UNIVERSITY FOR DEVELOPMENT STUDIES

EFFECTS OF TRADITIONAL AND SCIENTIFIC CLIMATE CHANGE ADAPTATION STRATEGIES ON FARM HOUSEHOLDS' WELFARE IN THE NORTHERN REGION, GHANA

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EFFECTS OF TRADITIONAL AND MODERN CLIMATE CHANGE ADAPTATION STRATEGIES ON FARM HOUSEHOLD WELFARE

BY

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JUNE, 2023

DECLARATION

Student

I hereby declare that, except for the references to the works of other researchers which have been duly acknowledged, this thesis is as a result of my own research and that no part of it has been presented for another degree in this University or elsewhere.

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Supervisors

We hereby declare that the preparation and presentation of the thesis was supervised in accordance with the guidelines on supervision of thesis laid down by the University for Development Studies.

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ABSTRACT

The study was set to investigate the effects of climate change adaptation strategies on farm household welfare in northern region. Drawing its roots from the sustainable climate change adaptation strategies, it first identified climate shocks faced by farmers in northern region, examine factors that influence farmer choice of climate adaptation strategies employed by farmers in Northern Ghana, examine the Effects of climate change information on adoption intensity, as well as determine the strength of traditional adaptation strategies against the modern strategies in promoting the welfare of farmers in the northern region. A lot of studies is been done in the climate change adaptation strategies and livelihoods of farmers, this research sought to segregate the climate change adaptation strategies into modern and traditional and their effects on the farm household welfare. The novelty in this research was the categorization of the climate change adaptation strategies into traditional and scientific adaptation strategies and testing the strength of the two in promoting the welfare of farmers in the northern region. The study discovered that traditional adaptation strategies of CAS had a beneficial impact on food diversity at home with a 1% level of significance starting with HDDS. Therefore, individual farmers who practice the traditional methods of climate change adaptation strategies saw an improvement of roughly 40% in their food diversity. Farmers who use the modern climate change adaptation strategies outperformed non-adopters by roughly 19% in their food diversity. Similar to joint adopters, non-adopters' dietary preferences decreased by roughly 13%. This outcome demonstrates how traditional food diversity is promoted by the introduction of traditional and scientific (improved) CAS.

The Household Food Insecurity Access Score is another element of the Food Security S measure. Only traditional adopters, according to the findings, had a statistically meaningful impact on the 1% of HFIAS. As a result, it is anticipated that the number of traditional CAS adopters who experience food insecurity will drop by roughly 43%. Although scientific and joint climate Adaptation strategies are statistically insignificant, The results show that severe drought and high temperatures were the main climate shock faced by farmers in the northern region of Ghana.

According to the study's descriptive data, climate shock is a significant factor that adversely affects output and productivity at the farm level. Severe drought was listed as the climate shock that occurs most frequently during the season. Rarely do wildfires break out in the studied area. Mulching, crop rotation, mixed farming, and reduced burning are adaptation measures that are frequently used in the region. To verify the methods' complementarity and substitutability, a correlation matrix was created

The farmers that use the indigenous CAS also enhanced their dietary diversity and decreased their risk of food insecurity, which brings us to the livelihood outcome. This was ascribed to the length of the practice as well as to its constant accessibility and availability

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“There is no god but He: that is the witness of Allah, His angels, and those endued with knowledge, standing firm on justice. There is no god but He, the Exalted in Power, the wise” (Quran, 3: 18), my strength is drawn from this verse that has pushed me further to come to the realization of this thesis.

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DEDICATION

I dedicate this work to my dad, Afa Adam Seidu and my mom, Mma Ayishetu whose responsibility, sacrifice and prayer have made me who I am today

TABLE OF CONTENT

Contents

LIST OF TABLES

CHAPTER ONE

1.0Introduction

It represents the introductory part of the study, which includes the research background, the problem statement, the research goals, the research questions, the hypotheses and the relevance.

1.1 Background

Generally speaking, climate is thought of as the anticipated weather for a certain geographic area. The weather in a certain location over a minimum of 30 years is what makes up climate change(Solomon, 2018). Four key global factors: the Intertropical Convergence Zone (ITCZ), El Nio – Southern Oscillation (ENSO), Indian Ocean circulation patterns and the West African monsoon have a significant impact on Africa's climate. All affect the continent's annual seasonal distribution and the variability of precipitation and temperature.

Some areas are predicted to become wetter due to climate change (Nowy and Lister, 2001). Climate change affects different sectors and regions of theworld. Extreme weather events such as sudden temperature changes, droughts, heavy rains, floods and storms are becoming more common and are already affecting natural and human systems around the world (Easterling et al., 2012).

Globally coordinated efforts are being made to mitigate the risks of climate change by increasing the adaptability of farmers and increasing the resilience and resource efficiency of agricultural production systems. Climate Smart Agriculture (CSA) is a system for reorienting agricultural production to support sustainable productivity and food security in the face of increasingly real climate change and land degradation (UN, FAO 2013). CSA and Sustainable Land Management (SLM) encourage farmers, scientists, the private sector, civil society, and policymakers to collaborate on sustainable and climate-resilient pathways in several key areas: (1) gathering and compiling evidence; (2) strengthen the potential and effectiveness of local institutions; (3) promote coherence between climate change and agricultural policies; and (4) linking climate change adaptation and mitigation, SLM and agricultural finance. They require a focus on the ability to implement flexible, contextual and localized solutions supported by innovative strategies (Castells-Quintana, Lopez-Uribe & McDermott, 2018; Lipper et al., 2014).

Creating a more sustainable and resilient agricultural sector is paramount to the economic development of sub-Saharan Africa, including Ghana. The sector in Ghana consists mainly of small subsistence farmers with few links to industry and other services, employs about 75% of rural households and contributes about 22.0% of the country's gross domestic product (MoFA, 2017). It is therefore an important source of food security and livelihood. However, many challenges, including climate change, pose serious threats to the agricultural sector, livelihoods and development aspirations of many countries, including Ghana, as evidenced by numerous studies (IPCC 2007 and 2014; Wossen et al., 2014; Adiku et al., 2015). Due to limited knowledge and resources, small farmers in developing countries are among the population groups most affected by climate change (Cacho et al., 2020).The ability of smallholders to adapt to climate change is generally limited, both technically and financially (FAO, 2015). It is important to study the adaptability of farmers to secure their livelihoods and reduce their vulnerability to climate change (Mendelsohn, 2012).

1.2 Problem statement

Scientists say that the warming of the Earth's surface, which is causing global temperatures to rise, is being caused by changes in the composition of the atmosphere caused by increases in the concentration of greenhouse gases (mainly carbon dioxide, methane and nitrous oxide). Changes in land cover and agricultural activities (Kihupi et al.,2015, Shivakumar et al., 2005). By the end of the 21st century, the average temperature in these countries is expected to increase by 3 to 4°C, or almost 1°C.Five times the world average (Bryan et al., 2013).

The Ghana Environmental Protection Agency forecasts that rainfall in all agroecological regions will decrease by an average of 18.6% by 2080 compared to base year 2010, while average temperatures will increase by an average of 3.9°C (Guodaar and Appiah, 2022). According to similar projections by the World Bank for climate change in Ghana in 2011, the country's average annual temperature will increase by 1.0 to 3.0 degrees Celsius by 2060.2 degrees at 2090.This temperature increase will cause a drought. According to Brown et al, repeated drought conditions have slowed down several SSA countries' GDP growth and jeopardized their economic growth (Brown et al., 2011). According to estimates by the FAO (2008), the effects of climate change alone will lead to a 2 to 7% drop in GDP in sub-Saharan Africa by 2100. Approximately 44.7% to 60% of Ghana's labor force is employed in agriculture, which also generates 20.2% to 27% of GDP (MoFA, 2016).

Losses in the agricultural sector tend to affect the economy as a whole, leading to a decline in gross domestic product, lower income/consumption of the most vulnerable population groups and lower overall household well-being (Odjugo, 2009). In Ghana, small-scale farming is the norm and farms are generally smaller than 2 hectares (MOFA, 2016). They also lack the resources and knowledge to adapt to changing circumstances (John et al., 2014).Poverty and food insecurity are expected to increase in the coming decades due to a lack of viable economic opportunities and adverse weather conditions. Although a lot of work is being done to link farmer welfare to the response strategies they employ, this research is done to determine the effects of traditional and scientific climate change adaptation strategies on farm household welfare in the northern region.

1.3 Study purpose

To investigate how the welfare of agricultural households in northern Ghana is affected by adaptation to traditional and scientific climate change adaptation strategies.

1.4 Research questions

1. What climate shocks are farmers in northern Ghana exposed to?

2. Which climate adaptation strategies are used by farmers in the northern region??

3. What influence does climate change information have on the intensity of

implementation of climate change adaptation strategies??

3. What are the effects of traditional and scientific climate adaptation strategies on farm livelihood outcomes?

1.5 Objectives

1. To identify the climate shocks facing farmers in Northern region.
2. To identify the climate change adaptation strategies used by farmers in northern region.
3. To analyze the impact of climate change information on the intensity of implementation of the climate change adaptation strategies.
4. To assess the effects of traditional and scientific climate change adaptation techniques on farm household welfare.

1.6 Significant of the study

The results of the study, where deemed relevant, will serve as a basis for decision makers to develop plans to improve farmer welfare. The result is used as a source for scientific research. It will advance our understanding of agricultural research. It will help farmers and ministries of agriculture to combat climate change and implement innovative agricultural techniques. It is up to NGOs and agricultural stakeholders to develop and plan initiatives to give farmers the support they need to deal with the impact of climate shocks.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction.

This section provides an overview of the literature on climate change and climate shocks, climate change adaptation practices, climate change information, and the impact of climate change on wealth.

2.1 Climatic shocks, farmers face in northern Ghana.

According to the Intergovernmental Panel on Climate Change (IPCC) 2007 Assessment Report, warming by 2100 will be worse than expected, with temperatures ranging from 1.8 to 4 degrees Celsius and possibly as high as 6.4 degrees Celsius. Impacts, particularly in the developing South, will be severe as temperatures rise (Riede et al., 2016).Along the same lines, the 2014 IPCC assessment indicates more confidently that global temperatures have risen by about 4°C since the late 20th century. This will increase global food insecurity due to growing demand for food. Wheat, rice and maize production in tropical and temperate regions is expected to be impacted by local temperature increases of 2°C or more from late 20th century levels.

Elevated temperature conditions at ENSO have been associated with increased variability and variability in precipitation in several regions of Africa, including the Sahel, eastern and southern regions of Africa (Haile, 2005; Plistnier, 2000;

Sivakumar et al., 2005). During the 20th century, the average temperature on the African continent increased by about 0.7°C, and some general circulation models predict that warming will continue to increase, increasing by 0.2°C every decade (low scenario) to more than 0 will increase.5°C per decade (Hulmet et al., 2001 & Parry & IPCC, 2007) increase in extreme events.

Since the last ice age, the Sahel has experienced several decades of drought with temperatures as low as 1.5°C, although simulation models suggest that countries in the Sahel and Horn of Africa could experience increased precipitation during the ice age and increased drought conditions during the wet season the dry season. (Collier et al., 2008 & Haile, 2005).

According to a study on climate change in Africa by Hulme et al. (2001), the continent's coasts are experiencing significant warming conditions that raise mean sea levels by about 25 cm. Droughts, floods, heat waves, storms and other extreme weather events will result from rising temperatures as they affect the natural interplay of these many factors in Africa's climate (Collier et al., 2008). According to a study by Funk et al., on (Ongoma et al., 2015), Drought patterns in Ethiopia and Equatorial Subtropical East Africa. The study confirmed the existence of drought conditions in equatorial and subtropical East Africa in the 1980s.

A study was conducted to determine the impact of current and future climate change and its variability in agriculture and forestry in the arid and semi-arid tropics. The models show that changes in the frequency and intensity of extreme events such as floods can occur when there is little climate change, and the results indicated that the continent as a whole has experienced a decrease in precipitation over the past 60 years (Sivakumar et al., 2005).Another study examined the impact of climate change adaptation strategies on household income and food security in Niger's Sahel region.. Most study participants reported noticing changes in precipitation patterns (9321%), total precipitation (91.25%) and precipitation intensity (81.82%) in the reference period.

Between 2015 and 2019, Indonesia experienced an increase in hydro-meteorological disasters linked to a changing climate, including floods, landslides, and droughts. In severely dry regions, drought more frequently occurs and decreases agricultural productivity, which has a considerable negative impact on the country's economic development (Penelitian et al.,2009)

In addition, it was noted that drought has intensified over the past 20 years and was the biggest problem in both areas. The focus group discussions and interviews showed that while droughts have occurred in the past, they were rare and their occurrence required a timeline before farmers could predict when the next drought would occur.

According to reports, there have been drought instances in the past around once every 10 to 15 years. However, the study found that most participants believed that, particularly since the 1980s, drought conditions have been more common and extreme in recent years. Interactions with the respondents indicated that drought conditions have been present recently virtually all year round or for several years in a row, leading to more crop failures and food insecurity for households (Mnguni Ba, 2016). Farmers assumed that their local climate had changed over the past three decades, including changes in temperature and precipitation, and linked these changes to environmental variability and climate change (Mnguni Ba, 2016).

A study was conducted on the impact of credit constraints and climate change adaptation policies on household well-being in Ethiopia. According to climate data, the region averages less than 135mm of rain per month for most of the year. Only between February and June does the district have significantly more rainfall, with the maximum amount being in February at 290 mm. Since 2010, rainfall in some (south) zones and the north has demonstrated a sharply declining tendency, which is consistent with predictions made by global climate models. The households surveyed were asked to rate other shocks in addition to precipitation patterns and whether they were adversely affected by those shocks. Households cited drought, heavy rainfall, severe crop losses to wildlife, and loss of livestock to disease or death as the biggest shocks to their well-being in 2011 and 2013. About 21% of households reported experiencing a drought shock in 2011, rising to 63% in 2013, suggesting that household vulnerability to drought has increased significantly over time. An unexpected torrential downpour in 2011, which caused flooding and destroyed crops for nearly 40% of households, was the second most devastating shock on record. Given the increased likelihood of droughts during this period, only 14% of households reported experiencing this shock in 2013 (Elias 2013).

A study titled "Water Management Modeling the Effects of Climate Change in Ethiopia" has found that the country's agriculture is particularly vulnerable to frequent extreme weather conditions such as frequent droughts and floods, which negatively impact the Ethiopian economy and society. and is expected to worsen due to climate change (Jiing-yun You, Claudia Ringler & Ringler, 2010).

A study was conducted in the arid and semi-arid tropics to assess the impact of recent and predicted climate variability on agriculture and forestry. According to the study, as temperatures become warmer and wetter, diseases and pathogens will continue to spread in tropical regions of Africa (Silvakumar et al., 2005). Temperature, precipitation, humidity, dew, radiation, wind speed and circulation patterns affect the spatial and temporal distribution and spread of agricultural pests, insects, weeds, fungi and pathogens (Collier et al., 2008, Rosenzweig and Iglesias, 1998).

A study was conducted to determine how climate change affects food supply and agricultural production in Africa. According to the study, greenhouse gases are the main cause of climate change because they absorb heat and release it into the atmosphere. Their increased availability in the atmosphere causes a warming effect (global warming) that changes the climate and e.g., hotter, drought and floods (Anabaraonye et al., 2018). The same review by Asante et al. (2015) showed an estimated 107% increase in MtCO2 (based on carbon dioxide, methane, nitrous oxide and fluorocarbons), with data showing that levels increased from 16.8% to 23.9% over the period 1990-2006 (Asante & Amuakwa-Mensah, 2015).

Currently, human activities account for around 80% of climate change through expanding industrialization, including activities like burning fossil fuels for transportation and industry, deforestation for agricultural activities, urbanization, or infrastructure improvements, among others (Antwi-Agyei et al., 2012). Rising sea levels, heat waves, droughts, floods, glacier melt, and decreased crop output are all results of the earth's warming (Di falco, 2014).

Between 2015 and 2019, Indonesia experienced an increase in the frequency of hydro-meteorological disasters linked to a shifting climatic pattern, such as floods, landslides, and droughts (Penelitian et al., 2009).

Increased flooding in low-lying places, more frequent and severe droughts in semi-arid and sub-humid regions, and extreme heat are just a few of the hazards that will affect livelihoods that depend on natural resources (Altieri et al., 2008 & Dokken & Morton, 2007) It has also become more evident that even the most aggressive mitigation measures will not be able to stop future effects of climate change for decades (Dokkens & Thornton, 2014).

Herbivorous insects can significantly affect plant productivity in agricultural systems and natural ecosystems. As climate change impacts insect dispersal and is likely to introduce new pests into agricultural systems, pest management challenges may increase in the future. With increasing temperatures, insect parasites are predicted to become more prevalent due to range expansion and phonological changes (Lin et al., 2011).

2.2 Climate adaptation strategies in Ghana

Today's SSA agriculture faces significant difficulties from climate change and variability since they not only raise production costs and crop failure risks but also jeopardize the integrity of the entire agricultural supply chain (T. Wheeler & Von Braun, 2013). Unless industry finds ways to adapt to climate change, the scientific evidence on climate change predicts that poor and stagnant agricultural performance in the SSA region will continue and even worsen even with a strong mitigation program (Dokken, 2001).

Farmers have developed and implemented a range of agricultural adaptation strategies that allow them to reduce vulnerability to changing conditions despite changing environmental and climatic conditions (Mnguni Ba, 2016). According to the IPCC (2001), adaptation to climate change is defined as the modification of natural and human systems in response to actual or anticipated climatic stimuli or impacts that reduce damage or take advantage of favorable opportunities.

Data was collected from 1,783 authentic rural households in the four main agricultural regions of Niger to analyze variables affecting climate change adaptation techniques, impacts on household income and food security in rural areas. The results showed that the most important household management techniques were crop diversification (72.74%), income diversification (67.97%) and planting delays (55%) (Zakaria et al., 2022).

Gebru et al. report that the introduction of drought-tolerant crop varieties, changing planting dates, crop rotation, intensive irrigation, expansion of arable land, implementation of various soil protection measures, and diversification of family income sources are just some of the coping strategies described in the literature (Gebru et al., 2020). Again, adaptive water management strategies, including scenario planning, learning-based strategies and no-regret adaptation solutions, can help build resilience to unclear hydrological changes and climate change impacts (IPCC, 2014).Various coping strategies are observed in Ethiopia. For example, Temesgen (2007) has shown that investments in technologies such as irrigation, cultivation of drought-tolerant and early maturing crop varieties, intensification of research, training of farmers and promotion of animal husbandry are means of coping with climate change.

The Nile Basin in Ethiopia is a region particularly vulnerable to shocks caused by long-term climate instability. Farmers have responded with various coping strategies. These techniques were developed by Difalco et al. (2011) in per formative and non-per formative terms. More than 95% of the measures relate to performance, while only 5% relate to failure rates. Crop-related measures include common management tactics of changing crop species, implementing soil and water conservation practices, planting trees that can collect rain water, and changing sowing and harvesting dates. The main non-agricultural methods are migration and change of agricultural practices from agricultural production to livestock and other sectors. Crop diversification is one of the techniques to combat climate change, including an increasingly wide range of tools and methods to increase production and ensure food security.

Crop diversification is generally understood to mean the transition from older, lower-yielding crops to newer, higher-yielding crops. It is also a tactic designed to make the best use of land, water and other resources for the overall agricultural development of the country. It offers farmers inexpensive ways to use their land to grow various crops. Diversification is believed to have two main characteristics. It also increases the farmer's production capacity or land allocation limit, thus increasing his ability to generate money and jobs. It also reduces the risk of laying all the eggs of a single crop or a small number of crops, presenting a potentially high risk of covariance (Sichoongwa et al., 2014).

According to the study, farmers have developed strategies over time to increase agricultural production and living standards in order to adapt to climate change. Measures include changing agricultural practices, using improved varieties through careful selection, using rainwater and protecting the soil (Otitoju and Adebanjo, 2013). Compared to local cultivars, improved cultivars are better able to survive extreme weather conditions, reducing vulnerability to climate change. In Ghana, Nigeria, Burkina Faso, and Senegal, rural farmers have adopted the use of drought resistant cultivars as a climatic adaptation strategy (Akinnagbe & Irohibe, 2015).

To reduce risk in agriculture, crop diversification entails changing the variety of crops and livestock. Agriculture diversification is a key tactic for enhancing and stabilizing farm income. Items to provide a greater selection in agricultural production to reduce risk (Otitoju & Adebanjo, 2013). According to Solomon and Edet's (2018) descriptive analysis, the majority of farmers, at 100% and 99%, respectively, adjusted their farming operation times and increased their usage of agricultural inputs as their primary adaptation tactics.

In their study of how climate change and violence affect the technical efficiency of rice production in Uganda, Akongo et al. (2016) found that displacement, off-farm income, experience, and use of improved seed varieties (Nerica) help rice farmers in the region increase productivity. The effects of climate change adaptation techniques on agricultural productivity were studied in central Chile by Roco et al. examined. (2017) using the stochastic production limit method. Their empirical results clearly showed an association between increasing agricultural productivity and the use of adaptive tactics. They found that using irrigation as an adaptive skill had the greatest impact on productivity. Given the current situation, they concluded that implementing adaptation strategies to increase farmer productivity is crucial.

According to Rademacher-Schulz et al. (2014), dry season migration and irrigation are the most common response mechanisms in the Upper West region of Ghana. Her research also shows that most people have been forced to leave their cities and move to other areas outside this zone to support their families during the dry season. Remittances from migrants, both international and domestic, are a key factor in reducing household poverty. According to Vander Geest (2011), it is environmental issues in northern Ghana that prompt people to move south where the land is more fertile to ensure food security and domestic prosperity for their loved ones.

Remittances are a visible link between finding work and improving a household's climate change resilience (Banerjee et al. 2017). To cope with the impacts of climate change, migrant families rely on various remittances (incash or in kind). Musah Surugu et al. (2016) examined how remittances helped Ghana in Greater Accra, Brong Ahafo and Northern Regions to close the adjustment gap.

According to Skinner (2002), technological advances such as the development of better crop varieties, access to climate data, and the construction of irrigation systems are critical to preparing for climate change and its impacts. Smallholder farmers adopt adaptation techniques such soil management, tree planting, agroforestry, intercropping systems, and judicious use of organic and organic pesticides to increase productivity and lessen the negative effects on both agricultural yields and crop health are improved by these practices. Farming practices that include the soil enrich the soil with nutrients, which benefits crop growth (Kuwornu & Demi., 2013)

In addition, socio-economic conditions influence farmers' decisions to use different tactics. For example, farmers with larger plots of land have more opportunities to implement strategies and increase their income (Belay et al., 2017). Farmers engaging in non-agricultural activities to generate income and thus reduce risk in agricultural production is referred to as income diversification. Most rural farmers use income diversification as a risk management strategy, both in preparing for and in responding to impending climate shocks (Ji et al., 2014). Participation in non-agricultural activities increases the income of small farmers and helps them achieve their goal of adapting agricultural production to climate change. Income inequality is expected to have a positive impact on the productive capacity of small farmers (Babatunde, 2012).

Rice production could be less affected by climate change if improved varieties are grown. By using modified seeds that withstand harsh environmental conditions, farmers can reduce the impact of climate change on their productivity. Early maturing rice varieties have a shorter growing cycle, which helps mitigate water stress during declining and unpredictable rainfall, as rice is very sensitive to prolonged water stress or flooding. It is important to take precautions to increase the technical yield of through improved seed varieties as rainfall can be unpredictable (early maturity) (Otitoju and Adebanjo, 2013).

2.3. Factors which influence farmers' climate adaption strategies.

Several factors influence farmers' decisions to take action to reduce the impact of climate change on household well-being. A recent study found that the homeowner's age, education, and gender, as well as household size and size, as well as wealth, livestock ownership, household financial status, and family were significantly related to family decisions. for adaptation to climate change (Funk et al., 2020). According to Difalco et al. (2011),Institutional factors (such as information, advisory services, access to credit) as well as socioeconomic and demographic factors (such as gender, age, education, family size and marital status) affect the way farm households adapt to climate change. Changes or acquisitions that may affect agricultural productivity.

Nabicolo et al. (2012), Nhemachena and Hassan (2008) and Hiley et al. (2010) found that female-headed households are more likely to make adjustment decisions than male-headed households. In rural smallholder groups, women tend to do most of the farming work while men live in urban areas. They tend to have better knowledge of different farming techniques and therefore more experience in farming. Farming experience increases the likelihood of being able to use all customization options.

However, a study by Oyekale and Oladel (2012) found that female-headed households were less likely than male to adopt climate change adaptation strategies. A similar study in the Nile Basin of Ethiopia by Deressa et al. (2010) showed that male-headed households used adaptive methods more often than female-headed households. With more household responsibilities and less control over financial resources, women would be less able to diversify their income sources and adapt to climate change.

The second factor determining eligibility is the age of the head of household. Research by Pycroft (2008), Oyekale and Oladel (2012) has shown that as the breadwinner ages, the likelihood of taking action to adapt to climate change decreases. The results of these studies show that older families are weak and do not find many alternative solutions. It can also be explained that young people are more willing to adopt new ideas and less willing to take risks.

Education is another important element in using coping strategies. To study how agricultural technology affects crop income and poverty reduction, Kassie et al. (2011) conducted research in Uganda. The study used cross-sectional data from 927 families. A propensity score matching was used for the analysis. According to Logit's Adoption propensity estimates, residential tenant market share, facility size, occupancy, and lost count have a significant and positive impact on adoption. Indeed, the involvement of farmer organizations and years of training have a similar effect. According to the study, education and membership in farming groups can be used as a substitute for access to information. Belonging to the circle of farmers gives an opportunity to share knowledge and experience in the field of the latest agricultural technologies. Likewise, educated farmers often have the opportunity to apply new knowledge and appreciate the importance of new technologies. Conversely, lacks of seed availability and distance from the market have a negative impact on acceptance (Kassie et al., 2011).

A study by Abid et al. (2014), confirm this statement. According to this study, a very important factor in family management, the likelihood of adapting to climate change increases with the length of school years. They change the type of crop (0.08%) and more often (09%) the planting date (0.17%), plant shade trees (0.08%), protect soil (0.08%), modify fertilizers (0.15%) and irrigate (0.08%).

Menberu et al. (2014) examined how land management practices in north-western Ethiopia influenced people's adaptation to climate change. According to the output of the binary logit model, the CEO's age and education level were not found to be significant predictors of benefit. However, factors such as household size, agro-ecological zone, livestock population, and access to climate information have a large and positive impact on the likelihood of adaptation.

A study by Hilery et al. (2013) came to an important conclusion. Age, education, farming experience, irrigation, local agroecology, farm and non-farm income, access to climate change information, access to credit, changes in temperature and precipitation, and household size had a significant impact on the likelihood of Heckman's selection model. selection model. Age, gender, education, household size, distance from market, irrigation, local agroecology, farm and non-farm income, access to climate change information, temperature changes.

However, factors such as gender, family size, distance to the nearest market, access to finance, and variable rainfall have negatively impacted the likelihood of adjustment. The study cites the following reasons for the unfavorable relationship between family size, market distance and adaptability: Family size is an indicator of job availability. As a result, households with a large number of family members are more likely to shift labor to non-agricultural activities to increase income and reduce the pressure to consume in a large household. Long distances to markets make adaptation to climate change less likely, as markets provide an important place for farmers to gather and exchange information. According to the study, farmers' lack of debt capacity could be at the root of the negative impact of access to credit on adaptive behavior.

The motivations behind farmers' decisions to adapt to climate change were analyzed in a study by Difalco et al. examined. (2010). the study results showed that access to formal and informal institutions, awareness of climate change and revenues from non-agricultural services increased the ability to implement adaptation. Furthermore, there is no doubt that climatic factors have a decisive influence on the likelihood of adaptation. The precipitation pattern during the "Belgian" and "Meheran" rainy seasons of has an inverted U-shape.

Research results showed that factors such as labor input, number of fertilizers applied and number of hectares had a positive impact on farmers' ability to grow while adapting to changing conditions (Mabe et al., 2018).

Antwi-Agyei and Stringer conducted a study on the effectiveness of farm extension services in helping farmers adapt to climate change: lessons learned from Northeast

Ghana. The main challenges faced by agricultural advisory agents in the study included the high ratio of agricultural advisors per farmer, lack of appropriate advisory materials, lack of transport infrastructure for intermediaries, and insufficient funds to implement adaptation practices. Farmers' reluctance to change and complex ownership systems that hamper investment are the two main obstacles that have hampered the effectiveness of expansion efforts.

To increase the acceptance of adaptive methods, research by Piya et al. (2013) on the marginalized indigenous community of Chepang in Chitwan, Nepal, propose disseminating information on weather conditions and agricultural production related to climate change and variability. This study also discovered that the accessibility of job training opportunities, unsecured microcredit, and counseling services all enhanced the likelihood of adoption.

The factors determining how smallholders respond to dangers associated with the climate are evaluated by Muva et al. (2017). This study, in contrast to the majority of earlier studies, assessed the simultaneous effects of outside factors on the use of a variety of coping mechanisms. In order to lessen the effects of climate change, farmers may choose to use a variety of techniques. Access to credit and the availability of weather data have a beneficial impact on farmers' adoption of the majority of techniques in Malawi. In particular, this study discovered that, notwithstanding financing crunch, manufacturers' decisions to invest in new farming equipment are supported by access to climate information.

If a farmer has access to improved education, unpaid farm revenue, farm and livestock services, and farm finance, he is more likely to adopt better agricultural techniques, claim Tilahun and Bedemo (2014), who noticed comparable results to earlier research carried out in Africa. Nearly 47% of farmers have not taken any effort to address the effects of climate change due to workforce shortages, and nearly 32% are having trouble obtaining loans.

In Chitwan, Nepal, rice farmers' perceptions of coping mechanisms and the influences on them were examined by Regmi (2020). The study analyzes the primary factors influencing the rate of adoption of adaptive techniques. The biggest barriers to adapting to climate change include a lack of information, a lack of technical expertise, and credit restrictions. The likelihood of households with migrants adapting to climate change is also lower. This might be because the agricultural industry is experiencing a labor crunch, which emphasizes the need for mechanization and the expansion of less labor-intensive agricultural techniques. The findings demonstrate that awareness and education about climate change, access to information, and usage of information services are the primary elements that boost the capacity to implement various adaptation measures. Results from adoption rates indicated that male-headed families are more likely than female-headed households to apply coping mechanisms, regardless of their levels of education, income, awareness of climate change, or usage of counseling services.

According to study, factors like family size, education level, financing availability, family labor availability, and agricultural experience severely restrict a farmer's capacity to adapt to change. The job offer is the primary incentive, among other factors. In actuality, some coping mechanisms need more effort than others. Therefore, farmers who have excess labor on hand or who are rich enough to recruit workers are more likely to consciously implement climate change adaptation methods (Olarinde et al., 2008). For instance, Thailand's rising need for labor is a result of the diversification of its agriculture.

To complete all types of agricultural tasks, from planting and land preparation to harvesting, farmers frequently need additional help (Kasem and Thapa, 2011). To increase the production of disadvantaged rural farmers, several climate change adaptation strategies are encouraged. Thus, improving food security and lowering poverty are encouraged. When determining if a method is appropriate for the adopters' existing socioeconomic situation, extra caution should be used. While some methods boost agricultural output without adding to input costs, others manage to do so without sacrificing the advantages received from the ability of the adaptation approach to boost yields. In addition to the price of employing better seeds, fertilizers, insecticides, and herbicides, labor costs are substantial. Poor farmers would be particularly affected by this because they have to deal with large opportunity costs and severe financing restrictions (Chistire et al., 2002). Farmers would therefore be wasting their time by employing labor-intensive adjustment strategies in areas with the worst labor shortages (Kasem and Thapa, 2011).

Goals of adaptation to climate change can include altering environmental conditions or decreasing harm to agricultural productivity. Through adaptation, the effects of climate change on the environment and the socioeconomic system can be mitigated. The two main types of adaptation to climate change are autonomous and planned adaptations. Changes in crops or harvest and planting dates are examples of autonomous adaptation to climate change, whereas planned adaptation to climate change refers to targeted policies or response strategies, frequently cross-sectoral in nature, that are intended to increase the adaptability of the agricultural system change or enable a particular customization. (Arimi, 2014)

In order to combat the detrimental effects of climate change on agriculture, crop, water, and land management techniques should be given priority. The most common adaptation strategy utilized in the nation as the temperature rises is irrigation. You can do this by increasing the volume or frequency of watering. Shifting planting dates, choosing heat-tolerant cultivars, applying insecticides and fertilizers, planting trees as fences around the farm, utilizing cover crops, and mulching fruit are some of the often-utilized coping mechanisms (Helmy et al., 2007).

Difalco et al. (2011) found that institutional factors (such as information, advisory services, and access to credit) and socioeconomic and demographic factors (such as gender, age, education, family size, and marital status) have an impact on how farm households decide whether to take over or adapt to climate change, which may have an impact on agricultural productivity. However, a different study by Oyekale and Oladel (2012) discovered that families with female heads are less likely to use climate change adaptation strategies than households with male heads. Male-headed families are more likely to employ adaptive strategies than female-headed households, according to a comparable study conducted in the Nile Basin of Ethiopia by Deressa et al. (2010).

Women would be less able to diversify their sources of income since they would have less control over their financial resources and more home duties.

According to logit estimates of propensity to adopt, there is a positive and significant association between farm size, employment, domestic market share of rents, and number of plots. Participation in farmers' unions and years of training have had a similar effect. Research shows that education and membership in farmer organizations can replace access to information. Belonging to the group of farmers gives the opportunity to exchange knowledge and experience in the field of the latest agricultural technology. Like educated farmers, they are more likely to apply new knowledge and appreciate the value of new technology.

This claim is further supported by a study by Abid et al. (2014). The length of school years appears to boost the possibility of adaptation to climate change, which is a highly significant family educational element in this study. Changes in planting date (0.17%), planting of shade trees (0.08%), soil protection (0.08%), fertilizer change (0.08%), irrigation (0.08%) and crop species (0.08%) are more likely than these. In Ethiopia, establishing a household head enhances the possibility of climate change adaption. The probability of soil protection increasing by 1% and the likelihood that planting dates will vary due to climate change increasing by 0.6%, respectively, with additional school years per unit. A correlation between education and effective adaptation to climate change is further suggested by the fact that almost all education thresholds are positive across all adaptation alternatives (Bryan et al., 2009).

The logit model was used in the model by Nbikolo et al. (2012) to assess the influences on households in eastern Uganda with male and female householders. The results of full-sample logit regression showed that characteristics like land ownership, the use of purchased inputs, the size of the leader's family by gender, the total area of the land, availability to financing, and the usage of personal bicycles had a significant impact on people's willingness to adapt to climate change. The size of the home, the chief's education, and the presence of animals, in contrast, had no bearing. Land ownership and breadwinner gender have a detrimental impact on the chances of adaptation. On the other hand, the choice of fitting was favorably influenced by elements including country coverage, inputs used, affordability, and bicycle ownership. Menberu et al. (2014) investigated the impact of land management techniques on how well residents in north-western Ethiopia adapted to climate change. Age and education level of the CEO were not discovered to be significant predictors of utility, according to the results of the binary logit model. The size of the family, the agroecological region, the number of animals, and the availability of climate information all have a significant and beneficial impact on the chance of successful adaptation.

The study by Hilery et al. (2013) likewise led to a significant conclusion. Heckman's selection model shows that a family's decision to take coping measures will be significantly influenced by factors like age, gender, education, household size, farming experience, distance to market, irrigation, local agroecology, farm and non-farm income, access to climate information, climate change, access to credit, temperature changes, and changes in precipitation. On the other hand, elements include age, education, agricultural experience, irrigation, neighborhood agroecology, farm and non-farm income, and information availability. However, the ability to adapt to climate change was negatively impacted by factors such as gender, family size, distance to the nearest market, accessibility to financial resources, and rainfall variability. According to the study, family size is a good predictor of employment availability, which accounts for the negative association between these factors and likelihood of affiliation. Multi-person households are therefore more inclined to switch from agriculture to non-agricultural jobs in order to raise their income and lessen the demand on large households to consume. Markets are a crucial gathering place for farmers to gather and exchange information, therefore being far from one decrease the likelihood of farmers adapting to climate change. The study suggests that the weak borrowing capability of farmers may account for the adverse effects of credit access on adjustment behavior.

In order to investigate the effects of crop rotation and reduction in agriculture on household well-being, Eliasz et al. (2014) undertook a study in Zambia. Heckman's Choice Estimator and Propensity Score matching techniques were utilized in the study, which made use of cross-sectional data gathered from 1,231 families in six districts of Zambia in 2012–2013. As a result of low tillage and crop rotation, corn crop production improved by 26% to 38% and 21% to 24%, respectively, according to the results. Due to little tillage, domestic corn production has increased overall. Crop rotation did not, however, significantly boost gross income or total corn production.

The findings of a prior investigation by Kassie et al. (2014) were verified. The investigation was based on 1,925 households and 2,937 maize farms in Malawi. The endogenous polynomial regression model's findings show a strong correlation between the adoption of crop rotation and low tillage and an improvement in maize yields. In fact, the study also demonstrated that combining the strategies can lead to greater profits than doing so separately. Farmers can get higher yields of up to 850 kg/ha with minimal tillage and concurrent crop rotation.

Factors including the breadwinner's age, livestock, soil fertility, and pesticide use have a good and significant impact on homework for both adopters and non-adopters. The requirement for household work rises with household head's age, but at a certain age, labor demand tends to decline. Young farmers will establish numerous farms employing different techniques, leased land, and shared crops. This has increased the stress on family work. It boosts the family's use of work, much like owning dogs. In fact, it ought to be obvious as the animals need to put up some effort on their own to graze and prepare better food. The requirement for labor increases as the number of animals on the farm increases. The usage of family labor is also positively and significantly influenced by fertility (Marye, 2016).

High household workload and high fertility are linked. Since good quality plots offer a high rate of fertility, their productivity will be high, increasing the overall work of the household and especially harvesting and threshing. The type of crops grown also influences the amount of housework. Barley, sorghum and corn have a significantly negative impact on housework distribution compared to wheat (Marye, 2016)

Additionally, it was shown that the climatic circumstances have a significant impact on how the household's labor is divided up. Both adopters and non-adopters think that the temperature has a non-linear and considerable impact on family work. As the temperature rises, the work on the farms initially increases, but after some time the ratio changes. Farmers will, in fact, employ a variety of mitigating techniques, such as: B. Water conservation measures. When the impact of the climate becomes too significant for farmers to maintain their activities, they will look for alternative careers outside of farming. As a result, household members spend less time working on agricultural tasks. Due to increased rainfall, both types of farms need less labor, albeit this has little bearing on non-users. In fact, enough rain can help farmers avoid crop failures and cut back on the time they spend on water conservation (Marye, 2016).

The study found that a farmer's choice of farming practices is influenced by variables like age, education, the availability of advisory services, credit score, farm size, and knowledge of the possibility of floods. Marital status, education, farm size, and awareness of flood episodes all had a significant impact on people's decisions to transition to non-agricultural activities. Other factors that affected how soon households recovered from the floods included age, education, FBO, and the perceived severity of the crisis. Alhassan is a 2020.

The main barriers to putting the measures into action were a lack of expertise, skills, and current information about the effects of climate change, as well as the need for a better institutional structure to implement adaptation (Akinnagbe and Irohibe 2015). Santos et al. (2011) also looked at the various shocks that Bangladeshi households experienced and their coping mechanisms. Her study demonstrates that those who are poorer than those who are not are less able to handle shocks and more likely to use coping mechanisms that can have long-term detrimental impacts on well-being, such as resource deprivation.

The size of the farm is anticipated to have a favorable influence on how farmers respond to climate change. Large farms have enormous resources and are more likely than small farms to adapt to climate change considerably earlier, claim Alauddin and Sarker (2014). This shows that the size of the farm and the use of climate strategies are positively correlated. Due to the high cost of implementing climate change adaptation strategies, small farms are unable to collect the necessary funds.

Family size is anticipated to have a favorable effect on the adoption of climate change solutions. A large family can redirect some family labor to non-agricultural pursuits to earn revenue, according to a 2009 study by Deressa et al. The results of this study also indicated a favorable relationship between household size and the use of climate adaption strategies. Larger families with lots of productive people have more labor resources, which aids in their ability to adjust to climate changes.

The duration of a farmer's active involvement in rice farming is utilized to gauge that farmer's level of farming experience, which is anticipated to have a favorable influence on the farmer's choice of the best coping mechanisms. Due to their capacity to disperse risks, experienced farmers are anticipated to be more likely to implement climate-related actions than less experienced ones (Osei-Owusu et al., 2012). Advisory services offer information on climate change in addition to guidance on agronomic practices and management. According to Etwire et al. (2013), farmers that interact with augmentation factors are more likely to be aware of climate change and potential retaliation mechanisms.

Planting times are affected by changes in rainfall patterns. Because plants aren't getting enough water, incorrect predictions of planting times result in lower profitability. To ensure adequate irrigation for seed germination, farmers plant crops during the rainy season. The harvest model and the precipitation model are interdependent.

Solomon and Edet (2018) examined the factors influencing farm adaptation to climate change in a study conducted in the Delta State of Nigeria. The findings of a binary logistic regression model showed that the head of household's age, gender, education level, farming experience, access to credit, farm/herd size, cooperative membership, family income, availability of meteorological data, and availability of supplementary information services were crucial. The Likelihood that farmers will use coping mechanisms. Therefore, it is advised that the elements that influence whether farmers use adaptation techniques in the appropriate direction, towards sustainable rural and agricultural growth, be carefully examined, used, and efficiently used.

A cross-sectional study examined whether the implementation of climate change adaptation strategies increased the productivity of small-scale rice farmers in Ghana's Volta Region's Hohoe Municipal. Changing the planting date is the most effective method of reducing the consequences of climate change, according to the findings of Friedman's two-way study. The adoption of adaptation measures is significantly influenced by experience, gender, the head of the household, knowledge of climate change, the diversity of the regions, and educational attainment. Efficiency has greatly decreased as a result of farmer adoption of greater diversity, crop diversification, income diversification, and other climate adaptation measures (Kumodzie, 2018).

2.4. Effects of climatic adaptation strategies on farm household welfare.

Agriculture is adjusting to the climate change by altering management practices (Otitoju and Adebanjo, 2013). Farmers have adapted their lifestyles and agricultural practices over time in response to climate change. Utilizing carefully chosen types, gathering rainwater, conserving soil, and altering farming practices are some of the activities. The analysis by Ndaki (2014) indicates that the speed and intensity of climate change are outpacing the capacity of smallholder farmers to adjust to it.

According to the study, coping mechanisms significantly and favorably affect household income and food security. Farmers who apply climate change adaptation approaches are more likely to see an FCFA 7,721,526 rise in household income compared to those without these measures. As opposed to those who have not, people who have embraced strategies are 7-9% more likely to obtain food (Zakari et al., 2022).

The outcomes of a study to look at how farmers' adaptation choices affect food security were as predicted. The employment of on-farm and off-farm catastrophe adaptation strategies to flooding had a favorable and significant influence on per capita food expenditure, according to the results. This demonstrates that adaptation, both on and off farms, is an effective strategy for enhancing household food security. The improvement of family food security results from an increase in production using agricultural techniques such B. the application of better agricultural technologies (Alhassan, 2020).

According to Adenle et al. (2017) and IPCC (2014), the expected rise in extreme weather events will also have a detrimental effect on the agriculture industry, which provides food for many families in sub-Saharan Africa (SSA). According to the research that is now available, floods, for instance, have a significant negative influence on crop yield, food security, and the economy (Amouzou et al., 2018). Extreme climate events in Africa are reportedly capable of shortening growing seasons, which could result in a 20–50% decrease in grain production by 2050 (Connoly-Boutin & Smith, 2016; Sarr, 2012).

Additionally, the sub-Saharan African agriculture industry, which supplies food for a large number of people, is anticipated to suffer from the anticipated rise in extreme weather events (Adenle et al., 2017). According to studies conducted by Amouzou et al. (2019), crop productivity, food security, and the economy are all negatively impacted by floods and other climate-related shocks. By 2050, the production of grains in Africa could be reduced by 20–50% due to shorter growing seasons brought on by extreme weather (Connoly-Boutin and Smith, 2016; Sarr, 2012). Crop diversification and the adoption of seed technology strategies considerably lessen the influence of climatic factors by improving the overall efficiency of agricultural systems in the face of changing climatic conditions (Di Falco et al., 2010; Di Falco and Chavas, 2008).

Crop diversification is a strategy for reducing greenhouse gas emissions that includes a variety of techniques and tools to boost output and guarantee food security. Moving from older, less profitable crops to newer, more profitable crops is usually believed to be crop diversification. It is also a technique for making the best use possible of land, water, and other resources for the overall development of the nation's agriculture. It offers farmers practical options to cultivate a range of crops on their property. Diversification is seen to have two key traits. First, it raises the farmer's maximum output capacity or land allocation, resulting in more opportunities to earn money and create jobs. Additionally, it lowers the possibility of producing a single culture or a small group of cultures with a high potential for covariance (Sichoongwe et al., 2014). Crop variety, according to a study by Lin et al. (2011), is essential for bringing down pest populations.

By cultivating and harvesting a variety of crops over the course of the year, diversity also lowers the risk of crop losses caused by climate variability (Kar et al., 2004). particular seed technologies have also demonstrated their value in particular circumstances as a buffer against variations in precipitation (Bezu et al., 2014). Crop rotation is also thought to offer a range of ecological services, including the fixation of nitrogen, carbon sequestration, interruption of the life cycles of pests, improved weed management, and pest control.

Farmers may cultivate crops that can be harvested at various times and in various locations thanks to diversification. To adapt to climatic or environmental stressors, farmers can simultaneously cultivate crops with various features (Difalco et al., 2010). Marye (2016) evaluated how climate change adaption measures affected farmer welfare in the Ethiopian Nile Basin. The findings indicate that the factors that have the biggest effects on household income, labor demand, and DC adoption are climate variables including temperature variations and precipitation during the growing season. The study also demonstrates that areas with high temperatures and little rainfall are more prone to adopt DC. The findings of this study show that plant diversity is a useful strategy for adapting to climate change that boosts output while cutting labor expenses.

Farmers who implemented these modifications in northern Ghana produced more sacks of rice than those who did not, according to studies by Mabe et al. (2012) on farmers' capacity to adapt to climate change and its effects on rice output. Their findings demonstrated that variables including labor input, fertilizer usage, and hectareage had an effect and enhanced farmers' adaptability. Overall, the authors came to the conclusion that the study area's rice producers had only minimally adapted to climate change.

To ascertain the effect of climate change adaptation measures on household well-being, a cross-sectional study was carried out in the Ethiopian Nile Basin (Amare et al. 2019). The findings indicate that whether or not crop diversification is implemented, the effect of climatic variables on farm income varies. The study also reveals that the introduction of CDs had a good and considerable influence on agricultural income and a decrease in the need for farm labor. The findings demonstrate how the application of CD promotes farm prosperity and the growth of a sound agricultural system.

Access to meteorological data appeared to have a beneficial influence on the decision to implement adaptation measures in response to climate change, and this influence was significant at the 1% level. This shows that farmers are more likely to use adaptation strategies if they have better access to information about climate change. Access to credit demonstrated a positive association and is significant at 10%, indicating that as farmers have greater access to credit, the number of coping mechanisms they employ will rise.

Further investigation revealed that the outcomes amply illustrated the advantages of offering credit to farmers in order to lessen their financial constraints on making investments in agricultural technology. Again, a substantial and positive correlation of 10% was found between access to advisory services and the adoption of adaptation measures, demonstrating that the more the availability to advisory services, the greater the likelihood that farmers will implement adaptation measures. As farmers become more aware of challenges related to climate change, the finding is consistent with a priori expectations demonstrating a positive connection between access to advisory services and application of adaption techniques (Solomon, 2018).

Up to a threshold of 29.9 °C, rice yields increased by 27 kg/ha (0.54 bushels/acre) for every 10 °C increase in daily temperature rise in the ripening period (85.820F), according to research by Karna (2014) on the effects of meteorological factors on rice production in Nepal. However, this study also discovered that rice yields start to fall off after the highest daily temperature exceeds 29.90°C Rice output, which is nonlinearly tied to rainfall, is severely harmed when rainfall falls in the last phases of harvests that are not favorable to growth.

A polynomial endogenous treatment effects model was used to investigate the effects of post-flood management methods on agricultural food security in Upper Eastern Ghana. Additionally, an ordered probit model was used to analyze variables influencing a household's capacity to recover from floods. Farmers use both agricultural and non-agricultural activities as coping mechanisms. According to estimates, farmers who engaged in both on- and off-farm activities increased their food security and recovered from floods more quickly (Alhassan, 2020).

When investigating the responsiveness of home farming patterns to price changes and credit availability, Komarek (2010) makes the observation that increased access to credit can result in considerable changes in household agricultural patterns. The availability of finance also tends to boost diversity at the farm level by facilitating access to a range of seeds. Even current cultivars appear to foster diversity rather than pose a danger to it in a resource-constrained system. Kassie et al. (2012) also looked at the effects of adopting better soil grid types on crop income and poverty in rural Uganda.

Using the Propensity Score Estimation (PSM) method, it has been demonstrated that the installation of better terrestrial network types has large and positive effects on crop yields and the alleviation of poverty. According to the findings, net yield increases per acre increased from \$159 to \$180. At the same time, poverty dropped by 6 percentage points as a result of increased land diversity.

2.5. Negative Effects of adaptation strategies

Statistics show that each year, desertification and soil erosion result in loss of between 100,000 and 120,000 hectares of land. When there is a drought, the cost of millet, sorghum, and other essentials rises, but the cost of livestock plummets sharply(Documents of the world Bank Niger Food Security Net, 2009).

According to a study by Acharya (2018), daily temperature fluctuations during the planting season affect land allocation for most crops, including rice. The study also evaluated yield function and area in the context of changing environmental and market conditions in Nepal. Farmers' ability to make decisions is likely to be limited by temperature fluctuations, which also occur when the monsoon arrives later than expected and the dry season lasts longer. In addition, the yield is enhanced by the many rainy days during the growing season and the high farmer literacy rate. According to empirical estimates, rice yields should decrease by 4.8%.

A major decline in agricultural output can be attributed to climate change due to changes in soil moisture and fertility, growing season length, and other factors. One of the climate shocks that has significantly contributed to farmer crop crises and food shortages is rainfall variability (Bezabih et al., 2014). The effects of climate change, such as extended droughts, droughts, floods, flash floods, landslides, and other extreme events, have a considerable impact on agricultural production. These effects lower food production by diminishing soil fertility, water resources, and natural resources (Climate Smart Farming Training Manual for Kenya Agricultural Development Agents, 2018).

Planting times in rainfed agriculture are impacted by changes in precipitation patterns. Inaccurate planting time estimations reduce revenue since plants aren't getting enough water. Farmers grow crops during the rainy season to guarantee sufficient irrigation for seed germination. There is a relationship between the harvest model and the precipitation model.

CHAPTER THREE

RESEARCH METHODOLOGY

3.0 Introduction

The study area, study design, sample size, sample and data source selection procedure, data collection tactics, data estimate, and the operationalization variables and their a priori expectations are all given a brief review in this section.An knowledge of the area in which the research was done is provided by the research field. The study's methodology is laid forth in the study design. The usage of the models for data analysis is discussed in the final section.

3.1 Study area

There are 2,310,939 people living in the Northern Region, which has a total size of about 26,524 square kilometers. It shares its northern boundary with the Northeast area, and its southern and eastern borders, respectively, with the Savana and Togo regions. There is only one rainy season in the area, which lasts from May to October. The annual amount of precipitation is measured to be between 750 and 1050 millimeters. The dry season's end (March–April) sees the highest temperatures, while December and January see the lowest. The harmattan winds, which blow from late December to early February, cause the dry season to begin at 40°C throughout the day. Extremely little humidity increases daytime heat exposure. Due to the region's hard climate, meningitis expanded to almost endemic levels and had a significant influence on both the health sector and economic activity. Additionally, onchocerciasis thrives in this region. Even though the illness is now under control, river blindness's effects historically left a huge area underpopulated and under cultivated. Large Guinean savannah forests coexist with grassland as the primary vegetation type. The acacia (Acacia longifolia), mango (Mangifera), baobab (Adansonia digitata Linn), shea (Vitellaria paradoxa), dadawawa, and neem (Azadirachta indica) are among the trees in these forests that are noted for their drought tolerance.

Three districts—Kumbungu, Savelugu, and Mion—were involved in the study. The areas have 212,048 agricultural households (GSS, 2020), and maize and rice are the two main crops grown there.

3.2 Study design

A research design is used to organize the study and demonstrate how all of the project's key components - the samples or groups, measurements, treatments or programs, and methodology assignment - connect to solve the main research questions. The research is held together by it since it acts as the glue. The research methodology used in this study is a quantitative study. One of the most important quantitative research tools in the social sciences is survey research. In this approach, the researcher selects a sample of respondents from a population and is then given a standardized questionnaire to fill out to find out how that group is currently performing on one or more factors.

Quantitative research is a systematic procedure for obtaining formal objective data to characterize variables and their interactions. Statistics are used in quantitative research to interpret, organize, and present collected data (Burns and Grove, 2001). Because the researcher used a structured questionnaire format to collect data from respondents in this study, the study design will be quantitative. Thanks to this technique, the researcher was able to ask all respondents the same questions, which made it possible to collect objective data during the study.

3.3 Sample size Determination

The study used Yamane's (1967, p. 886) formula for calculating sample size, assuming proportional divisions for each group, a level of confidence of 95%, and a margin of error of 5%.

$$n = \frac{N}{1+Ne^2}$$

Where "e" denotes the degree of accuracy and "n" denotes the sample size,

population size and "N". With degree of accuracy e=5% and N = 215048

$$\frac{212048}{1+215048(0.05)^2}$$

However, total of 422 participants were used to have a uniform distribution of questionnaire base on the sample design and techniques used.

3.4 Sampling procedure and source of data

To collect data that can be used to draw inferences about a much larger number of cases, Mugenda and Mugenda (2003) define sampling as the act of selecting a small number of cases. The study area's respondents will be chosen using a multistage sampling procedure. Three Traditional Councils; Kumbungu, Savelugu and Mion were deliberately chosen in the first phase. In a second phase, the same technique is used to select three communities from each traditional council based on the dominance of the peasants in each community. While the final step required choosing 422farm homes at random from each town so that the survey would have a total of 422sss respondents.

Primary data was collected for this study. The study employed 422 farm households in the study.

3.5 Data Estimation Strategies

Descriptive statistics were employed in this investigation, including averages, percentages, and frequencies. The variables that were employed in the estimation were described using descriptive statistics like frequency and percentages. The research employed polynomial endogenous treatment effects, endogenous Poisson switching, and a multivariate probit model. As a stand-in for measuring food security, the results of the Household Dietary Diversity Assessment (HDDS) and the Household Food Insecurity Access Score were employed.

3.5.1 MULTIVARIATE PROBIT MODE

The multivariate binary probit model was used to determine what influences both individual and group decisions about how to adapt to the climate. At a 1% level, it was determined that the Wald Chi2 test was highly statistically significant (Wald chi2= 780.24; p value= 0.0000). Also, highly significant at a 1% level was the likelihood ratio test that evaluated the joint estimation of the climate adaption methods (chi2(45) = 266.442 Prob > chi2 = 0.0000). This MVP model summary showed that the model was the best option for looking at the factors that influence smallholders' choice of climate adaption options, both positively and negatively. To determine their impact on smallholders' choice of climate adaption measures, a number of socioeconomic parameters were used.

The model is generally given as:

$$y^*_1 = x_1\beta'_1 + \varepsilon_1 \quad (1)$$

$$y^*_2 = x_2\beta'_2 + \varepsilon_2 \quad (2)$$

:

$$y^*_{m,} = x_m\beta'_m + \varepsilon_m \quad (3)$$

y^* = climate change adaptation strategies

β = factors influencing choice of Climate Change adaptation strategy

ε= the error term.

εim, m = 1,… M are the error terms distributed as a multivariate normal distribution, each with zero mean, and the variance-covariance matrix V, where V has values 1 on the main diagonal and the correlation Pkj = Pjk as off-diagonal elements.

Empirically, in the selection of variables, the study was guided by several hypotheses based on previous empirical studies in the past. Fifteen (15) factors were hypothesized to influence choices of ten (10) climate adaptation strategies. These factors include farmer-specific, technology specific, institutional, and climatic condition.

The MVP model is presented as:

$$Y_{ij} = \beta_0 + \beta_1 Agei + \beta_2 sexi + \beta_3 educationi + \beta_4 Adult_{labouri} +$$

$$\beta_5 Child\_labour + \beta_6 Old\_labour_i + \beta_7 farm\_size_i + \beta_8 Farm\_experience_i +$$

$$\beta_9 Access\_credit_i + \beta_{10} Climate\_information_i + \beta_{11} Financial\_access_i +$$

$\beta_{12}credit\_credit_i + \beta_{13}Rainfall\_perception_i + \beta_{14}pes\_invasioni +$
$\beta_{15}Disease\_infestationi + \varepsilon_i(1)$

Where Yij (j = 1, 2, 3 and 4; i = 1, …, n) represent the adaptation strategies available to the farmer. Ten(10) climate change adaptation strategies. The intersect is signified by $\beta0$, and the coefficients of the independent variables are represented by $\beta1$… $\beta15$. The error term is signified by εij.

3.5.2 ENDOGENOUS SWITCHING POISSON

The impact of climate change knowledge on the level of adoption of adaption techniques is examined using endogenous switching regression. Since the farmer's decision to adopt is presumed to be exogenous, estimating the impact of adoption can result in results that are skewed and inconsistent. This choice, however, might be endogenous since farmers themselves choose to increase their consumption, as is well-documented in the empirical literature (Heckman 1979). Additionally, there may be systematic differences between farmers who have access to climatic information and those who do not. Additional unseen variables influencing availability include farmers' intrinsic management abilities, also adoption intensity scores, resulting in biased and inconsistent estimates. We employ an endogenous switching regression (ESR) technique, which uses an access decision (access = 1 or 0 as an indication of change or adoption, to account for selectivity bias caused by observed and unobserved factors. giving rise to two patterns.

Intensity =$\boldsymbol{Xi\alpha}$+ εi (1)

Access to climate change information: $Qi1$=$\mathbf{Ki\gamma 1}$+$\mu i1$, if $Adopt$ =1 (2)

Lack of access to climate change information: $Qi0$ = $\mathbf{Ki\gamma 0}$+$\mu i0$ When $Aopt$ = 0 (3)

where $Qi1$ and $Qi0$ represent the values of access to climate change information and unavailable climate change information, XI is the vector farm. And agricultural characteristics of the household variables, $\boldsymbol{\alpha}$ is the vector of the estimated parameter, and εi is the vector of the error term.

3.5.3 MULTINOMIAL ENDOGENOUS SWITCHING REGRESSION

Bourguignon et al. (2007) developed the endogenous polynomial switching regression, which has since been employed in recent empirical studies on change (e.g., Di Falco and Veronesi, 2013, Ng'ombe et al., 2007). In our investigation, we adopted this strategy. J=1 denotes adoption rather than the reference category. Other practices: Farmers implement at least one climate-friendly agricultural practice (j = 2 traditional climate change adaptations, = 3 scientific climate change adaptations, and = 4 joint adaptations).

Regime 1: Y$\boldsymbol{i1 = Zi1a1 + Zi1Qj + Ui1}$ if V = 1 (1)

Regime j: yij = Zijaj + ZijQj + Uij when V = where yij is the outcome variable of the i-th possible tactical plan While the guess vector j reflects the parameters, j, Zi signifies the vector of company and household characteristics, and u specifies the error conditions with zero expected values and constant variance, Var (uiZi, X) = j 2. The term "j" stands for the essential parameters that need to be estimated, whereas the term "Zi" relates to the characteristics of the typical farmer (such as farm size, household wealth, and overall land use value). When a family chooses various adoption options, this is required to account for the unobserved variability `those results from the connection of various geographic Characteristics with household-level variables (Mundlak 1978).

To demonstrate the significance of adoption-specific heterogeneity, Wald's test of the null hypothesis that the total number of j vectors is zero is conducted (Teklewold et al. 2013). The selection correction terms must be incorporated into the polynomial selection procedure in order to guarantee the objectivity and consistency of the j estimations in the equation above. We adopt the Bourguignon et al. accordingly; the equation's outcome can be changed dependent on choices made with regard to load adjustment, as explained by Teklewold et al. (2013):

Scheme 1: $y_{i1}=Z_{i1}\alpha_1+\sigma_1\hat{\lambda}_{i1}+\bar{Z}_i\theta_j+\omega_{i1} \; if V_i=1$ (2)

Scheme J: $y_{ij}=Z_{ij}\alpha_j+\sigma_j\hat{\lambda}_{ij}+\bar{Z}_i\theta_M+\omega_{ij} if V_i=J$

The estimated probability that the graph in question is created by exercise j is represented by Pij, with the error conditions ij assumed to have a mean of zero. Effects of false assessment and treatment

Based on Di Falco and Veronesi (2013) and Ng'ombe et al. (2017), we predict expected outcomes in real and alternative scenarios. First, we obtain the anticipated outcomes from the expanded graphs, namely H. j=2...M in our study (j=1 is the reference category, not the assumption). On the basis of the outcome variable as adopters with adoption (actual adoption observed in the sample), the conditional expectations for each practice were chosen from Equation (2) as follows:

$E\,(y_{i2}|\,V_i=2) = \boldsymbol{Z_{i2}\alpha_2}+\sigma_2\hat{\lambda}_{i2}+\bar{Z}_i\theta_2 : E\,(y_{iJ}|\,V_i=J) = \boldsymbol{Z_{ij}\alpha_j}+\sigma_j\hat{\lambda}_{ij}+\boldsymbol{\bar{Z}_i\theta_j}$

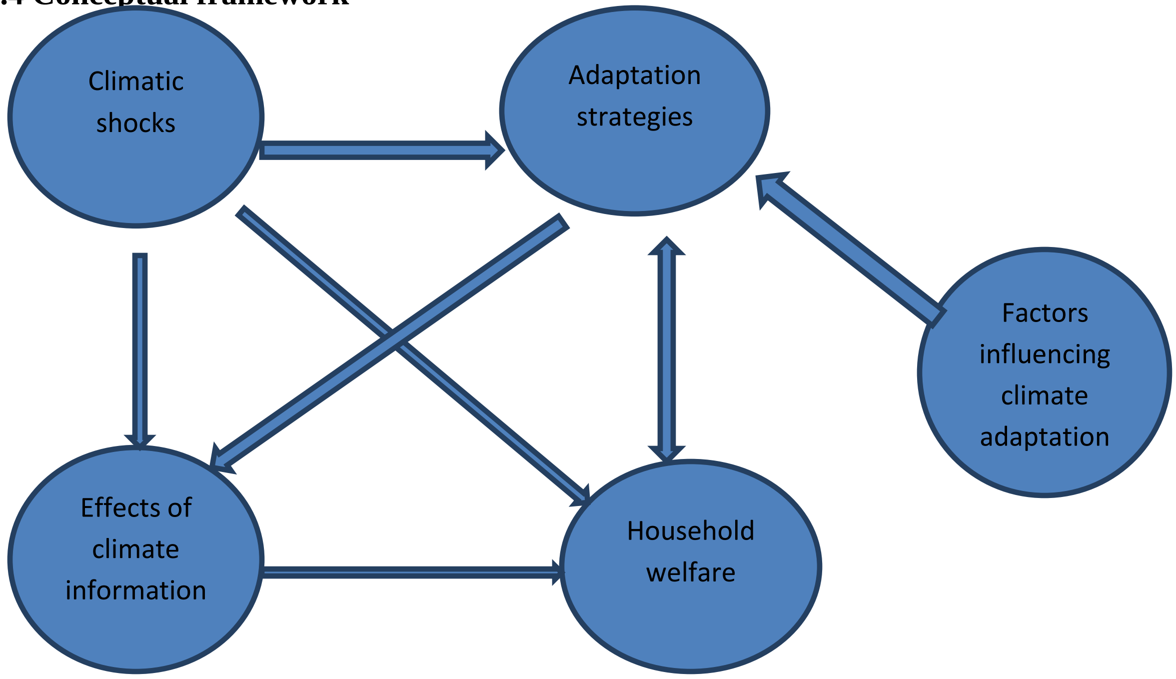
(3)

An alternative case that the adopters did not accept is also defined as: $E\,(y_{i1}\; V_i=2) = \boldsymbol{Z_{i2}\alpha_1}+\sigma_1\hat{\lambda}_{i2}+\boldsymbol{\bar{Z}_i\theta_1}$: $E\,(y_{i1}\; V_i=j) = \boldsymbol{Z_{ij}\alpha_1}+\sigma_1\hat{\lambda}_{ij}+\boldsymbol{\bar{Z}_i\theta_j}$ (4). The practical adoption effect j is called the mean contract healing effect (ATT), which is calculated by subtracting equation 3 from 4 as follows:

ATT = $E\ (y2iVi{=}2) - E\ (yi1\ Vi{=}2) = Zi2(\alpha2-\alpha1) + \boldsymbol{\bar{Z}i2}(\boldsymbol{\theta 2-\theta 1}) + \lambda i2(\sigma2-\sigma1)$ The expression $\hat{\lambda}ij$ (.) and Mundlak's device ($\boldsymbol{\bar{Z}\ i2}$) explain selection bias and endogeneity resulting from unobserved heterogeneity

Even when the independence of irrelevant alternatives (IIA) assumption is not met, the MESR technique enables a consistent and effective estimation of j and incorporates the necessary bias modifications in the equations that result (Bourguignon et al., 2007). The ability to evaluate the effects of individual behaviors and combinations of climate-friendly actions is another benefit of this strategy (Di Falco & Veronesi, 2013). Additionally, it loosens up the limiting presumptions of Lee's (1983) 4 selectivity model and offers a thorough explanation of how selectivity affects all of the options that farmers are considering.

3.5.4 Conceptual framework



The framework showed that the effects and type of farming approach to be used, as well as household wellbeing, are predicted by climatic shocks such as rainfall, pests, drought, flood, extreme sun score, and worms. For instance, crop growth and productivity can be significantly impacted by seasonal fluctuations and temperature extremes (Lin et al., 2011). Extreme climate events, according to reports, can shorten growing seasons in Africa, which could result in a 20–50% drop in grain production by 2050 (Connolly-Boutin and Smit, 2015; Sarr, 2012). Drought is more common and lowers agricultural productivity in extremely dry areas, which has a significant detrimental effect on economic growth. (Kementerian PPN/BAPPENAS 2019). The introduction of herbivorous insects can have a substantial impact on plant productivity in agricultural systems and natural ecosystems, as climate changes the range of insects and may introduce new pests into agricultural systems (Lin et al., 2011).

A few of the hazards affecting resource-dependent livelihoods include increased floods in low-lying areas, more frequent and severe droughts in semi-arid and semi-humid regions, and high heat (IPCC 2012; Altieri & Koohafkan2008; Mortona 2007). Additionally, it is asserted that crop failures and household food insecurity increase when drought conditions persist for the majority of the year or for several years in a row (Mngumi, 2016). Without a doubt, the likelihood of adaptation is significantly influenced by climatic conditions (Difalco et al., 2010).

The framework additionally demonstrated how coping techniques like intercropping, crop rotation, irrigated farming, and farm size influence and define agriculture and agricultural output, which in turn directly influences the farmer's household income (welfare). For instance, farmers are more likely to enjoy improvements in household income when they use climate change adaptation techniques. When compared to those who didn't, those who followed the strategies had a 7-9% higher chance of receiving food (Zakari et al., 2022).

Additionally, the framework demonstrated that family well-being levels might directly influence coping mechanisms or elements that support those mechanisms. According to the findings, farmers' capacity to adjust to shifting conditions was positively impacted by parameters like labor input, the quantity of fertilizer utilized, and the number of hectares (Mabe et al., 2012). Farmers that can afford to hire workers or who have extra labor on hand are more likely to adopt climate change adaptation strategies (Luke et al., 2014). In areas with a greater labor scarcity, it would be ineffective for farmers to apply adaptation strategies that require more labor (Sukallya et al, 2010).

According to a study, opportunities to adopt adaptation were boosted by access to formal and informal institutions, understanding of climate change, advisory services, and non-farm income (Difalco et al., 2010). Farm households' decisions about which climate change adaptation techniques to utilize or implement are influenced by institutional, socioeconomic, and demographic factors, which can have an impact on agricultural productivity (Difalco et al., 2011). The chance of adjustment has increased as a result of the accessibility of extension services, unsecured microcredit, and vocational training (Piya et al., 2013). Multi-member households are more inclined to shift labor from agricultural to non-agricultural sectors in order to boost income and lessen the effect on high levels of consumption. Markets are a crucial gathering place for farmers to gather and exchange information, therefore being far from one decreases the likelihood of farmers adapting to climate change. According to Hilery et al. (2013), the weak borrowing capability of farmers may account for the detrimental effects of loan access on adaptive behavior. Even in the face of finance restrictions, producers' decisions to invest in new agricultural equipment are supported by access to climatic information (Mulwa et al., 2017).

3.6 Operationalization variables and their *a-priori* expectation

Explanatory Variable	Description	Measurement	Apriori Expectation
Age	Age of farmer	Years	+
Gender	Sexual identification of the farmer	Dummy: 1 = Male 0 = Female	-/+
Household size	Number of people in a household	Number	+
Farm experience	Number of years in agriculture	years	+
Education	Farmers' years of formal schooling	Years	+
Extension services	Extension service received by a farmer	Average number of visits per annum	+
Total annual income	Total amount the farmers get from farming business	Ghc	+
Bank account	Farmer has a bank account	Dummy: 1 = yes, 0 = otherwise	+
Farmland	Total farm area cultivated by a farmer	Hectares	+
Access to climate change information	Climate change information received by farmers	Dummy: 1 = yes, 0 otherwise	+
Major crop	Consideration given to maize, rice, pepper and cowpea production	Dummy: 1 = Yes 0 = Otherwise	+

Disease infestation	Farm infested diseases	Dummy: 1 = yes, 0= otherwise	-
Off-farm	Farmer engages in off-farm activities	Dummy: 1 = yes 0 = Other	+
Access to credit	Access to credit services	Dummy: 1 = yes 0 = Other	+
Pest invasion	Farm infested with pest	Dummy: 1 = yes, 0 otherwise	-
Enough labour	Opinion of the farmer on the adequacy of labour for farm activities	Dummy: 1 = yes 0 = Other	+
Rainfall perception	Perception on rainfall	Dummy: 1 = Favorable 0 = Otherwise	+

CHARPTER FOUR

RESULTS AND DISCUSIONS

Determinants of smallholder farmers' choice of climate change adaptation strategies: Are complementarity and substitutability important?

4.0 Introduction

Results on the complementarity and substitutability of methods for adapting to climate change and their study-related factors are discussed in this section. The multivariate probit model was employed to evaluate factors that supported and constrained the adoption of farmer-specific climate change adaption techniques.

4.1 Socioeconomic characteristics of climate adaptation strategies adopters

Table 4.1 provides descriptive information on socioeconomic aspects and adaption options for climate change. According to the report, crop rotation had been implemented by almost 60% of farmers. About 90% and 67% of farmers, respectively, chose mixed farming and mixed cropping as a form of climate adaptation. About 84% and 50% of farmers, respectively, selected early maturity and drought-tolerant seed variants from enhanced seed variations. While roughly 75% of farmers used organic manure, about 25% mulched their fields. The study further revealed that about 81% of the farmers reduced/stop the burning of crop residue. Shifting cultivation is not more common among farmers since about 34% of the farmers adopted it. However, the scientific prescription was averaged subscripted/adopted as about 61% of the farmers adopted the technology.

Table 4.1. Socioeconomics descriptive statistics of farmers

Variable	Mean	Std. Dev.
Climate adaptation strategies		
Crop rotation	0.597	0.491
Mixed farming	0.896	0.306
Mixed cropping	0.666	0.472
Early maturing	0.841	0.366
Drought tolerant	0.498	0.501
Organic manure	0.746	0.436
Mulching	0.249	0.433
Reduce burning	0.810	0.392
Shifting cultivation	0.341	0.475
Scientific prescription	0.609	0.489
Socioeconomic factors		
Age	45.704	10.297
Sex	0.945	0.227
Education	3.675	5.91
#Adult labour	4.981	2.957
#Child labor	3.135	1.948
#Old labour (Above 64 years)	0.339	0.724
farming type (large scale)	0.396	0.494
Farm size	8.22	5.477
Total land	9.223	6.338
Experience	24.111	10.545
access extension	0.180	0.385
Climate information	0.455	.499
Financial assets	0.777	0.417
Credit	0.412	0.493
Rainfall perception	0.284	0.452
Pest invasion	0.749	0.434
Disease infestation	0.633	0.483

Source: Author's computation from field survey, 2022.

Additionally, it was discovered that the average farmer in the research area is 46 years old and has 4 years of formal schooling. Thus, the typical farmer in the research area has successfully completed elementary school. Men constituted almost 95% of the farmers surveyed. It's possible that men have easier access to resources for agricultural output than women do. Families' efforts are crucial to the uptake of technology and subsequent use of it. The findings showed that there were 4 and 5 family workers and children working respectively in the research region. A third of the farmers—34%—was engaged in industrial farming. The average overall land size was 9.2 acres, with an average farm size under cultivation of 8.2 acres. This demonstrates that there is a lack of available land since farmers do not have enough land to leave fallow.

The average farmer has been cultivating crops for over 24 years, and at the time of the survey, about 18% of farmers had access to agricultural extension services. 46% of farmers have access to knowledge about climate change. 41% of the farmers have access to a production credit, while 78% have financial assets. About 28% of the farmers said that the amount of rainfall had decreased. The consequences of pests and diseases on agricultural output are a public concern. According to the study, disease infection and insect invasion harmed roughly 75% and 63% of the farmers' fields, respectively.

4.2 The determinants of smallholder choice of climate change adaptation strategies

The multivariate binary probit model was used to determine what influences both individual and group decisions about how to adapt to the climate. At a 1% level, it was determined that the Wald Chi2 test was highly statistically significant (Wald chi2= 780.24; p value= 0.0000). Also highly significant at a 1% level was the likelihood ratio test that evaluated the joint estimation of the climate adaption methods (chi2(45) = 266.442 Prob > chi2 = 0.0000). This MVP model summary showed that the model was the best option for looking at the factors that influence smallholders' choice of climate adaption options, both positively and negatively. To determine their impact on smallholders' choice of climate adaption measures, a number of socioeconomic parameters were used.

Crop rotation, inter cropping, organic fertilizers, and mulching have all been demonstrated to be significantly negatively impacted by age. It has been discovered to have a favorable and considerable impact on scientific prescription, though. As a result, younger farmers are more inclined than older farmers to adopt crop rotation, inter cropping, organic fertilizers, and mulching, while older farmers are more likely than somewhat younger farmers to heed scientific advice. This result is not unexpected given that young farmers rely on rain-fed agriculture for their livelihoods. Although putting adaptation methods into practice requires a lot of work, young people are eager to start doing so. Building young or inexperienced farmers' capacity is essential for promoting climate change adaption techniques that will boost agricultural production and productivity.

At the 5% level, it was discovered that gender had a positive coefficient and a statistically significant impact on mixed farming. It simply indicates that men are more likely than women to practice mixed farming as a method of coping with climate change. Given that men predominate as family heads, male farmers have a competitive advantage over female farmers when it comes to mixed farming. As result, male farmers have control of household resources such as land, animals, farm inputs, and services. These put the male farmers in the frontier to practice mixed farming. Mixed farming demand high labour and male farmers control household labour allocation. The male farmers mostly prioritize labour allocation to their farms over their female counterparts. This discourages female farmers to practice mixed farming.

One of the most important elements in encouraging farmers' reaction tactics to the effects of climate change is formal education. The study discovered that while education has a big favorable impact on scientific guidance, it has a significant negative impact on mixed farming. This means that improving the farmer's level of education reduces the likelihood of adopting mixed farming but increases the likelihood of embracing scientific advice such as climate adaptation strategies. The intuition is that educated farmers move away from traditional climate adaptation strategies (mixed farming) to modern climate adaptation strategies (scientific prescription). Education is a tool that empowers farmers and increases farm resource allocation at the farmgate to enhance agricultural production and productivity. To break the barriers to climate adaptation strategies, enhancing farmers' literacy level through formal and informal school are critical as education widen farmers' knowledge and skill to manage farm resources.

Agriculture work is essential to climate change adaption plans. According to the findings, mixed farming and redevelopment in the research region are significantly harmed by the presence of children under the age of 14. The association between scaled cultivation and the number of adults per family is also adverse and was statistically significant at the 5% level. These findings imply that a decrease in household-level climate adaption measures will occur as the number of dependents increases. A high proportion of children and adults in a household suggest that there will likely be a labor shortage on farms, which will make farmers less likely to adopt solutions for mitigating climate change.

Crop rotation, mixed farming, and the decrease of burnout were shown to be positively and significantly impacted by large-scale farming; nevertheless, mulching and scientific guidance, as well as enhanced seed varieties (early and drought-tolerant kinds), were found to be negatively impacted. These demonstrate that large-scale farmers are more inclined to use crop rotation, mixed farming, and reduce burning techniques rather than better seed varieties, mulching, and scientific advice. To put this in perspective, small farmers are more likely to adopt improved seed, mulch and scientific advice than their peers. The reason for such finding is that large scale farmers lack the necessary resources to adapt improve seeds, mulching, and scientific prescription in their farms since this practice is capital demanding. Most at times large scale farmers apply technologies to some portions of their farmers due to high cost of using them compare to small-scale farmers. These findings contribute to the debate on large-scale versus small-scale agriculture in developing countries. Encouraging smallholder farmers to adopt climate change adaptation strategies is crucial to increasing food production to address food insecurity, as approximately 90% of farmers in Ghana are smallholder (GLSS, 2019; MoFA, 2021).

Additionally, early maturing and drought-tolerant seed kinds were found to have a positive and significant effect on farm size and scientific advice, however mixed farming was found to be significantly negatively impacted by farm size. In comparison to a farmer with a small farm plot, as a farmer's farm size grows, he or she is more likely to use improved climate adaptation strategies. However, farmers are less likely to use mixed farming as farm size increases. These results did not match study expectations since large farms were predicted to decrease farmers' likelihood of implementing techniques for coping with the effects of climate change while holding other parameters constant.

Farming experience employed in the estimation demonstrated to have a positive significant effect on mixed farming, mixed cropping, drought tolerance seed varieties, and organic manure use. This result suggests that, on average, as the number of years of agricultural activity increases, the likelihood of adopting climate change adaptation strategies increases in the same direction. Accumulated farming experience enhances farmers' ability to determine which farm technologies are suitable for a particular soil. This promotes adoption of climate adaptation strategies to enhance soil health while promoting ecosystem services.

Table 4.2: Multivariate Probit estimates of drivers' smallholder choice of climate adaptation strategies

Variable	Crop rotation	Mixed farming	Mixed cropping	Early maturity	Drought tolerant	Organic	R burning	Mulching	Shifting cultivation	Scientific prescription
	Coef. (Std. Err.)	Coef. (Std. Err.)	Coef. (Std. Err.)	Coef. (Std. Err.)	Coef. (Std. Err.)	Coef. (Std. Err.)	Coef. (Std. Err.)	Coef. (Std. Err.)	Coef. (Std. Err.)	Coef. (Std. Err.)
Age	-0.020**	-0.004	-0.035***	-0.005	-0.016	-0.029**	-0.015	-0.024**	-0.011	0.031***
	(0.010)	(0.016)	(0.011)	(0.011)	(0.010)	(0.012)	(0.011)	(0.012)	(0.010)	(0.011)
Sex	-0.229	1.103**	-0.274	0.464	0.214	0.369	-0.591	-0.420	-0.135	0.233
	(0.376)	(0.458)	(0.410)	(0.339)	(0.355)	(0.356)	(0.446)	(0.365)	(0.285)	(0.362)
Education (yrs)	-0.027	-0.067***	-0.020	0.016	0.002	0.001	-0.022	-0.001	-0.015	0.043**
	(0.018)	(0.025)	(0.017)	(0.020)	(0.017)	(0.019)	(0.019)	(0.019)	(0.018)	(0.018)
#Adult labor (15-65)	0.021	0.029	0.022	0.014	0.018	-0.006	-0.001	-0.002	-0.042	0.023
	(0.034)	(0.051)	(0.035)	(0.041)	(0.033)	(0.037)	(0.036)	(0.042)	(0.036)	(0.036)
#Child labor (<14)	-0.045	-0.036	-0.111***	-0.001	0.002	0.041	-0.038	0.058	-0.068*	0.055
	(0.040)	(0.058)	(0.041)	(0.046)	(0.042)	(0.051)	(0.040)	(0.041)	(0.038)	(0.041)
#Old labor (>65)	-0.066	-0.115	-0.112	-0.010	-0.032	-0.113	-0.060	-0.136	-0.320**	0.101
	(0.105)	(0.143)	(0.107)	(0.137)	(0.107)	(0.115)	(0.120)	(0.131)	(0.129)	(0.124)
Large-scale farming (1/0)	1.031***	0.495	0.737***	-0.684***	-1.604***	0.004	0.847***	-0.737***	0.039	-1.392***
	(0.210)	(0.322)	(0.220)	(0.246)	(0.204)	(0.233)	(0.221)	(0.241)	(0.204)	(0.215)
Farm size	-0.038	-0.172*	-0.034	0.107**	0.129***	-0.024	0.0001	-0.036	-0.057	0.069*
	(0.038)	(0.096)	(0.043)	(0.048)	(0.041)	(0.042)	(0.048)	(0.043)	(0.040)	(0.042)
Farm experience	0.015	0.028*	0.031***	0.013	0.022**	0.026**	0.003	0.018	0.014	-0.016
	(0.011)	(0.017)	(0.011)	(0.012)	(0.011)	(0.012)	(0.011)	(0.011)	(0.010)	(0.010)
Access extension	-0.239	-0.515*	-0.518*	0.418	0.432	-0.526*	-0.105	-0.464	-0.562	0.132
	(0.285)	(0.311)	(0.278)	(0.395)	(0.275)	(0.288)	(0.300)	(0.435)	(0.386)	(0.304)
Climate info.	-0.464	0.757*	-0.360	-0.335	-0.647**	0.664*	-0.151	0.647	0.419	0.660*
	(0.343)	(0.470)	(0.332)	(0.460)	(0.338)	(0.376)	(0.350)	(0.466)	(0.423)	(0.369)
Financial assets	-0.939***	0.464	-0.383*	0.497*	-0.452**	-0.347	-0.491**	-0.803***	-1.224***	0.333*
	(0.209)	(0.302)	(0.215)	(0.267)	(0.207)	(0.250)	(0.209)	(0.206)	(0.196)	(0.203)
Credit access	-0.264	0.186	0.073	0.809***	0.175	-0.562***	0.077	0.500***	0.073	0.564***
	(0.172)	(0.233)	(0.172)	(0.224)	(0.169)	(0.192)	(0.174)	(0.182)	(0.169)	(0.175)
Rainfall perception	-0.194	0.090	0.083	-0.150	0.534***	0.108	-0.468**	0.352*	0.331*	-0.187
	(0.199)	(0.319)	(0.207)	(0.221)	(0.198)	(0.223)	(0.195)	(0.209)	(0.182)	(0.198)
Pest invasion	0.644***	-0.259	0.412**	0.194	0.716***	0.333	-0.430**	0.889***	0.440**	0.067
	(0.205)	(0.258)	(0.209)	(0.228)	(0.199)	(0.223)	(0.215)	(0.288)	(0.225)	(0.242)
Disease infestation	0.444**	0.745**	0.443**	0.718***	0.018	0.709***	0.178	0.500**	0.305*	-0.413*
	(0.207)	(0.306)	(0.217)	(0.221)	(0.206)	(0.220)	(0.213)	(0.243)	(0.185)	(0.222)
_cons	1.693***	-0.282	2.041***	-0.814	-0.466	1.416***	2.542***	-0.418	0.339	-1.586***
	(0.610)	(0.780)	(0.659)	(0.644)	(0.593)	(0.618)	(0.687)	(0.664)	(0.541)	(0.589)
Model summary										
Number of obs.	422									
Wald chi2(180)	780.24									
Prob > chi2	0.0000									
Log likelihood	-1514.8875									

Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho61 = rho71 = rho81 = rho91 = rho101 = rho32 = rho42 = rho52 = rho62 = rho72 = rho82 = rho92 = rho102 = rho43 = rho53 = rho63 = rho73 = rho83 = rho93 = rho103 = rho54 = rho64 = rho74 = rho84 = rho94 = rho104 = rho65 = rho75 = rho85 = rho95 = rho105 = rho76 = rho86 = rho96 = rho106 = rho87 = rho97 = rho107 = rho98 = rho108 = rho109 = 0: chi2(45) = 266.442 Prob > chi2 = 0.0000

Despite this, due to their crucial role in the adoption of technology at the farm gate, agricultural extension services have been an important indicator that academics and policymakers have been pushing for decades. The results of the investigations revealed a negative and significant impact of access to extension services on mixed farming, mixed cropping, and organic manure. This indicates that access to extension services reduces the likelihood of these climate change adaption measures being used by farmers. The fact that farmers have been using organic manure (animals' excretions) and mixed farming and cropping for generations may be the cause of these findings. Farmers will therefore continue to use these agricultural strategies on their farms even without access to extension services.

In contrast to drought-tolerant seed varieties, mixed farming, organic fertilizers, and scientific guidance have been found to benefit significantly from climate knowledge. In contrast to drought-tolerant seed varieties, farmers who have access to climate change information services are more likely to adopt mixed farming, the use of organic fertilizers, and scientific advice. Researchers and decision-makers now consider the distribution of climate information services to farmers to be a tropical issue. Farmers are informed by the Climate Information Service on the mitigation measures they must take to lessen the effects of climate change on agriculture and other livelihoods. Farmers can learn about the projected rainy and dry seasons by reviewing climatic information. By using suitable climate adaptation measures, this aids farmers in adjusting to agricultural production and enhancing agricultural performance.

To counter the impact of climate change on agricultural productivity and food security, production credit encourages farmers to use better agricultural production technologies. According to the study, having access to production credit improves early maturing seed, mulch use, and scientific guidance while having a negative effect on organic fertilizer use. Through the adoption of climate adaption measures, having access to production finance influences farmers' decisions to invest in agriculture production technologies. Lack of farmer credit is a significant obstacle to the implementation of farm technologies.

According to the study's findings, under test conditions crop residue burning reduction is negatively impacted by precipitation perception, but has a favorable and significant impact on cultivars that are drought-tolerant, mulching, and change-tolerant. This indicates that adopting drought-tolerant varieties, mulching, and shifting cultivation as a form of climate adaptation is more likely for farmers who feel that rainfall is declining. It is conceivable that adopting seed varieties resistant to drought is the greatest way for farmers to deal with rainy-season variability while engaging in mulching and shifting cropping to improve soil health. Farmers must use better agricultural production technology as a result of decreasing rainfall if they want to enhance crop production in the face of climate change and instability.

Infestations of pests lower agricultural output and farmer income. Farmers are being forced to adopt agricultural production strategies as a result of recent insect (worm) infestations in order to lessen their impact on agricultural productivity. The research revealed that crop rotation, mixed farming, drought-tolerant types, mulching, and staggering were all associated with reduced insect infestations. This suggests that farmers are more inclined to use climate adaptation techniques when their farms are afflicted by pests. Similar to how farmers that have the illness on their farms are more likely to utilize crop rotation, early maturing, mixed cropping, organic fertilizers, mulching, and crop rotation but less likely to follow scientific advice.

4.2.1 the complimentarily and substitutability effects of climate adaptation strategies

The correlation matrix of climate adaptation techniques based on MVP estimations is shown in Table 4.1. The findings showed which solutions for coping with climate change are complementary (positive association) and which are replacements (negative association). In the first place, the Likelihood ratio test was highly statistically significant at a 1% level; meaning that these climate adaptation strategies can be adopted jointly to enhance agricultural production. Narrowing to individual interaction of the climate adaptation strategies, crop rotation and mixed farming, crop rotation and mixed cropping, crop rotation and organic manure, crop rotation and reduce burning, and crop rotation and shifting cultivation were having a positive association with each other. This implies that these practices are compliments at farm gate while crop rotation and scientific prescription are substitutes.

Also, mixed cropping and mixed farming and mixed farming and organic manure are complimentary while scientific prescription and mixed farming are substitutes. While mixed cropping and organic manure and shifting cultivation and mixed cropping are complementary, mixed cropping and scientific prescription are substitutes. Similarly, early maturity and drought seed varieties and early seed varieties and scientific prescription are found to be complimentary, and early seed varieties and organic manure use are substitutes.

Table 4.3 Correlation matrix

Interaction	Coef.	Std. Err.	P. value
Crop rotation by mixed farming (rho21)	0.461***	0.123	0.000
Mixed cropping by crop rotation (rho31)	0.515***	0.081	0.000
Early maturity by crop rotation (rho41)	-0.115	0.113	0.309
Drought tolerance by crop rotation (rho51)	0.056	0.088	0.521
Organic manure by crop rotation (rho61)	0.324***	0.101	0.001
Reduce burning by crop rotation (rho71)	0.288***	0.091	0.001
Mulching by crop rotation (rho81)	0.088	0.101	0.384
Shifting cultivation by crop rotation (rho91)	0.619***	0.077	0.000
Scientific prescriptions by crop rotation (rho101)	-0.330***	0.097	0.001
Mixed cropping by mixed farming (rho32)	0.437***	0.110	0.000
Early maturity by mixed farming (rho42)	0.062	0.126	0.622
Drought tolerant by mixed farming (rho52)	0.009	0.097	0.926
Organic by mixed farming (rho62)	0.435***	0.097	0.000
Reduce burning by mixed farming (rho72)	-0.002	0.104	0.983
Mulching by mixed farming (rho82)	0.012	0.113	0.917
Shifting cultivation by mixed farming (rho92)	0.155	0.127	0.223
Scientific prescription by mixed farming (rho102)	-0.332***	0.124	0.007
Early maturity by mixed cropping (rho43)	-0.037	0.124	0.766
Drought tolerant by mixed cropping (rho53)	-0.035	0.094	0.707
Organic by mixed cropping (rho63)	0.404***	0.104	0.000
Reduce burning by mixed cropping (rho73)	0.051	0.099	0.608
Mulching by mixed cropping (rho83)	0.085	0.110	0.439
Shifting cultivation by mixed cropping (rho93)	0.409***	0.092	0.000
Scientific prescriptions by mixed cropping (rho103)	-0.417***	0.104	0.000
Drought tolerant by early maturity (rho54)	0.379***	0.092	0.000
Organic by early maturity (rho64)	-0.207*	0.110	0.060
Reduce burning by early maturity (rho74)	0.113	0.105	0.283
Mulching by early maturity (rho84)	0.008	0.115	0.941
Shifting cultivation by early maturity (rho94)	-0.000	0.109	0.998
Scientific prescriptions by early maturity (rho104)	0.347***	0.115	0.002
Organic by drought (rho65)	-0.043	0.102	0.674
(Reduce burning by drought tolerance (rho75)	0.103	0.094	0.273
Mulching by drought tolerance (rho85)	0.296***	0.115	0.010
Shifting cultivation by drought tolerant (rho95)	0.090	0.106	0.397
Scientific prescriptions by drought tolerant (rho105)	0.240**	0.100	0.016
Reduce burning by organic (rho76)	0.170*	0.100	0.090
Mulching by organic (rho86)	0.214*	0.121	0.076
Shifting cultivation by organic (rho96)	0.244**	0.105	0.020
Scientific prescriptions by organic (rho106)	-0.260**	0.112	0.020
Mulching by reduce burning (rho87)	0.226**	0.100	0.024
Shifting cultivation by reduce burning (rho97)	0.346***	0.096	0.000
Scientific prescription by reduce burning (rho107)	0.054	0.104	0.603

Shifting cultivation by mulching (rho98)	0.436***	0.089	0.000
Scientific prescriptions by mulching (rho108)	0.098	0.104	0.346
Scientific prescription by shifting cultivation (rho109)	-0.073	0.100	0.466
Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho61 = rho71 = rho81 = rho91 = rho101 = rho32 = rho42 = rho52 = rho62 = rho72 = rho82 = rho92 = rho102 = rho43 = rho53 = rho63 = rho73 = rho83 = rho93 = rho103 = rho54 = rho64 = rho74 = rho84 = rho94 = rho104 = rho65 = rho75 = rho85 = rho95 = rho105 = rho76 = rho86 = rho96 = rho106 = rho87 = rho97 = rho107 = rho98 = rho108 = rho109 = 0: chi2(45) = 266.442 Prob > chi2 = 0.0000			

Effect of climate change information on adoption intensity of climate change adaptation strategies: endogenous switching Poisson model

4.3.0 Introduction

The findings are presented in this part, together with information on how factors impacting farmers' access to climate change knowledge and the intensity of adaptation techniques are affected. The estimations were based on the Poisson model with endogenous switching in 400 farmers. Following the adaptation intensity of the climate adaptation strategy, the impact of CC information on adaptation intensity and other determinants, and factors affecting farmers' access to CC information are presented in this section along with discussions of the descriptive statistics of the sampled farmers.

4.3.1 Descriptive statistics of sampled farmers

The results of sampled farmers' socioeconomic characteristics are presented in Table 5.1. The study revealed that approximately 46% of the farmers have access to CC information. The access to CC information was relatively good which could translate to higher adoption of climate adaptation strategies. An average farmer has 46 years with an educational attainment of approximately 4 years. About 95% of the sampled farmers were males and 18% belong to nuclear families. The household size was found to be approximately 9 people. The total area of the household was estimated at 9.22 acres, and the farm size devoted to agricultural production was 8.22 acres. About 26% of the farmers in the sample have a bank account and about 41% of them have access to production credit. This implies that banks or formal financial institutions are not the only sources of credit for farmers. Farmers access production credit from various sources such as family members, friends, and village savings and loan associations among others.

4.3.1: Descriptive Statistics of variables

Variable	Mean	Std. Dev.
CC Information	0.455	0.499
Age	45.704	10.297
Sex	0.945	0.227
Education	3.675	5.91
Nuclear family	0.18	0.385
Household size	9.287	4.459
Landholding	9.223	6.338
Farm size	8.22	5.477
Bank account	0.258	0.438
Credit access	0.412	0.493
Pest invasion	0.749	0.434
Large scale	0.396	0.494
Farming experience	24.111	10.545
Access extension	0.18	0.385
Primary occupation	0.818	0.387

Furthermore, about 75% of the sampled farmers experienced pest invasion in their crop production. Due to the increased pest invasion, farmers may start to decide to implement climate adaptation techniques to reduce or completely eradicate pest invasion. For instance, it might persuade farmers to use enhanced seed varieties that are disease-tolerant in their farming operations. The typical farmer has 24 years of farming experience. Farming accounts for around 82% of farmers' key livelihood activities in the research area, demonstrating that farming is their main source of livelihood.

4.3.2 Adoption intensity of climate adaptation strategies

The number of climate adaptation techniques that farmers have collectively implemented at the farm level to boost crop production and productivity is referred to as the intensity of climate adaptation strategy adoption in this context. The findings about the level of farmers' adoption of climate adaptation measures are displayed in Table 5.2. The findings demonstrated that every strategy for coping with climate change has been implemented in the research area.

According to the study, just roughly one person—or 0.24%—adopted more than three techniques. The survey also discovered that eight and seventeen farmers, or around 1.9% and 4% respectively, used five and six climate strategies. About 8% and 18% of farmers, respectively, employed seven and eight climate adaptation techniques. Nine climate adaption options were used by the majority (25%) of the farmers.

Table 4.3.2: Tabulation of adoption intensity climate adaptation strategies

Number adapted	Freq.	Percent
3	1	0.24
5	8	1.90
6	17	4.03
7	35	8.29
8	75	17.77
9	105	24.88
10	64	15.17
11	27	6.40
12	33	7.82
13	21	4.98
Adaptation intensity	9.585	
Standard deviation	2.229	

Additionally, 10, 11, 12, and 13 different climate adaptation tactics were used by around 15%, 6%, 8%, and 5% of the farmers, respectively. With a standard deviation of 2.2, it was discovered that the average adoption intensity was 9.6. This suggests that an average farmer used at least 10 farm-level climate adaption techniques to improve soil fertility and agricultural output.

4.4.0 Effect of climate information on adoption intensity of climate change adaptation strategies

The effect of CC knowledge on the level of adoption of climate change adaptation (CASA) measures is examined in this section. The estimation was done using both exogenous and endogenous Poisson switch regression models. To determine whether selectivity bias existed, these models were utilized. In other words, it investigates if elements that cannot be observed have an impact on the outcome variable (CC information). The results are displayed in Table 5.3's Model A. The presence of unobservable elements that are correlated with the intensity of CASA initiation is suggested by Rho's significance at the 1% level. The study's findings will be skewed and inconsistent if the right methods weren't used to account for selectivity bias. This will result in inappropriate policy suggestions.

The major goal of this section is to evaluate the effect that access to information about climate change has on the level of implementation of plot-level adaption methods. According to the study, having access to information about climate change has a favorable and significant influence on how intensely 5% of adaption techniques are implemented. This implies, intuitively, that farmers' access to information about climate change increases the intensity of their adoption of adaptation techniques. This suggests that if farmers have access to climate change information services, they are likely to use numerous response options at once. Social media (mostly television and radio), employment agencies, other farmers, and workshops/seminars for farmers are some of the ways that farmers learn about climate change. This method of gaining access to information on climate change enables farmers to make more informed decisions about when to grow crops and how best to implement field-level climate change adaptation methods. It has been demonstrated that Ethiopian farmers' exposure to climate change knowledge has a favorable and significant impact on climate change adaptation techniques that help increase agricultural productivity (Marie et al., 2020). In a similar vein, a different Ethiopian study discovered that having access to climate change information services influences farmers to use a variety of adaptation techniques (Belay et al., 2022).According to a study conducted in Ghana, farmers who have access to climate change information services are more productive than their contemporaries. Numerous additional researchers have discovered a positive correlation between farmers' climate adaptation techniques in Africa and availability to climate information services (Zamasiya et al., 2017; Jha et al., 2018; singing, 2020). This body of literature emphasizes the significance of farmers' access to climate change information services for enhancing agricultural output and climate change adaptation plans. Farmers are exposed to climate change information through a variety of channels, and this exposure encourages the development of adaptation plans to boost agricultural output.

Farmers' decisions to modify their agricultural practices in response to climate change depend on the scale of their farming operations, whether large- or small-scale. Due to the high expense of adopting these technologies, large-scale farmers might not be able to implement many adaptation techniques on their farms. Due to the enormous expenses needed, large farmers, for instance, might not be able to implement enhanced seeding, row planting, and precision farming. In contrast, compared to their peers, smallholder farmers may be more determined to employ more climate change adaptation techniques. The study discovered a 5% significant negative association between large-scale agriculture and the level of implementation of climate change adaptation techniques. Large farmers are less likely to embrace additional farm-level climate change adaptation measures if adoption intensity has a negative correlation. This could also imply that small farmers are more inclined to employ climate change adaptation techniques to boost agricultural output. This conclusion supports previous research (Schroth et al., 2016; Cai et al., 2022; Gabriel & Gandorfer, 2022; Liao et al., 2022) that shows small farmers have a significant role in increasing food baskets in developing nations. Farmers' adaptation choices can be improved by tailoring climate change adaptation techniques to small farmers and using an appropriate climate change adaptation framework.

Additionally, it was discovered that crop cultivation experience was positively correlated with the level of climate change adaptability, with a 10% significance level. According to this, farmers who have a history of producing more food than those who haven't are more likely to use various adaptation measures to combat climate change. In order to increase soil fertility and productivity, farmers with considerable agricultural expertise can identify and combine several farm-level climate adaption measures. This outcome is in line with findings from earlier research (Cooper et al., 2008; Guido et al., 2020).

Table 4.4.0: Effect of CC information on climate adaptation strategies and drivers of CC information

Variable	Endogenous-Switch Poisson Regression		Exogenous-Switch Poisson Regression	
Model A: Intensity CASA	Coef.	Std. Err.	Coef.	Std. Err.
Age	-0.003	0.002	-0.004*	0.002
Sex	0.025	0.073	0.024	0.073
Education	-0.003	0.004	-0.003	0.004
Family type	-0.051	0.055	-0.050	0.054
Household size	-0.004	0.005	-0.003	0.005
Large scale farming	-0.084**	0.041	-0.087**	0.040
Landholding	-0.003	0.007	-0.002	0.007
Farm size	0.008	0.008	0.008	0.008
Farm experience	0.004*	0.002	0.004*	0.002
Production credit	0.069*	0.037	0.069*	0.037
Pest invasion	0.131***	0.043	0.131***	0.043
CC information	**0.111****	**0.052**	**0.097*****	**0.033**
_cons	2.174***	0.122	2.183***	0.120
Model B: CC information				
Age	-0.021**	0.009	-0.021**	0.009
Sex	-0.123	0.292	-0.122	0.291
Education	0.005	0.016	0.004	0.016
Nuclear family	0.348	0.221	0.348	0.220
Household size	-0.000	0.019	-0.000	0.019
Large scale farming	-0.509***	0.150	-0.507***	0.150
Landholding	0.008	0.027	0.008	0.027
Farm size	-0.000	0.034	-0.000	0.034
Experience	0.029***	0.009	0.029***	0.009
Extension	-0.417**	0.175	-0.417**	0.175
Primary occupation	0.744***	0.252	0.733***	0.250
_cons	-0.238	0.527	-0.228	0.526
Model summary				
sigma	0.010	0.027	0.000	0.013
Rho	*-0.878****	*0.242*		
Several obs.	422		422	
Wald chi2(13)	57.40		62.91	
Prob > chi2	0.0000		0.0000	
Log-likelihood	-1205.8213		-1205.8913	

Source: Author's computation from field survey, 2022

The study also revealed a substantial beneficial relationship between farmers' access to production credits and the 10% level of climate change adaptation strategy implementation intensity. Compared to other farmers who do not have access to production credits, farmers who do have access to them are more likely to implement various climate change adaptation techniques. When decision-makers inform farmers about coping with climate change, producer credit is a crucial metric. Improved seeds, irrigation, fertilizer application, and automation (the use of tractors) are a few examples of capital-intensive climate adaptation measures. The acceptance of these coping mechanisms among farmers is currently limited and will remain so without access to loans.]In order to lessen the negative effects of climate change on rural households' livelihoods, farmers are encouraged to implement adaption techniques. According to a study conducted in south-west Nigeria, having access to financing helps farmers make better decisions about how to adapt to climate change and increases rice farmer production (Ojo & Baiyegunhi, 2021). Sustainable agricultural credit serves as a policy incentive for farmers to maintain the use of adaptation measures for climate change (Ojo et al., 2021). According to a different study conducted in Cameroon (Awazi et al., 2019), farm production credits encourage farmers to adopt climate-resilient methods that will increase agricultural output.

At the 1% level, it was discovered that disease/parasite invasion had a favorable and significant effect on how intensely the climate change adaptation strategy was implemented. This implies that farmers are more likely than their peers to use different adaptation strategies to climate change if their farm has been impacted by a crop disease or pest infestation. The enhanced seed variants are disease- and pest-resistant. Farmers who have experienced pests or diseases on their farms because they did not use improved seeds may start to value them when choosing which types to cultivate.

4.4.1The factors influencing farmers' access to climate change information

The outcomes of the variables influencing farmers' access to knowledge about climate change in the study area are shown in Model B in Table 5.3. Five of the eleven variables that were considered in the estimates exhibited a positive or negative relationship with farmers' access to information about climate change. These factors include the farmer's age, farm size, level of agricultural expertise, availability of extension services, and principal employment.

It was discovered that access to information about climate change was inversely connected with farmer age at a significant rate of 5%. Thus, the likelihood that a farmer will have access to information on climate change declines with age. If not, younger farmers are more likely than older ones to have access to information regarding climate change. Young farmers are inventive and continually look for fresh information to enhance the application of solutions for coping with climate change. Younger farmers also have access to more social networks and social media than older farmers have. This makes it possible for young farmers to use social media and social networks to get knowledge on climate change. This finding is consistent with research from Jiang et al. (2018) in China, Acquah-de Graft and Onumah (2011) in Ghana, and Deressa et al. (2008) in Ethiopia.

The intensity of adoption of solutions for coping with climate change was found to be negatively impacted by large-scale agriculture, with a statistical significance level of 1%. This implies that large-scale farmers are less likely to use a variety of adaptation measures to combat climate change. This makes intuitive sense given that large-scale farmers in rural areas have limited access to production tools and capital, which would increase their ability for adaptation. Large-scale farmers' inability to obtain production financing has an impact on how certain production technologies are applied at the farm level. They cultivate smaller farms than small-scale farmers, which enables them to use more agricultural production methods. Small-scale farmers become more productive and efficient by implementing climate adaption measures than large-scale farmers. The study's descriptive statistics revealed that small-scale farmers had approximately 98.81 kg, compared to large-scale farmers' (58.33 kg). This supports the argument made in the literature that smallholder agriculture is the foundation of agriculture in emerging nations like Ghana.

Access to information services on climate change is significantly influenced by farming experience. The more experience a farmer has in farming, the more beneficial it is for him to network with other farmers and consultants. As a result, these farmers are exposed to information services about climate change more frequently than farmers with less farming experience. According to the study, agricultural experience increased farmers' access to information on climate change because it was positively correlated with it at a statistically significant rate of 1%. However, there was a substantial 5% correlation between farmers' access to climate change knowledge and their use of extension services. This indicates that farmers are more likely than their peers to receive climate change information if they lack access to advising services. This is most likely a result of the study area's limited annual access to extension services. Farmers turn to other sources of information about climate change, such as radio, television, and farmer exchanges, when they do not have sufficient access to extension services.

The primary activity of farmers is one of the key variables influencing their access to knowledge about climate change. According to the findings (Table 5.1), agriculture accounts for about 92% of farmers' primary sources of income. This is in line with MoFA's (2021) estimate that 90% of farmers rely on agriculture for their primary source of income. The econometric findings also revealed a strong 1% correlation between access to information about climate change and the primary source of income for farmers. This indicates that compared to their colleagues in the research area, farmers whose primary occupation is farming are more likely to have access to knowledge concerning climate change. Agriculture responds to climate change and climate-related shocks with sensitivity. Most farmers depend on their crops for their primary source of income; thus, they are looking for more climate data to help them modify their plot-level management techniques.

4.5 Indigenous (Traditional) and Scientific Adaptation Strategies

4.5.0 Introduction

The outcomes of farmers in the study areas indigenous (traditional) and scientific climate adaption tactics are described in this section. The motivations for both individual and group climate change adaption techniques are also included. The output is estimated via the multinomial probit model. Additionally, it provides the findings and analysis of the socioeconomic variables affecting the household diet diversity score. The outcomes are estimated using the Multinomial Switching Regression MESR. If selectivity problems are present in the data, this fixes them. This section also discusses a factor that influences the Household Food Insecurity Access Scale, and the analysis used multinomial switching regression.

4.5.1 Farmers profile

According to the socioeconomic data of the sampled farmers, the average age of the farmers is 46 years old, and 95% of them are men with an average of 4 years of education. About nine people were thought to make up the family. The size of the agricultural farm was determined to be 8.22 acres, and the overall land area was 9.22 acres. An average farmer has been in the business for 24 years. Around 41% of farmers in the sample have access to production financing, while just 18% of farmers have access to extension services. This demonstrates that farmers have access to various finance sources than traditional banks and financial institutions. A little over 45% of farmers have access to climate change information.

Table 4.5.1: Characterization of farmers

Variable	Mean	Std. Dev.
Age	45.704	10.297
Sex	0.945	0.227
Education	3.675	5.910
household size	9.287	4.459
Farm Scale	0.607	0.489
Farm size	8.220	5.477
Landholding	9.223	6.338

Experience	24.111	10.545
Extension	0.180	0.385
Production credit	0.412	0.493
CC information	0.455	0.499
Maize price	5.285	1.560
Groundnut price	2.370	2.665
Pepper price	1.764	2.592
Soya price	1.702	2.762
TLU value	7.571	2.358

4.5.2 Indigenous and scientific climate adaptation strategies

The section provides the outcomes of farmers in the study areas indigenous (traditional) and scientific climate adaption practices. While the scientific approach to climate adaptation is the contrary, indigenous climate adaptation techniques, including research, relate to climate adaptation tactics that have been employed by farmers for a long time without being improved. Table 6.2 presents the descriptive statistic of the indigenous and scientific climate adaptation strategies. Beginning with the scientific climate adaptation strategies, about 84% and 50% of the farmers adopted early maturity and drought-tolerance-resistant varieties respectively. While about 97% of the farmers adopted fertilizer application, about 81% adopted soil and water conservation (bund construction, compost, etc.) in the study area. Farmers in recent times depend on scientific climate weather from meteorological services to adjust the planting of food crops. The study revealed that about 61% of the farmers adopted scientific weather prediction before planting food crops. This helps the farmer to avoid drought being affected by their food crops.

Furthermore, indigenous climate adaptation strategies considered in this study include crop rotation, mixed farming, mixed cropping, organic manure (animal droppings), mulching, and shifting cultivation. The results demonstrated about 60%, 90%, and 67% of the farmers adopted crop rotation, mixed farming, and mixed cropping respectively as climate adaptation strategies. About 75% of the farmers adopted organic manure and 25% adopted the mulching method at farm plot level adaptation strategies. For shifting cultivation, about 34% of the farmers adopted the strategy at the farm plot level to enhance crops to be residence to climate change.

Table 4.5.2: Indigenous and scientific climate adaptation strategies

Indicator	**Adoption level**	
	Frequency	**Percent**
Scientific CC adaptation strategies [K]		
Early maturing varieties	355	84.12
Cultivating drought resistant variety	210	49.76
Fertilizer application	411	97.39
soil and water conservation	342	81.04
scientific weather prediction	257	60.90
Traditional CC adaptation strategies		
Crop rotations	252	59.72
Mixed farming	378	89.57
Mixed cropping	281	66.59
Organic manure	315	74.64
Mulching	105	24.88
Shifting cultivation	144	34.12
Pooled CC adaptation		
Zero adaptation	41	9.72
Indigenous adaptation only	102	24.17
Scientific adaptation only	110	26.07
Joint adaptation	169	40.05
Total	**422**	**100.00**

Note: K denotes multiple choices

The data were also merged to create non-adopters, indigenous adopters exclusively, joint adopters, and scientific adopters. According to the survey, 10% or so of farmers were unable to use any indigenous or scientific adaptation measures. Approximately 24% of the farmers used solely indigenous and 26% used only scientific climate adaption techniques. The indigenous and scientific climate adaptation solutions were combined by the majority (40%) of people. This result revealed that in order to increase farm output, farmers should implement both traditional and modern climate adaptation techniques at the farm plot level. The best option for achieving sustainable food production systems is the integrated use of climate adaption measures.

4.5.3 Drivers of individuals and joint climate adaptation strategies

The adoption of climate adaption techniques (CAS) by local farmers and scientists may be the result of numerous factors acting alone or in concert. The polynomial probit model is the most effective estimating strategy if the response is sorted. Table 4.5.3 displays the outcome of the multinomial probit findings (selection model). The Wald test had a high level of statistical significance (Wald Chi2 62 = 309.73; Prob>Chi2 = 0.000). The multinomial probit model is best appropriate for the analysis, according to the significance of the Wald test. As a result, it is denied that the overall estimate is zero, which is the null hypothesis.

Only 1% of farmers were found to have a positive and significant impact on indigenous CAS. This suggests that older farmers have a larger likelihood of adopting exclusively traditional CAS than do younger farmers. Younger farmer turns to business oriented compared to older farmers. Such farmers are interested in short-term benefits but the older generation is interested sustainability of soil fertility for food production to feed the current and future generations. Therefore, this is not a surprise since older farmers have accumulated knowledge about time-test production practices at the farm plot level. They know how to combine indigenous CAS to enhance sustainable food production.

The study also discovered that the adoption of native, scientific, and common CAS was negatively impacted by size of farming by 5%, 10%, and 5%, respectively. These findings show that, when other determinants including unobserved factors are held constant, large farmers are less likely to adopt both native and scientific CAS. This could also suggest that small-scale farmers are more inclined than large-scale farms to adopt CAS. Small-scale farmers may readily deploy CAS to their farmers at the same time, however large-scale farmers, who farm more than 20 hectares of land, find it challenging to do so. This result confirms that smallholder agriculture is important to increase food basket production and counteract food insecurity.

The adoption of CAS by indigenous people was found to be positively and significantly impacted by extension services at a rate of only 1%, increasing the likelihood that CAS will be adopted by farmers who have access to these services. Small scale farmers have been strongly encouraged to embrace cutting-edge farming practices through agricultural extension agencies. The ability of farmers to mix traditional and modern agricultural methods to support soil health for long-term food production is improved, according to evidence, by modern agricultural extension services

Table 4.5.3: Determinants of individuals and joint climate adaptation strategies

Variable	Indigenous CAS		Scientific CAS		Joint adoption	
	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Age	0.103***	0.041	0.015	0.042	0.002	0.041
Sex	1.708	1.721	-0.288	1.434	0.195	1.450
Education	0.007	0.059	0.057	0.062	0.051	0.061
Household size	-0.067	0.079	-0.040	0.080	-0.086	0.079
Scale of farming	-1.666**	0.753	-1.350*	0.774	-1.566**	0.770
Farm size	0.011	0.161	0.042	0.169	-0.130	0.163
Total land size	-0.002	0.146	-0.127	0.152	0.052	0.143
Experience	-0.052	0.041	-0.013	0.044	0.004	0.042
Extension	1.948***	0.754	0.303	0.826	0.144	0.819
Credit	0.082	0.577	-0.695	0.619	0.071	0.606
Rainfall	1.095	0.850	0.488	0.852	0.272	0.851
Pest invasion	0.173	0.550	1.402**	0.616	1.510***	0.602
Crop disease	1.773**	0.804	2.013***	0.804	3.150***	0.796
Occupation	-0.266	0.820	2.633***	0.968	1.771**	0.884
CC information	0.987*	0.573	1.390**	0.596	0.545	0.588
_cons	-4.030*	2.444	-1.268	2.323	-0.573	2.280
obs.	422					
Wald chi2(62)	309.73					
Prob > chi2	0.0000					
Log-likelihood	-482.4119					

Note: Category1 is the control group (base category); Note: ***, **, and * represent significance levels of 1%, 5%, and 10%, respectively.

At 5% and 1% significance levels, it was discovered that pest invasion had a favorable impact on the scientific and collaborative adoption of CAS. Farmers that have experienced pest problems are more inclined to employ scientific CAS alone or to combine indigenous and scientific CAS. The greatest choice for controlling pest invasion is to use an integrated indigenous and scientific CAS because the pest has developed a resistance to chemicals. to successfully prevent insect invasion during crop production. One CAS approach cannot effectively increase farm production and productivity, as seen by the combined considerable impact of crops afflicted by illnesses.

With substantial amounts of 1% and 5%, farmers' primary occupation was found to have a favorable effect on the scientific and general acceptability of CAS. Agriculture-focused farmers are more likely to utilize CAS to advance soil health and crop productivity. Rain fed agriculture provides the majority of the income for farmers in Ghana, particularly in the northern region. They have drawn a number of NGOs that collaborate with the Ministry of Agriculture to improve the capacity of local farmers. Farmers have begun to use both natural and scientific CAS at the agricultural plot level to reduce the impact of climate change as a result of their concern over how it will affect agriculture.

The adoption of CAS by smallholders is significantly influenced by the Climate Change Information Service, which has received support from numerous policymakers in SSA. The study discovered that only indigenous peoples and scientists, at 10% and 5%, respectively, have access to climatic information that significantly improves CAS. According to this finding, farmers are more likely to use CAS if they have access to climate information services. Farmers that have access to climate change information services are better able to adapt to various tactics for diversifying their sources of income in addition to adopting CAS at the field level.

4.6. Drivers of household dietary diversity score for individual and joint adopters of CAS

The results and discussion of the socioeconomic factors influencing the Household Dietary Diversity Score (Index) (HDDS) in the research area are presented in this section of the chapter. Table 6.4 illustrates the significance of employing multinomial switching regression (MESR) to address selectivity issues when they are present in the gathered data set. Data were computed and presented for individual and joint CAS. The proof of selective bias was demonstrated by the significance of rho0, rho3, and rho4, and this bias has been rectified to provide an accurate and reliable estimation of the socioeconomic determinants impacting HDDs.

Researchers utilizing CAS were shown to have lower HDDS scores as they aged, which was only statistically significant at the 10% level. This implies that the more individuals who use scientific CAS, the more probable are that they will change their diets to improve their access to food and nutrition. This indicates that as time goes on, breadwinners are more inclined to change the family's diet to maintain their health.

The findings also demonstrate that, at the 5% level of significance, farm size has a detrimental impact on non-adopters, indigenous adopters, and scientific adopters. According to this, small scale farmers are more likely than large scale farmers to change up the food served in their homes. This is most likely because small scale farmers, who raise a range of crops to suit families' food needs, predominate in Ghana. Large-scale farmers primarily practice agricultural commercialization and monoculture (crop specialization), which reduces the nutritional diversity of their homes. Only scientists taking CAS are negatively impacted by farm size, and this effect was significant between at 5%. This implies that there is a strong likelihood that a farmer's household will have a less diverse diet as its size increases. The farmer starts to consider the marketing and production of particular crops as the size of the farm grows. Due to the farm's restricted ability to supply food baskets, they will no longer be able to diversify their food.

Table 4.6.1: Drivers of HDDS for individuals and joint adopters of CCAS-MESR-outcome function

Variable	Non-adopters		Indigenous CAS adopters		Scientific CAS adopters		Joint adopters	
	HDDS							
	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Age	-0.055	0.069	-0.003	0.008	-0.026*	0.016	-0.005	0.005
Sex	-1.013	0.670	-0.264	0.249	-0.228	0.223	-0.118	0.115
Education	-0.595	0.490	0.061	0.125	-0.089	0.252	-0.049	0.099
Household size	-0.049	0.073	-0.008	0.016	-0.003	0.019	-0.008	0.012
Scale of farming	-0.853**	0.380	-0.232**	0.101	-0.379**	0.176	-0.170	0.106
Farm size	-0.052	0.058	-0.011	0.013	-0.042**	0.020	-0.008	0.009
Maize price	0.066	0.044	-0.008	0.092	0.010	0.023	0.015	0.024
Groundnut price	-0.225*	0.124	-0.035*	0.021	-0.004	0.021	-0.026*	0.016
Pepper price	-0.001	0.036	-0.016	0.014	-0.045***	0.015	-0.019	0.016
Soya price	-0.038	0.035	0.002	0.012	-0.023	0.021	-0.007	0.008
TLU value	0.021**	0.011	0.010	0.010	0.018	0.020	0.024**	0.010
Credit	-0.590	0.627	0.006	0.102	-0.121	0.199	-0.164**	0.078
Farm experience	0.047	0.057	0.012	0.007	0.022*	0.012	0.005	0.004
_cons	8.863**	3.762	2.738***	0.880	3.268***	0.281	2.902***	0.445
Ancillary								
Sigma2	8.185	8.509	0.177	0.160	0.681	0.796	0.424	0.326
rho0	-0.189	0.284	-1.526**	0.746	0.135	1.036	-1.370**	0.601

rho1	-0.233	1.161	-0.228	0.189	-0.607	1.007	-0.542	0.632
rho2	2.059*	1.126	1.228***	0.460	0.891***	0.197	1.330**	0.660
rho3	0.452	0.850	-0.359	0.780	1.282***	0.433	-0.443**	0.231

Note: ***, **, and * represent significance levels of 1%, 5%, and 10%, respectively.

In the study area, it was discovered that the unit price of groundnut had a considerable negative impact on CAS non-adopters, indigenous adopters, and joint adopters. Keeping other things equal, this means that a rise in the unit price of groundnut will probably result in a decrease in the variety of diets found in homes. Similar to this, a rise in the price per unit of pepper, a micronutrient, is likely to lead to less variety in household diets. These findings demonstrated that in Ghana's rural and urban areas, rising commodity prices cause food and nutrition insecurity. A household is more likely to diversify its diet as its Total Livestock Unit (TLU) value rises in order to satisfy the nutritional needs of its members for optimal bodily function. Households may sell some animals as TLU value rises in order to buy other food items that the home could not generate at the farm level. This enables such households to increase the variety of meals their members eat each week to improve the human body's health.

4.7.Drivers of HFIAS for individual and joint adopters of CCAS

The Access to Food Insecure Households (HFIAS) scale results and socioeconomic factors impacting it are discussed in this section. The estimated findings are shown in Table 6.5, and based on the stated Rho’s significance, it is clear that MESR is more accurate for estimation. At the 5% level, it was discovered that farmer age had a considerably positive effect on CAS joint-adopters. This means that as the farmer ages, the likelihood of food insecurity increases. This means that older farmers are less vulnerable to food insecurity than younger farmers.

This could be because older farmers lack the energy to grow many crops, putting them at much higher risk of food insecurity than younger ones.

Only at the 10% level did it appear that the agricultural scale had a considerable positive impact on HFIAS non-adopters. This implies that, while other parameters stay constant, large-scale farmers are more susceptible to food insecurity than small-scale farmers. This is probably because small farmers started using mixed farming and mixed cropping to improve the amount of food available for consumption in the home. As a result, large-scale farmers experience greater food insecurity than small-scale farmers.

By assuming a 5% soybean unit price, it was discovered that this had a favorable and significant impact on HFIAS. This implies that the chance of food insecurity for households increases in the same direction as the unit price of soybeans increases. In Africa, soybean is a crucial crop for ensuring food security, particularly in rural regions where it is converted into a variety of dishes for consumption. This indicates that when soy prices rise, more households are anticipated to forego soybean goods, which are crucial for the security of one's food supply and diet.

Additionally, the primary source of income for households in northern Ghana is cattle rearing. In times of low agricultural food production, it aids farmers in getting food. According to the study, TLU had a detrimental effect on those who chose not to use HFIAS, which was statistically significant at the 5% level. Due to TLU's significance, animal production is crucial for enhancing household food security. For self-consumption, livestock produces a variety of goods, including meat, milk, and dairy products.

An important factor in both food security and food policy are production credits. Farmers that have access to producer credit can purchase agricultural inputs to raise household income and farm output. Due to the fact that only joint and scientific adopters of CAS had a positive and substantial effect from the variable, this study demonstrates that access to credit for agricultural production promotes household food insecurity. The study also discovered that adopters who had farming expertise only suffer a 1% reduction in adoption rates. This implies that farmers are less likely to be food insecure as they gain skill in raising food.

Table 4.5.2: Drivers of HFIAS for individuals and joint adopters of CAS-MESR-outcome function

Variable	Non-adopters		Indigenous adopters of CAS		Scientific adopters of CAS		Joint adopters of CAS	
	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Age	0.050	0.254	0.014	0.019	0.024	0.033	0.043**	0.022
sex	1.439	2.538	1.352	0.959	0.912	0.674	0.219	0.520
Education	0.331	2.148	0.308	0.488	0.276	0.530	0.288	0.382
Householdsize	0.064	0.161	0.026	0.063	-0.044	0.053	-0.020	0.060
Farm scale	3.060*	1.709	0.285	0.393	0.331	0.471	-0.080	0.317
Farmsize	0.146	0.174	0.019	0.036	0.105	0.081	0.024	0.060
Maize price	0.191	0.607	0.104	0.150	-0.044	0.042	-0.045	0.051
Groundnutprice	-0.174	0.490	0.023	0.100	-0.085	0.059	-0.045	0.047
Pepperprice	0.110	0.253	0.024	0.037	-0.012	0.032	-0.017	0.047
Soyaprice	0.172**	0.086	-0.024	0.037	-0.001	0.046	0.058	0.041
TLUvalue	-0.101**	0.043	-0.003	0.038	-0.103	0.066	0.025	0.054
Credit	0.523	2.135	0.323	0.417	1.801***	0.363	1.257***	0.231
Experience	-0.050	0.162	-0.020***	0.007	-0.011	0.026	-0.030	0.022
_cons	-15.270	12.277	-2.623	2.181	2.014	2.009	-2.104	1.446

Ancillary								
Sigma2	48.053	107.736	1.502	5.788	6.033	4.654	9.441	16.587
rho0	-0.019	0.268	1.588*	0.911	0.976	0.669	0.111	0.716
rho1	-0.976	1.219	0.211	0.394	-0.144	0.842	0.078	0.732
rho2	-1.108	1.339	-0.225	1.002	-1.231***	0.312	-1.842***	0.323
rho3	-1.443***	0.429	-0.670	1.066	-0.403	0.867	-0.295	0.382

Note: ***, **, and * represent significance levels of 1%, 5%, and 10%, respectively.

4.6.3: Individual and collective impact of CAS adoption on food safety outcomes

Impact analysis is one of the study's key goals. The results of the assessment of the effect of individual and communal CAS implementation on household food security are shown in Table 6.6. The study discovered that traditional adaptation strategies of CAS had a beneficial impact on food diversity at home with a 1% level of significance starting with HDDS. Therefore, individual farmers who practice the traditional methods of climate change adaptation strategies saw an improvement of roughly 40% in their food diversity. Farmers who use the modern climate change adaptation strategies outperformed non-adopters by roughly 19% in their food diversity. Similar to joint adopters, non-adopters' dietary preferences decreased by roughly 13%. This outcome demonstrates how traditional food diversity is promoted by the introduction of traditional and scientific (improved) CAS.

The Household Food Insecurity Access Score is another element of the Food Security S measure. Only traditional adopters, according to the findings, had a statistically meaningful impact on the 1% of HFIAS. As a result, it is anticipated that the number of traditional CAS adopters who experience food insecurity will drop by roughly 43%. Although scientific and joint climate Adaptation strategies are statistically insignificant, they contributed in reducing food insecurity.

Table 4.6.3: impact of CAS on food security

Variable	Decision stage		ATT-MESR	t-value	%Change
HDDS	**If adopters are adopted**	**If non-adopters are not adopted**			
Indigenous CAS adopters	14.752 (0.929)	10.694 (0.135)	4.058 (0.878)	4.624***	37.95
Scientific CAS adopters	10.431 (0.645)	8.775 (0.201)	1.656 (0.600)	2.758***	18.87
Joint adopters	10.312 (0.091)	9.113 (0.177)	1.199 (0.156)	7.679***	13.16
HFIAS					
Indigenous CAS adopters	2.063 (0.069)	3.603 (0.526)	-1.540 (0.522)	-2.952***	-42.74
Scientific CAS adopters	3.382 (0.487)	4.095 (0.332)	-0.713 (0.486)	-1.468	-17.41
Joint adopters	3.492 (0.164)	3.899 (0.499)	-0.408 (0.528)	-0.7729	-10.46

Note: *, **, and * represent significance levels of 1%, 5%, and 10%, respectively.**

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.0: Introduction

The study's primary findings, conclusions, and policy suggestions are summarized in the study's final chapter. The primary results of the investigation are presented in Section 5.2. The study's findings are presented in Section 5.3, which also includes a policy recommendation.

5.1: key Findings of the Study

Interesting insights from the study have shaped the creation and application of policy. Included in them are the following. First, the study's findings showed that the area's small farmers face significant climate shocks from severe drought, extreme heat, and worm infestation. For over 67% of the farmers in the region, the severe drought is a big climate shock. The study also showed that 56% of farmers experience high temperatures, while 53% have worm infestation.

Regarding the farmers' accepted mitigation techniques, only one farmer, or 0.24%, used more than three techniques. The study also discovered that eight and seventeen farmers, or roughly 1.9% and 4%, respectively, used five and six measures for coping with climate change. About 25% of the farmers used nine different tactics for adjusting to the climate.

Agricultural extension services are a significant indication that has been supported by research and policymakers over time. The study discovered that the adoption of mixed farming, mixed farming, and the usage of organic fertilizers are significantly negatively impacted by access to extension services. Therefore, farmers who have access to extension services are less inclined to use these tactics.

The study also demonstrated that the intensity with which adaption methods are implemented is positively and significantly impacted by access to knowledge about climate change. This implies that farmers who have access to information about climate change encourage the use of stronger climate change adaption measures.

The study divided the adaption techniques into two categories: traditional and scientific. Early maturing cultivars and drought-tolerant kinds were accepted by about 84% and 50% of the farmers, respectively. The use of fertilizer was adopted by almost 97% of the farmers. As a measure of climate adaptation, roughly 60%, 90%, and 67% of farmers, respectively, embraced crop rotation, mixed farming, and mixed cropping. The study found that in order to increase output, farmers used both traditional and modern climate adaption techniques.

The study also found that indigenous CAS adopters have a beneficial influence on household dietary diversity at a 1% significant level. This brings us full circle to the livelihood outcome. This suggests that CAS household variety would be improved by about 19% for adopters compared to non-adopters. The nutritional diversity of joint adopters increased by roughly 13% in comparison to non-adopters. The findings on food insecurity showed that only indigenous adopters had a statistically meaningful influence at the 1% level. The likelihood of food insecurity among the indigenous adopters falling by almost 43%.

5.2: Conclusions

The study set out to accomplish four main goals: identifying the climate shocks farmers in the northern region faced; examining the strategies farmers in the region used to adapt to climate change; assessing the volume of information on adaptation; and assessing the welfare effects of these adaptation strategies on households.

For this investigation, primary data were gathered. The impact of the climate shocks on northern farmers was examined using descriptive statistics. Strategies for coping with climate change were driven by a multivariate probit model. While multinomial endogenous switching regression was used to assess the effect of climate adaptation techniques on family well-being, endogenous switching regression was also utilized to examine the impact of climatic information on the intensity of adoption of adaptation strategies.

According to the study's descriptive data, climate shock is a significant factor that adversely affects output and productivity at the farm level. Severe drought was listed as the climate shock that occurs most frequently during the season. Rarely do wildfires break out in the studied area. Mulching, crop rotation, mixed farming, and reduced burning are adaptation measures that are frequently used in the region. To verify the methods' complementarity and substitutability, a correlation matrix was created. Crop rotation and reduced burning were shown by the study, and a beneficial relationship between crop rotation and the application of organic manure was also discovered. This suggests that crop rotation and scientific prescription are replacements for compliments at the farm gate.

In terms of the number of coping methods used, around 8% and 18% of the farmers, respectively, used seven and eight coping techniques. Nearly 25% of farmers have used nine tactics.

The farmers that use the indigenous CAS also enhanced their dietary variety and decreased their risk of food insecurity, which brings us to the livelihood outcome. This was ascribed to the length of the practice as well as to its constant accessibility and availability.

5.3: Policy recommendations.

The study's findings serve as a significant policy proposal for the nation given the difficulties facing the agricultural sector and the Sustainable Development Goals. The ministry of food and agriculture along with the irrigation development authority should come out with a policy to reduce the impact of climate shocks on the production of small-scale farms in the study region. In times of drought, the one village one dam policy would be better positioned to make water available for crops at all times.

Second, the government should create crop types that can withstand climatic shocks as well as broader climate smart agricultural technology and make them accessible to small-scale farmers through the crop research institute. The availability and accessibility of inputs for small-scale farmers has come under increased scrutiny. The study recommends a policy push for small-scale farmers to receive planting inputs.

The government and other development partners should invest in systems that help speed up the distribution of knowledge about climate change as we work to enlighten farmers about all facets of farming.

Last but not least, the government and other agricultural development partners should endeavor to boost small-scale farmers' asset accumulation and education so that farmers may increase their resistance to climate shocks and create their own adaptive potential. By boosting farmers' dietary diversity and lowering the risk of food insecurity, this will significantly help meet the sustainable development goal of eliminating hunger.

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