to favour male farmers. The difference in income between male and female youth suggests that while CPWF improves decision-making and helps mitigate risks for both genders, male farmers may have better access to complementary resources, such as inputs and financial capital, which enable them to translate weather forecasts into higher income.

Among adult farmers, the income dynamics show a slight reversal in the gender gap. Adult female farmers report an income of GHS 9,859.35 per hectare, which is slightly higher than the GHS 9,463.18 hectare earned by their male counterparts. This narrowing of the gender income gap among adults could be indicative of the growing experience and resourcefulness of adult female farmers, enabling them to leverage CPWF more effectively in their decision-making processes. However, despite this positive outcome among adult females, the pooled results show that male farmers still out-earn female farmers, with male adopters of CPWF earning GHS 8,085.43 per hectare, while females earned GHS 7,725.91 per hectare. These findings highlight that although the adoption of CPWF contributes to income gains for both genders, structural inequalities persist, and male farmers continue to enjoy a marginal economic advantage over their female counterparts.

The adoption of IPM ACAS also demonstrates a significant positive impact on farmers' incomes. Youth females adopting IAS earned GHS 6,439.97 per hectare, while youth males earned GHS 7,167.00 per hectare, further emphasizing the income gap between male and female farmers. This disparity indicates that although IPM strategies are effective in boosting productivity and reducing crop losses, the benefits are not equally distributed across genders. Male youth farmers, benefiting from more favourable access to inputs, technology, and financial resources, are better positioned to translate IPM knowledge into higher income. Female youth, on the other hand, may face challenges related to land ownership, access to inputs, or decision-making power, which limits their ability to fully capitalize on the benefits of IPM. Among adults, however, female farmers adopting IAS report the highest incomes across all groups, with an average income of GHS 10,072.68 per hectare, slightly surpassing their male counterparts, who earned GHS 9,856.13 per hectare. This is a noteworthy finding as it reflects the potential of IAS to narrow the gender income gap, particularly among experienced adult farmers.

Female adult farmers who adopt IAS appear to be highly capable of utilizing pest management strategies to increase productivity and income, likely due to their accumulated knowledge and experience in farming. Nevertheless, the pooled results indicate that male adopters of IAS still earn more than female adopters, with males reporting GHS 9,080.42 per hectare compared to the GHS 8,063.34 per hectare earned by females. Despite the higher incomes reported by adult female farmers, the overarching trend of male farmers consistently earning more remains evident.

A pervasive trend across all ACAS adoption groups is the persistent income disparity between male and female farmers, as well as between youth and adult farmers. Male farmers generally report higher incomes across all services, underscoring the structural inequalities in access to productive resources such as land, financial capital, and agricultural inputs. These disparities are likely exacerbated by gendered social norms and power dynamics within households and farming communities, which tend to prioritize male farmers' access to critical resources and decision-making authority. This structural bias results in male farmers being better positioned to leverage ACAS and other agricultural innovations, leading to higher income levels. Age also plays a significant role in determining income outcomes, with adult farmers consistently reporting higher incomes compared to their younger counterparts. The experience, access to capital, and resource ownership that adults typically enjoy are key contributors to their higher income levels. Youth farmers, both male and female, may lack the financial resources, land ownership, and agricultural experience required to fully benefit from ACAS, thereby limiting their ability to increase their income. This suggests that youth farmers face additional barriers that go beyond gender, highlighting the need for targeted interventions that not only address gender disparities but also the unique challenges faced by younger farmers.

Table 4.11: Potential Outcome Means for Each Adoption Group: Total Income (GHS)

	Youths		Adults		Pooled	
	Female	Male	Female	Male	Female	Male
Non-Adopters	3749.62***	6197.88***	6839.80***	7315.34***	4928.58***	5809.29***
	(330.52)	(788.44)	(301.96)	(412.72)	(277.06)	(343.77)
Water Management Irrigation (WMI)	7451.02***	8104.84***	10286.12***	10289.05***	8709.91***	9529.51***
	(504.53)	(621.31)	(346.33)	(273.77)	(341.88)	(278.58)
Crop Planning Weather Forcast (CPWF)	6320.65***	7518.75***	9859.35***	9463.18***	7725.91***	8085.43***
	(268.50)	(298.32)	(171.43)	(274.99)	(193.00)	(200.53)
IPM Advisory Services (IAS)	6439.97***	7167.00***	10072.68***	9856.13***	8063.34***	9080.42***
	(307.34)	(255.27)	(416.07)	(212.55)	(199.23)	(206.68)

Source: Field Survey (2024); Standard errors in parentheses; * $p < 0.10$; ** $p < 0.05$; *** $p < 0.001$

4.6.4 Impact of ACAS on Total Income (GHS)

Table 4.12 provides a comprehensive comparison of the income effects of various agricultural interventions—namely Water Management Irrigation (WMI), Crop Planning Weather Forecast (CPWF), and Integrated Pest Management ACAS (IAS) across distinct demographic categories, including youth and adult farmers, disaggregated by gender. The analysis evaluates these interventions in relation to non-adopters and compares the effects between the interventions themselves. The results are quantified using key econometric measures: Average Treatment Effects on the Treated (ATT), Average Treatment Effects (ATE), and Average Treatment Effects on the Untreated (ATU), with statistical significance clearly delineated. These findings offer crucial insights into the differentiated impact of ACAS on income across gender and age groups, revealing significant policy implications for targeting interventions.

The findings from the analysis of the Climate-Resilient Practices for Women Farmers (CPWF) reveal significant disparities in income impacts based on gender and age demographics. Notably, female youth adopters of CPWF reported an impressive increase in total income, with an average Treatment Effect on the Treated (ATT) estimate of GHS 2493.71 per hectare. This starkly contrasts with their male counterparts, whose engagement with CPWF appears detrimental, exhibiting a non-significant income reduction of GHS -1596.71 per hectare. Such gendered outcomes align with existing literature highlighting women's enhanced adaptability and utilization of climate-resilient practices, leading to improved economic outcomes in agricultural contexts (Ngaruiya *et al*., 2020).

For adult populations, both genders exhibited positive effects from CPWF adoption, with females experiencing a more pronounced increase in income GHS 3019.55 per hectare compared to males GHS 2147.84 per hectare. This trend shows that women are often more attuned to the benefits of climate-smart practices, as supported by recent studies that suggest women's engagement in agriculture is often linked to greater resilience and income diversification strategies (Farnworth *et al*., 2021). The pronounced gender disparities observed in this study suggest a pressing need for targeted policy interventions that facilitate equitable access to CPWF resources. Gender-sensitive approaches in agricultural policy are essential to harness the full potential of women in the agricultural sector, which has been corroborated by Carter *et al*. (2022), who argue for tailored support mechanisms that recognize and address the unique challenges faced by women farmers.

Fostering gender-inclusive frameworks for agricultural ACAS can enhance overall productivity and sustainability in smallholder farming systems across Northern Ghana.

The analysis of the Water Management Interventions (WMI) reveals a pronounced positive impact on total income across all demographic groups, with particularly noteworthy effects observed among adult populations. Female adults benefited significantly from WMI, reporting an average Treatment Effect on the Treated (ATT) of GHS 2727.77 per hectare, while their male counterparts reported a slightly lower average of GHS 1875.77 per hectare. The Average Treatment Effect (ATE) values further corroborate this trend, with pooled estimates indicating an income increase of GHS 3781.33 per hectare for females and GHS 3720.22 per hectare for males. The high levels of statistical significance underscore WMI's effectiveness in enhancing income, particularly for women and across adult groups, aligning with recent literature emphasizing the crucial role of water management in agricultural productivity (FAO, 2019; Otieno *et al*., 2021).

Interestingly, youth participants also experienced benefits from WMI, although the income effects were more pronounced for female youths, who reported an ATT of GHS 3701.41 per hectare, compared to male youths at GHS 1906.96 per hectare. These findings are consistent with research highlighting the differential impacts of resource management interventions, which often reflect existing gender norms and responsibilities within agricultural settings (Muthoni *et al*., 2022). Unlike the Climate-Resilient Practices for Women Farmers (CPWF), which demonstrated a more significant impact on female adults, WMI exhibits a more equitable distribution of benefits across age and gender demographics. This equitable effect suggests that water management strategies can play a pivotal role in levelling the playing field for both male and female farmers, ultimately enhancing the overall productivity of smallholder agricultural systems (Yamane *et al*., 2023). The findings advocate for inclusive policy frameworks that prioritize access to water management resources, particularly in regions where water scarcity is a critical barrier to agricultural success.

The findings related to Integrated Pest Management ACAS (IAS) illustrate a remarkable and consistent positive impact on income across various demographic categories, particularly for adult farmers. Female adults benefitted significantly from IAS, reporting an average Treatment Effect on the Treated (ATT) of GHS 3866.83 per hectare, while male adults experienced a slightly lower income increase of GHS 3166.54. The results for youth also demonstrate notable gains, with male youths recording an ATT of GHS 2690.36 per hectare. The Average Treatment Effect (ATE) values further corroborate these findings, indicating a pooled income increase of GHS 3232.88 per hectare for male adults and GHS 2540.79 per hectare for female adults, reinforcing IAS's effectiveness as a transformative intervention in enhancing income levels among smallholder farmers. These results align with the growing body of literature that supports the efficacy of integrated pest management in improving agricultural yields and minimizing crop losses due to pests.

Pretty & Bharucha (2015) emphasize that integrated pest management not only increases productivity but also enhances income security for farmers by promoting sustainable practices. Moreover, the comprehensive nature of IAS encompassing a wide array of pest control strategies—may contribute to its superior performance compared to other interventions. A study by Sulaiman *et al*. (2021) indicates that ACAS that provide holistic and diverse solutions tend to yield greater benefits, as they address multiple aspects of farming challenges faced by smallholders. The pronounced income benefits observed for both male and female adults indicate that IAS may serve as a pivotal mechanism for promoting gender equity in agricultural productivity. This supports the assertion by Quisumbing & McClafferty (2020) that inclusive agricultural interventions can mitigate gender disparities in income and resource access. Consequently, the robust findings from this study advocate for the scaling up of IAS to maximize its potential in fostering economic resilience and sustainability within smallholder farming systems in Northern Ghana.

The comparative analysis of Climate-Resilient Practices for Women Farmers (CPWF) and Water Management Interventions (WMI) reveals distinct patterns in their impact on income generation, particularly across gender and age demographics. For youths, CPWF demonstrates a marginal income increase for females GHS 320.44 per hectare, while male youth participants experience a notable decline in income GHS -851.77 per hectare. Among adults, CPWF yields only a slight increase in income for females GHS 130.77 per hectare, contrasted by a reduction for males GHS -340.90 per hectare. Although these effects are relatively small, the overall pooled results suggest a more negative outcome for male participants under CPWF when compared to WMI, with a pooled ATT value showing a decrease of GHS -1007.39 per hectare. These findings suggest that WMI is a more effective intervention in driving income growth, particularly for male farmers.

These results align with recent studies that compare the efficacy of climate-resilient agricultural practices and water management interventions. For instance, Kato *et al*. (2020) emphasize that while climate-resilient farming systems are critical for long-term sustainability, their short-term impact on income is often less pronounced compared to water management practices. WMI addresses immediate water-related constraints, which are crucial for improving agricultural productivity and farmer income, particularly in water-scarce regions (Rockström *et al*., 2017). The superior performance of WMI in this context highlights the importance of targeted interventions that directly address key limiting factors in agricultural production. Furthermore, these findings suggest that gender dynamics play a significant role in the differential outcomes of CPWF and

WMI. As noted by Ntare *et al*. (2022), water management interventions often provide more equitable benefits across gender lines due to their immediate impact on productivity. In contrast, the benefits of climate-resilient practices may require more time to materialize, particularly in contexts where male farmers dominate water-intensive crop production.

The comparative analysis of Integrated Pest Management ACAS (IAS) and Water Management Interventions (WMI) presents nuanced differences in income outcomes, particularly across gender and age categories. Female adults under IAS experience an income reduction of GHS -846.85 per hectare, while male adults report a more modest decrease of GHS -282.24 per hectare. These findings suggest that while WMI may yield more immediate income gains for adult farmers, particularly women, the potential long-term benefits of IAS should not be overlooked. The ATE results further indicate that IAS underperforms relative to WMI for pooled female participants, with an income reduction of GHS -646.58 per hectare, reinforcing the observation that WMI is more effective in boosting short-term income for both genders. However, the broader implications of IAS must be considered within the context of sustainable agricultural practices.

Current literature supports the notion that IAS, despite its comparatively lower short-term income effects, plays a crucial role in enhancing agricultural resilience and sustainability. Studies such as those by Altieri *et al*. (2018) highlight the importance of integrated pest management in reducing crop losses and mitigating long-term risks associated with pest infestations. The lower immediate income gains observed with IAS compared to WMI may be offset by its ability to address systemic issues in pest control, which is essential for sustaining productivity in the face of climate variability. Considering these findings, the relative underperformance of IAS in terms of immediate income benefits should not discount its value. The intervention may offer significant advantages in promoting sustainable agricultural systems, particularly in regions where pest pressures undermine productivity over time. Therefore, IAS remains a critical tool for smallholder farmers, especially in agro-ecological zones where pest management challenges are prevalent.

The comparative analysis of Integrated Pest Management ACAS (IAS) and Climate-Resilient Practices with Forecasting (CPWF) reveals distinct patterns in income generation, particularly across gender and age groups. IAS consistently demonstrates a stronger income effect than CPWF, especially for female farmers. The ATT results indicate that female adults experience a positive income impact of 334.9 GHS per hectare when adopting IAS over CPWF, underscoring the value of pest management in enhancing agricultural productivity. Conversely, male adults report a decrease of GHS -851.37 per hectare under IAS compared to CPWF, suggesting that CPWF may offer marginally better results for some male farmers, although these effects are less pronounced.

This finding aligns with research emphasizing the gendered impact of agricultural interventions, where the nature of the intervention may disproportionately benefit women or men depending on their roles in farming systems (Beuchelt & Badstue, 2019). Moreover, the ATE values provide further support for these observations. Female farmers consistently exhibit higher income increases under IAS, with an ATE of GHS 993.34 per hectare, while males report a negative ATE of GHS -919.99 per hectare. This disparity in outcomes can be attributed to the immediate and tangible benefits of pest control, which directly influence crop yields by mitigating losses due to pest infestations (Savary *et al*., 2019). In contrast, CPWF's emphasis on climate resilience and weather forecasting, while critical for long-term planning, may not offer the same short-term income boosts, particularly for male farmers engaged in high-input, high-risk farming activities where weather variability poses more immediate threats (Rockström *et al*., 2017).

The pooled analysis further reinforces IAS's superior performance, particularly for female farmers, highlighting its broader applicability and effectiveness in addressing the specific challenges they face. This outcome is consistent with the growing body of literature suggesting that women in agriculture often benefit more from interventions that address productivity bottlenecks, such as pest management, than from those focused solely on climate adaptation (Pretty & Bharucha, 2020).

IAS's direct focus on controlling pests translates to immediate improvements in yield and income, making it a particularly attractive option for female smallholders who are typically more engaged in crop management activities than their male counterparts (Altieri *et al*., 2018). In contrast, CPWF appears to offer mixed results, especially for male farmers. While CPWF promotes long-term climate resilience, its immediate income effects are less substantial, particularly for males in both youth and adult categories. This finding suggests that while CPWF has potential for future benefits by improving adaptive capacity and reducing vulnerability to climate shocks, it may not generate significant income increases in the short run, especially for those farmers whose livelihoods are less directly impacted by weather variability. This outcome is corroborated by recent studies which highlight that the benefits of climate ACAS are often gradual and more apparent in regions where extreme weather events are more frequent (Belete *et al*., 2021).

Overall, these findings underscore the importance of tailoring agricultural interventions to the specific needs and constraints of different demographic groups. WMI, IAS, and CPWF each offer unique advantages, but their effectiveness varies across gender and age. IAS emerges as the most consistent intervention in raising incomes, particularly for female farmers, by addressing pest-related challenges that directly impact crop yields. Conversely, CPWF, while essential for long-term climate resilience, may require complementary interventions to generate immediate income benefits, especially for male farmers. These insights suggest that an integrated approach to agricultural support, which combines pest management with climate ACAS, may be necessary to achieve equitable and sustainable income gains for smallholder farmers in Northern Ghana.

Table 4.12: Average Treatment Effects Estimates for Each Adoption Group: Total Income (GHS)

	ATT						ATE						ATU					
	Youths		Adults		Pooled		Youths		Adults		Pooled		Youths		Adults		Pooled	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
WMI Vs. Non-Adopters	4398.48***	-509.13	2727.77***	1875.77*	3719.48***	2802.83***	3701.41***	1906.96	3446.33***	2973.71***	3781.33***	3720.22***	3516.31***	5133.89**	4093.70***	2561.03***	3847.53***	3450.58***
	(629.37)	(1442.37)	(511.07)	(975.35)	(476.87)	(593.46)	(578.65)	(964.09)	(463.27)	(486.69)	(433.39)	(432.18)	(660.25)	(2940.08)	(621.22)	(815.64)	(445.09)	(591.53)
CPWF Vs. Non-Adopters	2425.09***	-1596.71	2493.71***	1689.57*	2262.53***	1642.35***	2571.03***	1320.87	3019.55***	2147.84***	2797.33***	2276.14***	2723.29***	6176.78***	2608.22***	1617.78***	2799.64***	1828.76***
	(589.28)	(1515.75)	(469.25)	(985.10)	(394.46)	(628.06)	(417.70)	(858.45)	(335.43)	(494.07)	(326.38)	(394.64)	(540.03)	(777.62)	(495.99)	(801.92)	(350.14)	(575.21)
IAS Vs. Non-Adopters	2929.76***	-558.03	3866.83***	1092.09	3166.53***	2461.29***	2690.36***	969.12	3232.88***	2540.79***	3134.76***	3271.13***	2480.64***	2706.84***	3437.09***	2174.18***	2932.08***	3112.23***
	(569.48)	(1382.20)	(662.06)	(1021.58)	(372.36)	(614.08)	(437.67)	(830.00)	(526.80)	(479.42)	(333.23)	(395.75)	(503.25)	(787.71)	(649.60)	(822.37)	(363.83)	(576.66)
CPWF Vs. WMI	-236.44	-815.77	-470.53	-103.77	-384.09	-1007.39**	-1130.38	-586.09	-426.78	-825.87	-984.01*	-1444.08***	-3632.07**	-5364.54	-3134.53	-1799.76***	-3514.42	-2574.22***
	(578.17)	(805.78)	(604.75)	(557.96)	(387.70)	(434.03)	(582.50)	(682.93)	(414.99)	(391.83)	(387.67)	(335.70)	(1632.72)	(3679.42)	(2490.28)	(813.66)	(3371.91)	(545.63)
IAS Vs. WMI	-936.67	-816.09	-846.85	388.7	-282.24	-432.39	-1011.05	-937.84	-213.44	-432.92	-646.58	-449.08	-3281.83	-3641.83	-3311.24***	-2074.49	-3500.77***	-3132.56
	(601.45)	(713.91)	(817.80)	(603.86)	(386.99)	(469.27)	(580.16)	(619.21)	(544.68)	(338.63)	(391.88)	(341.61)	(2507.51)	(2671.11)	(537.10)	(1801.09)	(373.29)	(2546.24)
IAS Vs. CPWF	334.9	-973.44	-851.37**	730.03	137.52	919.99***	119.33	-351.75	213.33	392.95	337.43	994.99***	-2687.90***	-4111.23	-2628.92	-1687.20	-2780.42	-2479.34
	(448.33)	(655.50)	(388.73)	(502.02)	(337.39)	(347.68)	(415.81)	(377.66)	(455.09)	(339.52)	(265.73)	(286.55)	(454.80)	(2623.97)	(1676.45)	(1793.15)	(2325.53)	(1544.30)

Source: Field Survey (2024); Standard errors in parentheses; * $p < 0.10$; ** $p < 0.05$; *** $p < 0.001$

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter presents a summary of the major findings, the major conclusions, and policy implications suggestions are given based on the major results. This chapter also includes ideas for further research.

5.2 Summary of The Study and All Major Findings

- The background of respondents highlights the socio-economic characteristics of smallholder grain farmers, focusing on age, gender, education, marital status, access to finance, and sources of finance, as well as household and farm characteristics. The study reveals noticeable variations in these characteristics, particularly between gender and age groups.
- The average age of female farmers is 39.8 years, while male farmers are older at 43.6 years, reflecting gendered patterns in agricultural participation. Youths average 28.7 years compared to adults at 54 years, highlighting a generational gap in farming. The pooled sample's average age of 41.7 years indicates a diverse age range, crucial for understanding productivity and technology adoption among diverse groups.
- Household size affects labour availability and economic sustainability. Female-headed households average 4.8 members, slightly fewer than male-headed ones at 4.9 members. Youth households are smaller, averaging 3.98 members, while adults have larger households at 5.65 members. The overall average household size is 4.84 members, reflecting variations in family structures that impact farm management and resource allocation.

- The study shows gender and age disparities in land ownership. Male farmers manage larger farms (3.16 acres) than female farmers (2.54 acres), reflecting gendered access to land. Youths and adults have similar average farm sizes of 2.81 acres and 2.89 acres, respectively. The pooled sample's average farm size of 2.85 acres underscores significant variations in landholdings, affecting productivity and technology adoption, particularly for women.

- Farming experience varies by gender and age. Male farmers average 12.46 years of experience, compared to 10.73 years for female farmers. Youths have significantly less experience (5.97 years) than adults (16.93 years), emphasizing the need for targeted support for younger farmers. The pooled sample's average farming experience is 11.60 years, reflecting a wide range where many farmers are experienced, but a notable portion has limited experience.

- Access to ACAS is relatively equitable across gender and age groups. Female farmers receive advisory information an average of 75.79 times, slightly more than male farmers at 71.39 times. Youths and adults have similar averages of 74.03 and 73.14 instances, respectively. While this indicates progress in inclusive information dissemination, variability persists due to factors like location and social networks.

- The gender distribution of respondents in Northern Ghana shows higher male participation in farming. Among adults, 60.33% are male, compared to 42.27% female, reflecting sociocultural norms favouring male involvement in formal agriculture. A similar trend is seen among youths, with 57.73% male and 39.67% female. This disparity suggests potential gender biases in access to ACAS, financial resources, or agricultural inputs in the region.

- Despite disparities within age groups, the overall gender distribution is nearly equal, with males at 50.41% and females at 49.59%. This balance indicates significant female participation in smallholder grain farming, despite male dominance in specific age categories. It underscores the need for a gender-sensitive approach in FM for ACAS to ensure equitable access to agricultural resources and support for both genders.

- The findings show that most adult respondents are married, with 83.01% of females and 77.48% of males, as shown in Table 4.2. Among youths, 78.95% of females and 67.81% of males are married. The high marriage rates among adults reflect rural community norms where marriage is associated with farming and household responsibilities. Among the youth, the percentage of single individuals is notably higher, with 19.64% of males and 12.77% of females reporting being single. This aligns with societal norms where younger individuals are less likely to be married compared to older adults.

- A significant portion of the population lacks formal education, especially adult females (61.44%) and adult males (40.09%). Among youths, 55.02% of females and 49.32% of males have no formal education, indicating better access to education for youths compared to adults. However, most youths only have primary or junior high school education, with secondary and tertiary education remaining low across all groups. This limited education may affect their access to advanced farming technologies and ACAS.

- Access to finance is crucial for smallholder farmers. The data shows that female farmers have slightly better access to finance than males. Specifically, 35.95% of adult females and

28.23% of female youths have access, compared to 34.05% of adult males and 23.09% of male youths. The primary sources of finance for the respondents include microfinance institutions, money lenders, village savings and loan associations, and support from family and friends. The results shows that money lenders and microfinance institutions are the most common sources of finance for all demographic groups, with family and friends also playing a significant role, particularly among adults.

- The FM supporting ACAS for smallholder farmers in Northern Ghana are diverse, varying by institutional sources, funding types, and community needs. These include grants, corporate sponsorships, government funding, service revenue, multilateral funding, private foundations, loans from commercial banks, Village Savings and Loan Associations, subscription fees, and international donors.

- The study uses Tobit analysis to examine factors influencing ACAS adoption by male and female farmers in Northern Ghana, highlighting key socio-economic and environmental drivers. Older male farmers prefer water management irrigation (WMI) due to experience, while younger farmers favor integrated pest management (IAS). Marital status affects the adoption of crop planning weather forecasts (CPWF), with married farmers being more cautious. Education enhances adoption of CPWF and IAS, as educated farmers can better understand complex tools. Household size impacts WMI adoption due to labor availability, while youthfulness encourages IAS adoption. Farming experience influences CPWF adoption, and smaller farms are more likely to adopt IAS for pest management. Land ownership has no significant effect, likely due to informal land tenure systems. Social capital, like membership in farmer-based organizations, supports WMI adoption. Awareness of ACAS is crucial for WMI and CPWF adoption, while traditional platforms like community centers are less effective, while radio remains a key source of information for WMI and IAS, and television has limited influence in rural areas.

- The analysis examines the factors influencing female grain farmers' adoption of ACAS in Northern Ghana, focusing on Water Management Irrigation (WMI), Crop Planning Weather Forecast (CPWF), and Integrated Pest Management (IAS). Key socio-economic, demographic, and educational factors such as age, marital status, formal education, household size, youthfulness, farming experience, and farm size shape adoption decisions. Younger farmers are more likely to adopt WMI, while older farmers often resist IAS due to traditional practices. Marital status positively affects CPWF adoption but not WMI or IAS. Formal education promotes WMI adoption but reduces reliance on CPWF and IAS, as educated farmers may access other information sources.
- The study explores the factors influencing the adoption of climate-smart agricultural services (ACAS) in Northern Ghana, with a particular focus on gender and age-related differences in agricultural productivity. It highlights that household size negatively impacts the adoption of Crop Planning Weather Forecasts (CPWF) but has no effect on Water Management Irrigation (WMI) or Integrated Pest Management (IAS). Farming experience and land ownership significantly influence WMI adoption, while larger farms are more likely to adopt CPWF. The study underscores the need for targeted interventions to address these factors and improve the adoption of climate-smart practices, particularly among female farmers.
- The analysis reveals that non-adopters consistently show lower productivity compared to adopters. Among youth non-adopters, females have higher productivity than males, but this trend reverses among adults, where males exhibit higher productivity. Adoption of

WMI significantly boosts productivity across all groups, with youth females producing 606.48 kg/acre and males 786.22 kg/acre. Both adult females and males achieve nearly identical productivity at 966.28 kg/acre and 966.74 kg/acre, respectively.

- Adoption of CPWF also leads to productivity gains, especially among adults, with youth females producing 563.01 kg/acre and males 466.02 kg/acre. Among adults, females produce 874.06 kg/acre, while males achieve 913.44 kg/acre. The adoption of IPM shows the highest productivity gains, with youth females producing 683.91 kg/acre and males 611.00 kg/acre. Among adults, females produce 885.06 kg/acre, while males achieve 957.35 kg/acre.

- The study highlights the transformative impact of ACAS adoption on agricultural productivity and emphasizes the importance of enhancing financial mechanisms to improve access to these services, especially for vulnerable groups like youth and female farmers. The Average Treatment Effects (ATE) and Average Treatment on the Treated (ATT) analyses reveal that WMI adoption leads to significant productivity improvements, with female youth adopters showing a higher increase (324.59 kg/acre) compared to male youth adopters (256.58 kg/acre). Among adults, female adopters experience a productivity gain of 603.56 kg/acre, nearly double that of male adopters (299.15 kg/acre). These findings emphasize the critical role of WMI in enhancing agricultural outcomes, particularly for female youth farmers.

5.3 Conclusions

The study concludes that gender and age significantly shape the socio-economic profile of smallholder grain farmers in Northern Ghana. Male farmers manage larger farms than females, reflecting persistent gender disparities in land ownership. Youths are generally less experienced, highlighting the need for targeted interventions to support their entry and success in farming. Household size, marital status, and education further influence labour availability, access to information, and adoption of agricultural innovations.

Access to Agricultural Climate Advisory Services (ACAS) appears relatively equitable across gender and age groups, but disparities persist. Female farmers and youths show slightly higher awareness and use of certain services, suggesting that gender-sensitive outreach improves adoption. Differences in location, social networks, and household characteristics influence access, underlining the importance of tailored delivery mechanisms.

Multiple financing mechanisms thus, grants, corporate sponsorships, government funding, commercial bank loans, VSLAs, subscription fees, and international donor support play a role in enabling access to ACAS. Each mechanism presents trade-offs between sustainability, scalability, and inclusivity. Women and resource-poor farmers face barriers to formal financing, emphasizing the need for gender-sensitive and specific financial frameworks.

The adoption of ACAS, particularly Water Management Irrigation (WMI), Crop Planning Weather Forecast (CPWF), and Integrated Pest Management (IPM) significantly improves productivity and income. Female farmers often experience larger gains when interventions are designed with gender considerations. Younger and better-educated farmers are more likely to adopt innovative practices, while older farmers rely on traditional methods. These findings demonstrate the importance of aligning ACAS delivery with socio-economic and demographic factors to maximize impact.

5.4 Recommendations

Agricultural Climate ACAS play a vital role in supporting smallholder farmers by providing timely climate information and climate-smart agricultural practices to enhance resilience and productivity in the face of climate change. For ACAS to be effective and sustainable, diversified funding from private, corporate, and governmental sources is essential. Private-sector partnerships and government support ensure continuous service delivery, while community-driven financing models, such as Village Savings and Loan Associations, empower farmers to invest in their agricultural future. This sustainable approach to ACAS financing fosters long-term resilience and supports farmers in navigating climate challenges, thereby contributing to national food security and rural development. Based on the results and discussions, the study proposes the following seventeen recommendations and policy actions.

1. **Establish Long-Term Funding Partnerships with Private Foundations, Corporations, and Government Entities:** Sustainable funding for ACAS requires robust partnerships that bring together resources and expertise from diverse stakeholders. Private foundations, corporate entities, and government agencies each play a critical role in the agricultural development ecosystem, and long-term collaboration among these sectors can provide consistent resources for ACAS, mitigating the risk of funding disruptions. Corporate foundations and international organizations often seek projects that align with their social impact goals, making them potential allies in building a resilient agricultural advisory infrastructure. Private-sector involvement, through corporate social responsibility initiatives, can support ACAS delivery and enhance service quality, as corporations may provide advanced technology and data analytics capabilities. Furthermore, governments

should prioritize establishing formal agreements and memoranda of understanding with these entities to secure predictable funding and ensure accountability.

2. **Design Grant Programs with Sustainability Plans to Transition from Dependency to Self-Sufficiency:** Grants are essential initial funding sources, especially for establishing new services in regions like Northern Ghana, where infrastructure and funding gaps are pervasive. However, over-reliance on grants may lead to issues of financial instability once grant periods conclude. To address this, grants should incorporate well-defined sustainability plans that aim to reduce dependency over time. This can involve creating exit strategies, whereby services transition towards self-sufficiency through locally driven financing models or revenue-generating activities. For instance, ACAS providers could implement a graduated fee structure, where smallholder farmers contribute nominal fees as their productivity and financial capacity increase. Establishing localized savings and credit groups, which align with the community's socio-economic structure, can provide farmers with microfinancing options to support ongoing ACAS access post-grant.

3. **Leverage Corporate Sponsorship for Digital ACAS Development in Underserved Regions:** Corporate sponsorship presents a valuable opportunity for expanding digital ACAS infrastructure to remote and underserved areas. Corporations can support the development and deployment of mobile applications, digital platforms, and other technology-based solutions that provide real-time climate and agricultural data to farmers, enhancing their adaptive capacity. For instance, companies involved in telecommunications or agricultural technology can offer expertise, infrastructure, and funding to promote ACAS in rural areas, thereby addressing the digital divide between urban and rural communities. Aligning these digital services with corporate CSR goals and

environmental sustainability objectives may encourage corporate investment, as it demonstrates social responsibility and enhances brand image within local communities. Government agencies should incentivize these contributions by recognizing corporate sponsors as key partners in rural development and exploring co-funding arrangements that maximize impact.

4. **Implement Tax Incentives for Corporations Investing in Rural Climate Services:** Tax incentives can be instrumental in motivating corporations to extend their reach into rural areas by investing in climate-focused ACAS projects. Reducing tax obligations for companies that fund ACAS initiatives enables these corporations to channel more resources towards rural development without sacrificing profitability. Tax incentives, such as deductions for costs associated with technology deployment in rural areas or reduced tax rates for CSR investments in climate resilience, can be particularly attractive to companies in the agribusiness and financial sectors. By lowering the financial barriers to corporate participation, such incentives encourage businesses to establish a sustained presence in rural communities and contribute to the resilience and productivity of smallholder farmers. Moreover, incorporating these incentives into national policy frameworks will enhance government oversight and ensure accountability among corporate contributors.

5. **Ensure Consistent Government Budgets Dedicated to ACAS:** Stable government funding is fundamental to the long-term viability of ACAS programs. Without reliable funding allocations from national and local government budgets, smallholder farmers risk losing access to vital climate-related ACAS that help them mitigate and adapt to climate variability. To address this, the government should establish a dedicated budget line for

ACAS within the national agricultural budget, thereby institutionalizing its support for these services. Such a budget line would facilitate improved financial planning, enabling government agencies to allocate resources predictably and consistently. Stable government funding is particularly critical for public ACAS programs aimed at low-income and marginalized farmers, who may lack alternative means to access these services.

6. **Develop Rural Outreach Programs to Enhance Accessibility of ACAS in Remote Areas:** Ensuring the reach and accessibility of ACAS in remote, underserved regions is essential to promote equitable service delivery. Rural outreach programs could include mobile advisory units, regional training centers, and collaborations with local organizations to deliver climate information directly to farmers. Government and NGO collaboration in such outreach initiatives can enhance sustainability by pooling resources and leveraging the networks of local organizations. For instance, mobile units that disseminate real-time climate data and farming recommendations can help bridge the gap for farmers located far from urban centers. Regional training centers, similarly, can provide smallholder farmers with knowledge on climate-smart agriculture practices, empowering them to independently apply ACAS recommendations. Additionally, establishing partnerships with community-based organizations allows for cultural adaptation and the provision of gender-sensitive training that aligns with local norms and needs.

7. **Reduce Collateral Requirements and Interest Rates for Climate-Focused Loans Tailored to Smallholder Farmers:** Access to affordable credit is a critical factor for smallholder farmers who wish to adopt climate-resilient farming practices and technologies. However, many smallholders face significant barriers in accessing formal financial services due to high collateral requirements and prohibitive interest rates. To

address this issue, financial institutions should design loan products specifically tailored for climate adaptation, with reduced collateral requirements and interest rates that reflect the financial realities of rural farmers. Lowering these barriers will enable farmers to invest in inputs, such as drought-resistant seeds and water-efficient irrigation systems, which are essential for resilience in the face of climate change. This approach aligns with the broader objective of inclusive finance and has been shown to improve adoption rates of sustainable practices among resource-constrained farmers.

8. **Enhancing Financial Accessibility through Literacy and Community-Based Mechanisms:** Financial accessibility remains a cornerstone for adopting climate-resilient agricultural practices. Smallholder farmers, particularly in underserved regions, often lack the skills and resources to access traditional loans, creating a need for targeted financial literacy programs. Providing financial literacy training tailored to the needs of smallholder farmers is essential for empowering them to manage credit, navigate loan applications, and make informed investment decisions.

   A comprehensive financial literacy initiative would cover topics such as budgeting, credit management, and investment in climate-resilient agricultural inputs, enhancing farmers' capacity to utilize available financing effectively for climate adaptation. In areas with limited access to formal banking, expanding Village Savings and Loan Associations (VSLAs) provides an accessible and reliable financial model. VSLAs offer community-based savings and lending options, enabling farmers to accumulate small savings and take out loans for productivity-enhancing investments without the constraints of traditional banking services. By fostering the expansion of VSLAs, policymakers can help strengthen local financial ecosystems that support climate-smart investments and build resilience within farming communities. To maximize the impact of VSLAs, these organizations could also serve as hubs for both financial and climate information dissemination. VSLAs convene community members regularly, making them ideal venues for disseminating information on climate-smart agricultural practices and offering ACAS training sessions. By integrating ACAS into VSLA activities, these associations can become multipurpose spaces that support both financial literacy and agricultural adaptation, creating synergies that enhance local resilience.

9. **Implementing Subsidies and Sliding-Scale Pricing for Vulnerable Farmers:** A significant barrier to accessing ACAS services for low-income farmers is cost. Policymakers should consider sliding-scale pricing models for ACAS, allowing service costs to be adjusted according to farmers' income levels. This pricing model ensures affordability for the most vulnerable farmers while maintaining cost recovery for service providers. By making ACAS services financially accessible, a sliding-scale fee structure could significantly enhance the reach of climate ACAS and enable low-income farmers to benefit from critical information on climate resilience. Further, targeted subsidies in collaboration with NGOs and government entities can ensure that even the poorest farmers are not excluded from accessing ACAS. NGOs and government agencies can partner to subsidize the costs associated with climate ACAS, such as training fees, data costs, or input prices, providing essential support to low-income farmers. By pooling resources from diverse funding sources, targeted subsidies can make ACAS financially sustainable while ensuring that the economically disadvantaged farmers can access vital climate services.

10. **Fostering Gender-Sensitive Approaches to ACAS Delivery:** A gendered approach to ACAS financing and delivery is crucial for ensuring equitable participation. Women

farmers face unique challenges, including restricted mobility, time constraints due to household responsibilities, and limited decision-making power within agricultural settings. Therefore, it is vital to design gender-sensitive programs that cater specifically to women's needs. For instance, women-only training sessions and mobile outreach programs can help overcome barriers to participation, enabling more women to access climate ACAS. By structuring these programs around women's schedules and using culturally appropriate communication channels, ACAS services can increase female engagement and support women's roles in agricultural decision-making. In addition to creating women-centered training, encouraging women's leadership within farmer organizations is essential to fostering a gender-sensitive agricultural environment.

Promoting women in leadership positions within farmer-based organizations (FBOs) helps ensure that ACAS programs reflect the needs and perspectives of women farmers, ultimately enhancing program inclusivity. Policies supporting gender-balanced leadership within FBOs can lead to more inclusive decision-making processes, fostering a supportive environment for both male and female farmers. Moreover, the use of gender-specific communication channels can enhance the effectiveness of ACAS. In many communities, men and women access information through different means—men may prefer radio broadcasts, while women may rely on community networks. Adapting communication strategies to these differences can significantly improve the reach and impact of climate ACAS, ensuring that information reaches farmers effectively regardless of gender.

11. **Adapting Advisory Content for Local Contexts and Youth Engagement:** To ensure that climate advisory content is accessible and applicable, it is essential to adapt ACAS materials to local languages and literacy levels. Given the diversity of literacy levels among

smallholder farmers, especially in rural areas, ACAS materials should incorporate visual aids, audio content, and translations into local languages to make climate information universally accessible. By tailoring ACAS content to the linguistic and educational backgrounds of local farmers, policymakers can improve understanding and enable broader adoption of climate-smart practices. Engaging youth in climate-resilient agriculture is equally important for ensuring a sustainable future for Ghana's agricultural sector. Developing mentorship, training, and loan programs tailored for young farmers can play a significant role in this regard. Such programs would provide young farmers with the necessary skills, resources, and confidence to adopt climate-smart practices and become leaders within their communities. Mentorship from experienced young farmers can further incentivize youth engagement by offering relatable role models and fostering a sense of community and shared purpose. Establishing youth-focused cooperatives is another effective strategy to support climate-smart agriculture among younger farmers. Youth cooperatives provide a platform for shared resources, peer learning, and collective bargaining, helping young farmers to overcome the challenges of limited access to resources and information. Additionally, youth cooperatives give young farmers a stronger voice in agricultural policymaking, allowing them to advocate for the resources and support they need to thrive.

12. **Utilizing Technological Solutions for Real-Time ACAS Delivery:** With the growing accessibility of mobile technology, developing SMS- and app-based services for real-time climate information is a practical solution to reach remote farmers. Mobile services can deliver timely updates on weather forecasts, pest outbreaks, and soil health, allowing farmers to make informed decisions that enhance climate resilience. The use of mobile

technology makes ACAS more accessible to farmers in isolated areas, reducing the need for physical ACAS, which may be logistically challenging and resource intensive. To ensure that mobile ACAS services are universally accessible, policymakers should partner with NGOs to provide mobile devices and subsidize data costs for farmers. This collaboration can make mobile technology more affordable for farmers, especially in low-income households, by providing devices at reduced costs and supporting data plans. Such partnerships can address economic barriers to digital ACAS access, promoting equitable access to essential climate information.

13. **Promoting Inclusivity in Farmer-Based Organizations:** Farmer-Based Organizations (FBOs) are instrumental in disseminating climate advisory information and supporting collective action. However, many FBOs fail to consider the specific needs of women farmers. Adjusting meeting times and offering women-specific training can help make FBOs more inclusive, encouraging greater female participation. Simple adaptations, such as scheduling meetings at times convenient for women or providing childcare during sessions, can significantly improve female attendance and engagement within FBOs. Additionally, providing subsidies or allowances for women's participation in FBO activities can help reduce economic barriers. Financial support for travel, training fees, or other related expenses allows women to participate fully in FBO initiatives, strengthening their role in climate-smart agricultural practices. Through these inclusive measures, FBOs can create a supportive environment that empowers women to take an active role in climate resilience initiatives and agricultural development.

14. **Establishing Long-Term Projects with International Donors for Capacity-Building and Training:** Collaborative, long-term projects with international donors play a crucial

role in building local institutional capacity and reducing dependency on temporary funding sources. By engaging in multi-year projects, international donors and local institutions can establish comprehensive training and capacity-building initiatives that enhance both the quality and scope of ACAS. These projects are designed to equip local institutions with the necessary skills, resources, and technical knowledge to manage ACAS independently. Capacity-building programs can focus on critical areas, including climate data analysis, advisory dissemination, and the integration of ACAS with local agricultural practices. Moreover, building institutional expertise fosters knowledge retention within local organizations, ensuring that they can deliver ACAS effectively beyond the timeframe of external funding. Such collaborations can result in a strengthened local ACAS infrastructure, better prepared to address the evolving needs of smallholder farmers.

15. **Phased Co-Financing Models to Support Sustainability and Local Ownership:** To promote sustainable ACAS funding, a co-financing model in which international donors and local institutions gradually share the funding responsibility can be highly effective. In this model, international donors provide initial funding, supporting foundational ACAS activities while allowing local institutions to build the necessary capacity to manage these services over time. A phased approach enables local agencies to progressively assume greater financial responsibility, ensuring that by the project's end, local actors are fully equipped and prepared to sustain ACAS delivery. This co-financing structure fosters a sense of local ownership and accountability, which enhances the likelihood of continued support for ACAS among local stakeholders. Moreover, co-financing establishes a foundation for financial sustainability, ensuring that ACAS initiatives remain functional and responsive to the needs of smallholder farmers even after donor support ends.

16. **Expanding Financial Literacy Programs for Climate-Smart Investment:** Financial literacy is essential for smallholder farmers to manage their finances effectively and make informed decisions regarding climate-smart investments. Offering budgeting and savings training to farmers can empower them to manage their resources efficiently and maximize the benefits of available funding sources. Training programs in financial literacy should address practical skills, such as savings management, budgeting, and financial planning, to help farmers allocate resources toward climate-smart agricultural technologies and practices. Developing strong budgeting skills among farmers can also facilitate a smoother transition to sustainable climate-smart practices, as farmers gain the capacity to manage ongoing expenses related to ACAS independently. Financial literacy also enables farmers to plan for future costs, reducing reliance on external financial aid and fostering self-sufficiency in adopting climate-resilient practices.

    To maximize the reach and effectiveness of financial literacy training, partnerships with local organizations are crucial. Local entities, such as community groups, cooperatives, and farmer associations, possess in-depth knowledge of local contexts and enjoy high levels of trust among community members. By collaborating with these local organizations, ACAS stakeholders can deliver tailored financial literacy programs that resonate with rural farmers, ultimately driving greater program participation and engagement. Financial literacy programs delivered by trusted local organizations are likely to achieve higher levels of farmer buy-in and can facilitate more meaningful impacts on financial behavior and resource allocation for climate adaptation.

17. **Ensuring Land Rights for Women to Enhance Access to ACAS and Financing:** Access to land ownership and formal land-use rights is a pivotal factor in empowering female

farmers to participate fully in climate-smart agriculture and access financing for ACAS. In many rural communities, women face significant barriers to land ownership, limiting their eligibility for loans and hindering their ability to invest in climate-smart technologies and practices. Therefore, securing land rights for women is a critical policy priority. Legal reforms aimed at ensuring women's land ownership rights are fundamental for improving their economic standing and enabling them to access financial resources for ACAS.

Secure land rights provide women with the collateral required to obtain loans, thereby facilitating investment in productivity-enhancing and climate-resilient agricultural technologies. In addition to broader land ownership rights, targeted legal support for formalizing land use agreements can further stabilize women's access to land. Many women rely on informal agreements to access land, which may be vulnerable to sudden changes or disputes. By providing legal aid services to assist women in formalizing these agreements, policymakers can offer women greater security in their land tenure. Formalized land rights encourage long-term investment in farms, as women can plan and invest without fear of losing access to their land. In turn, these investments improve both individual and household resilience to climate change, enabling women to implement ACAS recommendations that support sustainable agriculture.

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APPENDICES

Appendix 1 : QUESTIONNAIRE

FINANCING MECHANISMS FOR ACAS FOR SMALLHOLDER GRAIN FARMERS IN NORTHERN GHANA: A GENDERED ANALYSIS

You're invited to join a research study focusing on the financial mechanisms available to smallholder grain farmers in Northern Ghana for accessing ACAS and the influencing factors. The goal is to enhance access to ACAS through affordable FM. The interview, with your consent, may be audio or video recorded. Minimal risks, mainly related to data confidentiality, are addressed with safeguards. You can decline questions, and there are no significant anticipated risks. While no direct personal benefits exist, your contribution is crucial for shaping policies and programs. Your personal data will be confidential, not used in reports, and recordings will be deleted. Participation is voluntary, and you can withdraw without consequences. This research is for academic purposes only. Questions are welcome. You can contact the **PRINCIPAL SUPERVISOR** Prof. Irene S. Egyir on **0240932768** and **RESEARCHER** Maureen Erekua Odoi on 0244383293 for further enquiries.

SECTION A: ***[Gathers identifying details of the respondent including name, phone number, location (region, district, community), and their role (farmer, financial institution, research institution, etc). This establishes who is providing the survey responses.]***

Name of enumerator	
Date	
Telephone number	
Region	a) Northern b) Savannah
District	a) Saboba district b) Guishegu district c) Yendi district d) West Gonja district
Community	a) Saboba b) Guishegu

	c) Yendi d) Supuni e) Busunu
Role of respondent	a) Farmer b) Financial institution c) Research institution/University d) NGO e) Metropolitan, Municipal and District Assemblies (MMDAs) f) FBO g) Private institution
If respondent is not a farmer, skip all other sections and focus on SECTION G part B to part E	

SECTION B: HOUSEHOLD INFORMATION (Objective 3) ***(Asks questions to understand the demographic and socioeconomic characteristics of the respondent farmer and their household. It covers details like gender, age, education level, marital status, household size, age, and gender composition of members. This provides insights into the farmer's background.)***

Gender of respondent	a) Male b) Female c) Other
What is the age of the respondent?	
Please select the age group you belong to	a) Below or = 14 years b) 15 years to 24 years c) 25 years to 60 years d) Above 60 years
Is the respondent the household head?	a) Yes b) No
If no, what is the relationship of the respondent to the head	a) Wife b) Husband c) Adult child living at home d) Other relative
What is the marital status of the respondent?	a) Single b) Married

	c) Consensual union d) Divorced e) Widowed f) Separated	
What is the highest level of education attained by the respondent?	a) No formal education b) Basic education c) Secondary education d) Tertiary education e) Vocational f) Other	
Can the respondent read a phrase/ sentence in English	a) Yes b) No	
What is the household size (number of members)?		
What is the age category of the members of the household?	Male	Female
Bellow or = 14 years		
15 years to 24 years		
25 years to 60 years		
60 years and above		

1) Are you part of a farmer-based organization?

a) Yes

b) No

2) If yes, what benefits do you get?

a) Training on good agronomic practices

b) Access to climate information

c) Access to financing

d) Labour help from farmer (Building social capital)

e) Others (specify);

…………………………………………………………………………

3) What is the distance from your house to the nearest Agricultural extension agent/ service provider's office? (Select the one you can provide an answer for)

a) Kilometers (km)

b) Hours

4) Please state distance……………………………(km)

5) Please state distance …………………………….(hours)

SECTION C: LAND HOLDING STATUS (Objective 3) ***(Focuses on getting comprehensive data on the farmer's land holding status across owned, rented, shared, and communal land. It captures ownership details, size of holdings, duration of farming, and whether grain farming is the main livelihood. This indicates the farmer's asset base, scale of operations, and dependence on agriculture.)***

Ownership Type	**Yes = 1 No = 0**	**In whose name is the land owned/ shared/ rented**	**Distance from home to the land (km)**
Owned			
Rented from others			
Rented to others			
Sharecropped			
Temporary offer for cropping			
Communal land			

1. Size of land (fill in the one applicable to you)
   a. Acre: ……………………………..
   b. Hectares:……………………………..

c. Plot:…………………………………
d. Poles:……………………………………
e. Ropes:………………………………….

2. How many years have you been farming on the land? ……………………….Years
3. Is farming your main occupation?

a. Yes

b. No

4. If yes, is grain farming your main production practice?

a. Yes

b. No

5. If yes, which grains do you mainly produce?

a. Maize and others

b. Soya bean and others

c. Both

d. None of the above

SECTION D: CLIMATE INFORMATION USAGE AND SERVICES ***(Gathers information on the farmer's experience with accessing and using climate information services for farming. It covers awareness, type of information received, perceived usefulness, trusted sources, duration, frequency, and costs. This helps assess climate information needs and gaps.)***

1. Do you have access to climate information?

a. Yes

b. No

2. If yes, what type of information?

a. Rainfall on-set

b. First cessation

c. Second cessation

d. Temperature

e. Humidity

f. Rainfall on-set

g. Rainfall volume

h. Any other, please specify

……………………………………………………………….

3. How useful is the climate information?

a. Very useful

b. Somewhat useful

c. Not useful

4. What is the source of the climate information?

a. NGO (please list):

……………………………………………………………………….

b. FBO

c. Other farmers

d. Media (Radio, TV, Community information centres, Public address systems)

e. Digital media (SMS and social media)

f. Extension agents

g. Other: ………………………………………………………………………………

5. Do you trust the source?

a. Yes

b. No

6. How long(Years) have you been receiving climate information?...........................Years
7. How frequently have you received climate information in the past year?
    a. Daily
    b. Weekly
    c. Monthly
    d. Annually
8. Do you pay for the information?
    a. Yes
    b. No
9. If yes, how much do you pay per information?.......................................GHS

SECTION E: CLIMATE SMART AGRICULTURAL PRACTICES (Evaluates climate-smart agricultural practices adopted by the farmer for grain farming using a multi-criteria prioritization approach. It captures awareness, current use, sources of learning, year of starting, coverage, and reasons for preference based on climate-smartness, gender, health, end-user, and other criteria. This identifies sustainable practices with higher adoption appeal.)

1. Are you aware of climate-smart agricultural practices?
    a. Yes
    b. No
2. Which of the following CSA practices are you aware of? (select all that applies to you)
    a. Conservation Agriculture (Minimum tillage)
    b. Improved crop varieties [Stress(drought, early maturing, striga and low N) tolerant]

c. Agroforestry (intercropping maize and tree crops on the farm land)

d. Water Harvesting and Management?

e. Other:

……………………………………………………………………………….

3. Do you use the selected practices?

a. Yes

b. No

4. Where do you get information on the practices?

a. NGO

b. FBO

c. Other farmers

d. Media (Radio, TV, Community information center, and Public address systems)

e. Digital media (SMS and social media)

f. Agricultural extension agents

g. Other (Specify):…………………………………………………….

5. How many acres of your land do you practice these CSAs on?..

SECTION F: COST OF PRODUCTION (Objective 3 and 5) (Focuses on capturing granular data on costs associated with priority climate-smart agricultural practices from section E. It includes source, distance, unit costs of items like seeds, chemicals, implements, land, etc., and farmer's perception of affordability. This indicates the economic accessibility of CSA practices.)

6. Where do you buy your inputs for production?

a. Agriculture input seller in my community
b. Agriculture input sellers in nearby community
c. Colleague farmer
d. FBOs
e. A major city
f. Other specify…………………………………………………….

7. What is the distance from your house to where you buy your input?(Please select and fill in what applies to you)
    a. Kilometers:………………………………………..
    b. Hours:………………………………………..
8. Which of the following farm inputs did you use in the last cropping season?
    a. Fertilizer
    b. Seeds
    c. Pesticides (weedicide, insecticide, and pesticides)
    d. Smaller farm implements
9. How much did you spend on fertilizer per acre in the last cropping season?..................................(GHS)

10. How much did you spend on seeds per acre in the last cropping season?..................................(GHS)

11. How much did you spend on pesticides (weedicide, insecticide, and pesticides) per acre in the last cropping season?...................................(GHS)

12. How much did you spend on smaller farm implements in the last cropping season?...................................(GHS)

13. What is your perception of the cost of farm inputs?

    a. Expensive
    b. Moderate
    c. Cheap/Low

14. What is your source of labour?

    a. Family labour
    b. Hired labour
    c. Other

15. How much do you spend on hired labour for grain cultivation in a season?

    ……………………………(GHS)

SECTION G: ACAS (Objectives 2 and 3) (Specifically looks at farmers' awareness, access, and use of bundled ACAS. It identifies information sources, trust, frequency, usefulness, willingness to pay, constraints faced, and types of services accessed. This helps evaluate effective delivery models.)

1. Are you aware of ACAS (a bundle of climate information and climate-smart agriculture)?

   a. Yes

b. No

2. From what source did you hear about ACAS?

    a. NGO

    b. FBO

    c. Other farmers

    d. Media (Radio, TV, Community information center, and Public address systems)

    e. Digital media (SMS and social media)

    f. Agricultural extension agents

    g. Other (Specify):…………………………………………………

3. Do you trust the source?

    a. Yes

    b. No

4. Have you received any ACAS?

    a. Yes

    b. No

5. How frequently have you received ACAS in the past year?

    a. Daily (please specify number of times):………………………………………...

    b. Weekly (please specify number of times):……………………………………........

    c. Monthly (please specify number of times):……………………….....................

    d. Annually (please specify number of times):……………………………………..

6. On average, how many times in the cropping season did you receive ACAS?:……………………………………………………………………..

7. Are the ACAS useful to you?

a. Yes

b. No

8. What constrains your access to these advisories?

………………………………………………………………………………………..

Commodities	**Agro-climatic advisory service**	**Tick for the agro-climatic advisory service you have had access to**
Maize and Soya bean	Crop planning and weather forecasting service	
	Water management and irrigation scheduling service	
	Integrated pest management advisory service	

SECTION H (a): FM (Farmer as the respondent) (Objective 1 and 4) (Targets various stakeholders to map existing FM for ACAS (ACAS). It captures details around specific products, eligibility criteria, monitoring processes, gender considerations, conditionalities, training/support provided, and suggestions for improvement. This highlights finance-related gaps and opportunities.)

1. Are you currently accessing any financial services for ACAS?

a. Yes

b. No

2. If yes, what sources do you use to finance your access to ACAS?

   a. Relatives and friends

   b. Informal savings and credit groups

   c. Money lender

   d. Government credit schemes

   e. NGO (Please state the NGO) :…………………………………………..

   f. Bank

   g. Micro-finance institution

   h. Other(S) please specify:………………………………………………………….

3. Have you received credit from any financial institutions?

   a. Yes

   b. No

4. What type of collateral was required for the loan?

   ……………………………………………………………………………………………

5. What challenges did you face in obtaining financing?

   ………………………………………………………………………………………

6. If no, what is your reason for not accessing financial services?

   ……………………………………………………………………………………………

7. Has access to the final services enabled you to use more ACAS?

   a. Yes

   b. No

8. If yes, which specific

   ACAS?...

9. How has financing facilitated use of the

   ACAS?...

SECTION H (b): FM (Financial institution as respondents) (Objective 1) (Implementation)

1. Which group(s) do you provide services for?

   a. FBOs

   b. Smallholder farmers

   c. Others (Please specify):……………………………………………………….

2. What financing does your institution currently provide for smallholder grain farmers in Northern Ghana?

   a. Loans

   b. Grants

   c. Investments

   d. Insurance

   e. Other (specify):…………………………………………………………….

3. What financing does your institution currently provide for FBOs in Northern Ghana?

   a. Loans

   b. Grants

   c. Investments

   d. Insurance

   e. Other (specify):…………………………………………………………….

4. Does your institution provide ACAS (a bundled service of CSA and CIS plus others) for smallholder grain farmers in northern Ghana?
    a. Yes
    b. No
5. If yes, please describe the key features……………………………………………………………………………………… ………………………………………………………………………………………………
6. Does your institution provide ACAS (a bundled service of CSA and CIS plus others) for FBOs in northern Ghana?
    a. Yes
    b. No
7. If yes, please describe the key features……………………………………………………………………………………… ………………………………………………………………………………………………
8. Where do get funding for the ACAS?
    a. Government grants
    b. Development agency funds
    c. Corporate Sponsorships
    d. Financial institutions
    e. Institutional funds
    f. Other (specify):………………………………………………..
9. What conditions does your primary funding source place on agro-climatic advisory service funding regarding gender and youth?

a. Funding must support women farmers equally

b. Percentage of funding must support young farmers under 30

c. Funded programs must collect data of farmers disaggregated by gender and age

d. No specific gender or youth requirements

e. Other(Specify):……………………………………………………………………….

How many small holder farmers benefited from your funding source	Male	Female
Government grants		
Development agency funds		
Corporate Sponsorships		
Financial institutions		
Institutional funds		

10. What are the eligibility criteria for smallholder grain farmers to qualify for financing for the implementation of ACAS from your institution?...

....

11. Does your institution offer special financial products, priority incentives or benefits targeted specifically towards women smallholder grain farmers for accessing/implementing ACAS?

a. Yes

b. No

12. If yes please select the applicable options

    a. Reserved quota of loans for only women borrowers
    b. Lower interest rates on loans for women farmers
    c. Relaxed collateral requirements for women farmers
    d. Capacity building and training programs tailored to women
    e. No specific targeting or benefits for women borrowers

13. What kind of ACAS can be financed using your loan/grant products?

    a. Crop planning and weather forecasting service
    b. Water management and irrigation scheduling service
    c. Integrated pest management advisory service
    d. Other

       (Specify):…………………………………………………………………………………

       …………………………………………………………………………………………

14. Is there any specific criteria for a smallholder farmer to qualify for the funds specifically for supporting ACAS?

    a. Yes
    b. No

15. If yes, please specify:……………………………………………………………………..

16. Is there any specific criteria for an FBO to qualify for the funds specifically for supporting ACAS?

    a. Yes
    b. No

17. If yes, please specify:……………………………………………………………………..

18. What are the main challenges faced by smallholder grain farmers in accessing financing from your institution for the implementation of ACAS?
    a. Poor credit history
    b. Low or irregular income
    c. High debt-to-income ratio
    d. Lack of credit history
    e. Insufficient collateral/security
    f. Other (Specify):………………………………………………………………
19. In your view, what can be done to increase uptake of financing for implementation of ACAS among smallholder farmers in Northern Ghana?...
    ....
20. Do you have other suggestions of financing to improve small holder grain farmers access to ACAS?...
    ....
21. How many employees does your institution currently have? ……………………………
22. What is your institution's annual operating budget? ……………………………GHS
23. In how many geographic regions does your institution operate?
    a. Norther region
    b. Savanna region
    c. Both
    d. Other In
24. Has your institution ever defaulted on a loan or failed to repay a grant?
    a. Yes
    b. No
25. What is your institution's credit rating from major credit rating agencies?
    a. High
    b. Low

26. What are your institution's primary areas of focus?
    a. Developing farmer-centric financial products
    b. Providing affordable credit and weather-indexed insurance
    c. Partnering with agro-input providers for bundled services
    d. Evaluating gender-specific financing needs
    e. Other
27. What is your institution's risk tolerance for different FM?
    a. Aggressive
    b. Moderate
    c. Conservative
28. What is your institution's legal structure?
    a. Nonprofit
    b. Government agency
    c. Private Company
    d. Other
29. Does your institution's legal structure impact its financing options?
    a. Yes
    b. No
30. Are there any legal restrictions or requirements related to your institution's financing activities?
    a. Yes
    b. No
31. Does your institution have any partnerships or collaborations with other organizations?
    a. Yes
    b. No
32. What types of FM has your institution used in the past?
    a. Donor funds
    b. Government subsidies
    c. Loans
    d. Private sector initiatives
    e. Cooperative financing
33. Are there any specific regulations or compliance requirements related to different FM?
    a. Yes
    b. No
34. Do the individual preferences and biases of decision-makers within your institution influence the choice of FM?
    a. Yes
    b. No
35. Does your institution's organizational culture shape decision-making processes related to financing?
    a. Yes
    b. No
36. Are there specific FM that are perceived as riskier or less risky within your institution?

a. Yes
b. No

37. How important is your institution's trustworthiness and reputation in the financial community when it comes to accessing certain FM?
    a. Very important
    b. Not so important
38. Have changes in market sentiment affected your institution's ability to access certain financing options in the past?
    a. Yes
    b. No
39. Are there any political pressures or incentives that influence your institution's choice of financing mechanism?
    a. Yes
    b. No
40. What measures are in place to ensure that all relevant information is considered during the financing decision-making process?..
41. What processes are in place to incorporate future expectations into financing decisions?..
42. What is your level of investment in agroclimatic data and information technology?
    a. High
    b. Medium
    c. Low
43. What is the expertise of your staff in areas like meteorology, agriculture, and climate science?
    a. Very experienced
    b. Somewhat experienced
    c. Limited experience
44. How do you engage with local communities to understand their advisory service needs?..
45. To what extent have you adopted innovative agroclimatic advisory approaches?
    a. Extensively
    b. Moderately
    c. Limited

46. What mechanisms do you use to collect feedback from advisory service users?
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47. What measures do you have in place to ensure quality of your ACAS?
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48. How do you allocate resources to support agroclimatic ACAS?
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SECTION H (c): FM (NGOs as respondents) (Objective 1)

1. Does your organization have any programs focused on smallholder grain farmers in Northern Ghana?
   a. Yes
   b. No
2. Please list the programs:……………………………………………………………………..
3. Does your organization provide ACAS (a bundled service of CSA and CIS plus others) for smallholder grain farmers in northern Ghana?
   a. Yes
   b. No
4. If yes, please describe they key features

   …………………………………………………………………………………………………

   ………

5. Does your organization provide any financing assistance to grain farmers for accessing ACAS?
    a. Yes
    b. No
6. Where do you get funding for ACAS?
    a. Government grants
    b. Development agency funds
    c. Corporate Sponsorships
    d. Financial institutions
    e. Institutional funds
    f. Other (specify):……………………………………………..
7. What conditions does your primary funding source place on agro-climatic advisory service funding regarding gender and youth?
    a. Funding must support women farmers equally
    b. Percentage of funding must support young farmers under 30
    c. Funded programs must collect data of farmers disaggregated by gender and age
    d. No specific gender or youth requirements
    e. Other(Specify):…………………………………………………………………….

How many small holder farmers benefited from your funding source	Male	Female
Government grants		
Development agency funds		

Corporate Sponsorships		
Financial institutions		
Institutional funds		

8. What types of ACAS does your programs offer?
    a. Crop planning and weather forecasting service
    b. Water management and irrigation scheduling service
    c. Integrated pest management advisory service
    d. Other

       (Specify):………………………………………………………………………………

       ………………………………………………………………………………………
9. What is the criteria that a smallholder farmer must meet to be part of these programs?……………………………………………………………
10. Do women smallholder grain farmers get any special priority or benefits in your organization's program for financing ACAS?
    a. Yes
    b. No
11. If yes, please specify:…………………………………………………………………

12. Does your organization provide any training, guidance or handholding support to assist farmers in effectively utilizing financing for ACAS (ACAS)?
    a. Yes
    b. No
13. If yes, Please specify some of the activities:……………………………………………………………………………….
14. In your view, what are the main challenges and adoption barriers faced by smallholder grain farmers in terms of accessing and utilizing financing for agro-climatic advisories?..
15. Please suggest ways that accessibility and affordability of ACAS can be increased for smallholder grain farmers in Northern Ghana
    ……………………………………………………………
16. How many full-time and part-time employees does your NGO currently have?......................
17. What is your NGO's annual operating budget?................................GHS
18. In which geographic regions or countries does your NGO operate?
    a. Norther region
    b. Savanna region
    c. Both
    d. Other
19. Has your NGO ever defaulted on a loan or failed to meet the terms of a grant agreement?
    a. Yes
    b. No
20. What is your NGO's primary areas of focus?
    a. Advocating for gender-equitable access policies
    b. Facilitating farmer-finance provider linkages
    c. Piloting alternative FM
    d. Conducting gender assessments of advisory needs
    e. Other

21. What is your institution's risk tolerance for different FM?
    a. Aggressive
    b. Moderate
    c. Conservative
22. What is your NGO's legal structure?
    a. Nonprofit
    b. Charitable Organization
    c. Foundation
23. Does your NGO's legal structure impact its ability to access certain financing options?
    a. Yes
    b. No
24. Does your NGO have any partnerships with other organisations?
    a. Yes
    b. No
25. What types of FM has your institution used in the past?
    a. Donor funds
    b. Government subsidies
    c. Loans
    d. Private sector initiatives
    e. Cooperative financing
26. Are there any specific regulations or compliance requirements related to different FM?
    a. Yes
    b. No
27. Do the individual preferences and biases of decision-makers within your institution influence the choice of FM?
    a. Yes
    b. No
28. Does your institution's organizational culture shape decision-making processes related to financing?
    a. Yes
    b. No
29. Are there specific FM that are perceived as riskier or less risky within your institution?
    a. Yes
    b. No
30. How important is your institution's trustworthiness and reputation in the financial community when it comes to accessing certain FM?
    a. Very important
    b. Not so important
31. Have changes in market sentiment affected your institution's ability to access certain financing options in the past?
    a. Yes
    b. No

32. Are there any political pressures or incentives that influence your institution's choice of financing mechanism?
    a. Yes
    b. No
33. What measures are in place to ensure that all relevant information is considered during the financing decision-making process?..
    ....
    ....
34. What processes are in place to incorporate future expectations into financing decisions?..
    ....
    ....
35. What is your level of investment in agroclimatic data and information technology?
    a. High
    b. Medium
    c. Low
36. What is the expertise of your staff in areas like meteorology, agriculture, and climate science?
    a. Very experienced
    b. Somewhat experienced
    c. Limited experience
37. How do you engage with local communities to understand their advisory service needs?..
    ....
    ....
    ....
    ....
38. To what extent have you adopted innovative agroclimatic advisory approaches?
    a. Extensively
    b. Moderately
    c. Limited
39. What mechanisms do you use to collect feedback from advisory service users?
    ....
    ....
    ....
    ....
    ....
40. What measures do you have in place to ensure quality of your ACAS?
    ....
    ....
    ....

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41. How do you allocate resources to support agroclimatic ACAS?
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SECTION H (d): FM (Research institutions and/or Universities as respondents) (Objective 1)

1. Does your institution provide research and programs focused on smallholder grain farmers in Northern Ghana?
   a. Yes
   b. No
2. Does your institution provide research and programs focused on ACAS (a bundled service of CSA and CIS plus others) for smallholder grain farmers in Northern Ghana?
   a. Yes
   b. No
3. Where do you get funding for your projects?
   a. Government grants
   b. Development agency funds
   c. Corporate Sponsorships
   d. Financial institutions
   e. Institutional funds
   f. Other (specify):……………………………………………..
4. What conditions does your primary funding source place on agro-climatic advisory service funding regarding gender and youth?

a. Funding must support women farmers equally

b. Percentage of funding must support young farmers under 30

c. Funded programs must collect data of farmers disaggregated by gender and age

d. No specific gender or youth requirements

e. Other(Specify):……………………………………………………………………….

How many small holder farmers benefited from your funding source	Male	Female
Government grants		
Development agency funds		
Corporate Sponsorships		
Financial institutions		
Institutional funds		

5. What considerations does your institution make regarding gender dynamics in FM for ACAS for smallholder grain farmers?

a. Gender-disaggregated data collection for targeted support

b. Specific training or capacity-building programs for women in agriculture

c. Inclusion of gender perspective in project planning and implementation

d. Assessing differential impacts on men and women in farming communities

e. Other:……………………………………………………………………………………
……………………………………………………………………………………………

6. In your experience, what are the key barriers faced by smallholder farmers in accessing and using financial support for ACAS

(ACAS)?..

....

7. In your view, what are some of the challenges associated with the adoption of

   ACAS?..

8. In your view, what are some policy recommendations for the adoption of

   ACAS?...

9. How many full-time faculty members, researchers, and staff are employed by your institution?.................................
10. What is your institution's annual operating budget for research activities?...........................GHS
11. In how many geographic locations or campuses does your institution operate?
    a. Norther region
    b. Savanna region
    c. Both
    d. Other
12. Has your institution ever defaulted on a research grant or failed to meet the terms of a funding agreement?
    a. Yes
    b. No
13. What is your institution's primary areas of research focus?
    a. Gender-responsive research on financing barriers
    b. Evaluating impacts of FM
    c. Developing innovative financial models
    d. Providing technical assistance to stakeholders
    e. Other
14. What is your institution's risk tolerance for different FM?
    a. Aggressive
    b. Moderate
    c. Conservative
15. What is your institution's legal structure?
    a. public university
    b. private research institute
    c. non-profit organization
16. Does your institution's legal structure impact its ability to access certain research funding sources or financing options?
    a. Yes
    b. No
17. Does your institution have any partnerships with other organisations?

a. Yes
b. No

18. What types of FM has your institution used in the past?
    a. Donor funds
    b. Government subsidies
    c. Loans
    d. Private sector initiatives
    e. Cooperative financing
19. Are there any specific regulations or compliance requirements related to different research FM?
    a. Yes
    b. No
20. Do the individual preferences and biases of decision-makers within your institution influence the choice of FM?
    a. Yes
    b. No
21. Does your institution's organizational culture shape decision-making processes related to financing?
    a. Yes
    b. No
22. Are there specific FM that are perceived as riskier or less risky within your institution?
    a. Yes
    b. No
23. How important is your institution's trustworthiness and reputation in the financial community when it comes to accessing certain FM?
    a. Very important
    b. Not so important
24. Have changes in market sentiment affected your institution's ability to access certain financing options in the past?
    a. Yes
    b. No
25. Are there any political pressures or incentives that influence your institution's choice of financing mechanism?
    a. Yes
    b. No
26. What measures are in place to ensure that all relevant information is considered during the financing decision-making process?..
27. What processes are in place to incorporate future expectations into financing decisions?...

....
....

28. What is your level of investment in agroclimatic data and information technology?
    a. High
    b. Medium
    c. Low
29. What is the expertise of your staff in areas like meteorology, agriculture, and climate science?
    a. Very experienced
    b. Somewhat experienced
    c. Limited experience
30. How do you engage with local communities to understand their advisory service needs?..
    ....
    ....
    ....
    ....
31. To what extent have you adopted innovative agroclimatic advisory approaches?
    a. Extensively
    b. Moderately
    c. Limited
32. What mechanisms do you use to collect feedback from advisory service users?
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    ....
    ....
33. What measures do you have in place to ensure quality of your ACAS?
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34. How do you allocate resources to support agroclimatic ACAS?
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SECTION H (e): FM (Metropolitan, Municipal and District Assemblies as respondents)

(Objective 1)

1. Does your district assembly have any agriculture development programs that provide financing to smallholder grain farmers in Northern Ghana?
    a. Yes
    b. No
2. Does your district assembly currently have any agriculture development programs that provide financing to smallholder grain farmers for accessing ACAS (a bundled service of CSA and CIS plus others)?
    a. Yes
    b. No
2. If yes, where does your district get funding for the agricultural development programs?
    a. Government grants
    b. Development agency funds
    c. Corporate Sponsorships
    d. Financial institutions
    e. Institutional funds
    f. Other (specify):……………………………………………..
3. What conditions does your primary funding source place on agro-climatic advisory service funding regarding gender and youth?
    a. Funding must support women farmers equally
    b. Percentage of funding must support young farmers under 30
    c. Funded programs must collect data of farmers disaggregated by gender and age
    d. No specific gender or youth requirements
    e. Other(Specify):……………………………………………………………….

How many small holder farmers benefited from your funding source	Male	Female
Government grants		
Development agency funds		
Corporate Sponsorships		
Financial institutions		
Institutional funds		

4. What specific eligibility criteria does your Assembly utilize for smallholder grain farmers to access financing schemes aimed at ACAS (ACAS)?
    a. Farm size or landholding
    b. Location within the district
    c. Previous farming experience
    d. Type of crops cultivated
    e. Financial history or credit score
    f. Willingness to adopt new agricultural practices
    g. Other (Please specify): ……………………………..
5. What are the procedures followed by smallholder grain farmers to apply for and obtain financing/funds for agro-climatic advisories from the Assembly?
    h. Submission of an application form with specific farming details
    i. Presentation or proposal outlining the need for ACAS (ACAS)
    j. Verification of farming activities by agricultural officers
    k. Assessment of financial need or viability of the farming project

l. Approval by a designated committee or authority
m. Orientation or training sessions prior to fund disbursement
n. Other (Please specify): ………………………………………..

6. Are there any training or guidance mechanisms to assist beneficiary farmers optimally utilize the agro-climatic advisories enabled through such financing support?
   a. Yes
   b. No

35. In your assessment, what are the main challenges faced by smallholder farmers in terms of accessing and productively utilizing district assembly financing/funds for agro-climatic advisories?
:……………………………………………………………………………………………
……………………………………………………………………………

36. Kindly suggest initiatives the district assembly could implement to enhance grain farmers' adoption of institutional financing support meant for enabling access to agro-climatic information services:……………………………………………………………………………
…………………………………………………………………………………………

37. How could partnerships with other government, private or civil society agencies help expand the reach and effectiveness of the district's FM for provision of climate ACAS?
:……………………………………………………………………………………………
……………………………………………………………………………

38. How many full-time employees are currently working for you?................................
39. What is your annual operating budget?.................................GHS
40. What is the geographical coverage area of your MMDA's jurisdiction?
   a. Norther region

b. Savanna region
c. Both
d. Other

41. What is your MMDA's primary areas of focus?
    a. Gender-responsive research on financing barriers
    b. Evaluating impacts of FM
    c. Developing innovative financial models
    d. Providing technical assistance to stakeholders
    e. Other (please specify)
42. What is your institution's risk tolerance for different FM?
    a. Aggressive
    b. Moderate
    c. Conservative
43. What is your MMDA's legal structure?
    a. Local government entity
    b. Decentralized administrative body
    c. Other
44. Does your MMDA's legal structure impact its ability to access certain financing options?
    a. Yes
    b. No
45. Does your MMDA have partnerships with other organizations?
    a. Yes
    b. No
46. What types of FM has your institution used in the past?
    a. Donor funds
    b. Government subsidies
    c. Loans
    d. Private sector initiatives
    e. Cooperative financing
47. Are there any specific regulations or compliance requirements related to different FM?
    a. Yes
    b. No
48. Do the individual preferences and biases of decision-makers within your institution influence the choice of FM?
    a. Yes
    b. No
49. Does your institution's organizational culture shape decision-making processes related to financing?
    a. Yes
    b. No
50. Are there specific FM that are perceived as riskier or less risky within your institution?
    a. Yes
    b. No

51. How important is your institution's trustworthiness and reputation in the financial community when it comes to accessing certain FM?
    a. Very important
    b. Not so important
52. Have changes in market sentiment affected your institution's ability to access certain financing options in the past?
    a. Yes
    b. No
53. Are there any political pressures or incentives that influence your institution's choice of financing mechanism?
    a. Yes
    b. No
54. What measures are in place to ensure that all relevant information is considered during the financing decision-making process?...
    ....
    ....
55. What processes are in place to incorporate future expectations into financing decisions?...
    ....
    ....
56. What is your level of investment in agroclimatic data and information technology?
    a. High
    b. Medium
    c. Low
57. What is the expertise of your staff in areas like meteorology, agriculture, and climate science?
    a. Very experienced
    b. Somewhat experienced
    c. Limited experience
58. How do you engage with local communities to understand their advisory service needs?..
    ....
    ....
    ....
    ....
59. To what extent have you adopted innovative agroclimatic advisory approaches?
    a. Extensively
    b. Moderately
    c. Limited
60. What mechanisms do you use to collect feedback from advisory service users?
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61. What measures do you have in place to ensure quality of your ACAS?
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62. How do you allocate resources to support agroclimatic ACAS?
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SECTION H (f): FM (FBOs as respondents) (Objective 1)

1. What is the purpose/aim of the organization?
2. Does your organization provide ACAS (a bundled service of CSA and CIS plus others) for member farmers?
    a. Yes
    b. No
3. Please specify then types of ACAS that your organization provides:…………………………………………………………………………………
…………………………………………………………………………………………………
……………………..
4. What is your source of funding?
    a. Donor support
    b. Corporate Sponsorships
    c. Financial institutions
    d. Dues from members

e. Other (specify):……………………………………………..

5. What conditions does your primary funding source place on agro-climatic advisory service funding regarding gender and youth?
    a. Funding must support women farmers equally
    b. Percentage of funding must support young farmers under 30
    c. Funded programs must collect data of farmers disaggregated by gender and age
    d. No specific gender or youth requirements
    e. Other(Specify):………………………………………………………………….
6. What constraints do you face in accessing funding for the ACAS?
7. In your view, what policy recommendations can you give to improve funding for ACAS?
8. How many full-time and part-time employees or volunteers work for your FBO?.....................
9. What is your FBO's annual operating budget?..........................GHS
10. In which geographic regions does FBO operate?
    a. Norther region
    b. Savanna region
    c. Both
    d. Other
11. Has your FBO ever defaulted on a loan or failed to meet the terms of a grant agreement?
    a. Yes
    b. No
12. What is your FBO's primary areas of focus?
    a. Aggregating farmer financing needs
    b. Establishing community-based funds/schemes
    c. Facilitating digital financial service uptake
    d. Advocating for women farmers' access
    e. Other
13. What is your institution's legal structure?
    a. Registered Cooperative
    b. Community-Based Organisation
    c. Producer association
    d. Farmer-owned company
    e. Unregistered farmer group
14. Does your institution's legal structure impact its ability to access certain financing options?

a. Yes
b. No

15. What is your institution's risk tolerance for different FM?
    a. Aggressive
    b. Moderate
    c. Conservative
16. What types of FM has your institution used in the past?
    a. Donor funds
    b. Government subsidies
    c. Loans
    d. Private sector initiatives
    e. Cooperative financing
17. Are there any specific regulations or compliance requirements related to different FM?
    a. Yes
    b. No
18. Do the individual preferences and biases of decision-makers within your institution influence the choice of FM?
    a. Yes
    b. No
19. Does your institution's organizational culture shape decision-making processes related to financing?
    a. Yes
    b. No
20. Are there specific FM that are perceived as riskier or less risky within your institution?
    a. Yes
    b. No
21. How important is your institution's trustworthiness and reputation in the financial community when it comes to accessing certain FM?
    a. Very important
    b. Not so important
22. Have changes in market sentiment affected your institution's ability to access certain financing options in the past?
    a. Yes
    b. No
23. Are there any political pressures or incentives that influence your institution's choice of financing mechanism?
    a. Yes
    b. No
24. What measures are in place to ensure that all relevant information is considered during the financing decision-making process?...
    ....
    ....

25. What processes are in place to incorporate future expectations into financing decisions?..

26. What is your level of investment in agroclimatic data and information technology?
    a. High
    b. Medium
    c. Low

27. What is the expertise of your staff in areas like meteorology, agriculture, and climate science?
    a. Very experienced
    b. Somewhat experienced
    c. Limited experience

28. How do you engage with local communities to understand their advisory service needs?..

29. To what extent have you adopted innovative agroclimatic advisory approaches?
    a. Extensively
    b. Moderately
    c. Limited

30. What mechanisms do you use to collect feedback from advisory service users? ....

31. What measures do you have in place to ensure quality of your ACAS? ....

32. How do you allocate resources to support agroclimatic ACAS? ....

SECTION H (g): FM (Private institutions as respondents)

1. What is the purpose/aim of the institution?..

2. Does your institution provide ACAS?

   a. Yes

   b. No

3. Please specify then types of ACAS that your institution provides………..

4. Where do you get funding for ACAS?

   a. Government grants

   b. Development agency funds

   c. Corporate Sponsorships

   d. Financial institutions

   e. Institutional funds

   f. Other (specify):…………………………………………….

5. What conditions does your primary funding source place on agro-climatic advisory service funding regarding gender and youth?

   a. Funding must support women farmers equally

   b. Percentage of funding must support young farmers under 30

   c. Funded programs must collect data of farmers disaggregated by gender and age

   d. No specific gender or youth requirements

   e. Other(Specify):………………………………………………………………….

6. What constraints do you face in accessing funding for the

   ACAS?...

7. In your view, what policy recommendations can you give to improve funding for

   ACAS?..

8. How many full-time and part-time employees does your institution currently have?.................
9. What is your institution's annual operating budget?............................GHS
10. In how many geographic regions or countries does your institution operate?
    a. Norther region
    b. Savanna region
    c. Both
11. Has your institution ever defaulted on a loan or failed to meet the terms of a financing agreement?
    a. Yes
    b. No
12. What is your institution's primary areas of focus?
    a. Designing digital advisory and financial services
    b. Offering credit-based input and equipment provision
    c. Partnering with finance providers for bundled products
    d. Implementing gender-responsive policies and practices
    e. Other
13. What is your institution's risk tolerance for different FM?
    a. Aggressive
    b. Moderate
    c. Conservative
14. What is your institution's legal structure?
    a. Corporation
    b. Limited liability company
    c. Partnership
15. Does your institution's legal structure impact its ability to access certain financing options?
    a. Yes
    b. No
16. Does your institution have any partnerships?
    a. Yes
    b. No
17. What types of FM has your institution used in the past?
    a. Donor funds
    b. Government subsidies
    c. Loans

d. Private sector initiatives
e. Cooperative financing

18. Are there any specific regulations or compliance requirements related to different FM?
    a. Yes
    b. No
19. Do the individual preferences and biases of decision-makers within your institution influence the choice of FM?
    a. Yes
    b. No
20. Does your institution's organizational culture shape decision-making processes related to financing?
    a. Yes
    b. No
21. Are there specific FM that are perceived as riskier or less risky within your institution?
    a. Yes
    b. No
22. How important is your institution's trustworthiness and reputation in the financial community when it comes to accessing certain FM?
    a. Very important
    b. Not so important
23. Have changes in market sentiment affected your institution's ability to access certain financing options in the past?
    a. Yes
    b. No
24. Are there any political pressures or incentives that influence your institution's choice of financing mechanism?
    a. Yes
    b. No
25. What measures are in place to ensure that all relevant information is considered during the financing decision-making process?..
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26. What processes are in place to incorporate future expectations into financing decisions?...
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....
27. What is your level of investment in agroclimatic data and information technology?
    a. High
    b. Medium
    c. Low
28. What is the expertise of your staff in areas like meteorology, agriculture, and climate science?

a. Very experienced
b. Somewhat experienced
c. Limited experience

29. How do you engage with local communities to understand their advisory service needs?...
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30. To what extent have you adopted innovative agroclimatic advisory approaches?
    a. Extensively
    b. Moderately
    c. Limited
31. What mechanisms do you use to collect feedback from advisory service users?
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32. What measures do you have in place to ensure quality of your ACAS?
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33. How do you allocate resources to support agroclimatic ACAS?
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SECTION I: PRODUCTIVITY AND INCOME (Objective 5) (Aims to measure on-farm productivity and income parameters to assess the impact of using agro-climatic advisories. It asks about acreage, yields, produce sold, prices, income, and the farmer's perception of yield and income gains attributable to the advisories. This quantifies the benefits realized from access to climate services.)

1. What is the total acreage(s) cultivated for maize in the last cropping season (major) 2023?....................acre

2. What is the total acreage(s) cultivated for soya bean in the last cropping season (major) 2023?....................acre

3. What was the total quantity harvested per acre for maize in the last cropping season (major) 2023? ………………………………………. bags/acre

4. What was the total quantity harvested per acre for soybean in the last cropping season (major) 2023? …………………………………. bags/acre

5. What is the total quantity of your harvested maize sold in the last cropping season(major) 2023?...bags

6. What is the total quantity of your harvested soya bean sold in the last cropping season(major) 2023?...bags

7. What was the average price for maize in the last cropping season?................................GHS/bag

8. What was the average price for soya bean in the last cropping season?................................GHS/bag

9. What was your total income from bags of grain sales in the last season?...................................(GHS)

10. Have ACAS helped increase your productivity?

    a. Yes

    b. No

11. If yes, by how much?.....................................(Kg/acre)

12. Have ACAS helped increase your income?

c. Yes

d. No

13. If yes, by how much?.................................(GHS)

14. In your opinion, what has been the effect of using agro-climatic advisories on your yield and income? (Likert scale)

e. Very good

f. Good

g. Neutral

h. Bad

i. Very Bad

15. How can access to credit further improve the use of ACAS, productivity, and income?...

SECTION J: ALLOCATION OF CROP HARVEST (Collects detailed data on the allocation of grain harvest by farmers for consumption, seed, sales, payments, losses, etc. This indicates how farm households utilize produce and provides insights into food security.)

Please provide information about the use of your Crop in the last cropping season

	Quantity Consumed	**Quantity kept for planting (seed)**	**Quantity used as payment for inputs**	**Quantity bartered or exchanged for goods and services**	**Quantity lost through Post-harvest losses**	**Quantity for other uses**
MAIZE						

SOYA BEAN						

Appendix 2

RESULTS

Table 4.11a: Unadjusted pre-treatment characteristics of agro-climatic advisory service adopters and non-adopters

Variables	Non-Adopters	WMI	CPWF	IAS	WMI vs Non-Adopters	CPWF vs Non-Adopters	IAS vs Non-Adopters
					Absolute standardized difference		
Age of Farmer (Yrs.)	42.826	42.078	39.950	41.358	0.054	**0.213**	0.105
Farmer is Married	1.237	1.208	1.227	1.242	0.068	0.023	0.013
Farmer has Formal Education	1.512	1.531	1.447	1.511	0.038	0.131	0.003
Number of People in the HH	5.058	4.698	4.681	4.858	**0.177**	**0.186**	0.094
Farmer is a Youth	0.459	0.479	0.525	0.495	0.040	0.132	0.072
Farming as a Major Occupation	1.816	1.807	1.794	1.832	0.023	0.056	0.040
Farming Experience (in Years)	12.333	11.609	10.482	11.621	0.074	**0.200**	0.073
Size of Farm (acres)	2.697	2.856	3.006	2.899	0.105	**0.184**	0.128
Farmer Owns Farmland	0.237	0.161	0.227	0.216	**0.189**	0.023	0.050
Farmer is a Member of FBO	1.454	1.510	1.489	1.432	0.113	0.070	0.045
Awareness of ACAS	1.700	1.615	1.652	1.668	**0.181**	0.102	0.069
Access to ACAS	1.425	1.458	1.270	1.426	0.067	**0.330**	0.002
Information from Community Information Center	1.295	1.344	1.277	1.416	0.105	0.040	**0.254**
Information from Radio	1.556	1.406	1.305	1.395	**0.301**	**0.522**	**0.325**
Information from TV	1.415	1.203	1.326	1.353	**0.471**	**0.185**	0.129
Information from Other Farmers	1.362	1.365	1.397	1.442	0.005	0.072	**0.163**
Information from NGO	1.324	1.271	1.355	1.389	0.116	0.065	0.137
Information from FBO	1.411	1.250	1.277	1.374	**0.346**	**0.284**	0.076

Perceived Usefulness of Information	2.411	2.568	2.433	2.432	0.125	0.017	0.016

Source: Field Survey (2024)

Table 4.11b: Adjusted pre-treatment characteristics of agro-climatic advisory service adopters and non-adopters

					Absolute standardized difference		
Variables	Non-Adopters	WMI	CPWF	IAS	WMI vs Non-Adopters	CPWF vs Non-Adopters	IAS vs Non-Adopters
Age of Farmer (Yrs.)	41.290	41.721	41.973	41.861	0.032	0.050	0.041
Farmer is Married	1.203	1.227	1.208	1.212	0.059	0.013	0.023
Farmer has Formal Education	1.486	1.511	1.481	1.528	0.050	0.011	0.082
Number of People in the HH	4.757	4.787	4.602	4.844	0.015	0.075	0.042
Farmer is a Youth	0.514	0.478	0.482	0.483	0.072	0.062	0.061
Farming as a Major Occupation	1.826	1.834	1.824	1.833	0.020	0.006	0.018
Farming Experience (in Years)	10.929	11.775	11.378	11.689	0.089	0.047	0.081
Size of Farm (acres)	2.737	2.831	2.742	2.910	0.063	0.003	0.109
Farmer Owns Farmland	0.193	0.192	0.232	0.218	0.005	0.093	0.061
Farmer is a Member of FBO	1.476	1.470	1.459	1.462	0.013	0.035	0.030
Awareness of ACAS	1.594	1.624	1.614	1.614	0.063	0.042	0.042
Access to ACAS	1.402	1.392	1.383	1.407	0.022	0.039	0.010
Information from Community Information Center	1.302	1.310	1.302	1.334	0.017	0.001	0.068
Information from Radio	1.400	1.408	1.42	1.417	0.015	0.040	0.033
Information from TV	1.281	1.310	1.31	1.280	0.063	0.063	0.003
Information from Other Farmers	1.366	1.389	1.362	1.373	0.049	0.008	0.016
Information from NGO	1.323	1.311	1.321	1.327	0.026	0.005	0.007
Information from FBO	1.294	1.330	1.295	1.309	0.079	0.003	0.034
Perceived Usefulness of Information	2.377	2.456	2.391	2.399	0.062	0.011	0.018