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IMPACT OF ACCESS TO CLIMATE INFORMATION SERVICE AND UPTAKE OF CLIMATE SMART AGRICULTURAL TECHNOLOGIES ON MAIZE YIELD IN GHANA

FATIMA ABUKARI

2025

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BY

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(UDS/MEC/0003/21)

THESIS SUBMITTED TO THE DEPARTMENT OF AGRICULTURAL AND FOOD ECONOMICS, FACULTY OF AGRICULTURE, FOOD AND CONSUMER SCIENCES, UNIVERSITY FOR DEVELOPMENT STUDIES IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF MASTER OF PHILOSOPHY DEGREE IN AGRICULTURAL ECONOMICS

MARCH, 2025

UNIVERSITY FOR DEVELOPMENT STUDIES

DECLARATION

STUDENT

I hereby declare that, this thesis is the result of my original work, and no part of it has been presented for another degree in this University or elsewhere.

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We hereby declare that; the preparation and presentation of this thesis was supervised following the guidelines on supervision of thesis laid down by the University for Development Studies.

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ABSTRACT

Climate information service (CIS) and Climate-smart agriculture (CSA) are complementary measures that has gain much attention in trying to adjust to and reduce the influence of the changing climate. This study explores the impact of access to CIS on CSA technologies uptake, the respective sources and channels they are received by farmers and consequently the impact on yield of maize. Descriptive statistics, Multivariate Probit Analysis (MVP) and Multinomial Endogenous Switching Regression Model (MESR) were used to assess the data. The finding shows that, access to various CIS are complementary. Generally, access to CIS was significant for uptake of various CSA technologies with 90% and 89.81% having access to CIS and uptake of various combinations of CSA technologies respectively. The major CIS accessed and CSA adopted were rainfall prediction & amount and planting time & fertilizer application and the combination of soil fertility management practices and pest & disease management practices respectively. MoFA and extension agents were the major source and channel of CIS/CSA access. Age, gender, status in the household, membership of FBO, VSLA, perception of climate change, access to extension and credit significantly determined various CIS access and CSA technologies uptake. The results however reveal that, the impact of uptake of some individual and combinations of CSA practices on maize yield was significantly negative, suggesting that, farmers who adopted such CSA technologies had lower yields and could have better yield had they not adopted. Stakeholders within the CIS and CSA nexus should partner to enforce bundled CIS and CSA technologies dissemination reflective of the various stages of production, whiles subsidized fertilizers and improved seeds made available at the districts for improve yield.

ACKNOWLEDGEMENT

I thank and praise God for all the mercy, favor, protection and blessings bestowed on me throughout the period of acquiring this Master of philosophy degree.

To Dr. Osman Tahidu Damba and Dr. Abdul-Basit Tampuli Abukari, a very big thank you for your generosity, and for willingly accepting to oversee and supervise my research. I am even more grateful for your guidance and contribution that brought forth this write-up.

A special thank you to Dr. Osman Tahidu Damba for the opportunities given to me that brought me close to practical and field work which has broaden my scope and brought the best out of me in conducting this research.

I am also very thankful to AICCRA-GHANA for providing me with data and technical support throughout this research work as a Master of Philosophy student.

DEDICATION

I dedicate this work to my beloved husband, Mr. Abubakar Benjamin Afful, my children, Farhaan Afful and Faizaan, my mother, Hajia Mariama Seidu and to the memory of my late father, Alhaji Abubakar Alhassan.

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ACRONYMS AND ABBREVIATIONS

CCAFS	Climate Change ,Agriculture and Food Security
CI	Climate Information
CIS	Climate Information Service
CSA	Climate Smart Agriculture
CSIR	Council dor Scientific and Industrial Research
ECA	Economic Commisipon for Africa
EPA	Evironmrntal protection Agency
FAO	Food and Agriculture Organisation
GHG	Green House Emission
GMET	Ghana Meteorological Agency
GSS	Ghana Statistical Service
IPCC	Intergovernmenta Panel on Climate Chnage
MESR	Multinomial Endogenous Switching Regression
MESTI	Ministry of Environment,Science,Technology and Innovation
MNL	Multinomial Logistics Model
MoFA	Ministry of Food and Agriculture
MVP	Multivariate Probit Model
NCCC	National Climate Change Commission
NMHSs	National Meteorological and Hydrological Services
OECD	Organisation for Economic and Co-operation Development
SDGs	Sustainable Development Goals
SSA	Sub-Saharan Africa
WCIS	Weather and Climate Information Services
WMO	World Meteorological Organization

CHAPTER ONE

INTRODUCTION

1.1 Background

Climate change is a worldwide phenomenon ,that affects the lives of every individual especially agriculture producers (Agbenyo et al., 2022). The local weather patterns will become increasingly unpredictable as the global climate system changes, and several smallholder farmers would unavoidably lose livestock and see a decrease in crop yields, and possibly crop failure (Collins-Sowah, 2018). Climate system inconstancy may also affect the options made by farmers, including whether they put in money for inputs and resources their field needs (Scherr et al., 2012). Farmers' livelihoods are being dramatically impacted by climate change worldwide, necessitating the development of adaptive agricultural livelihoods techniques (McOmber et al., 2013). Since major livelihood activities are gravely threatened by climate change, smallholder households are under a lot of stress due to livelihood instability (Aniah et al., 2016). In tens of years to come, the changing climate will continue to have an influence on agriculture and forest production systems, and thus the need to sustain both existing levels of food output and boost productivity to satisfy the needs of the expanding global population (Way & Long, 2015). The biggest obstacle to achieving the first Sustainable Development Goal(SDGs), which calls for reducing global poverty and food insecurity through boosting agricultural productivity in developing nations, is thought to be climate variability and change (Amikuzuno & Donkoh, 2012).

Africa suffers disproportionately from the effects of global warming haven imparted the tiniest to greenhouse gas emissions as relative to developed nations (Shimada, 2022). The agriculture industry is particularly hard-hit by climate change in Africa (Mbilinyi et al., 2013). Future warming will have a severe impact on food systems in Africa by reducing growing seasons and increasing water stress (Adelekan et al., 2022).

Though everyone is affected by climate change, the vulnerable populations, including children, women, low-income households, small scale producers Indigenous and other minority groups, are frequently more at risk of starvation, loss of means of subsistence, increased costs, and competition over resources (Bezner Kerr et al., 2022). The exposure of rain-fed agriculture to the changing climate is increased by its high reliance on rainfall (Muema et al., 2018). Climate change has a significant influence on West Africa's agriculture industry (Sorgho et al., 2020). It is however challenging to develop a paradigm that can effectively supply society's fundamental demands for food, water, and health because of all these forecasts' inherent uncertainty (Mazza, 2017).

Climate information services (CIS) may possibly be an important resource for producers to specially handle climatic risks (Diouf et al., 2019). According to Ouedraogo et al. (2022), weather forecasting has the ability to increase farmers' resilience, and is viewed as a crucial component of agricultural development. With climate information services, farmers can build expectations for the upcoming season using historical rain patterns as a basic framework (Nyadzi et al., 2021). Since smallholder agriculture is a vital source of livelihood and endangered by climate change and variability, access to climate information via CIS is important (Brief, 2017). An important element in the development of adaptation measures to climate change is enhanced and meaningful use of information channel; the more applicable and helpful the message is to the user, the more the user may be in position to adjust to changes in climate, (McOmber et al., 2013)and hence effective choices and decisions. With the aid of climate information, farmers can meaningfully plan agricultural activities and implement measures that increase capacity for adaptation to climate hazards (Partey et al., 2018). Smallholder farmers who receive climate information services are less exposed to climate change hazards due to critical decisions taken, backed by the appropriate tools to make their own decisions, diversify their sources of income (livelihood), and safeguard their assets (Box & Pleasant, 2020). Developing tailor made CIS tools has received strong interest from public, private and non-governmental organizations due to the critical role it plays in end-user decision making. As such, the Ghana Metrological Agency (GMET), Esoko and CARE International are examples of facilitators and service providers of climate information to farmers across Ghana, however, women and men who play distinct roles have varying access to this information, control over resources, and influence in decisions made in the home and community, all of which affects how well they can manage climate risks. Increased climate change effects further increases end-users vulnerability (Dazé, 2013). For all groups of persons at more risk to benefit from CIS, these groups must be specifically considered (Westermann et al., 2015). As reported by Baffour-Ata et al. (2022) male farmers' access to information was mainly through phones and radios as a result of their control of financial resources in the households as opposed to their female counterparts. Consequently, if the advantages of an intervention are captured by a group of people, largely men, the intervention may enhance the marginalization and relative poverty of those who are not reached, such as women in remote rural areas, hence increasing disparities (Machingura et al., 2018; Mittal et al., 2016). Access to climate information is a requirement for CSA uptake decision and other decisions of livelihoods especially in Northern Ghana. These decisions informs for CSA adaptation, mitigation and increased nutrition at the household level and therefore impacts on CSA valuation at the individual level (Kramer et al., 2023).

Attention on the role of CIS on CSA uptake and utilization has not received much attention to understand the complexities and by extension, its impact on yield. Increased yield is one aspect of adopting CSA technologies based on informed climate information to the specific requirement of a geographical area.

Until recently, developing countries have not placed emphasis on targeted CIS solutions to informed choice of CSA technologies and the need for integrating climate change into the planning and implementation of sustainable agricultural strategies (Lipper et al., 2014). CIS is a critical requirement for CSA because more effective resource use boosts farm productivity and incomes, lowers emissions per unit of output, and aids in climate change mitigation and adaptation (Lipper et al., 2014). Aside current efforts at identifying best-bet solutions to CIS, emphasis is still on few climate variables such as rainfall volume, onset, and length of season which is required by farmers and other end-users for critical decision making. Studies conducted in the northern part of Ghana suggested that, temperature volatility and annual rainfall had significant impact on maize and groundnut yields . (Baffour-Ata et al., 2021). The authors, Baffour-Ata et al. (2021) further pointed out that, non-climatic components such as CSA use could however have notable beneficial out-turn on yield if they were adopted.

The agricultural system globally is primarily focused on a one crop, which is maize, along with a heavy reliance on rain-fed agriculture that will heighten households' susceptibility to unpredictable rainfall and fluctuations in weather (Oseni & Masarirambi, 2011). It is the most commonly grown crop in the world with over a billion tons per year and thus ,considered important in alleviating world food insecurity (Leroux et al., 2019). Maize is also considered as one of the major staple crops consumed globally (Wang et al., 2018). Its production has been characterized by significant fluctuation in yields as a result of climate change(Oseni & Masarirambi, 2011). In southern Africa region, the production of maize is projected to reduce between 12% and 40%, (Nhamo et al., 2019; Ramirez-Villegas & Thornton, 2015). According to Defrance et al. (2020) , there exists a difference between the current agricultural output and the possible yields of the staple crops that could be realized in west Africa. Stuch et al. (2021) found out that, the average yield of maize in central and west Africa had reduced by 13% and 10% respective as a result of higher temperatures. However, significant studies have shown a significant increase in maize yield as a result of CSA adoption(Baffour-Ata et al., 2023; Khonje et al., 2015; Martey et al., 2023) .

1.2 Problem Statement

Ghana's climate is changing, which is contributing to desertification, endangering national growth, and compromising the country's ability to sustain its agriculture and economy (UNCCD, 2020). Baffour-Ata et al. (2021) identified early rainfall, more dry spells, late rainy season onset, shorter rainy season and early rainfall cessation seasons as contributors to reduced yields of staple food crops such as maize. This therefore required tailor-made CI for decision-making and planning purposes. Climate information services is a new, but expanding topic in bridging the gap between creating of scientific data and the need for practical, application-relevant data (Vogel et al., 2017). Making choices in agricultural systems in many instances focuses heavily on environmental and climate knowledge, especially as climate change-related susceptibility and uncertainty increase (Georgeson et al., 2017). It is well known that enhancing climate information services can reduce the effects of climatic uncertainty and facilitate better crop management decision-making (Antwi-Agyei et al., 2021). However, one of the biggest impediments to effective climate change adaptation is an absence of precise, applicable information about the climate (Muema et al., 2018). Inadequate and timeliness of seasonal forecast data for future planning, limited access to climate information, a disconnect between the information supplied and farmers' needs, and a high illiteracy rate are some of the obstacles to accessing climate information services (Antwi-Agyei et al., 2021). CSA on the other hand is an innovative and strategic approach to tackling the complicated issues related to global climate change (Chandra et al., 2018). To boost yields from agriculture, enhance resilience, and lower GHG emissions, a variety of CSA strategies, technologies, and solutions have been recommended (Khatri-Chhetri et al., 2019).The uptake of climate-smart technology is considered to depend on the accessibility and availability of climatic information (Khatri-Chhetri et al., 2019; Mwongera et al., 2017) for informed decision-making. There is diverse research on determinants and predictors of access to CIS and uptake of CSA practices/technologies (P. Antwi-Agyei et al., 2021; Baffour-Ata et al., 2022). However, bivariate methods have been used as in Alidu et al. (2022); Djido et al. (2021); (Ngigi & Muange, 2022), to assess the joint adoption of CIS and CSA technologies,and the effect of access to CIS on uptake of CSA technologies, limiting the scope to general access and uptake without considering the different climate information services which are targeted for different CSA technologies uptake decision-making, Aside that, none of these studies also distinguished between sources and channels of climate information thus, they are used interchangeably. Again, less literature is found on how the linkages between access to CIS and CSA technologies uptake affects yield of crops in Ghana. Issahaku and Abdulai (2020) ,looked at adoption of CSA technologies on crop revenue, however, the focus was on only two CSA technologies and crop revenue of different crops on the same farmland, but inflationary tendencies of the revenues accrued may affect net incomes of crops cultivated based on geographical locations. Aside from that, geographical location and context specific CIS and CSA technologies have seen focus of past research in Upper East, Upper West and Northern regions of the Ghana, however effects of climate change result in spillovers, and the worst-case scenarios, volatility transmission are observed across borders. More so, policies and programs of climate change and CI are national in design although, implementation is usually site specific hence the need to cover more regions. The study concentrates on maize yield because, it is a major food security crop grown by almost all the farmers who were included in this study. This study therefore, fills the gaps by extending finding to cover six regions in Ghana comprising of Northern, Upper East and Upper West, Bono East, Central, and Greater Accra based on climate risk. Climate information is critical to an effective uptake of CSA technologies and hence adoption in the long-run hinges on targeted-based CIS and the sources and channels from which the information's are received

1.3 Justification of the study

Ghana's agriculture is primarily dependent on rainfall, but the unpredictability of the rainfall pattern has severely reduced agricultural productivity causing more than two-thirds of the country to experience an increasing unimodal rainfall pattern (ACEP, 2020).

This study was focused on contributing to showing the various linkages between farmers' access to climate information services, the sources and channels, and the uptake of CSA technologies on maize yield.

The study adds to a context-specific understanding of the interrelationship (whether they are substitutes or complements) that exists between various climate information services access and the effectiveness of the use of these climate information services on the uptake decision of climate-smart agricultural technologies. It distinguishes between the sources and channels from which different climate information is accessed most by farmers. The findings further provide service providers with relevant information to shape and improve the timeliness and frequency of dissemination of climate information on the preferred sources and channels.

The discoveries of this study also provide a practical guide for policymakers, development organizations, and all actors in the CIS and CSA nexus for designing, implementing, upscale, and out-scale projects on climate change adaptation and mitigation strategies that meet the needs of farmers and also rectify the major challenges associated with productivity in ways that will protect and sustain farmers livelihood.

This research contributes to methodology by the use of the Multinomial endogenous regression model to capture the linkages that exists between CIS access, uptake of CSA technologies, and the yield of maize, while complementing and adding to the empirical literature on the impact of CIS access on uptake of CSA technologies and yield in Ghana by serving as a reference for more research.

1.4 Research Questions

The main question this research aims to answer is: what are the sources and channels of CIS access and the effect of access to CIS on CSA technology uptake and maize yield?

Specifically, the research will find out:

1. What are the sources and channels of dissemination of CIS?
2. What factors influence farmers' access to various CIS?
3. What is the effect of CIS access on CSA technology uptake?
4. What is the impact of uptake of CSA on maize yield?

1.5 Research Objectives

The main objective is to investigate sources and channels of CIS and assess the effects of CIS access on uptake of CSA technologies and maize yield in Ghana.

Specifically, the research seeks to

1. To identify the sources and channels of access to various CIS.
2. To assess the factors that influence access to various CIS.
3. To examine the effect of CIS access on CSA technologies uptake.
4. To assess the impact of uptake of CSA technologies on maize yield.

1.6 Organization of the study

This thesis is laid out in five principal chapters divided into different sections. The opening chapter, that is chapter one, presents the introduction of the study with sections arranged as; background, problem statement, justification, research questions, and research objectives, with the last section highlighting the arrangement of the study. Assessment of relevant literature is represented in chapter two whilst chapter three presents the methodology of the study, which is divided into, the study area, design of the study, conceptual and theoretical frameworks, and empirical models used to achieve the objectives set. Chapter four lays out the results and discussion of the study and Chapter five presents, a summary of the findings, conclusion, policy recommendation, and limitations of this research.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter assesses literature on critical concepts associated to the study. The ideas used in this study are also clarified. The order of the discussions is; climate information services, climate change and agriculture, climate change and gender, climate information services and gender, climate information services sources & channels of dissemination, access to and use of climate information services. Climate smart agriculture, climate smart agriculture and gender, climate smart agriculture technology uptake and the effects of climate information services on uptake of climate smart agricultural technologies presented in different sections.

2.2 Climate Information Services

Climatic information Services (CIS) is defined as the delivery of data and information on both short-term weather conditions and long-term climatic events (Serra & McKune, 2016). Climate services are instruments that enable decision-making that are created based on a process of transforming climate information into pertinent advisory services that help individuals and organizations in a society make decisions (Tall et al., 2013). Climate services is also referred to as the production, translation, transfer, and use of climate knowledge and information in climate-informed decision making and climate-smart policy and planning (Ouédraogo et al., 2018). These activities also involve preparing users for the weather they will actually experience in order to support climate resilient development (Ouédraogo et al., 2018). One of the primary ways that farmers can deal with climate change and unpredictability to enhance agricultural decision-making is through the provision of CIS (Ouédraogo et al., 2018). Where small-scale agriculture is a vital component of means of subsistence and is affected by climate unpredictability, access to climate information via CIS is essential (Brief, 2017). The timely delivery of targeted climate-related knowledge and information that can be used to lower losses and increase profits is what the climate information service is concerned with (Ouedraogo et al., 2018). Depending on the climatic data present, a climate service supplies personalized, applicable, and practical advisories for decision-makers and vulnerable people (Tall et al., 2013). Using sectoral and customized climate services, focused dynamic adaption techniques can help to mitigate yield losses and, in some situations, even turn them into gains (Toreti et al., 2022). Demand-driven and context-specific CIS and climate change literacy could make the difference between coping and well-informed adaptation responses (Adelekan et al., 2022). Effective climate information services will enable the economy's climate-dependent sectors to better manage growing climatic variability while maintaining high productivity and better lifestyles across the continent (UN.ECA, 2021). Climate services understand that in order to increase its likelihood of facilitating adaptation, relevant and accessible information it should be timely and personalized, therefore, climate services are specifically created to meet recognized user demands (Vincent et al., 2018). Through the direct delivery of seasonal and shorter-term weather and CI's into farmers' hands, climate forecasting has the potential to improve the means of subsistence of disadvantaged, resource-dependent producers (Tall et al., 2014).

Accurate and timely CIS would be required to assist small farm holders in Ghana due to the impact of climate change on the country's agriculture. This will give them access to useful information on potential risks associated with climate change that could disrupt their way of life P. Antwi-Agyei et al. (2021). In Burkina Faso, Ouédraogo et al. (2018) discovered that farmers' readiness to pay for climate information services was greatly affected by their age, gender, education, their awareness of climate information. Communities that depend on farming, herding, and fishing that are impacted by the shortened rainy season, increasing frequency of extreme weather events, and decreasing rainfall distribution in area and time are the main beneficiaries of the CIS (Ouedraogo et al., 2018).

2.3 Climate Change and Agriculture

The agriculture industry is very important and offers significant abilities for decreasing emissions while also decreasing poverty and food insecurity, (Lipper et al., 2017). A significant source of negative emissions from agriculture could come from the ability of agriculture to store carbon in the soil and in above- and below-ground biomass (Wollenberg, 2017). Increasing unpredictable climate events has negative impact on agriculture production and forest ecosystems by increasing incidents of altered crop health by different organisms, (Barik et al., 2022). According to the WMO (2023) , the global average temperature in 2022, which incorporates measurements on the surface of the sea and on land, was 1.15 [1.02-1.28] °C greater than the pre-industrial mean of 1850–1900 with intensified drought in Africa , particularly in Kenya, Somalia and southern Ethiopia with a decreased rainfall below average across the region which is affecting agriculture and food security. Given that 90% of water worldwide is used for irrigation, changing climatic conditions will have an impact on agriculture and animal production (Ahmed et al., 2016). Prolong, persistent, and more intense climate events, are all results of climate change that leads to loss of farmlands (Grigore & Vicente, 2023). Trade between nations further modifies the effect of change in climate on agriculture by redistributing production and consumption across the world (Nelson et al., 2014). According to Adelekan et al. (2022), future warming in Africa will have a severe impact on food systems by reducing growing seasons and causing more water stress. Given that West African agriculture is primarily rain-fed, the seasonal patterns of rainfall have a significant impact on how well it performs (Ouédraogo et al., 2018).

Through the provision of food/nutrition, raw materials, employment, income, Ghana's agricultural sector persist in playing crucial function in the country's economic growth and, therefore has major influence on poverty reduction(Sam et al., 2020). Studies have shown that, there has been numerous instances of floods and droughts, as well as high seasonal volatility in rainfall with continues swings above the average of roughly 959 mm in the Northern part of Ghana (Amikuzuno & Donkoh, 2012). According to Mazza (2017), the changes in climate will be geographic shifts which will affect crop growth and food production either favorably or unfavorably , making it challenging to develop an efficient model to satisfy society's fundamental needs, given the unpredictability of all these projections. Additionally, climate change-related changes in temperature and rainfall could affect the development of organisms and adds to production of toxins, which pose serious health concerns to humans, in agricultural food products (Ahmed et al., 2016). Since agricultural productivity is subject to weather, climate change has a direct impact on it (Nelson et al., 2014). Considering that major livelihood activities are gravely threatened by climate change, smallholder households are under a great deal of stress due to their uncertain means of subsistence (Aniah et al., 2016). Major food production sectors are anticipated to be severely affected by climate change, with the tropics possibly seeing losses in both agriculture and fisheries (Cinner et al., 2022). Through decreased agricultural productivity and incomes, increased hazards, and market disruption, climate change threatens both rural and urban populations' access to food (Lipper et al., 2014). Numerous ecosystem services relating to soil regeneration, pollination, organic pest control, and resilience to climate change have an impact on agricultural output (Omer, 2023). Most plants are unable to adjust to the fast altering of ecosystems brought on by increasing atmospheric and oceanic temperature , Kumar et al. (2022) and thereby reducing yields (Ncube et al., 2016).

Crops are subject to a variety of living and non-living stresses, such as high salinity, extreme temperatures, flooding, heavy metals, radiation, drought, and a variety of pests, such as viruses, bacteria, fungus, insect predation, etc., that significantly inhibit plant growth by affecting their metabolic processes making it necessary to increased crop production in developing nations where the population is expanding in order to feed the growing population (Kumar et al., 2022). The fundamental reason for the fall in agricultural productivity and output is that the resource base, including farmland, grazing area, and forests, has reached a critical stage of degradation due to the effects of climate change (Aniah et al., 2016). Additionally, rainfall amounts during the planting season have an impact on agricultural yields in Northern Ghana , Amikuzuno and Hathie (2013) , affecting the livelihood of an estimated 38.3 percent of the Ghanaian population employed in the agriculture sector (MoFA, 2018).

To safeguard and enhance the livelihoods of vulnerable groups and enable agriculture sector to reduce food insecurity, it is crucial to decrease the sensitivity of agriculture systems to climate change, (Lipper et al., 2017). The agricultural production systems need to be more risk- and shock-resistant, productive, efficient, less variable, and stable in their outputs to be able to adjust to climate change (Dhenge et al., 2016). Access and on time release of CI can help lower the adverse effects of climate unpredictability through enough preparations and arrangement, thereby helping agriculture producers improve on their adaptability to (UN.ECA, 2021).

2.4 Climate Change and Gender

In small holder farming, being a male or a female is a factor when privilege's, obligations, and risks are shared in relation to, handling, and who is charge of resources, notably farmland (Jerneck, 2018) . This is a ranking process in social institutions and therefore important. Men and women may perceive the dangers of climate and other shocks differently and may be exposed to different shocks, with distinct repercussions from climatic shocks, such as asset disposal, due to the gendered features of agricultural labor and smallholder subsistence strategies (Bernier et al., 2015). Men and women may also react to climate change in different ways, as the implications of climate change differ depending on gender (Gender & Alliance, 2016). An awareness of how gender is affected by climate-related threats differently and by implementing coping and mitigation measures is promoted by "gender analysis" in relation to climate change (Abedin et al., 2013).

In addition , climate change effects is not only influence by inequalities within gender, but also other socio demographic characteristic, (Gender & Alliance, 2016)**.** On the outermost level, gendered factors do not appear to be affected by climate change, but the effects on women continue to change as a result of shifting environmental factors (Md et al., 2022). It is widely acknowledged that susceptibility to climate-related hazards and climate variability depends on context, and that perceived vulnerabilities to climate events are complicated by factors such as poverty, gender discrimination, and pervasive injustice (Abedin et al., 2013). Men and women suffer different consequences of climate change depending on geography, generation, income level, and occupation; however, women are more susceptible to climate change than men (Shahjalal, 2021). In Senegal, Tall et al. (2014) found that, there were considerable differences between male and female farmers in terms of climate change vulnerabilities, local ability to deal with them, and subsequent demands for support during adaptation.

2.5 Climate information Services and Gender

Investing in productive CIS has emerged as a top development precedence and is seen as a prerequisite for initiating thriving adaption efforts, particularly in regions of the world that are likely to undergo the worst effects of climate change (Serra & McKune, 2016). Meaningful use of CI enables households and communities to perfectly predict and prepare towards climate-related shocks, enhance decision-making in difficult situations and livelihood security (Tall et al., 2014).

Given the significance of having access to information about climate change, those who are most at risk from it and other environmental shocks frequently have the least access to it (McOmber et al., 2013). Although solutions for tackling the vulnerabilities of agricultural populations globally such as climate services for development have enormous possibilities, this possibilities are not evenly distributed (Carr et al., 2016). CIS that are less responsive to demands can aggravate inequality while also increasing poverty and exclusion (Machingura et al., 2018). Planning, controlling, monitoring, and product marketing on farms are impacted by the ways that gender influences market transactions and adjustments at the farm level (Smith et al., 2017). Ngigi and Muange (2022) found that, different factors affect male and female access to CIS differently because of existing inequalities in socio-economic characteristics and also farmers who had high income and were mainly men had the highest probability of accessing CIS. Partey et al. (2018) pointed out that, if women had better access to and use of CIS, they could play a significant role in planning for household climate change adaptation (CCA). In Senegal, women and men producers needed distinct kinds of CIS for decision making, however, women farmers in particular needed information on projections for dry spells and rainfall deficits as well as the expected time when the growing season will end (Tall et al., 2014).

2.6 Climate Information Service Sources and Channels of Dissemination

The World Meteorological Organization (WMO) has the mandate to produce and provide up-to-date climate information and products for climate services to the National Meteorological and Hydrological Services (NMHSs) through the Regional Offices for Africa (Singh et al., 2016). In Ghana, the Ghana Meteorological Agency (GMet) provides weather and climate related information on onset of rain, prediction of rain, intensity of sun, etc. on daily and monthly bases to the public. However, the private sector and non-governmental organizations including like e-agricultural platform, Climate Change, Agriculture and Food Security (CCAFS), African Cashew Initiative, Esoko, Ignitia, Technical Centre for Agricultural and Rural Cooperation ACP-EU (CTA), Mfarms, US

Agency for International Development (USAID), Agricultural Cooperative Development International and Volunteers in Overseas Cooperative Assistance (ACDI/VOCA) and Farmerline Sarku et al. (2021), are strategic partners who play key roles in providing CIS to farmers in Ghana. Seasonal CIS and advisories were release to farmers via phones in the form of written messages and voice alert, in the past, thanks to a partnership between the Ghana Meteorological Agency and the ICT business Esoko (Partey et al., 2018). Also, the Council for Scientific and Industrial Research (CSIR), in partnership with Esoko offers agriculture-advisories to producers to assist them in implementing the most appropriate CSA practices on the basis of CIS received (Partey et al., 2018). The Ghana Meteorological Agency (GMET), the Ministry of Food and Agriculture (MoFA), the Ministry of Environment, Science, Technology and Innovation (MESTI), the Environmental Protection Agency (EPA), the National Climate Change Committee (NCCC), and the Council for Scientific and Industrial Research (CSIR) are the national institutions tasked with producing and disseminating CS (Naab et al., 2019).

Distribution channels of CIS highly influence its access and use. To reach those who are more exposed to and remove specific gender barriers to accessing climate information, innovative communication methods are required (Tall et al., 2014). Accessible, efficient, timely, and continuous communication routes between producers and users are required for CI to be effective (Box & Pleasant, 2020). Farmer field schools, training and visits, extension services, and better access to ICTs like community radio stations, rural TV, and mobile phones are some of the alternative inventive extension channels developed to fulfill the increasing demand for agricultural extension support (Djido et al., 2021). Jost et al. (2016) revealed that, gender would rather receive WCIS from the radio, extension agents via religious announcements in their local language in Ghana. Similarly, in Kenya, Radio and television were the primary dissemination mediums used by most families to access climate information services (Muema et al., 2018). However, widespread use of mobile phones in Sub-Saharan Africa (SSA) presents an opportunity for the dissemination of climate information as household in the area is thought to have at least one mobile phone user (Naab et al., 2019).Distribution channels, like “television, mobile phones and newspapers”, were found not to be useful as a result of limited ownership and language barriers (Jost et al., 2016).

2.7 Access to and use of climate information services

Access to information and knowledge about relevant technologies that promote resilience to climate unpredictability and change is key to farmers' ability to adapt to climate change (Nyasimi et al., 2016). Access to any form of technology is a pre-requisite to its use and uptake. For expanding and scaling up CSA technology, access to CIS offers a promising route (Ngigi & Muange, 2022). For farmers to adopt climate smart practices, climate information should be made accessible (Alidu et al., 2022). Findings in Kenya shows, that about 94% of households accessed seasonal climate information services but only about 40% of the households used the information in their farms decision making (Muema et al., 2018). Accessibility to several CIS distribution channels affected both spouses’ access to CIS in a favorable way (Ngigi & Muange, 2022). In order to reduce crop failures and raise household food security for both genders, farmers used the CIS they received to help them make a variety of deliberate decisions (Partey et al., 2018; Partey et al., 2019).

2.8 Climate Smart Agriculture

All over the world, CSA is being accepted as a strategy to improve and safeguard the agriculture sector (Chandra et al., 2018). It is a three in one strategy, which combines aims for 'intensification, adaptation, and mitigation' under one framework (Taylor, 2018). Climate-smart agriculture (CSA) is a strategy for changing and remodeling agricultural systems to enhance food security in changing climate (Lipper et al., 2014). To accomplish sustainable agricultural development for food security given climate changes, CSA is a way of creating technological, policy, and investment prerequisites (Nelson & Huyer, 2016). According to Waaswa et al. (2021) CSA practices are any widely used farmed production techniques that have undergone rigorous analysis and been found to be very effective in minimizing or excluding the effects of climate change on a particular system. It is crucial to understand that , food security is not possible without combining different approaches such as climate smart agriculture as climate change continues to impact on agriculture (Ifeanyi-Obi et al., 2022). In addition to helping to achieve SDG 13(Climate action), CSA is also strongly connected to several other SDGs, such as SDG 1(No Poverty) and SDG 2(Zero Hunger) (Hellin & Fisher, 2019b). The creation of technologies and practices, the production of climate change models and scenarios, information technologies, insurance programs, and the improvement of institutional and political enabling contexts are just a few of the many entrance points for CSA (Dhenge et al., 2016). These integrated strategies for climate change adaptation include agroecological methods, sustainable resource management, and ecosystem management and can include action on agricultural value chains, food waste, and consumption as an umbrella (Nyasimi et al., 2014). Driven by its clear demand for change, the CSA has quickly emerged as a crucial organizing principle for international organizations working at the interface of climate change, agriculture, and development (Taylor, 2018). The term "climate-smart agriculture" has arisen as a paradigm for expressing the idea that agricultural systems can be created and put into use in a way that simultaneously enhances food security and rural livelihoods, makes it easier to adapt to climate change, and has benefits for mitigation (Scherr et al., 2012).

Most integrated choices that are part of CSA methods and technology draw on the diversity of farming and fishing techniques in Africa and thus ,Africa has a chance to find, investigate, develop, and scale-up technical and practical applications that can withstand the changes in climate and satisfy rising food demand through climate-smart agriculture (Nyasimi et al., 2014). Far off from on farm practices, climate smart agriculture also encompasses ‘landscape-level interventions’ services (particularly information and finance), institutions (primarily market governance and adoption incentives), and the food system (primarily consumption patterns and broader climate-informed safety nets)’ (Rodríguez et al., 2017). Through developing international and regional (African) Alliances, Climate-Smart Agriculture (ACSA) provides a forum for mutual learning and collaboration among all interested parties (Dhenge et al., 2016). Damba et al. (2021), identified 22 CSA technologies within the Accelerating Impacts of C-GIAR Climate Research in Africa (AICCRA) intervention areas in Ghana with focus on maize, yam potato, tomato, and cowpea. The technologies identified included but not limited to, water and soil conservation technologies, soil fertility enhancement technologies, pest and diseases management technologies, seed and vine use technologies, agroforestry etc. Sam et al. (2020) on the other hand identified, crop and livestock integration, agroforestry community-led bushfire control, stone bunding or ridging, composting, crop rotation, mixed cropping, and chemical fertilizer were prioritized CSA practices in the Upper West region of Ghana. Yameogo et al. (2017) argued that, there is no complete list of CSA practices; rather, all agricultural strategies that support these three main objectives are categorized as climate smart.

2.9 Climate smart agriculture and gender

In order to combat climatic variability and change, farmers must develop coping mechanisms and improve their adaptive capability (Nyang'au et al., 2021). A greater use of CSA techniques will boost farmers' adaptability to climate change, boost output, and lower greenhouse gas emissions (Nyang'au et al., 2021). However, when it comes to making crucial decisions regarding altering agricultural techniques, women farmers may not have the same influence as men farmers (Murray et al., 2016). More so, the gender gap in agriculture is important because it can leave women and men in uneven positions to engage in and gain from site-specific CSA practices and opportunities (Nelson & Huyer, 2016). For CSA approach to be gender responsive it must take into consideration the important issues, gender roles, responsibilities, and resources ownership at the community and household levels (Nyasimi & Huyer, 2017). Similarly to how CSA techniques may be climate-smart in one context but not another, they may also have diverse impacts on gender roles depending on the geographical and cultural context, thus, gender roles, control over and access to productive assets, and power relations must be taken into account in the design, implementation, and dissemination of each CSA practice in order to better appreciate the potential and obstacles to CSA adoption (Murray et al., 2016). Access to credit, extension, limited membership in cooperatives and water user associations, lack of access to or user rights to land, skill training, information, and restricted mobility all had an impact on the uptake of conservation agriculture and small-scale irrigation schemes by female smallholder farmers (Acosta et al., 2021; Tsige et al., 2020). According to Sam et al. (2020), The usage of the prioritized CSA technologies and practices was not gender-restricted, male and females, had equal accessibility ,although the majority of CSA technology and techniques were predominately used by men. For policy recommendations that support the development and integration of gender-responsive climate smart agricultural (CSA) interventions into agricultural development programs, understanding the gender dimension of climate change perception and choice of adaption measures is essential (Diarra et al., 2021). Also, to encourage investment at scale, it is essential to comprehend the viability and incentives of the various CSA packages designed to equally benefit women and male farmers across geographies (Mutenje et al., 2019). Moreover, the uptake of technologies is impacted differently by various institutional and socioeconomic elements, for instance, in some areas, a farmer's age may restrict the adoption of labor-intensive technology, income may make high-value technologies more accessible, and gender may present obstacles for women in particular civilizations to obtaining recommended technologies (Waaswa et al., 2022). Thus, for CSA to continue to be relevant and long-lasting within global agendas on combating climate change and achieving the SDGs, it is essential that the social, economic, and political aspects of agricultural development are acknowledged (Hellin & Fisher, 2019a).

2.10 Climate Smart Agriculture Technology Uptake

To encourage widespread implementation of CSA in West Africa, it is necessary to comprehend the degree of acceptance of CSA technologies and practices as well as its drivers (Ouédraogo et al., 2019). According to Mungai et al. (2017), the adoption of CSA may depend on the needs and priorities of farming communities and may be context-specific and also different from one location to another. However, the information that farm households have access to and the amount of resources needed will determine how effectively the adopted technology is used (Ogada et al., 2018). Whereas in Mali, farm mechanization, new crop, organic and compost manure, monoculture were the most adopted CSA practices with a higher rate of over 80%, farmers in Niger adopted crop association, organic and compost manure, assisted natural regeneration were mostly adopted with over 80% of adoption rate (Mungai et al., 2017). In the Upper West region of Ghana, multiple cropping and erosion control were the most adopted CSA management practices with high adoption rates of 90% and 80% respectively (Djido et al., 2021). In Nigeria, Tiamiyu et al. (2018) recorded low adoption rates for most CSAs. This poor adoption of CSAs in sub-Saharan Africa may be related to the fact that CSA deployment needs upfront inputs that take time to provide productivity advantages (Ifeanyi-Obi et al., 2022; Shittu et al., 2021). In some cases, the adoption rate of such CSA practices as fertilizers, improved seed varieties, and water management practices, are low because they are capital intensive but have an enormous potential of increasing yield (Mossie, 2022). Because, smallholder farmers often need funds and/or credit to be able to purchase agricultural inputs (land, machinery, labor, seeds, and other farm inputs), and they risk failing in their attempts to adopt this technologies if any one or more of these inputs are unavailable or only available in irregular or inadequate supply (Yameogo et al., 2017). The likelihood that smallholder farmers will adopt climate-smart adaptation strategies is increased by factors such as gender, age, farm size, revenue from the farm, access to agricultural extension services, social group membership, and assets (Alidu et al., 2022). In Senegal, uptake of CSA practices was based mostly on traditional knowledge, family and neighbors with a minimum uptake based on radio campaigns and extension services(Serra & McKune, 2016). However, Adopting CSA techniques is anticipated to boost farm household welfare and present options for employment in addition to contributing to an increase in output (Mutenje et al., 2019).

2.11 Empirical review of the effects of Climate Information Services access on uptake of climate smart agricultural technologies

Various studies have been carried out to analyze the effects of access to climate information services on uptake of climate smart agricultural practices in farm decision making. In Ghana, Djido et al. (2021) analyzed the extent to which weather and climate information services(WCIS) derived CSA adoption based on a pilot project where mobile phones were the main channel of disseminating climate information in the Upper West region. Their findings suggested that, the usage of weather climate information service (WCIS) considerably raises the adoption of multiple cropping strategies and water management by 6.8% and 5.6%, respectively but with no statistically significance on adoption rates for integrated pest management, pest-resistant crops, or erosion control. The analysis was carried out using a simultaneous equation system with a recursive bivariate probit model. However, both the outcome (CSA practices) and the endogenous treatment variable (WCIS) were considered as binary variable.

Ngigi and Muange (2022) analyzed the differences in male and female access to CIS on the adoption of climate-smart agriculture (CSA) technology in Kenya, using an intrahousehold survey of husbands and wives. Recursive bivariate probit model was used with the results demonstrating that, the adoption of CSA technologies by husbands and wives was considerably and favorably impacted by climate information on early warning systems and advice services. While wives' decisions to embrace CSA technologies were not significantly influenced, husbands' access to seasonal forecasts had a positive impact on their adoption of CSA technology. Conversely, wives' intentions to embrace CSA technology were negatively affected by their access to weather forecast information. Although the study was a gendered base one, the heterogenous nature of countries may not allow for these findings to apply to other countries such as Ghana.

Alidu et al. (2022) on the other hand, analyzed Smallholder farmers access to climate information and climate smart adaptation practices in the northern region of Ghana using bivariate probit analysis, thus analyzing the joint decision of access to CIS and adoption of CSA strategies. The research however failed to show the kind/types of climate information services and climate smart agricultural practices that were accessed and adopted jointly. It further did not show how the bivariate probit model took care of endogeneity in a simultaneous equation system. Serra and McKune (2016) also analyzed the effects of access to CIS on adoption of CSA using a qualitative approach. Findings showed that only a small percentage of farmers who have access to CIS through radio used this information in their decision to adopt CSA. However, this research luck empirical basis.

For this study, descriptive statistic, the Multivariate Probit Model (MVP) and the Multinomial Endogenous Switching Regression (MESR) will be adapted for the analysis. Descriptive statistics will be used to analyze the sources and channels of access to CIS.

The MVP will be used to analyze the factors the influence access to various CIS and the MESR will be used to analyzed the impact of access to CIS on uptake CSA technologies and its impact on maize yield.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter outlines the various processes used in conducting this research. The sections are discussed in the following order; the study area, types and sources of data, data collection procedures, the sampling technique, sample size, and the methodologies used in the analysis of the collected data.

3.2 Study Area

This study was carried out in six regions in Ghana; Northern Region, Upper East Region, Upper West Region, Greater Accra Region, Central Region, and Bono East Region, covering eleven metropolitan/district assemblies and thirty-six communities. In the Tolon District of the Northern region, the communities include Nyankpala, Kpana, Woribog kukuo, Woribog, Lingbin-Vawagri, and Yizeigu.

In the Upper East region, the district/municipal assembly included are the Kasena-Nankana municipal (Tampola and Gaani) and Bongo district (Yidongo and Aleba).

Lawra District (Boompari, Toto and Yagra), and Jirapa municipal (Doggoh, Wulling and Dzuuri) are districts included in the Upper West Region.

One district from the Greater Accra region, the Ga south district (Tuba and, Langba) Cape Coast Metropolitan Assembly (Mempeasem, Effutu-Dehyia, Effutu-Mampong and, Kroforodo) and Komenda-Edena-Eguuafo-Abrem District (Dompoase, Enyinase, Kukuado, and Nsagyir) from the Central Region.

Kintampo North Municipal (Adomano, Bawakura, Tahirukura, and Asuogya), Kintampo South District (Adiemra, Agyegyemakunu, and Krabunso), Techiman North District (Offuman, Tanoboase, and Tanokrom) in the Bono East Region.

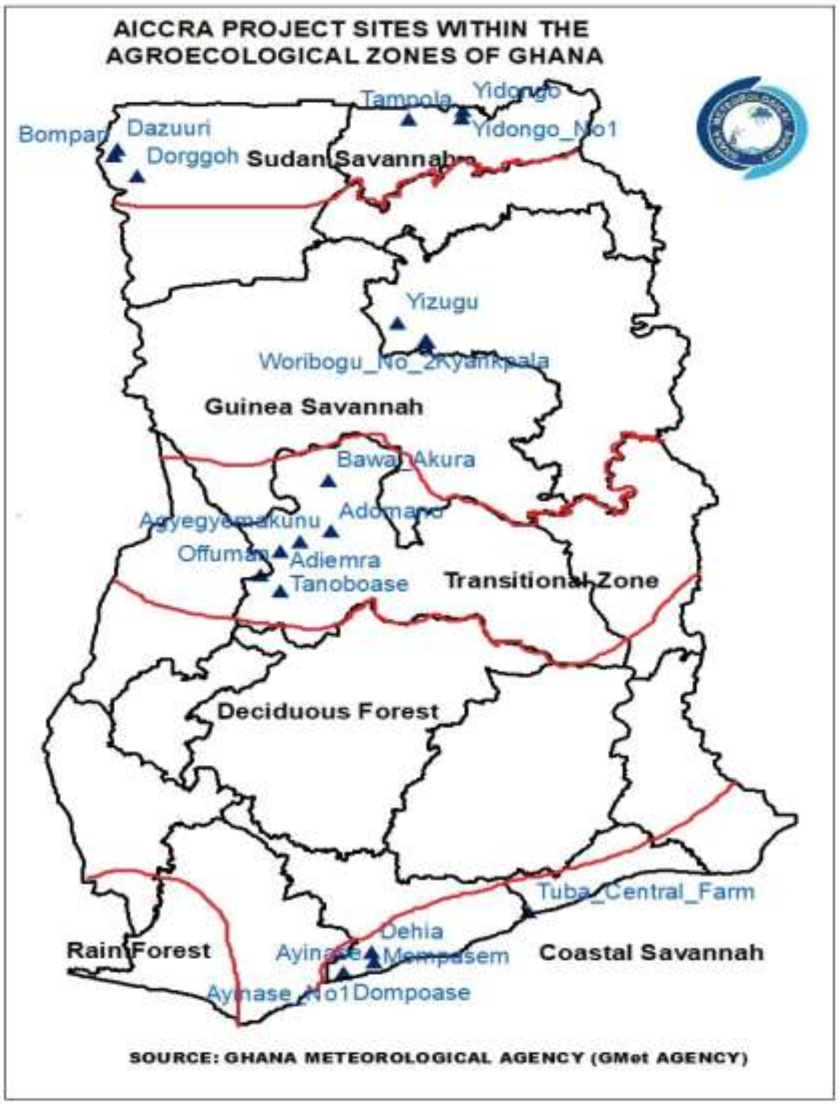

Figure 3.0.1: Map of the study area

3.2.1 Climate

Ghana predominantly has a tropical climate. However, this study covered four out of the five Agro Climatic Zones (ACZ) in Ghana, the Sudan Savanna Zone (Upper East), Guinea Savanna (Northern and Upper West), Transitional Zone (Bono East), and Coastal Zone (Central and Greater Accra). The average yearly rainfall figures range from 800mm for the Sudan Savanna,900mm for the Coastal zone,1100 for the Guinea Savanna zone, and <1900mm for the transition zone. The country's average yearly temperature, ranges from approximately 25.5 °C in the southwestern coastal regions to roughly 30 °C in the northern regions (Yamba et al., 2023).

The Sudan Savanna zone and Guinea Savanna zone experience unimodal seasonal rainfall, whereas the Transition zone and Coastal zone are characterized by bi-modal rainfall with two rainy seasons, a major and minor season but with the minor season of the Coastal zone less noticeable (Yamba et al., 2023).

3.2.2 Agriculture

In Ghana, Agriculture is mostly traditional, and characterized by small holdings with a majority of farm holdings less than 2 hectares in size with the use of hoes and cutlasses and little mechanized farming. The most important factors that determine differences in production are the amount and distribution of rainfall accompanied by soil texture, nutrient levels, pH, etc. (MoFA, 2018).

3.3 Research design, type and sources of data

3.3.1 Research design

This research used a cross-sectional design for the data collection on the impact of access to climate information services the on uptake of climate-smart agricultural technologies and yield among smallholder farmers in Ghana. Semi-structured questionnaire was used to collect quantitative data from selected households through face-to-face interview. Descriptive statistics and quantitative analysis were used to achieve the set objectives

3.3.2 Type of Data

Primary data was collected from the sampled households. The collected data included variables that were measured on a discrete, continuous, and categorical basis. The Data collected was based on the following crops: maize, tomatoes, cowpea, rice soybeans, and sweet potato as per AICCRA intervention. The data collected included crop types, educational level, sex and occupation (on-farm and off-farm), access to CIS, uptake of CSA, membership of associations, farmers' age, land size, and yield per hector etc.

Table 3.1:Summary statistic of variables

IV	Variable	Measurement	Mean	Std. Dev.	Min	Max
x_1	Age	Years	45.289	12.999	18	77
x_2	Status in household	1 if head;0 if others	.702	.458	0	1
x_3	Education	Years of education	5.107	5.675	0	16
x_4	Crop diversification	1 if more than 1 crop;0 if 1crop	.763	.426	0	1
x_5	Access to CIS	1 if yes;0 if not/otherwise	.9	.3	0	1
x_6	Cash crop production	1 if yes;0 if not/otherwise	.398	.49	0	1
x_7	Nonfarm activities	1 if yes;0 if not/otherwise	.254	.436	0	1
x_8	Farmer based organization	1 if yes;0 if not/otherwise	.526	.5	0	1
x_9	Membership of VSLA	1 if yes;0 if not/otherwise	.467	.499	0	1
x_{10}	Maize Farm size	hectors	1.14	1.88	0	30
x_{11}	Perception of climate change	1 if yes;0 if not/otherwise	.965	.184	0	1
x_{12}	Livestock production	1 if yes;0 if not/otherwise	.563	.496	0	1
x_{13}	Access to credit	1 if yes;0 if not/otherwise	.722	.448	0	1
x_{14}	Access to extension	1 if yes;0 if not/otherwise	.693	.462	0	1
x_{15}	Rating of the season	1 if yes;0 if not/otherwise	2.311	.815	1	3
x_{16}	Fertilizer expenditure	Amount spent in Ghana cedi	959.431	1750.319	0	20000
x_{17}	Herbicide expenditure	Amount spent in Ghana cedi	360.548	988.018	0	20000

3.3.3 Source of data

The data used is a part of AICCRA baseline intrahousehold data, obtained from primary and secondary decision-makers on agricultural activities within the small farm households on crop types, education, age, sex, land size under production, yield of crops, access to various CIS, use of CIS, uptake of various CSAs, channels and sources of access to CIS, membership of social groups, participation in animal production, nonfarm activities using semi-structured questionnaire.

3.4 Sampling Techniques and Sample Size

3.4.1 Sample Size

A total sample size of five hundred and forty (540) small-farm households was obtained from the six regions, based on the Accelerating Impacts of CGIAR Climate Research in Africa (AICCRA) intervention project on climate change in the regions. The sample size used is made up of only the primary decision-makers. The justification for the use of only the primary decision makers is that produce from the farms of these decision-makers is used to feed the entire household and cater to other needs of the household members.

For each AICCRA intervention community, a control community was randomly selected 12km away due to the leakage nature of climate information and CSA practices, yielding a total of 19 treatment and 19 control communities.

Table 3.2: Sample Size

Region	District	Control	Treated	Total
Bono East	Kintampo North	28	29	57
	Kintampo South	28	31	59
	Techiman North	30	35	65
Central Region	Cape Coast Metro	23	28	51
	Komenda-Edena Eguafo Abrem	30	22	52
Greater Accra	Ga South	13	17	30
Northern Region	Tolon	43	43	86
Upper East	Bongo	15	15	30
	Kasina Nankana	15	12	27
Upper West	Jirapa	17	14	31
	Lawra	26	26	52
Total		**268**	**272**	**540**

3.4.2 Sampling Techniques

Multi-stage sampling techniques was employed in the selection of farm households. In the first stage, the regions and districts were purposively chosen based on the location of the AICCRA intervention project while considering the population, risk of climate, and agricultural production. In the second stage, the communities were clustered and a sample frame was drawn with the help of community leaders from which 19 treatment and 19 control communities were randomly selected. However, the control communities were selected 12km away from the treatment communities due to the leakage nature of climate information. In the last stage, both treatment (272) and control (268) households were selected using simple random sampling.

3.5 Conceptual Framework

This study depicts the linkages between CIS access and its effect on the choice of CSA practices toward improved farm yield. It also illustrates the factors that influence access to CIS, uptake of CSA practices, and maize yield. It is hypothesized that access to climate information is a first step to climate change adaptation. Once farmers receive these CIS from various sources and channels, they can then use it in decisions pertaining uptake of various CSA practices in their farm operation based on the kind of information received which in effect translates to improvement in yields. Factors such as farmer socio-demographic characteristics (age, status in the household, educational level, gender), organizational/institutional elements (access to credit, access to extension services) and livelihood outcomes (crop diversification, cash crop production, non-farm activities, livestock production) are all possible determinants of access to CIS and the uptake of CSA practices as shown in Figure 3.2 below. For uptake of CSA, it is assumed that it is dependent on all factors including access to CIS, however, it is suspected that access to CIS is endogenous. Intuitively, depending on the climate information farmers have access to, they can plan their farm operations by adopting as many CSA technologies as possible that best fit. However, farmers may also access CIS because they are already adopting CSA practices. Also, there is a possibility that factors that affect access to CIS are possible determinants of the uptake of CSA practices.

For this research, sources of CIS are defined as the origin of climate information and advisories, be they primary or secondary, whereas channels are the mediums from which farmers receive climate information and advisories. Uptake is operationalized as using climate-smart agricultural technologies either consistently or not, while access means receiving and making use of the received information. Yield is measured as the total output of maize in kilograms divided by the total farm size in hectares used in the cultivation of maize. Also, uptake and adoption are used interchangeably, and so are practices and technologies.

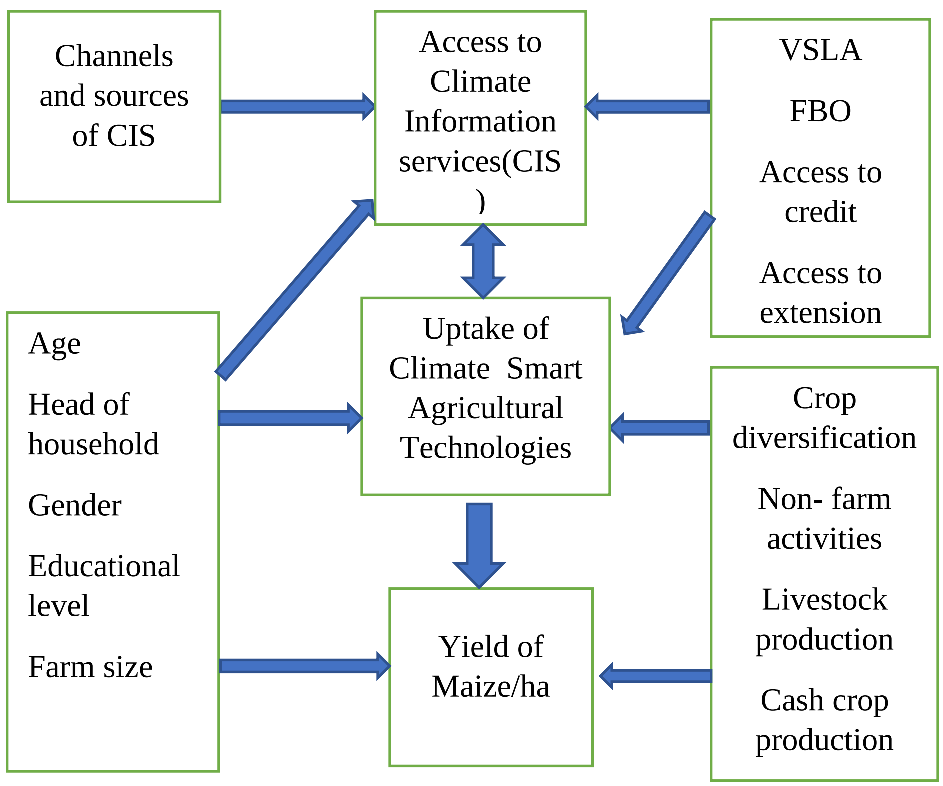

Figure 3.2: Conceptual Framework

3.6 Theoretical Framework

Climate information services (CIS) is the provision of data and information on both weather conditions over the short period and climate events over the long-term period,(Serra & McKune, 2016). It serves as a support tool for the uptake of CSA practices.

This research leverages the AICCRA climate change intervention in Ghana and is focused on the linkages between access to CIS and its effects on the uptake of CSA practices and maize yield. The study considered 19 CIS (crop selection, planting time, variety selection, field selection, weed management, cropping calendar, fertilizer application, water management, cropping calendar, soil management, pest and disease outbreak, pest and disease management, predicting rainfall, start of the rain/ season, end of rain /season, expected amount of rainfall, intensity of cloud coverage, intensity of sun, drought prediction, and intensity of drought grouped into 7 major CIS. Fifteen CSA practices were identified and includes: intercropping, agroforestry, crop rotation, irrigation, zero tillage, zero residue burning, integrated pest management, stress and drought tolerant seed varieties, organic manure, agricultural insurance, on and off-farm composting, enhanced biopesticide usage, contour stone bunds, leguminous crop as a previous crop, pest management using sticky traps, grouped into 7 major CSA based on purpose and availability to farmers via various sources and channels. In effect, access to CIS is a prerequisite for uptake the of CSA practices. Therefore, the decision of farmers to access CIS is based on the perceived benefits that are expected to be gained. However, the effect can only be measured if this information is used to make farm decisions such as the uptake of CSA practices, that may have an impact on yield (utility), therefore the decision of farmers to access CIS and uptake different CSA is based on the theory of random utility maximization.

Based on Danso-Abbeam et al. (2017), farmers' decision to access/use a combination of CIS through any combination of channels and subsequently uptake multiple CSA practices is based on an underlying utility function U which is dependent on demographics and socioeconomic characteristics ,x.

Thus, for maximum satisfaction between two packages j and m, the utility function is

$$U_{ij} > U_{im} \qquad j \neq m$$

$$U_{ij}^{*} = X_{ij}\beta_{ij} + e_{ij} \tag{1}$$

3.7 Models for data analysis

3.7.1 Analysis of factors that influence access to CIS

The ability to withstand the effects of changing climate involves having access to climate information. Depending on individual socio-economic, and organizational characteristics, farmers are at liberty to access different CIS. Therefore, to examine these factors that affect access to various CIS, multivariate probit (MVP) regression was employed. The MVP is the generalization of the probit analysis well known for its ability to model for multiple correlated binary dependent variables. The MVP is an extension of more than two dependent variables. This is carried out by adding more equations of dependent variables. The MVP regression is estimated using maximum likelihood (ML).

For this study, seven (7) grouped CIS were considered (rainfall prediction/amount, selection of crops/varieties, planting time/fertilizer application information, pest and disease outbreak/management, crop management, intensity of sun/cloud cover). In this case, a total of 7 separate binary equations could have been estimated for the factors that influence farmers' access to CIS differently. However, this could generate a bias and inconsistent estimate because of possible interdependence between the dependent variables that will lead to correlation of the error terms. To account for the potential a correlation of the error terms and possible endogeneity (unobserved differences), the MVP was used to jointly model the factors that affect access to various CIS.

3.7.2 Factors influencing access to climate information services

Following Mulwa et al. (2017), the multivariate probit analysis involves an estimation of n equations model with n binary unobserved dependent variables thus, for the seven CIS, the MVP is specified such that:

$$Y_{ij}^{*} = x_{ij}b_{ij} + u_{ij}, \qquad Y_{ij} = \begin{pmatrix} 1 \ if \ Y_{ij}^{*} > 0 \\ 0 \ if \ Y_{ij}^{*} \leq 0 \end{pmatrix} \tag{2}$$

Where

y_{ij}^{*} is an unobserved variable that represents the binary dependent variable access to CIS and captures the observed and unobserved characteristics associated with the j_{th} CIS. x_{ij} is a vector of the explanatory variables for j_{th} CIS , β_{ij} are parameter estimates and u_{ij} are errors distributed as a multivariate normal distribution with zero means, constant variance, and an $n \times n$ correlation matrix.

However, as in (Donkoh et al., 2019; Kolapo et al., 2022) the specification of the multivariate normal(MVN) distributed error is expressed as $(\mu_N, \mu_H, \mu_S, \mu_I, \mu_B, \mu_{I,}\mu_B) \approx MVN(0, \Omega)$ with a variance-covariance matrix Ω specified as:

$$\Omega = \begin{bmatrix} 1 & \rho NH & . & \rho NB \\ \rho HN & 1 & . & . \\ . & . & 1 & IB \\ \rho IN & . & BI & 1 \end{bmatrix} \pm \tag{3}$$

Where ρ is the pairwise correlation coefficient of error terms given any two of the estimated access to CIS equation in the model. The non-zero off-diagonal represents the correlation of the error terms across the various latent access to CIS equation.

Empirically, as in Kariuki et al (2016), the seven (7) CIS is given as:

$$\left\{\begin{array}{c} y_1 = x_1'\beta_1 + u_2\,, y_1 = 1\; if\; y_1^* > 0{,}0\; if\; otherwise \\ y_2 = x_2'\beta_2 + u_2\,, y_2 = 2\; if\; y_2^* > 0{,}0\; if\; otherwise \\ y_3 = x_3'\beta_3 + u_3\,, y_3 = 3\; if\; y_3^* > 0{,}0\; if\; otherwise \\ y_4 = x_4'\beta_4 + u_4\,, y_4 = 4\; if\; y_4^* > 0{,}0\; if\; otherwise \\ y_5 = x_5'\beta_5 + u_5\,, y_5 = 5\; if\; y_5^* > 0{,}0\; if\; otherwise \\ y_6 = x_6'\beta_6 + u_6\,, y_6 = 6\; if\; y_6^* > 0{,}0\; if\; otherwise \\ y_7 = x_7'\beta_7 + u_7\,, y_7 = 7\; if\; y_7^* > 0{,}0\; if\; otherwise \end{array}\right\} \quad (4)$$

3.7.3 Multinomial Endogenous Switching Regression Model

The multinomial endogenous switching regression (MESR) model was used in this investigation to consider selectivity bias resulting from both observed and unobserved factors. Although previous studies focused on impact analysis using bivariate approaches, such as the Endogenous Switching Regression (ESR), Propensity Score Matching, Recursive Bivariate methods, farmers often tend to adopt a combination of practices at a point in time in their quest to adjust to the negative effects of climate change. Using the traditional Endogenous Switching Regression or propensity score matching will lead to the measurement of estimates that are inconsistent and biased. The MESR method therefore is preferred because it allows for estimating the impact of multiple choices.

The MESR model is carried out in two stages concurrently, thus the uptake(selection) and outcome equations. In the first step, the uptake(selection) equation, a Multinomial logit model MNL is estimated to examine factors that influence uptake of complementary CSA practices while accounting for unobserved heterogeneity and also determining the inverse mills ratio IMR, (Baiyegunhi et al., 2022).

In the second stage, thus the outcome equations, the impact of uptake of complementary CSA practices is then determined using the endogenous switching outcome model with IMR introduced as a covariate to take care of selection bias and unobserved heterogeneity (Baiyegunhi et al., 2022).

For proper identification of the MESR model, some variables (perception of climate change, farmers rating of the 2022 season, and membership of FBO) are added to the selection equation but not included in the outcome equation as identifying instruments (Issahaku & Abdulai, 2020; Shafiwu et al., 2022). The intuition behind the use of these instruments is that they may affect the decision to uptake CSA practices but might not necessarily affect maize yield directly. A falsification test is conducted to ensure the chosen instruments are valid, such that, it affects the decision to uptake CSA technologies but does not have a direct effect on the yield of the group that did not uptake(Issahaku & Abdulai, 2020). For this purpose, OLS is used to regress the yields on all covariates conditional on the CSA technologies adopted. To account for possible endogeneity the control function approach is adapted by retrieving the residual (using probit analysis) of the suspected endogenous variable(CIS) and adding it to the selection equation with the observed endogenous variable (Issahaku & Abdulai, 2020).

3.7.3.1 Multinomial logit (Selection) Model

Following Shafiwu et al. (2022),the multinomial logit regression was used to determine all possible combination of 3 CSA practices (soil fertility management, water management and pest & disease management) resulting in 8 categories of CSA practices that farmers uptake .

The multinomial logistics selection model is expressed as

$$y_{ij}^{*} = X_{ij}\beta_{ij} + \varepsilon_{ij}$$

Where y_{ij}^{*} is the unobserved utility associated with the jth choice, X_{ij} are a set of observed exogenous variables with ε_{ij} being the error term following an independent, identical gumbel distribution, following the independent, irrelevant alternative (IIA) assumption, and a probability of farmer i choosing bundle j as

$$p_{ij} = p\left(\varepsilon_{ij} < 0 \,/ x_i\right)\frac{\exp\,(x_i\beta_j)}{\sum_{m=1}^{k}\exp\,(x_i\beta_j)} \qquad (5)$$

3.7.3.2 Endogenous Switching Regression

In this step, the endogenous switching outcome model is used to determine the impact of uptake choices of CSA practices on maize yield, specified as:

$$m_{ij=}z_{ij}\alpha_{ij} + e_{ij} \qquad (6)$$

Where m_{ij}, is the vector of outcome variable for an i farmer in regime j given other explanatory variables z and unobserved error term e_{ij} with expected value of zero $[E(e_i|x_i z_i) = 0]$ and a variance $v\left(e_{ij}\middle|x_i z_i\right) = \sigma_j^2$ whiles considering for selection bias. m_{ij} is observed if a combination of CSA practices is adopted, implying $U_{ij} > U_{im}$.To get an unbiased and consistent estimate of covariance σ, a selection correction term of all alternatives is included, given an assumption that e_{ij} *and* ε_{ij} are linearly correlated such that

$E(e_{ij}|\varepsilon_{i1} \dots \dots \varepsilon_{ij}) = \sigma_j \sum_{m\neq j}^{j} \rho_j(\varepsilon_{im} - E(\varepsilon_{im}))$, where ρ is the correlation coefficient between e_{ij} *and* ε_{ij} *and* σ.

With a total of 8 regimes faced by a farmer with $j = 0$ being the reference category (non-up-takers) and other regimes ; $j = 1$ (soil fertility management practices only), $j = 2$ (water management practices only), $j = 3$ (pest & disease management practices only), $j = 4$ (soil fertility and water management practices only), $j = 5$ soil and pest & disease management practices only) and $j = 6$ (water and pest & disease management practices only), $j = 7$ (combination of all three practices) taken into consideration the bias correction expressed as

$$regime1\ m_{ij} = z_i\alpha_1 + \sigma_1\lambda_1 + \mu_{i1} if\ i = 1 \qquad (7a)$$

$$regimej\ \_m_{ij} = z_i\alpha_j 1 + \sigma_j\lambda_j + \mu_{ij}\ if\ i = \ j \qquad (7b)$$

Where μ_{ij} is an error term with an expected value of zero,

The mills ratio λ is then expressed as $\lambda_j = \sum_{m\neq j}^{j} \rho_j \left[\frac{\rho_{im}\, ln(\rho_{im})}{1-\rho_m} + ln(\rho_{ij})\right]$.

3.7.3.3 Estimation of average treatment effect on the treated (ATT)

The Average treatment effect is the difference between the expected outcomes of uptakes when they uptake (actual) CSA practices and the up-takers if they had not uptake(counterfactual) the CSA practices.

Up takers with uptake(actual)

$$E(m_{i2}|i = 2) = z_i\sigma_2 + \sigma_2\lambda_2 \quad (8a)$$

$$E\left(m_{ij}\middle|i = j\right) = z_i\sigma_j + \sigma_j\lambda_j \quad (8b)$$

Up takers if they had not uptake(counterfactual)

$$E(m_{i1}|i = 2) = z_i\sigma_1 + \sigma_1\lambda_2 \quad (9a)$$

$$E(m_{i1}|i = j) = z_i\sigma_1 + \sigma_1\lambda_{j2} \quad (9b)$$

Therefore, the average treatment effect on the treated is specified as

$$ATT = E(m_{i2}|i = 2) - E(m_{i1}|i = 2) = z_i(\sigma_2\sigma_1) + \lambda_2(\rho_2\rho_1) \quad (10)$$

3.8 Variable definition and a priori expectation

As shown in Table 3.3 below, the various a prior expectation and the means of measurement indicate the variables under the study.

Table 3.3: Variable definitions and a priori expectation

variables	Nature/ measurement	Exp sign on access to various CIS	Exp sign on uptake of CSA technologies
Age	Continues	-	+
Status in household	Dummy :1 if head of household;0 otherwise	+	+
Sex	Dummy :1 if male;0 if female	+/-	+/-
Education	Continues(years)	+/-	+/-
Crop diversification	Dummy: 1 if two or more;0 if otherwise	+	+
Size of maize farm in ha	Continues(ha)	+	+/-
Member of VSLA	Dummy: 1 if member;0 if otherwise	+	+
Member of FBO	Dummy:1 if member;0 if otherwise	+	+
Participation in non-farm income activities	Dummy:1 if yes;0 if otherwise	+/-	+
Livestock production	Dummy:1 if yes;0 if otherwise	+/-	+
Access to credit	Dummy:1 if yes;0 if otherwise	+/-	+
Access to CIS	Dummy:1 if yes;0 if otherwise		+
Perception of climate change	Dummy:1if yes ;0 if otherwise	+	+/-
Rating of the season	Categorical:0=bad;1=moderate and 2=good	+/-	+/-

Age

As farmers increase in age, they turn to have more experience and knowledge on the climate and agricultural technologies, and therefore are more likely to use their indigenous knowledge of climate reducing their interest in access to climate information. Therefore, the outcome is expected to influence the uptake decision of CSA positively but negatively on access to CIS.

Status in the household

Access to CIS and uptake of CSA technologies requires more resources. Farmers who are household heads are the custodians of household resources and thus have full control over them which gives them the upper hand in the use of such resources. Household heads are also seen as the main providers for the household and thus are more likely to take steps to improve their farm outcome. This is therefore expected to positively influence access to Climate information services and also the uptake decision of CSA technologies.

Sex

The direction of this variable could either be positive or negative. Men and women have different controls of resources. Men turn to have more access to and control over resources and are also able to move around increasing their access to information.

Educational Level

As the level of education increases, access to information also increases because educated farmers can understand the implication of climate change and also have can understand climate information and apply it in the uptake of climate-smart technologies, therefore the direction of this variable is expected to be positive on both access to CIS and uptake of CSA technologies.

Maize Farm Size

This variable is expected to have a positive effect on the kind of climate-smart technologies to uptake and access climate information. Farmers with larger farm sizes have the likelihood of accessing climate information but are less likely to adopt multiple climate-smart agricultural technologies.

Crop diversification

This variable is hoped to have a beneficial effect on the uptake of CSA. Farmers who cultivate more than one crop are more likely to intercrop and rotate their crops. This also prompts farmers to access CIS in planning which crop to plant and at what time.

Membership of VSLA

Being a member of the VSLA group means access to more information and also access to credit based on savings. The direction of this variable on access to CIS and uptake of CSA is expected to be positive because farmers will be able to acquire credit for the purchase of inputs and also get varied information from other members of the group.

Membership of a farmers' association /cooperation (FBO)

This is expected to be positive and significant and thus increase farmers' access to CIS and uptake of CSA. Because being a member of a farmers' group means more exposure to extension services and discussions on adaptation strategies. Farmers are also able to try on new technologies based on other members' success in the use of such technologies

Participation in non -farm activities (artisanship, trading etc.)

This variable is expected to have a positive influence on uptake of CSA practices because this means additional income. However, its direction on access to CIS could be positive or negative.

Participation in Livestock production

The effect of this variable on the uptake of CSA practices is hoped to be positive because it means additional income and farm manure. Its effect on access to CIS could however be positive or negative.

Perception of climate Change

Farmers who think the climate is changing are more likely to have access to climate information and also adopt climate-smart agricultural practices as a measure of coping and resilience.

Rating of the season's weather

Rating the season as either, bad, moderate, or good will have either a negative or positive influence in access to climate information and uptake of climate smart agricultural technologies.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter outlines and discusses the results of the research work. It gives in-depth discussions on the socio-demographic characteristics and livelihood options of smallholder farmers interviewed. It further elaborates on the sources and access to climate information, uptake of climate-smart agricultural practices and the effect on maize yield using descriptive statistics, multivariate probit model and the multinomial endogenous regression.

4.2 Socio-demographic characteristics

4.2.1 Age distribution, Educational level, Farm size and Maize yield

Results as shown in Table 4.1 below indicate that about 64.07% and 35.93% of the respondents were male and female respectively with an average age of female and male being 47 and 45 years old. The minimum age of respondents was 22 and 18 years and a maximum of 77 years for both females and males, respectively. This means that, men who are characterized as the heads of households start farming at an early age, compared to their female counterparts who at that stage are more involved in household chores. It suggests that labor in crop production in Ghana is mainly within the active youth age. This however contradicts Muema et al. (2018) who found the average age of respondents as 59 years. The table shows that the average number of years of education by farmers is 5 with a maximum of 16 years of education. This indicates that agriculture in Ghana is dominated by males with limited to no formal/conventional education but agrees with Alidu et al., (2022), who revealed that 77% of farmers in their study area were males and with a mean number of years of education being 4 years indicating low formal/conventional education.

Table 4.1: Distribution of age by sex, Educational level, Farm size and Maize yield

Variable	Obs	percentage	Mean	Std. Dev.	Min	Max
Age						
Male	346	64.07	44.5	13.107	18	77
Female	194	35.93	46.696	12.715	22	77
Total	540	100				
Education(years)	540	100	5.107	5.675	0	16
Farm size	540		1.14	1.88	0	30
Maize yield/ha	540		878.898	795.677	0	4375

Source: Field survey, 2022

Table 4.1, also shows that the average farm size used in the cultivation of maize is about 1.14 hectares with an average yield of 879 kilograms per hectare and a maximum yield of 4375 kilograms per hectare. This result is however below MoFA's (2018) stipulated average yield of 2.26 metric tons per hectare.

4.2.2 Status in the household, membership of groups and participation in other income earning activities by sex

Individuals interviewed represent primary decision-makers on agricultural activities in the household. 35.93% (194) and 64.07(346) females and males' respectively. The results in Table 4.2 show that, out of the 540 respondents, about 70% (379) were household heads, 74 female household heads and 305 male household heads. These female heads were mainly widowed and or separated from their spouses. Out of 540 respondents, about 137(25.37%), made up of 62 females and 75 males participated in non-farm income-earning activities, suggesting that about 74.62 % of the respondents are predominantly farmers. Also, 56.29% (304), made up of 81 females and 223 males also participated in the production of small and large livestock, including sheep, goats, cattle, and poultry as shown in Table 4.2 below.

Table 4.2: Status in the household, membership of groups and participation in other income earning activities

Variables	Sex		
	Female	Male	Total
Status in the household			
Head in household	74	305	379
Others	120	41	161
Total	194	346	540
Farmer based organization (FBO)			
No	101	155	265
Yes	93	191	284
Total	194	346	540
VSLA			
No	96	192	288
Yes	98	154	252
Total	194	346	540
Livestock production			
No	113	123	236
Yes	81	223	304
Total	194	346	540
Non -farm activities			
No	132	271	403
Yes	62	75	137
Total	194	346	540

Membership in social groups is very important and drives collective action in times of challenges and difficulties. Table 4.2 shows that 52.59% (284) of the respondents,93 females, and 191 males were members of farmer-based organizations. Additionally, 98 females and 154 males making a total of 252(46.66%) respondents were members of the village savings and loans group giving them access to informal credit based on contribution.

4.2.3 Distribution of major crops cultivated and crop diversification

As shown in Table 4.3 below, about 82.22% (444) of 540 respondents cultivated maize either as the first major crop or second or third major crop. This conforms with MoFA's (2018) estimates of Maize being the largest produced crop across the country. Maize is produced mainly for household consumption. Also, 109 respondents, cultivated yam either as a first major crop, second major crop, or third major crop.

Table 4.3:Distribution of three major crops cultivated and crop diversification

Crop1	Freq.	**crop2**	Freq.	**crop3**	Freq.	**Total**
Other crops	123	Other crops	125	Other crops	23	271
Cowpea	14	Cowpea	69	Cowpea	11	94
Maize	305	Maize	129	Maize	10	444
Pepper	9	Pepper	21	Pepper	39	69
Potato	3	Potato	7	Potato	8	18
Tomato	33	Tomato	13	Tomato	11	57
Yam	53	Yam	47	Yam	9	109
Total	540	Total	411	Total	111	
Crop diversification						
Yes	128					
No	412					
Total	540					

Source: Field Survey, 2022

Other crops including rice, groundnut, millet, beans, guinea corn, watermelon, pineapple, garden eggs, oil palm, cocoa, oil palm, sorghum, rubber, soybean, okra, ginger, cashew, and cabbage also cultivated by 271 respondents either as a first major crop, second major crop or third major crop. Among the 540 respondents, 76.30% (412) diversified into at least two crops with the remaining 23.70% (128) cultivating one crop as shown in Table 4.3 above.

4.2.4 Ratings of the 2022 season weather and Perception of Climate Change Access to Credit and Extension services

Table 4.4 below shows that 22.41% (121) rated the 2022 cropping season weather as bad,24.0% (130) rated it as moderate while the remaining 53.52% (289) said the season's weather was good. Also, 96.48% of the respondents agreed that the climate was changing. The remaining 3.52 % however felt there was no change in the climate. Table 4.4 also shows that 72.22(390) had access to informal credit based on their savings in the VSLA group with the remaining 27.78% (150) having credit constraints in getting credit. Also,69.26% (374) had access to extension services and visits whereas the remaining 30.74% lacked access to extension services.

Table 4.4:Rating of the 2022 season weather, perception of climate change, access to credit and extension services

Variable	Freq.	Percent
Rating of the 2022 season		
Bad	121	22.41
Moderate	130	24.07
Good	289	53.52
Total	540	100.00
Perception of Climate Change		
No change	19	3.52
Change	521	96.48
Total	540	100.00
Access to credit		
No	150	27.78
yes	390	72.22
Total	540	100
Access to extension		
No	166	30.74
yes	374	69.26
Total	540	100.00

4.3 Sources and channels of access to climate information services

4.3.1 Sources of access to CIS

Table 4.5 shows that, generally, MoFA is the major source of climate information accessed by farmers with 42.96% accessing information on the selection of crops&varieties,63.52% on planting time and fertilizer application,42.04% on rainfall prediction and amount,17.41 % on drought prediction and intensity,46.85 on pest/disease management,27.41% on crop management practices and only 8.33% on intensity of sun and cloud cover. This could be attributed to the fact that MoFA breaks down climate information for a better understanding of farmers. The results further show that various NGOs were second to MoFA in access to information on the selection of crops &varieties, planting time &fertilizer application, pest & disease outbreak and management, and integrated crop management practices, whereas GMET was a source of access to information on rainfall prediction and amount and prediction, ESOKO on the other hand was second to MoFA as a source of access to information on drought prediction and intensity. The table further shows that, for all categories and sources of climate information services, men had more access compared to women. The possible reason for low access to climate information from GMET and ESOKO is that climate information from ESOKO is demand-driven while climate information from GMET is more complex for farmers' understanding.

Table 4.5:Sources of climate information services

CIS variable/Sources	GMET	Esoko	MoFA	NGOs
Selection of crops and variety (SCV)				
Female	2	0	72	2
Male	5	14	160	14
Total access	7	14	232	16
Percentage	1.30	2.59	42.96	2.96
Planting time and fertilizer application (PTFA)				
Female	8	2	121	7
male	11	16	222	15
Total access	19	18	343	22
percentage	3.52	3.33	63.52	4.07
Rainfall prediction and amount (RPA)				
Female	32	5	75	0
Male	68	47	152	0
Total	100	52	227	0
Percentage	18.52	9.63	42.04	0.00
Intensity of sun and cloud cover (ISC)				
Female	2	3	8	0
male	9	17	37	1
Total access	11	20	45	4
Percentage	2.04	3.70	8.33	5
Drought prediction and intensity (DPI)				
Female	9	4	20	1
Male	9	34	74	2

Total access	18	38	94	5
percentage	3.33	7.04	17.41	7
Pest and disease outbreak & management (PDOM)				
Female	0	2	79	2
Male	1	5	174	68
Total access	1	7	253	142
Percentage	0.19	1.30	46.85	210
Integrated crop management practices (CMP)				
Female	66	3	46	68
Male	141	9	102	142
Total access	207	12	148	210
Percentage	38.33	2.22	27.41	38.89

4.3.2 Channels of access to climate information

Results of the channels of CIS access, as shown in Table 4.6 below, indicate that, for all CIS categories, the major channels of access to climate information were extension agents with 40.76% accessing information on the selection of crops and varieties,57.96% on fertilizer application,36.48% on rainfall prediction and amount,15% on drought prediction and intensity,42.41% on pest and disease outbreak and management, 42.41% on crop management practices and only 6.4% on intensity of sun and cloud cover. Similarly, Baffour-Ata et al. (2022) reported that 52% of their respondents had access to climate information via extension agents, though radio was the major channel of access to climate information. Furthermore, the result conforms with Waaswa et al. (2021) who found out that, extension agents were the principal source of information for farmers. On the contrary, Muema et al. (2018); Oyekale (2015); Serra and McKune (2016) reported radio as the principal channel of access to climate information. The results further show that, for all the various disseminating channels of CIS men had more access to each channel than women. Aside from extension agents, a considerable number of respondents also accessed CIS on the Radio and neighboring farmers. Other channels of access to CIS were farmer-based organizations, TV, and mobile phones.

Table 4.6:Channels of access to climate information services

Channels	Radio	TV	FBO	Extension agent	Neighbor farmer	Mobile phone
Selection of crops and variety (SCV)						
Female	10	3	10	72	15	0
Male	47	13	15	148	20	14
Total access	57	16	25	220	35	14
Percentage	10.56	2.96	4.63	40.76	6.48	2.59
Standard deviation	0.31	0.17	0.21	0.50	0.25	0.16
Planting time and fertilizer application (PTFA)						
Female	26	3	16	109	19	5
male	65	12	16	204	32	16
Total access	91	15	32	313	59	21
percentage	16.85	2.78	5.93	57.96	9.44	3.98
Standard deviation	0.38	0.16	0.24	0.49	0.29	0.19
Rainfall prediction and amount (RPA)						
Female	53	7	10	66	9	7
Male	131	38	15	131	21	47
Total	184	45	25	194	30	54
Percentage	34.07	8.33	4.63	36.48	5.56	10.00
Standard deviation	0.47	0.28	0.21	0.48	0.23	0.30
Intensity of sun and cloud cover (ISC)						
Female	4	2	0	8	0	2
male	23	11	1	27	3	16
Total access	27	13	1	35	3	18
Percentage	5.00	2.41	0.19	6.48	0.56	3.33
Standard deviation	0.22	0.15	0.04	0.25	0.07	0.18
Drought prediction and intensity (DPI)						
Female	15	2	1	17	0	3
Male	37	5	2	64	4	28
Total access	52	7	3	81	4	31
percentage	9.63	1.30	0.56	15.00	0.74	5.74
Standard deviation	0.30	0.11	0.07	0.34	0.09	0.23
Pest and disease outbreak & management (PDOM)						
Female	11	2	6	76	13	0
Male	35	5	6	153	17	7
Total access	46	7	12	229	30	7
Percentage	8.52	1.30	2.22	42.41	5.56	1.30
Std deviation	0.28	0.11	0.15	0.50	0.23	0.11
Integrated crop management practices (ICMP)						

Female	10	1	6	76	12	2
Male	27	8	16	153	12	12
Total access	37	9	22	229	24	14
Percentage	6.85	1.67	4.07	42.41	4.44	2.59
Standard deviation	0.25	0.13	0.20	0.50	0.21	1.60

4.4 Access to Climate Information Services

Access to CIS is a prerequisite to making major decisions in agricultural production. Having early information on various climate-related variables and agricultural advisories is of great significance for agricultural decision-making and efficient and effective use of resources. Generally, 486(90%) of respondents had access to various CIS, consisting of 319 males and 167 females. Table 4.7 below also shows that 338(62.59%), consisting of 104 females and 234 males had access to information on rainfall prediction and amount (start, end, prediction, and amount of rainfall), this result is similar to Baffour-Ata et al. (2022) who found 70% of respondents accessed rainfall related information. Also,128(23.70%) respondents consisting of 28 females and 100 males had access to information on prediction and intensity of drought. Additionally,239 (44.26) consisting of 73 females and 166 males had access to information on the selection of crops & varieties. Also, 360(66.67%) of respondents making up 125 females and 235 males had access to information on planting time and fertilizer application.

Table 4.7 percentage access to climate information by gender

CIS Variables	Gender			
	Female	**Male**	**Total**	**Percentage**
Access to CIS				
No	27	27	54	10
Yes	167	319	486	90
Total	194	346	540	100
Rainfall prediction &Amount				
No	90	112	202	37.41
Yes	104	234	338	62.95
Total	194	346	540	100
Intensity of sun and cloud cover				
No	183	294	477	88.33
Yes	11	52	63	11.67
Total	194	346	540	100
Prediction of drought and intensity				
No	166	246	412	76.30
Yes	28	100	128	23.70
Total	194	346	540	100
Selection of crops and variety				
No	121	180	301	55.75
Yes	73	166	239	44.26
Total	194	346	540	100
Planting time and fertilizer application				
No	69	111	180	33.33
Yes	125	235	360	66.67
Total	194	346	540	100
Outbreak /mgt of pest and diseases				
No	114	171	285	52.78
Yes	80	175	255	47.22
Total	194	346	540	100
Crop management practices				
No	123	192	315	58.33
Yes	71	154	225	41.67
Total	194	346	540	100

Also,255(47.22%) respondents had access to information on pest and disease outbreaks & management and crop management (water, weed, and soil) practices. However, the intensity of sun/cloud cover recorded the lowest access with 63 respondents representing 11.67%. This low access rate could be due to inadequate information from service providers.

Table 4.8 below presents the descriptive statistics of socio-demographic characteristics of farmers that influence access to climate information services. The table shows, there is a significant statistical gender disparity in the access of CIS among farmers with access to CIS (66%) compared to those without access (50%). In the study region, male farmers are more inclined to utilize CIS than female farmers. This is in line with (Alidu et al., 2022; Djido et al., 2021; Kramer et al., 2023). Table 4.8 shows that the average age is approximately 45 years. Farmers whose mean age is about 62 years are more likely to not have access to climate information .70% of the farmers are household heads. Depending on the farmers' status in the household, there is a significant difference between those who had access to CIS and those who did not have access. However, household heads are 20% more likely to have access to CIS. The average formal education attained by farmers was 5.12 years, with farmers who did not have access to climate information having less (4.07years) of formal education with no statistically significant disparity between those who had access and those who did not.47% of the farmers were members of VSLA with significant disparity between those who have access to CISD and those who do not. However, those who are members of VSLA are more likely to have access to climate information. This conforms with (Kramer et al., 2023).

Table 4.8 Socio-demographic characteristic disaggregated by access to CIS

variables	Combined	Std dev.	No access	Std dev.	Access	Std dev	Diff.
Age	45.289	12.999	46.278	13.765	45.179	12.999	1.099
Sex(male=1)	0.641	0.480	0.500	0.505	0.656	0.475	**-0.156****
Status in household	0.702	0.458	0.519	0.504	0.722	0.448	**-0.204*****
Education(years)	0.502	0.500	0.426	0.499	0.510	0.500	-0.084
FBO	0.526	0.500	0.537	0.503	0.525	0.500	0.012
VSLA	0.467	0.499	0.278	0.452	0.488	0.500	**-0.210*****
Cash-crop production	0.398	0.490	0.500	0.505	0.387	0.488	0.113
Crop diversification	0.763	0.426	0.500	0.505	0.792	0.406	**-0.292*****
Access to Credit	0.722	0.448	0.685	0.469	0.726	0.446	-0.041
Livestock production	0.563	0.496	0.463	0.503	0.574	0.495	-0.111
Access to extension	0.693	0.462	0.704	0.461	0.691	0.462	0.012
Non-farm activities	0.254	0.436	0.296	0.461	0.249	0.433	0.047
Farm size of maize	1.143	1.882	0.767	1.726	1.185	1.896	-0.419

*Note: ***, ** and * stands for the significance level at 1%, 5% and 10% respectively*

Source: Field Survey,2022.

Table 4.8 also shows that 76% of the farmers diversified into more than one crop, with a 29% significance difference between those who had access to climate information services. The average farm size is 1.14 hectares. Those who do not have access to climate information have a lower farm size of approximately 0.77 hectares compared to those who have access

There was no significant difference between those who had access to and those who did not regarding membership of FBO, access to credit and extension, livestock production, nonfarm activities, and farm size of maize.

4.4.1 Correlation of CIS's

Table 4.9 reports the correlation of the error terms of the various CIS variables estimated from the multivariate probit regression. It shows that all the errors are correlated hence the likelihood ratio test of chi2(21) = 487.807, Wald chi2(84) = 268.53, and Prob> chi2 = 0.0000***, implying dismissal of the null hypothesis of no association of error terms of the individual CIS access equations and therefore the use of the multivariate probit regression. Table 4.9 further shows that, all combinations of CIS are positively significant from zero at a 1% significance level, suggesting that, access to all CIS is complementary. The combination with the highest correlation was planting time/fertilization application and selection of crops/varieties (61.1%) while the combination with the lowest correlation was selection of crops &varieties and rainfall prediction/amount. This suggests that farmers receive climate information in bundles, which helps them to make critical decisions on specific uptake of climate-smart agricultural technologies.

Table 4.9:Correlation of various climate information services

CIS	Coefficients	Standard errors
ISC & RPA	0.604***	0.087
DPI & RPA	0.551***	0.066
SCV & RPA	0.211***	0.066
PTFA & RPA	0.442***	0.061
PDOM & RPA	0.469***	0.057
CMP & RPA	0.279***	0.064
DPI & ISC	0.570***	0.067
SCV & ISC	0.295***	0.070
PTFA & ISC	0.379***	0.079
PDOM & ISC	0.437***	0.071
CMP & ISC	0.405***	0.073
SCV & DPI	0.225***	0.070
PTFA & DPI	0.312***	0.073
PDOM & DPI	0.414***	0.063
CMP & DPI	0.293***	0.065
PTFA & SCV	0.611***	0.051
PDOM & SCV	0.326***	0.064
CMP & SCV	0.536***	0.054
PDOM & PTFA	0.421***	0.062
CMP & PTFA	0.461***	0.061
CMP & PDOM	0.592***	0.051

Joint significant test of the independent equations: chi2(21) =487.807 Prob > chi2 = 0.0000

*Note: ***, ** and * stands for the significance level at 1%, 5% and 10% respectively.*

RPA=Rain fall prediction/amount, ISC= Intensity of sun/cloud cover, DPI= Drought prediction and intensity, SCV= Selection of Crop and variety, PTFA= Planting time and fertilizer application, PDOM= Pest & disease management (PDOM) and CMP=Crop management practices.

4.5 CSA technology uptake

For this research, the uptake is defined as using CSA technologies during a recall period of 2 years either consistently, or inconsistently. Uptake of the technologies could be using one practice at a time or a combination of different practices. These technologies include soil/ fertility management practices (crop rotation, manure, on/off farm composting, agroforestry, zero/minimum tillage, zero residue burning, and legumes as a previous crop), water management practices (irrigation, use of stress/drought tolerant varieties and contour stone bonds), pest and disease management practices (use of sticky traps, enhanced biopesticides, and integrated pest management). Table 4.10 below shows that 55 respondents, 29 females and 26 males representing 10.2% used neither of the three CSA practices. The results also show that 15.72% made up of 23 females and 62 males used only soil management practices. Also, 39(7.22%) respondents used only pest & disease management practices, and 55 (10.19%) used only water management practices. Also,96 (17.78%) used soil and pest /disease management only, whereas 102 (18.89 %) made up of 27 females and 98 males used soil management and water management only. The results further show that 26 (4.81%) used water and pest & disease management practices only.

Table 4.10: Climate smart agriculture technologies uptake by gender

CSA practices	Gender			
	Female	male	Total	Percentage
Non -uptake	29	26	55	10.19
Soil fertility management (SFMP)only	23	62	85	15.74
Water management practices (WMP) only	23	16	39	7.22
Pest & disease management practices (PDMP) only	30	25	55	10.19
SFMP&WMP only	23	73	96	17.78
SFMP&PDMP only	34	68	102	18.89
WMP&PDMP only	14	12	26	4.81
All three practices	18	64	82	15.19
Total	194	346	540	100.00

However, 82 (15.19%) respondents, consisting of 18 females and 64 males used all three practices together. This result shows that Ghanaian farmers are more interested in adopting soil management and pest & disease management.

4.6 Empirical estimates

4.6.1 Factors that influence access to CIS

According to most literature, access to CIS is influenced by many factors. Notable among these factors are farmers' characteristics (age, gender, education, head of house status), livelihood choices (crop diversification, livestock production, non-farm income earning activities), membership of social groups (FBO, VSLA), access to formal and informal financial resources (loans, credits) and access to extension.

The multivariate probit regression was used to estimate the various determinants of farmers' access to CIS. The results are presented and discussed for each independent and CIS variable in Table 4.11. The results in Table 4.11 show age insignificantly decreases the probability of access to all forms of CIS. Thus, aging farmers are less likely to access CIS as they depend on their indigenous knowledge and experience. This conforms with P. Antwi-Agyei et al. (2021). Farmers who are household heads were significantly less likely to access information on drought prediction & intensity. This did not meet expectations because droughts are associated with financial resource use and decisions like when to plant and when to apply fertilizer and thus, the need to have on hand information on them to better prepare and manage these resources efficiently to reduce additional costs as household heads. The results on sex are very much consistent with most literature. Gender positively and significantly influenced access to information on rainfall prediction & amount, intensity of sun & cloud cover, drought prediction & intensity. This means that Male farmers had an increased likelihood of access to information on rainfall prediction & amount, the intensity of sun & cloud cover, and drought prediction & intensity than their female counterparts. This result conforms with Alidu et al. (2022); Djido et al. (2021); Ngigi and Muange (2022) associated this with the ability of men to use and also possess ownership of technological devices like mobile phones and TV radio. Further, the results show that, as the years of education increase, the probability of access to information on the selection of crops & varieties increases. The results show that being a member of a farmer-based organization increases the probability of accessing information on rainfall prediction & amount and drought prediction & intensity. The table also shows that farmers who are members of VSLA were more likely to access information on pest & disease outbreaks & management but less likely to access information on selecting crops & varieties. Also, respondents who produced cash crops were more likely to access information on rainfall prediction and amount, intensity of sun & cloud cover, drought prediction & intensity, and pest and disease outbreak and management. This is because cash crops are major contributors to the national income of the country and therefore farmers who produce such crops are more careful and are also seen as priority farmers giving them more opportunity to access more information. The results further show that respondents who diversified their crops had a high probability of accessing information on rainfall prediction and amount, planting time and fertilizer application, intensity of sun and cloud cover, prediction of pest/disease outbreak & management, and integrated crop management practices. Access to the combination of this information is very necessary for decision-making on which crop to plant first and at what time in other to meet water requirements and also for efficient management of time and resources.

Furthermore, farmers who had access to credit had a decreased likelihood to access information on rainfall prediction & amount, this contradicts, Oyekale (2015) who found that access to credit positively increased access to climate forecast. Additionally, farmers who had extension services access had a higher likelihood of accessing information on the selection of crops & varieties and integrated crop management practices. This could be associated with the fact that it is the expertise and principal role of extension officers to communicate issues relating to farm management to farmers. These results conform with previous studies on determinants of access to climate information, (Baffour-Ata et al., 2022).

The results further reveal that respondents who diversified their livelihood into non-farm activities were more likely to access information on the Intensity of sun and cloud cover, selection of crops & varieties, and integrated crop management practices but less likely to access information on drought prediction & intensity. This is however surprising because involvement in other activities means increased income and welfare and therefore less attention on crop production leading to decreased access to CIS. The results also show that farmers who diversified their farming activities into animal production were more likely to access information on integrated crop management practices, planting time, and fertilizer application. This is expected because producing animals gives them the chance to use the farm yard manure to complement inorganic fertilizer application and also apply before planting.

Table 4.11: Factors that influence access to various climate information services

Variables	RPA	ISC	DPI	SCV	PTFA	PDOM	ICMP
Age	-0.002 (0.005)	-0.003 (0.007)	4.30e-06 (0.005)	-0.003 (0.005)	-0.004 (0.005)	0.005 (0.004)	-0.002 (0.004)
Status in household	0.032 (0.156)	-0.306 (0.229)	**-0.386**** (0.178)	-0.0344 (0.156)	0.0341 (0.158)	0.108 (0.151)	-0.127 (0.153)
Gender	**0.314**** (0.147)	**0.650***** (0.230)	**0.515***** (0.173)	0.215 (0.144)	-0.115 (0.148)	0.0947 (0.140)	0.167 (0.142)
Education (years)	0.008 (0.011)	0.017 (0.015)	0.008 (0.012)	**0.020*** (0.010)	0.011 (0.011)	0.001 (0.010)	0.002 (0.010)
FBO	**0.425*** (0.234)	-0.396 (0.264)	**0.438*** (0.229)	-0.317 (0.221)	0.065 (0.240)	-0.045 (0.218)	-0.329 (0.214)
VSLA	0.162 (0.165)	0.204 (0.227)	0.211 (0.177)	**-0.287* (0.157)**	0.271 (0.168)	**0.293* (0.158)**	-0.032 (0.157)
Cash-crop production	**0.348** (0.165)**	**0.687*** (0.228)**	**0.861*** (0.172)**	-0.221 (0.156)	0.257 (0.168)	**0.279* (0.156)**	-0.162 (0.154)

Crop diversification	**0.426*** (0.141)**	**-0.625*** (0.202)**	0.226 (0.165)	-0.011 (0.140)	**0.590*** (0.141)**	**0.367*** (0.142)**	**0.574*** (0.146)**
Access-to credit	**-0.581** (0.234)**	0.010 (0.322)	0.052 (0.257)	0.291 (0.228)	0.123 (0.237)	-0.066 (0.227)	0.302 (0.228)
Access-to extension	-0.194 (0.244)	0.351 (0.333)	-0.362 (0.258)	**0.464** (0.232)**	0.317 (0.246)	0.304 (0.231)	**0.464** (0.229)**
Non-farm activities	0.127 (0.139)	**0.374** (0.173)**	**-0.349** (0.154)**	**0.362*** (0.134)**	0.147 (0.139)	0.0496 (0.133)	**0.446*** (0.133)**
Livestock production	0.0403 (0.121)	0.249 (0.172)	0.153 (0.135)	0.0856 (0.117)	**0.267** (0.121)**	0.0904 (0.117)	**0.257**** (0.118)
Constant	-0.0818 (0.283)	**-1.740*** (0.414)**	**-1.511*** (0.337)**	**-0.503* (0.278)**	**-0.558** (0.284)**	**-1.155*** (0.282)**	**-1.121*** (0.286)**
Observations	540	540	540	540	540	540	540

Joint significant test of the independent equations: chi2(21) = 487.807 Prob > chi2 = 0.0000.
*Note: ***, ** and * stands for the significance level at 1%, 5% and 10% respectively.*
RPA=Rain fall prediction/amount, ISC= Intensity of sun /cloud cover, DPI= Drought prediction and intensity, SCV= Selection of Crop and variety, PTFA= Planting time and fertilizer application, PDOM= Pest and disease outbreak and management (PDOM) and ICMP Integrated Crop management practices

Source: Field survey,2022.

4.6.2 Effect of CIS access on uptake of CSA practice

For the effect of access to CIS on the uptake of various CSA technologies, the coefficients are used to show the direction of uptake. The Likelihood Ratio test is 420.97 at a 1% significance level, which implies that the data fits well in the Multinomial logistic regression (MNL). The instruments (perception of climate, rating of the season, and FBO) are also jointly significant for the uptake of all CSA practices but insignificant for the maize yield outcome of those who did not uptake any CSA practices. As shown in Table 4.12 below, when farmers' age increases, the likelihood of uptake of only the combination of water and pest & disease management practices increases significantly. This result is similar to Khatri-Chhetri et al. (2017), who reported that aging farmers are more likely to use integrated pest management technologies in association with other technologies. The results also show that being head of house as a farmer significantly reduces the probability of uptake of five categories of CSA practices but insignificant for the uptake of only water management practices, and the combination of soil and water management practices.

Table 4.12:CIS and others factors that affect uptake of climate smart agriculture technologies

Variables	**SFMP**	**WMP**	**PDMP**	**SFMP/ WMP**	**SFMP& PDMP**	**WMP& PDMP**	**All three**
Age	-0.012 (0.017)	0.000 (0.022)	0.006 (0.018)	-0.013 (0.016)	-0.020 (0.018)	**0.047*** (0.025)	0.007 (0.018)
Status in household	**-2.387**** (1.000)	-1.775 (1.201)	**-2.445**** (1.046)	-0.922 (0.988)	**-3.583***** (1.091)	**-2.692*** (1.617)	**-2.789***** (1.060)
Gender	1.311 (0.927)	0.078 (1.132)	0.136 (1.018)	1.225 (0.905)	-0.818 (0.979)	-0.884 (1.367)	0.501 (1.009)
Education level	-0.021 (0.108)	-0.139 (0.144)	0.0523 (0.122)	-0.012 (0.107)	0.044 (0.118)	0.122 (0.169)	0.132 (0.116)
Crop diversification	-1.046 (1.108)	-1.761 (1.308)	-0.672 (1.046)	-0.559 (1.019)	**-4.050***** (1.293)	-1.329 (1.946)	-1.180 (1.098)
Access to CIS	**25.56***** (8.915)	**24.47***** (9.315)	**13.49*** (7.226)	**15.12**** (7.524)	**53.16***** (11.47)	54.63 (804.1)	**26.66***** (8.515)
Cash crop production	0.600 (1.187)	**3.856**** (1.555)	-0.254 (1.427)	0.502 (1.140)	**4.094***** (1.215)	**4.004**** (1.730)	**2.774**** (1.192)
Non farm activities	2.085 (7.301)	2.525 (9.310)	-3.723 (8.518)	3.034 (7.205)	-9.139 (7.843)	-4.561 (11.27)	-5.311 (7.475)
Farm size of maize	-0.0206 (0.087)	-0.232 (0.230)	-0.258 (0.218)	-0.0441 (0.087)	-0.0887 (0.091)	-0.198 (0.275)	0.005 (0.028)
Livestock production	-0.187 (0.470)	-0.746 (0.556)	**-0.848*** (0.498)	-0.028 (0.454)	-0.397 (0.472)	**-1.359**** (0.655)	-0.611 (0.475)
Access to credit	**1.013*** (0.578)	0.843 (0.689)	0.102 (0.630)	0.690 (0.590)	-0.933 (0.665)	0.270 (0.881)	-0.181 (0.676)

Access to extension	-1.203 (0.986)	**-3.773*** ** (1.268)	-0.758 (1.206)	-1.121 (0.935)	**-1.700*** (0.997)	**-3.748**** (1.585)	0.080 (1.013)
Expenditure on fertilizer	-8.55e-05 (0.000)	-0.000 (0.000)	-0.000 (0.000)	-8.26e-05 (0.000)	7.76e-06 (0.000)	-0.000 (0.000)	0.000 (0.000)
Expenditure on herbicides	0.000 (0.000)	0.000 (0.000)	-0.000 (0.001)	0.000 (0.001)	**-0.001**** (0.001)	0.000 (0.001)	-0.001 (0.001)
Perception of climate change	**-3.966*** (2.155)	**-5.585**** (2.507)	**-3.422*** (1.972)	-1.780 (2.013)	**-8.411***** (2.600)	6.571 (891.8)	-3.341 (2.249)
Rating of the season weather (moderate)	0.974 (0.744)	-0.304 (0.910)	0.946 (0.792)	0.929 (0.730)	**2.989***** (0.821)	-0.357 (1.103)	0.361 (0.762)
Rating of the season weather (good)	**1.376*** (0.794)	0.139 (0.986)	0.507 (0.815)	**1.309*** (0.737)	**3.180***** (0.971)	0.944 (1.325)	0.934 (0.800)
FBO membership	-0.626 (0.897)	0.789 (0.982)	0.490 (1.139)	0.428 (0.855)	**1.974**** (0.950)	**2.580*** (1.537)	1.032 (0.895)
Residual_CIS	**-24.49***** (8.877)	**-23.02**** (9.400)	**-12.66*** (7.226)	**-12.71*** (7.511)	**-50.73***** (11.41)	**-39.31**** (18.63)	**-23.10***** (8.450)
Constant	**-17.26***** (6.117)	**-13.85**** (6.263)	-5.470 (4.811)	**-11.67**** (5.044)	**-32.45***** (7.986)	-56.21 (1,201)	**-19.12***** (5.966)
Joint sig of instruments, $\chi^2(15)$	**35.01*****	**39.91*****	**36.30*****	**33.39*****	**35.77*****	**33.39*****	**34.01*****
Wald test, χ^2 (127)	**262.58*****						
Observations	540	540	540	540	540	540	540

Note: ***, ** and * stands for the significant levels at 1%, 5% and 10% respectively.
SFMP=Soil fertility management practices, WMP=Water management practices, and PDMP=pest & disease management practices.

Source: Field survey,2022.

Sex and years of Education have been major issues of discussion in the uptake and adoption of CSA practices worldwide. The results reveal that they are not significant for the uptake of all individuals and combinations of CSA practices. Also, diversification of crops decreases the likelihood of uptake of soil and pest &disease management practices significantly. Access to CIS is very important for farm decision-making. The results confirm that access to CIS significantly increases the uptake of individual and combined CSA practices except only the combination of water and pest & disease management practices. This demonstrates how important CIS is and the availability of such information that is required for the uptake decision of CSA technologies. This finding is in line with (Mulwa et al., 2017). The results also show that cash crop production significantly increases the likelihood of uptake of only water management practices and the combination of water and pest & disease management but significantly decreases the probability of uptake of only water management practices. Similarly to Mulwa et al. (2017), farmers who were into livestock production were less likely to adopt only pest & disease management practices and the combination of water and pest &disease management practices only. This could be attributed to the use of crop residue in feeding animals. To reduce the toxicity level of such residue to animals, farmers who produce animals tend not to use pesticides in their crops. Access to credit serves as a proxy for meeting the cost involved in technology adoptions and access to resources. Similarly to Danso-Abbeam et al. (2017), farmers who had credit access had a significantly increased likelihood to uptake a combination of soil fertility and water management practices only and also, the combination of water and pest & disease management practices only. This conforms with Mulwa et al. (2017), who found that access to credit is a major factor that affects farmers' decision to adapt to the changing climate. Contrarily to Danso-Abbeam et al. (2017); Issahaku and Abdulai (2020); Mulwa et al. (2017), access to extension significantly decreases the likelihood of uptake of only water management, only soil and pest & disease and management practices and water and pest & disease management practices. This result conforms with Donkoh et al. (2019). Perception of climate change decreased the likelihood of adopting all individual CSA practices and the combination of soil fertility and water management practices. This contradicts Issahaku and Abdulai (2020), who found that farmers' perception of drought increased their probability of adopting climate-smart technologies.

Farmers who rated the season weather as moderate had an increased likelihood of adopting the combination of soils and pest & disease management practices than those who rated the season weather as bad. Similarly, farmers who rated the season weather as good had an increased likelihood of uptake of soil fertility management practices and the combination of soil and water management practices and soil and pest & disease management practices than those who rated the season weather as bad. Contrary to Mulwa et al. (2017), membership of farmer-based organizations significantly increases the likelihood of uptake of the combination of soil fertility management and water management practices only and the combination of water and pest & disease management practices only. This conforms with (Danso-Abbeam et al., 2017).

The estimates of the residual are negative and significant, showing access to CIS is endogenous as suspected.

4.6.3 Impact of CSA uptake on maize yield

The results shown in Table 4.13 below indicate the average treatment effects of using different CSA technologies on the log of the yield of maize. It is the difference between the average yield of maize if a farmer used CSA practices and if the same farmer had not used any CSA practices. Table 4.13 shows no significant difference in the average yield related to the use of soil fertility management, and the combination of water and pest & disease management practices. The findings also show that using only water management, pest & disease management only, soil fertility & water management practices only, soil and pest & disease management only, and the combination of all three CSA practices significantly reduce the yield of maize. It means that the farmers who adopted these technologies had lower yields and could have had better yields if they had not used this CSA practice. This result contradicts (Martey et al., 2023), who found that adopting a combination of CSA technologies increases the yield of maize.it is intuitive because, CSA practices take time to produce good results. Also, the majority of the respondents do not use improved and high-yielding maize varieties because of the high cost. They tend to reserve seeds for the coming season. There were also prolonged dry spells during the 2022 crop season, and finally, inadequate to no use of inorganic fertilizers because of the high and drastic increase in prices of inorganic fertilizers during the previous cropping season. The combination of inorganic fertilizer and organic manure is suggested to be climate-smart (Palombi & Sessa, 2013; Tiamiyu et al., 201.

Table 4.13:Impact of climate smart agricultural technologies uptake on maize yield

Adoption choices	obs	Uptake Decision		ATT
		Actual	Counterfactual	
Soil fertility mgt only	85	1105.82 (85.04)	4.64e+13 (4.64e+13)	-4.64e+13 (4.64e+13)
Water mgt only	39	1552.02 (528.05)	6221.77 (1400.20)	**-** **4669.75***** (1202.)
Pest &disease mgt only	55	1472.55 (214.01)	2614.59 (750.18)	-1142 (767.74)
Soil fertility and water mgt	96	968.18 (57.11)	2469.75 (486.25)	**-** **1497.57***** (499.25)
Soil fertility and pest & disease mgt	102	1004.49 (57.72)	3963.72 (1043.14)	**-2959.22**** (1058.06)
Water and pest &disease mgt	26	1967.76.936 (511.85)	4125.93 (965.08)	-2158.16 (1118.09)
All three	82	973.45. (56.38)	2621.20 (462.26)	-1647.75 (479.40)

Note: ***, **, * stand for significant levels at 1%, 5% and 10% significance, respectively. Standard error in parenthesis

Source: Field survey,2022

CHAPTER FIVE

SUMMARY, CONCLUSION, AND RECOMMENDATIONS

5.1 Introduction

This chapter presents an outline of the processes and significant findings of this study. The various sections are outlined in the following order, starting with summary of key findings, conclusions based on the findings, key recommendation for policy consideration and ends with the limitation of this study.

5.2 Summary of findings

The agriculture industry in Ghana is greatly affected by the adverse effects of climate variability and change. Climate information services and climate-smart agricultural practices are mechanisms that can help farmers cope, reduce, and improve their livelihood outcomes (productivity). This study established the linkages between access to climate information service, and uptake of climate-smart agricultural practices by examining the impact of CIS access on CSA technology uptake and the translated effect on the yield of maize.

The study first established that rain-fed crops like yams, rice, cowpea millet, soybeans, groundnuts, maize, and a range of vegetables are all crops cultivated in the study area, and maize being the crop grown by most farmers mainly for household consumption.

Secondly, the study disclosed that the Ministry of Food and Agriculture in Ghana is the major source of all seven identified climate information with an access rate of 42.96% on selection of crops and varieties, 63.52% on planting time and fertilizer application, 42.04%

on rainfall prediction and amount, 8.33% on intensity of sun and cloud cover, 17.41% on drought prediction and intensity, 46.85% on pest & disease management and 27.41% on other crop management practices. It further revealed that the main channel of CIS access is through the extension agents at an access rate of 40.76% on the selection of crops & varieties,57.96% on planting time and fertilizer application,36.48% on rainfall prediction and amount,6.48% on the intensity of sun and cloud cover,15% on drought prediction and intensity,42.41% on pest & disease management and 42.41% on other crop management practices.

Furthermore, the majority of respondents (62.59%) had access to information on rainfall prediction and volume (start, end, prediction, and volume of rainfall), 23.70% of respondents had access to information on prediction and intensity of drought, 44.26% had access to information on selection of crops and crop varieties, 66.67% on planting time and time of fertilizer application, 47.22% on pest & disease management, 41.67% on crop management (water, weed, and soil) practices, with intensity of sun or cloud cover, recording the lowest access rate of 11.66%.

The study also confirms that all climate information services are complementary. The key determinants are farmers' status in the household, sex, membership of FBO, membership of VSLA, cash-crop production, crop diversification, access to credit, non-farm income activities, extension access, and livestock production with varying effects.

The study also reveals that 10.2% of the respondents used neither of the three CSA practices, 15.72% used only soil management practices,7.22%used only pest &

disease management practices, 10.19% used only water management practices,17.78% used the combination of soil and pest & disease management only,18.89 % used the combination soil management and water management only,4.81% used the combination of water and pest & disease management practices only,15.19% used all the three practices together.

The key factors that determined the uptake of single and the combination of CSA practices from the multinomial logistics regression are age, sex, and educational level, for soil fertility management only, access to extension and cash crop production for water management practices only, cash crop production and respondent status in the household for pest & disease management only, sex, non-farm income activities, access to credit, ratings of the season, for the combination of soil and water management practices only, age, membership of FBO, non-farm income activities, access to extension and credit, and ratings of the season for soil and pest & disease management practices, cash crop production, access to extension, livestock production, membership of FBO, non-farm income activities and educational level for water and pest& disease management practices and only gender and educational level for the combination of all CSA practices..

5.3 Conclusions

Access to CIS and uptake of CSA practices are linked, such that, most factors that affects access to CIS affects uptake of CSA as well. Critical to CSA uptake decision is access CIS.

Access to various CIS is complementary and are therefore access together. The major CIS accessed by farmers are rainfall prediction & amount and planting time & fertilizer application, whereas drought prediction & intensity, and intensity of sun & cloud cover are the least CI accessed which poses which reflects in uptake of water management technologies. Status in the household, gender, FBO, cash-crop production, non-farm activities, Access to extension and credit are all determining factors of access to various CIS but with varying effects.

The combination of soil fertility management & water management technologies, and soil fertility management & pest & disease management practices were the two major CSA's adopted by farmers. Access to CIS, status in the household crop diversification, cash-crop production, access to extension, expenditure on herbicides, perception of climate change, membership of FBO and ratings of the season as moderate and good are all determinants of uptake of single and combination of CSA technologies with varying effects.

Though CSA technologies uptake is to improve on yield of produce, it is clear that, uptake of water management practices only, the combination of soil fertility and water management practices only and the combination of soil fertility management and pest & disease management practices only, significantly didn't reflect positively in the yield of maize for the 2022 cropping season.

5.4 Recommendation

On the basis of the findings in this study, it is suggested that, the Ghana Meteorological Agency (GMet) should partner with Ministry of Food and Agriculture (MoFA) and climate information service providers to enforce bundled tailor-made, context and user specific climate information and climate smart technologies dissemination to satisfy the needs of farmers reflective of the various stages of production in a farming season in a given geographical area.

It is clear that farmers rely heavily on MoFA extension agents for various CI and hence the need for frequent and improve forms of contact and engagement with farmers. This will allow for enhance access to CIS from the extension agents which seems reliable and easier for farmer usage.

Farmers should take advantage of the numerous CI provided by development agencies and existing digital platforms such as Esoko and Farmerline to ensure improved access.

Improved seeds and subsidized fertilizers should be made available and affordable and on time across the districts for easy access by farmers whiles farmers are encouraged to take full advantage of government initiatives such as the planting for food and jobs.

5.5 Limitation of the study

A major limitation of this study involves the use of a recall period of 2 years on access to CIS and uptake of CSA technologies. Also, the benefit regarding CSA technologies uptake is beyond productivity but includes mitigation and adaptation, however, inadequate resources and time constraint does not allow for scope expansion of the study. Future studies should expand the scope to include the economic valuation that consider the three key backbones of CSA, that is, mitigation, adaption and productivity.

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APPENDICES

Determinants of maize yield and selection correction terms from MESR model

Variables	Non uptake	Soil fertility	Water	Pest/disease	Soil&Water	Soil&Pest/disease	Water&Pest/disease	All three
Constant	1.969	4.199	-14.21	9.997	11.29**	9.317***	12.92	8.860
	(222.1)	(3.004)	(27.15)	(84.08)	(4.721)	(2.173)	(11.59)	(7.154)
Age	0.0345	0.00834	0.0486	-0.0362	-0.0434	-0.0523**	-0.117	-0.00854
	(0.530)	(0.0247)	(0.244)	(0.601)	(0.0360)	(0.0261)	(0.104)	(0.0522)
Status in household	1.461	-0.715	-0.0779	-0.133	-0.275	1.078	0.930	1.030
	(127.6)	(0.552)	(8.795)	(9.354)	(0.968)	(0.755)	(1.745)	(1.173)
Gender	-0.110	0.204	1.686	0.599	-0.0863	-0.658	1.822	-0.924
	(28.29)	(0.636)	(8.140)	(15.25)	(0.884)	(0.636)	(1.836)	(1.107)
Education	-0.0226	0.0412	-0.0222	0.0526	0.0398	-0.111**	0.0111	-0.0318
	(3.191)	(0.0412)	(0.671)	(1.625)	(0.0565)	(0.0504)	(0.249)	(0.0854)
Crop diversification	-0.640	1.050	-0.274	-0.185	1.427	-0.117	2.294	-0.156
	(31.75)	(0.893)	(12.12)	(25.03)	(1.204)	(0.850)	(3.070)	(1.190)
Access to CIS	1.786	-0.159	6.130	0.205	0.463	-0.598	0	0
	(152.9)	(1.277)	(7.705)	(43.40)	(1.763)	(1.129)	(0)	(0)
Cash crop production	-0.415	-0.205	6.667	0.430	0.189	-0.360	-2.938	1.182
	(21.99)	(0.756)	(16.77)	(23.84)	(0.953)	(0.813)	(2.538)	(1.268)

Non farm activities	1.172	0.0511	1.563	-0.0821	-0.455	0.141	1.153	-0.755
	(112.8)	(0.494)	(6.428)	(10.07)	(0.743)	(0.616)	(2.045)	(0.675)
Farm size of maize	-0.222	-0.463	-0.0814	-0.399	-0.321	-0.204	-1.353*	0.00181
	(4.096)	(0.286)	(4.187)	(8.201)	(0.196)	(0.190)	(0.791)	(0.246)
Livestock production	-0.780	-0.192	1.223	0.210	0.327	0.576	2.522	0.799
	(80.25)	(0.564)	(4.343)	(9.841)	(0.849)	(0.493)	(2.059)	(0.886)
Access to credit	4.171	0.485	3.582	-0.461	-0.667	-0.125	2.029	-0.138
	(19.45)	(0.635)	(8.991)	(18.37)	(0.921)	(0.798)	(2.348)	(1.029)
Access to extension	-1.365	-0.407	-0.708	0.463	-1.539	-1.065	-3.295	-0.306
	(12.72)	(0.829)	(24.85)	(21.18)	(1.457)	(1.013)	(2.722)	(2.408)
Expenditure on fertilizer	-4.37e-05	1.71e-05	0.000554	0.000119	-1.36e-05	-0.000185	-0.000165	-1.13e-06
	(0.00755)	(0.000176)	(0.00255)	(0.00290)	(0.000276)	(0.000234)	(0.000711)	(0.000340)
Expenditure on herbicides	0.00186	1.67e-05	0.00291	-0.000407	-0.000366	-0.000230	0.00344	0.000172
	(0.0378)	(0.000376)	(0.0115)	(0.0181)	(0.000960)	(0.00113)	(0.00233)	(0.00135)
Selection correction terms								
_m0		-1.535	-4.903	-0.546	-2.677	1.271	-15.77*	4.717
		(2.537)	(32.30)	(107.9)	(2.795)	(2.665)	(8.810)	(4.877)
_m1	0.640		-7.752	3.513	3.513	-0.587	12.42**	-0.382
	(244.3)		(25.88)	(61.53)	(3.245)	(2.708)	(5.093)	(3.787)
_m2	-2.296	-1.098		-1.779	0.388	2.767	1.035	1.928

	(258.6)	(1.638)		(29.56)	(2.299)	(1.833)	(3.836)	(2.578)
_m3	0.572	1.137	-11.11		-0.786	-0.253	-1.476	-6.864*
	(65.37)	(2.589)	(26.32)		(2.361)	(1.906)	(3.538)	(3.528)
_m4	7.524	-2.764	20.85	-1.892		4.326	13.75***	1.286
	(314.1)	(2.587)	(27.58)	(38.12)		(3.680)	(3.144)	(3.981)
_m5	-7.417	0.527	-6.080	0.792	2.535		2.422	1.086
	(228.2)	(1.580)	(12.20)	(27.23)	(2.426)		(2.649)	(3.320)
_m6	3.398	1.984	-2.920	-0.570	0.237	-2.022		-0.835
	(496.4)	(1.858)	(16.39)	(43.06)	(2.696)	(1.417)		(3.094)
_m7	-2.087	0.805	9.694	1.063	-2.373	-6.332***	-12.29	
	(32.53)	(2.159)	(19.62)	(44.07)	(4.118)	(2.280)	(8.000)	

***, ** and * stands for significant levels at 1%, 5% and 10% respectively, standard errors in parenthesis.