

UNIVERSITY FOR DEVELOPMENT STUDIES, TAMALE

**SOCIO-ECONOMIC ANALYSIS OF CLIMATE ADAPTATION AMONG
SMALLHOLDER FARMERS IN THE NORTHERN REGION OF GHANA**

MAHAMA SULEMANA SAAMANI ELISHA

2023

UNIVERSITY FOR DEVELOPMENT STUDIES, TAMALE



**FACULTY OF AGRICULTURE, FOOD AND CONSUMER SCIENCES
DEPARTMENT OF AGRICULTURAL INNOVATION COMMUNICATION**

**SOCIO-ECONOMIC ANALYSIS OF CLIMATE ADAPTATION AMONG
SMALLHOLDER FARMERS IN THE NORTHERN REGION OF GHANA**

BY

MAHAMA SULEMANA SAAMANI ELISHA

(UDS/MIC/0003/20)

**THIS THESIS IS SUBMITTED TO THE DEPARTMENT OF AGRICULTURAL
INNOVATION COMMUNICATION, FACULTY OF AGRICULTURE, FOOD
AND CONSUMER SCIENCES, UNIVERSITY FOR DEVELOPMENT STUDIES,
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF
MASTER OF PHILOSOPHY IN INNOVATION COMMUNICATION DEGREE**

OCTOBER, 2023



DECLARATION

I hereby declare that, except for references to other people's work, which have been duly acknowledged, this thesis is the result of my own research work carried out in the Department of Agricultural Innovation Communication under the supervision of Prof. Nashiru Sulemana and it is further declared that this thesis has never been presented either in whole or in part for the award of any degree in this University or elsewhere.

Sign

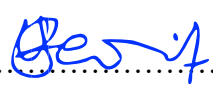


Date 10th February, 2025

Mahama Sulemana Saamani Elisha

(Student)

I 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.

Sign.....

Date: 11/02/2025

Prof. Nashiru Sulemana

(Supervisor)



DEDICATION

I dedicate this thesis to the Almighty Allah, my creator for his guidance and protection, my late father, Sulemana Mahama and to my entire family for their prayers and care.



ACKNOWLEDGEMENTS

I wish to express my gratitude to the Almighty God for His loving kindness throughout this program. Special thanks to Dr. Nashiru Sulemana, my supervisor for his patience and relentless effort to guide me through enormous support and constructive criticism. A special thanks also goes to my group members who have played key roles in making this study a reality and to Kumbungu, Tolon and Savelugu district MoFA offices for their kind support throughout my data collection.



ABSTRACT

The primary objective of this study was to determine the socioeconomic effects of smallholder farmers' adaptation to climate change in Ghana's Northern region. In this study, a quantitative research approach was used to systematically measure and analyse the variables related to climate adaptation and resilience among smallholder farmers. The research was conducted in the Northern region of Ghana, focusing on smallholder farmers involved in different agricultural activities. This approach focuses on gathering numerical data to explore relationships and quantify the impact of socio-economic factors on climate adaptation using 532 smallholder farmers. The data was collected using a semi-structure questionnaire through face-to-face questionnaires administration. The study was analysis



using frequency, percentage and Kendal coefficient of concordance analysis. The study reveals that smallholder farmers in Northern Ghana employ diverse adaptation strategies to address climate change. The study revealed that crop rotation is adopted by 79% of farmers, crucial for soil fertility. Also, the study revealed that adoption of planting early maturing crops is influenced by various economic factors. The sex of the farmer has a positive and statistically significant impact ($\beta = 0.345$, $p = 0.004$), indicating that male farmers are more likely to adopt this strategy. The top-ranked barrier is limited access to credit and financing, with a mean rank of 1.35. This finding underscores how crucial financial resources are for adaptation efforts. The study further revealed that intercropping, where farmers grow multiple crops together in the same field, is practiced by an overwhelming 97.7% of farmers. This high adoption rate underscores the importance of maximizing land use efficiency and reducing the risk of total crop failure. The study further shows that economic factors significantly influence the adoption of early maturing crops. This study concluded that smallholder farmers in the Northern Region of Ghana predominantly adopt various improved traditional farming practices to enhance agricultural productivity and sustainability. Also, the study recommends that, to support and enhance traditional farming practices in the Northern Region of Ghana, the Ministry of Food and Agriculture (MOFA) and the government should implement a comprehensive support program focused on the provision of resources and training.

TABLE OF CONTENT

Content	Page
DECLARATION	Error! Bookmark not defined.
DEDICATION	ii
ACKNOWLEDGEMENTS	iii
ABSTRACT	iii
TABLE OF CONTENT	v
Content	Page..... v
LIST OF TABLES	viii
LIST OF FIGURES	ix
ABBREVIATION AND ACRONYM	x
CHAPTER ONE	1
1.1 Introduction	1
1.2 Problem Statement	9
1.3 Research Question	15
1.3.1 Main Research Question	15
1.3.2 Specific Research Questions	15
1.4 Objectives of the Study	16
1.4.1 Main Objectives of the Study	16
1.4.2 Specific Objectives	16
1.5 Justification of the Study	17
1.6 Scope of the Study	18
1.7 Organization of the Study	19
CHAPTER TWO	20
LITERATURE REVIEW	20
2.1 Introduction	20
2.2 Reasons for Climate Adaptation	20
2.3 Definitions of Key Concepts and Terms	22
2.3.1. Climate	22
2.3.2 Climate change	23
2.3.3 Adaptation	24





2.3.4 Resilience	25
2.3.5 Climate change adaptation	27
2.4 Smallholder Farmers in Ghana	29
2.5 Climatic Conditions in Ghana	30
2.6 Global efforts and key challenges	31
2.7 Impacts and Vulnerability	32
2.8 Smallholder Farmers Adapting to Stresses	35
2.9 Vulnerability and Adaptation in Key Sectors	39
2.10 Climate Change Impacts on Agriculture	40
2.11 Climate Change and Adaptation in Africa	42
2.12 Social Ecological Resilience Framework	44
2.13 Economic Factors	46
2.14 Social and Cultural Factors	47
2.15 Policy, Governance and Institutional Factors	49
2.16 Technological Factors	51
2.17 Demographic factors	52
2.18 Conceptual framework	53
CHAPTER THREE	55
METHODOLOGY	55
3.1 Introduction	55
3.2 The Study Area	55
Figure 3.1: The Map of Ghana showing the Northern Region of Ghana.	59
3.3 Research design	60
3.4 Research Approach	60
3.5 Population of the study	61
3.6 Sampling and Sampling Procedure	61
3.6.1 Sample Size Determination	62
3.7 Sources of Data	64
3.8 Data Collection Techniques	64
3.8.1 Questionnaire	65
3.9 Data Analysis	65
3.9.1 Empirical Model for the Generalized Multivariate Regression	66



CHAPTER FOUR	67
RESULTS AND DISCUSSION	67
4.1 Introduction	67
4.2 Demographic Characteristics of Smallholder Farmers	67
4.2.1 Sex of smallholder farmers	67
4.2.2 Age of smallholder farmers.....	68
4.2.3 Marital Status of agrarian households.....	69
Figure 4.1 Marital Status of Agrarian Households.....	70
4.2.4 Educational level of smallholder farmers	70
Figure 4.2 Bar Chart illustrating the educational level of smallholder farmers.....	71
4.2.5 Household size of smallholder farmers	71
Table 4.3 Frequency distribution of household size of smallholder farmers	71
CHAPTER FIVE	103
SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS	103
5.1 Introduction	103
5.2 Summary of Findings.....	103
REFERENCES.....	114
APPENDIX.....	123

LIST OF TABLES

Table 4.3 Frequency distribution of household size of smallholder farmers.....	71
Table 4.4 Adaptation Strategies employed by smallholder farmers	Error! Bookmark not defined.
Table 4.5 Economic predictors of climate change adaptation	Error! Bookmark not defined.
Table 4.6; Frequency Distribution of policy and Tactical intervention..	Error! Bookmark not defined.



LIST OF FIGURES

Figure 2.1: Conceptual framework	Error! Bookmark not defined.
Figure 3.1: The Map of Ghana showing the Northern Region of Ghana.	59
Figure 4.1 Marital Status of Agrarian Households.	70
Figure 4.2 Bar Chart illustrating the educational level of smallholder farmers.....	71
Figure 4.4: A Chart Illustrating Enhance Traditional Farming Methods.....	Error! Bookmark not defined.



ABBREVIATION AND ACRONYM

AfDB	African Development Bank
CO ₂	Carbon dioxide
FAO	Food and Agricultural Organization
FGD	Focus Group Discussion
GCMs	General Circulation Models
GDP	Gross Domestic Product
GHG	Greenhouse Gases
HIV/AIDS	Human Immunodeficiency Virus infection / Acquired Immunodeficiency Syndrome
IFAD	International Fund for Agricultural Development
IPCC	Intergovernmental Panel on Climate Change
MoFA	Ministry of Food and Agriculture
LDC	Least Developed Countries
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UN-Habitat	United Nations Human Settlements Programme
UN	United Nations
WHO	World Health Organisation
WMO	World Meteorological Organisation





CHAPTER ONE

1.1 Introduction

Recent years have seen a substantial challenge to smallholder farmers from climate change, which also poses a threat to global advancements in eradicating poverty, ensuring food security, and fostering sustainable development. Around the world, there are an estimated 475 million smallholder farmers working less than 2 ha of land, many of them live in extremely difficult circumstances, are food insecure, and are financially underprivileged (Tazeze et al., 2012). Due to their reliance on rain-fed agriculture, cultivation of marginal land, and lack of access to technical or financial support that could enable them to invest in more climate-resilient agriculture, smallholder farmers are particularly vulnerable to climate change. Despite mounting evidence of smallholder farmers' sensitivity to climate change and growing interest in ensuring food security in the face of it, adaptation efforts are still hampered by a dearth of knowledge about how smallholder farmers are coping with and adapting to the change.

In most continents throughout the world over the last few decades, climate change has had a negative impact on both physical and biological systems (Change et al., 2023; Parry et al., 2001; Tsutsumi et al., 2009). In the last 30 years, climate change has caused a 1-5% per decade decline in worldwide agricultural production, according to Porter (2014) and Haughton (2009). Additionally, it is anticipated that its effects will have negative repercussions on the worldwide agricultural sector, particularly in tropical and subtropical areas (Asare-Nuamah & Amungwa, 2021). The effects of climate change are particularly severe in regions like sub-Saharan Africa where the agriculture sector dominates the GDP of most nations. The subcontinent's quick and unpredictable variations in temperature and





rainfall patterns make agricultural systems, particularly food production, much more vulnerable (AGRA, 2014). With the anticipated climate change in tropical countries, which is anticipated to result in a considerable drop in the production of key and staple food crops in such locations, this tendency is anticipated to accelerate in the future (Komba & Muchapondwa, 2012; Nelson et al., 2009). Governments have increased their efforts to enable the agricultural sector to effectively adapt to climate change at the national and local levels in response to anticipated changes, with the help of international collaboration. The human quest for socioeconomic development, which includes industrial and other socioeconomic activity, has increased the atmospheric concentration of carbon dioxide (CO₂), the main Green House Gas (GHG) with the highest radioactive forces, responsible for global warming (Technical & Vi, n.d.; Tsutsumi et al., 2009); and other GHGs (IPCC, 2007c; Haughton, 2009; WMO, 2009; 2012). From 280 parts per million (ppm) in the pre-industrial era (before 1750 AD) to 390.9 ppm in 2011 (WMO, 2012; Al Gore, 2006; IPCC, 2007c; UNEP/GRID-Arendal, 2009; UNEP, 2012a), the GHG increased by 140% during that time. According to the most recent analysis of observations from the WMO Global Atmosphere Watch (GAW) Programme, the global averaged mole fractions of carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O) reached new highs in 2012, with CO₂ at 393.10.1 ppm, CH₄ at 18191 ppb, and N₂O at 325.10.1 ppb. These numbers correspond to 141%, 260%, and 120% of pre-industrial levels (before to 1750), respectively. The increase in atmospheric CO₂ from 2011 to 2012 is larger than the average growth rate over the previous ten years (WMO, 2013).

Adjustments to ecological, social, or economic systems in response to real or anticipated climatic stimuli and their effects or impacts are referred to as adaptation. In order to



mitigate possible harm or take advantage of opportunities brought on by climate change, systems, methods, and structures must be changed. In its simplest form, adaptation to climate change refers to preparing for probable consequences of a changing climate. In order to help smallholder farmers, adjust to these concerns, it is crucial to understand the socioeconomic challenges that smallholder farmers are facing as a result of climate change. One of the most adaptive animal species on the planet is the human species (Tazeze et al., 2012). Since then, they have adapted to deteriorating weather circumstances and changes in their surroundings (Komba & Muchapondwa, 2012; Rechtswissenschaften, 2014). Inventions in human settlements, agricultural production techniques, and even new human lifestyles have all resulted from this kind of adaptability. However, it might be argued that the challenge given by anthropogenic induced climate change is bigger than any other transition that mankind have ever gone through in history. Climate change has likely given adaptation new meaning and relevance. The primary difference between the typical adaptation process that people have known and used for ages and one related to the impacts of climate change is the degree and size involved. Almost every aspect of human life is currently threatened by the effects of climate change, including agriculture, human settlements, physical infrastructures, water supplies, ecosystems and biodiversity, and the overall economy (Alidu et al., 2022; Antwi-Agyei et al., 2015; Rechtswissenschaften, 2014). This puts the ability of ecosystems to support human livelihoods as well as the continued survival of plant and animal species under danger. It is also true that developed nations have consistently fallen short of their emission reduction targets under the Protocol's First Commitment Period and have been unwilling to commit themselves to higher targets in line with available scientific information, despite the international



community's efforts over many years to address climate change through mitigation, particularly after the Kyoto Protocol came into force. Considering that adaptation needs to receive high priority due to the fact that the effects of climate change, particularly on underdeveloped nations, are not only projected but also expected to get worse. Since it is employed in various contexts and domains of research, resilience is conceptualized in a variety of ways. It refers to a system's capacity to withstand shocks, or to alter in reaction to stress while still performing the necessary activities (Rechtswissenschaften, 2014). According to the IPCC, it is a social or ecological system's capacity for self-organization, its ability to adapt to stress, including change, and its ability to absorb perturbations while maintaining its fundamental structure and ways of functioning (Technical & Vi, n.d.). Human activity has been the main cause of the acceleration of climate change during the past century, and the climate is changing. No matter how effective we are in reducing the underlying causes of our planet's warming, society will still be negatively impacted by more frequent and severe weather, warming and acidification of the oceans, prolonged droughts, high heat, and other negative consequences of climate change. Climate resilience, as defined by the Center for Climate and Energy Solutions (C2ES, 2019), is the capacity to mitigate, recover from, and adapt to these effects. The term "resilience" is becoming more and more prominent in the context of climate change. Due to the fact that climate change is both a global and a hyper-local concern, extreme weather occurrences have demonstrated the importance of resilience as a component of any comprehensive program to combat the issue. Everyone on the globe is impacted by the causes and the general effects, but resilience activities must be carried out at the onset, neighborhood, or personal level. To solve this problem, a coordinated and unified effort unlike any other will be

required. The good news is that mitigating these risks can lead to economic activity that will support domestic employment and prosperity in addition to protecting persons and property.

Furthermore, it is critical to keep in mind that despite current efforts to reduce emissions, a significant quantity of GHGs have already been deposited in the atmosphere. This shows that even if emissions were to be totally removed today, the impacts of climate change would still persist (Solomon et al., 2009). Climate adaptation and resilience are essential and unavoidable solutions in order to assist those who will be affected by climate change.

In addition to effective knowledge management, governments must actively and consistently engage stakeholders, including national, regional, multilateral, and international organizations, the public and private sectors, civil society, and other relevant stakeholders, to achieve successful climate adaptation and resilience. Adapting to the effects of climate change can be done at different levels, in different industries, and across different geographic areas. In order to develop policies, institutional responses, and strategies for smallholder farmer adaptation, policy makers, donors, and practitioners need precise, context-specific data on the effects of climate change on smallholder farmers and whether they are modifying their management practices to address these effects. More knowledge is also required regarding the variations in smallholder farmer vulnerability and responses across various farming systems and socioeconomic contexts. In the Northern region, where small-scale agriculture is essential to economic development, food security, and local livelihoods, analysing the socioeconomic impact of climate change on smallholder farmers and establishing appropriate adaption techniques are crucial problems.





In the Northern region, a large number of smallholder farmers also grow soybeans, an export crop that significantly boosts agricultural GDP and creates a sizable number of jobs. Production of rice and maize is very important culturally in the area. Because their crops are sensitive to rising temperatures and shifting rainfall patterns, smallholder farmers rice and basic grain producers are particularly vulnerable to climate change. It is well recognized that increasing temperatures have a detrimental impact on rice flowering, fruit set, and bean quality. This is especially true for Ghana's Northern area, one of the driest savannah regions in the country, where an increasing frequency of droughts, floods, and bushfires have a negative impact on both nature and people (Alidu et al., 2022). It is discovered to be one of Ghana's most exposed and susceptible areas to climate change (Rechtswissenschaften, 2014).

Numerous thousands of marginalized, poor smallholder farmers who mostly depend on nature for food and money and have few other options for a living are affected by these effects (Alidu et al., 2022). Their rain-fed agriculture, which accounts for the majority of the region's economic activity (Antwi-Agyei et al., 2015), is primarily dependent on a single, already-modified rainy season. Numerous research on potential strategies to improve these farmers' resistance to the effects of local climate change have been conducted during the past ten years. This research is mostly focused on farm-level adaptation techniques and tactics (Alidu et al., 2022). Only a few studies have examined the socioeconomic adaptation and resilience of smallholder farmers in the area to the new environment. However, understanding who among those we anticipate to be most vulnerable to climate change has a higher or lower adaptive capacity to climate change and what the pertinent determinants for these capacities are provides a basis for finding more



effective ways to support smallholder farmers in the Northern region of Ghana as they attempt to sustain their agricultural production, which serves as the foundation of their livelihoods and urban centers in the area. Therefore, the key data for the formulation of climate change adaptation policy is brought to the decision-making table by socioeconomic analysis of climate adaptation and resilience. As a result, in-depth studies that concentrate on the resilience and adaptability of smallholder farmers provide vital information on their significant advantages and disadvantages and support the development of policies and interventions for climate change mitigation methods.

The future of global food security and agriculture play a significant role in climate change negotiations. The objective is to ensure stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent "dangerous anthropogenic interference with the climate system," as stated in Article II of the United Nations Framework Convention on Climate Change (UNFCCC). It states that "such a level should be achieved within a time-frame sufficient to let ecosystems to naturally adjust to climate change, to ensure that food supply is not jeopardized, and to permit economic development to proceed in a sustainable manner."

The development and climate change concerns of the twenty-first century are intricately tied to agriculture, rural livelihoods, sustainable use of natural resources, and food security. In fact, the World Food Summit, the Millennium Development Goals, and the UNFCCC all explicitly state that food security is an issue as a result of climate change, and that successful adaptation and mitigation measures in agriculture can only be performed within these frameworks.



These current trends will be reinforced by climate change, which will significantly increase production risk and rural vulnerability, especially in areas that already experience chronic soil and water resource depletion, high exposure to climatic extremes like drought and flooding, poverty, and hunger. The acute lack of knowledge, infrastructure, organization, and resources that local populations and national governments require to deal with and adapt to climate change will exacerbate the stresses brought on by it. This will be especially true in numerous underdeveloped tropical dry and semi-arid regions, raising the possibility of significant long-term adverse effects on rural livelihoods, natural resources, and food security. It will further widen the gap between developing and wealthy nations.

All over the West, the effects of climate change are being felt. The volume of precipitation experienced annually as a whole and the ratio of rain to snowfall are both changing due to global warming, which has an impact on water supply. Communities are increasingly struggling with issues including drought, flooding, and greater threats of forest fires as well as a lack of water.

Urban areas are increasingly affected by climate change. About 200 years ago, the French scientist Jean-Baptiste Fourier discovered that an augmented greenhouse effect had a warming impact, which helped to establish the existence of climate change. Svante Arrhenius, a Swedish chemist, continued his investigation into this warming effect in 1896 and predicted that if atmospheric CO₂ doubles, global temperatures might rise by 5 to 6 C. On whether or not there has been climate change, a variety of arguments have been made. However, in 2007, the Intergovernmental Panel on Climatic Change (IPCC) came to the conclusion that there is a 90% chance that manmade influences are causing the



Anthropogenic, which is a period of climate change. Since the beginning of time, climate change has been a pressing concern, and the majority of nations have been actively engaged in its mitigation as the first generation of solutions, followed by adaptation measures. Global climate change is a problem that affects people's rights and social issues more than it does the physical and economic growth of nations and communities. Due to its high risk and exposure to climatic factors including precipitation, temperature, and wind on which it depends, agriculture continues to be one of the primary industries that is particularly vulnerable to climate change. Due to the degree of risk in this industry, the necessity for adaptability is therefore quite clear. Cities now have to adjust to shifting pressures and extreme weather conditions, including heat waves, droughts, cloudbursts, and stronger, more frequent storms.

1.2 Problem Statement

Climate change is increasingly recognized as a significant global challenge, with profound implications for agricultural productivity, food security, and the socio-economic well-being of rural populations. In regions where agriculture is the economic backbone, particularly in the northern parts of many countries, smallholder farmers face heightened vulnerability to climate-related disruptions. These include extreme weather events such as droughts, floods, unpredictable rainfall, and shifts in temperature patterns. Such impacts often worsen existing poverty and inequality, thereby posing substantial challenges to sustainable development.

Northern regions are typically characterized by marginal agricultural land, limited access to advanced technology, and underdeveloped infrastructure, which make them especially prone to the negative effects of climate change. Smallholder farmers in these areas often



resort to various coping strategies, such as modifying crop patterns, altering livestock management, or adopting new agricultural practices. However, their ability to adapt to climate change is not determined solely by environmental factors. Socio-economic elements such as access to financial resources, education, information, social networks, and institutional support also play a critical role in shaping how farmers adapt to changing climatic conditions.

Existing literature underscores that smallholder farmers, particularly in developing countries, face multiple barriers to effective climate adaptation. According to Thornton et al. (2014), adaptation strategies are often constrained by limited access to financial capital, technology, and knowledge. Adger et al. (2003) emphasize the importance of social capital and community networks in fostering adaptation in rural areas, yet socio-economic disparities often hinder marginalized groups from engaging in adaptive measures. Challinor et al. (2014) further highlight that factors such as socio-economic status, gender, and land tenure systems significantly influence the adoption of climate adaptation strategies. Despite this growing body of research, there remains a significant gap in understanding how these socio-economic factors interact to shape the outcomes of climate adaptation, particularly in northern regions where challenges are compounded by extreme climatic conditions and inadequate infrastructure.

While research on climate adaptation in agriculture continues to expand, there is insufficient evidence regarding the specific socio-economic drivers of adaptive capacity among smallholder farmers in northern regions. The current literature often treats adaptation as a one-size-fits-all response to climate change, overlooking the region-specific, context-sensitive barriers and opportunities that smallholder farmers face.



Furthermore, policies designed to enhance climate adaptation frequently fail to address the socio-economic realities of farmers in these areas, leading to interventions that may be ineffective or even exacerbate existing inequalities.

This study seeks to fill this gap by conducting a socio-economic analysis of climate adaptation strategies among smallholder farmers in northern regions. By examining the relationship between socio-economic factors such as income, education, access to technology, and social networks and farmers' adaptive capacity, the research will identify the key drivers of successful adaptation. The findings will inform targeted interventions that are not only environmentally sustainable but also socio-economically inclusive, ultimately improving the resilience of smallholder farming communities to the impacts of climate change.

Climate change adaptation among smallholder farmers in northern regions is a highly complex and multifaceted issue involving a wide array of socio-economic, environmental, and institutional factors. While the literature offers valuable insights into the drivers and barriers to adaptation, there are significant debates surrounding the relative importance of these factors and how they interact. These controversies stem from differing interpretations of empirical data, conflicting policy recommendations, and challenges in applying general adaptation frameworks to specific regional contexts.

A key controversy revolves around the relative importance of socio-economic factors (such as income, education, and social networks) versus environmental factors (like climate variability and land quality) in shaping climate adaptation strategies. Some scholars argue that socio-economic factors, particularly access to financial resources, information, and technology, are the primary drivers of successful adaptation. For instance, Schipper and



Pelling (2006) argue that environmental stressors, such as unpredictable rainfall and temperature shifts, are the main forces driving adaptation in regions that rely heavily on rain-fed agriculture. This raises the question: should adaptation policies focus more on improving socio-economic conditions, or should they prioritize mitigating environmental risks through technological advancements and climate-smart practices?

Conversely, Mertz et al. (2009) suggest that access to technology and financial resources often overshadows environmental constraints, indicating that overcoming socio-economic barriers is essential to enhancing adaptive capacity, particularly in regions with limited access to advanced agricultural technologies.

Another major debate concerns whether climate adaptation should be seen primarily as a local or a global phenomenon. Scholars such as Carter et al. (2007) argue that adaptation must be local and context-specific, as it needs to take into account regional climate risks, cultural contexts, and socio-economic realities. Local-level adaptation strategies often emphasize community-driven initiatives to build resilience through the strengthening of local capacities, knowledge systems, and governance structures.

In contrast, Smit and Wandel (2006) advocate for a more global approach, calling for large-scale, systemic interventions that address underlying socio-economic vulnerabilities and global environmental shifts. This debate is also reflected in climate finance discussions, where scholars disagree on whether funding should be directed towards large infrastructure projects such as irrigation systems or drought-resistant crops or smaller, community-based resilience efforts.



Gender and social inequality are increasingly recognized as crucial factors in determining adaptive capacity. A growing body of literature highlights those women, particularly in rural areas, face distinct barriers to adaptation due to limited access to land, credit, and agricultural extension services. For example, Bryan et al. (2013) found that gender disparities significantly hinder women's ability to engage in adaptive practices. Similarly, Meinzen-Dick et al. (2014) stress that gendered power dynamics often influence who participates in adaptation decision-making and who benefits from adaptation interventions.

However, critics argue that an excessive focus on gender may oversimplify the complex interactions between various social, economic, and environmental factors. For instance, emphasizing gender in isolation may overlook broader structural issues such as land tenure, economic inequalities, and market access, which are equally important in determining the capacity of marginalized groups to adapt to climate change.

The role of technology versus indigenous knowledge in climate adaptation is another contentious issue. Some scholars advocate for technological solutions, such as drought-resistant crops, weather forecasting systems, and irrigation technologies, as key to enhancing resilience. Thornton et al. (2014) argue that technological innovations can significantly boost the adaptive capacity of smallholder farmers facing unpredictable climate patterns.

However, others, such as Nightingale (2011) and Davidson et al. (2013), argue that indigenous knowledge systems rooted in local, community-based practices often offer more context-specific and sustainable solutions. For instance, traditional agro-ecological practices like crop diversification, local weather forecasting, and water conservation methods are seen as integral to adapting to climate variability. The controversy arises from



the tension between advocating for high-tech solutions and valuing traditional knowledge that may be more accessible and culturally appropriate.

There is a divide in the literature regarding whether climate adaptation should be driven by market forces or state-led interventions. Pelling and High (2005) argue that market-based solutions, such as insurance schemes, private-sector investments in agricultural technology, and demand for climate-resilient products, can drive large-scale adaptation efforts.

On the other hand, Adger et al. (2003) and Moser and Ekstrom (2010) contend that state-led initiatives are crucial for addressing systemic barriers to adaptation, particularly in areas with weak market structures and limited access to services. They argue that government programs focusing on infrastructure, education, and access to credit are essential for enabling adaptation, especially for marginalized groups.

This debate is particularly relevant in the context of international climate finance, where scholars and policymakers differ on whether funding should prioritize market-driven solutions or focus on strengthening local and national institutional capacities for adaptation.

A final area of controversy involves the tension between addressing immediate climate shocks (e.g., droughts and floods) and developing long-term adaptation strategies. Ribot (2014) argues that many adaptation strategies are reactive, designed to respond to acute climate events, rather than focusing on proactive measures to build long-term resilience. This short-term focus, according to Ribot, can undermine efforts to address the deeper,

systemic issues, such as poverty and land degradation that exacerbate vulnerability to climate change.

However, Watson et al. (2018) argue that immediate responses to climate shocks are necessary for protecting livelihoods in the short term, particularly in regions where farmers have limited coping mechanisms. The debate here centers on how to strike the right balance between emergency responses and long-term adaptation planning.

The actual factors that influence households to decide to change their farming practices and their choice of a particular adaptation measure at a given time in these areas were still not well known scientifically, despite the fact that it is possible to speculate and generalize the drivers, such as changes in the local climate, influence of markets or of researchers, political leaders, etc. Therefore, a scientific investigation was necessary to clarify the situation and provide pertinent and long-lasting strategic and policy answers to help the local community adapt to changes that force them to shift their farming practices.

1.3 Research Question

1.3.1 Main Research Question

What are the socioeconomic effects of smallholder farmers' adaptation to climate change in Ghana's Northern region?

1.3.2 Specific Research Questions

1. What adaptation strategies are employed by smallholder farmers in the study area in response to climate change?
2. What economic factors influence climate change adaptation among smallholder farmers?



3. What are the socio-economic barriers hindering climate change adaptation in the study area?
4. What improved traditional farming practices are adopted by farmers in the research area?



1.4 Objectives of the Study

1.4.1 Main Objectives of the Study

To determine the socioeconomic effects of smallholder farmers' adaptation to climate change in Ghana's Northern region.

1.4.2 Specific Objectives

1. To investigate the adaptation strategies employed by smallholder farmers in the study area in response to climate change.



2. To analyse the economic factors influencing climate change adaptation among smallholder farmers.
3. To identify the socio-economic barriers hindering climate change adaptation in the study area.
4. To explore improved traditional farming practices adopted by farmers in the research area

1.5 Justification of the Study

Smallholder farmers are particularly vulnerable to the impacts of climate change due to their limited access to resources, reliance on rain-fed agriculture, and lack of adaptive capacity. Understanding how these farmers are adapting to climate change is crucial for developing effective strategies to support them. Smallholder farmers play a significant role in ensuring food security in Ghana. Climate change can disrupt agricultural production, leading to food insecurity. The study provide insights into improving food security in the region. The findings of the study can inform policymakers and stakeholders about the challenges faced by smallholder farmers in adapting to climate change. This study will contribute to designing policies and programs that support these farmers in building resilience to climate change impacts. Climate change have significant socioeconomic impacts on smallholder farmers, affecting their livelihoods and well-being. The study identify the factors influencing farmers' adaptation strategies and their effectiveness in mitigating the impacts of climate change. There are limited research on the socioeconomic aspects of climate adaptation among smallholder farmers in Northern Ghana. This study can help fill this knowledge gap and contribute to the existing literature on climate

adaptation in the Northern region. The study is important for understanding the challenges and opportunities for building resilience to climate change in the agricultural sector, ultimately benefiting both the farmers and the broader community.

1.6 Scope of the Study

Geographically, the inquiry was carried out in three districts of the Northern Region. This region was chosen due to the high levels of food insecurity, which are aggravated by socioeconomic and environmental stress, as well as the availability of active programs designed to promote resource conservation and sustainable agriculture practices as components of adaptation strategies. The study's background concentrated on the resilience and adaptation strategies utilized by smallholder farmers in the context of the social and economic environment. The study also focused on neighborhood organizations to assess how well they assisted smallholder farmers in creating plans for coping with climate change.





1.7 Organization of the Study

The thesis is organized into five chapters. Chapter one deals with the introduction of the study. It focuses on the background of the study, problem statement of the research, objectives and questions of the study, the justification of the study, and definitions of key terms use for the study.

The chapter two reviews and discusses literature relevant to the topic to establish a theoretical approach for the research. The areas of literature considered very relevant to the study and provides enough evidence for analytical discussion to support the study.

Chapter three focuses on instruments used to collect needed information for this study, it also presents research design, sampling procedure, data collection and analysis. Chapter four presents results and discussions of findings of the research within the context of the study objectives. Chapter five, the last chapter, focuses on conclusion, implications and recommendations base on the findings of the research.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

In this chapter, a review of the literature is given with an emphasis on the outcomes, adaptation, and adaptability of smallholder farmers as well as their sensitivity to climate change and unpredictability. The chapter is divided into three main sections: a description of climate change, its effects and vulnerabilities, and a summary of the most important takeaways from the review. The international community has come together to confront the problems related to climate adaptation and resilience due to the urgency, anxiety, and concern about the existing effects, uncertainties, and future climate trends.

Concerns have been raised about the possible threats posed by climate change to human and national security, human and natural ecosystems, food security, water availability, the sustainability of natural systems, national and international economies, as well as a variety of other issues. Through the UN Framework Convention on Climate Change, a number of parties including researchers, negotiators, governmental and non-governmental actors, and indigenous people convene at various levels to talk about how they can best and mutually assume responsibility, including policies and strategies to address the impacts of climate change. The global community should be concerned about climate change, but why?

2.2 Reasons for Climate Adaptation

The global community is growing more worried about the effects of climate change as a result of scientific understanding of the climate system. The Sun's energy heats the Earth after passing through the atmosphere as light waves (Mitchell, 1989). The energy is split





between warming the Earth and returning to the atmosphere as infrared radiation, according to Mitchell (1989). Typically, greenhouse gases in the atmosphere regulate the Earth's temperature, keeping it comfortable and habitable and sustaining the balance between social and natural processes (Al Gore, 2006; Haughton, 2009; McMullen, 2009; Mitchell, 1989). This helps to prevent greenhouse gases from entering the Earth's atmosphere, which in turn serves to slow down global warming. As a result, the conditions for life on Earth have always been favourable. The layer of atmospheric greenhouse gases is currently getting thicker as a result of the significant emissions of carbon dioxide and other greenhouse gases caused by human activity (Mitchell, 1989). More infrared radiation that would ordinarily escape from the atmosphere is retained as the thickness rises (Al Gore, 2006). As a result, the Earth's oceans and atmosphere are warming at worrisome rates (Haughton 2009; Al Gore 2007; McMullen 2009). As a result of this knowledge, the IPCC listed five causes for concern regarding climate change in its Third Assessment Report, which was published in 2001. The five factors identified by the IPCC (IPCC, 2001) include the risk to rare and threatened ecosystems, the risk of extreme weather events, the distribution of impacts, the extent of aggregate impacts, and the dangers of large-scale discontinuities.

Adger and Barnett (2009) draw attention to concerns concerning adaptability in the global society. They also incorporate the relationship between the magnitude of a change and its outcomes. The issue is that if the degree of change and link to the consequences are so close together, giving little time for adaptation to take place, the likelihood of successful adaptation is reduced and the likelihood of catastrophe is enhanced. As a result of the global community's inability to address this mitigation, emissions are continuously rising (WMO,



2012; 2013). Despite arguments and the Kyoto Protocol's emission goals, this is the case. This suggests that if emissions increase, it will be hard to adequately build resilience because both the impacts and their severity would worsen over time. The possible gap between adaptable capacity and actual adaptation and responsiveness on the ground, or between adaptable capacity and adaptation as action (Eisenack and Stecker, 2011), is another cause for concern (Roperto, 2009). Having institutions, funding, technology, early warning systems, and other components of adaptive capabilities to climate change in place does not ensure that there will be genuine adaptation activities on the ground at the household, municipal, national, and institutional levels (Roperto, 2009). Everything is dependent on a number of other variables, including the size of the shift, its timing, and how closely it relates to prospective outcomes. Other issues include the distribution and application of resources to guarantee the success of adaption measures. A description of how Hurricane Katrina damaged New Orleans in 2005 is given by Adger and Barnett (2009). The authors assert that numerous people perished and significant losses in property and other things were incurred even though the United States of America met all the criteria, showing that the nation had the capacity to adapt and had managed climate resiliency.

2.3 Definitions of Key Concepts and Terms

2.3.1. Climate

According to the Intergovernmental Panel on Climate Change IPCC (2018), climate refers to the mean meteorological conditions or a numerical depiction of the mean and variability of appropriate variables across time, such as temperature, rainfall, and wind. For the purposes of this study, climate is defined as the ordinary weather or as the

statistical analysis of significant variables like temperature, precipitation, and wind through time in terms of their mean and variability. The period of time is typically 30 years.

2.3.2 Climate change

Both a location's typical annual rainfall and its average annual temperature are prone to fluctuation. Climate change is defined as a long-term shift in the statistical distribution of weather patterns (temperature, precipitation, etc.) over a time span of decades to a million years (Rahman, 2012; Kasuli, 2022). A climate change, as defined by the UNFCCC (2012), is any change in the weather that can be directly or indirectly linked to human activity, is noticeable over a specific time period, and modifies the makeup of the entire atmosphere. Climate change is any change in the climate over time, whether brought on by natural variability or human action, according to the IPCC (2001).

It is amazing how similar the definitions of climate change are among well-known international organizations. As a result, as opposed to climatic variability, which has natural origins, the IPCC and UNFCCC describe climate change as the outcome of human activity modifying the planet's atmospheric composition. Similar to this, the IPCC's definition of climate change takes a wider view and acknowledges that human action as well as natural variability can contribute to it. According to this study, a change in a region's climate that can be connected either directly or indirectly to human activity that modifies the earth's atmosphere is referred to as climate change.





2.3.3 Adaptation

"Adaptation" has been defined in a variety of ways in a variety of contexts, like many other technical terminologies used in social scientific research. adaptation to current or future climatic stimuli, as well as to those stimuli's effects or side effects, on biological, social, or economic systems. This expression refers to modifications made to practices, routines, or organizational structures in an effort to mitigate potential harms, make up for them, or take advantage of possibilities brought on by climatic change. It involves making adjustments to minimize the sensitivity of communities, regions, or activities to climatic change and volatility; (2001). responses or measures taken to make vulnerable systems more resilient, hence minimizing harm from climate change and variability to human and natural systems Grambsch and Séraga (1998).

The process of adjusting to the effects or risks brought on by climate change is known as adaptation to climate change (Nyong, et al.). Systemic changes are discussed, whether they are ecological, social, or economic changes (Smit et al., 1999). Climate change adaptation is the process through which people, groups, civilizations, or systems modify their normal behaviors in response to climate change stimuli, independent of the origin, time, scope, location, impacts, form, or performance of those actions (Smith et al., 1999).

These alterations are a reaction to either the actual or prospective effects of climate change. Depending on the economic activity, a human system or an individual will have a number of possibilities to pick from; as a result, one must carefully analyse each option and choose which is the most practical at the time. It is incorrect to believe that adaptation is a separate process. It typically depends on the operation and effect of a number of factors, including



economic, cultural, political, geographical, ecological, and institutional aspects. Each of these influences' human-environment interactions individually and/or collectively (Eriksen et al., 2011). According to certain scholarly publications (Eriksen et al., 2011; Adger et al., 2003), there are various types of adaptation, such as reactive vs. anticipatory, planned vs. natural, replace vs. complement, and short-term vs. long-term. Due to their practical connection, there may be a thin line in nomenclature separating each situation.

The growing interest in mainstreaming climate change adaptation into sector planning and budgets in developing nations during UNFCCC negotiations is evidence of the practical, bottom-up analysis method. The cause is that, in the near term, adaption management necessitates a project - based strategy that ignores sustainability concerns. Adaptability must be considered in planning and budgeting by local organizations, as well as by governmental and non-governmental groups. It is only feasible if thorough research are conducted that reveal the adaption requirements of particular locales and account for all relevant local factors. To determine needs and the kind of support required, when and how, taking into account the social-ecological system setting, localized studies are required. Broad-based simulations and models may be useful for forecasting the future based on information currently in the public domain, but they are unable to account for the social-ecological system's context.

2.3.4 Resilience

Since it is employed in many contexts and academic fields, resilience is understood in various ways. Shock tolerance is the capacity of a system to withstand shocks or to adapt in response to stress while still performing its essential activities (Nelson et al., 2007). The



IPCC (IPCC, 2007e) defines it as a social or ecological system's ability to self-organize, its capacity to adapt to stress, including change, and its capacity to withstand perturbations while keeping its fundamental structure and modes of operation. As opposed to this, other studies (Carpenter et al., 2001; Berkes et al., 2003; Folke, 2006) define resilience as the amount or level of stress that a system can withstand while undergoing a state change, including the capability to adapt to the acceptance of additional shocks. The sustainability idea must include resilience. According to Gunderson and Holling (2002), Berkes and colleagues (2003), Carpenter and others (2001), and other researchers, resilience in this context refers to a system's ability to regenerate, restructure, and undergo development, or to be able to maintain itself despite any forces applied to it.

For instance, Adger (2006) argues that resilience offers the potential for positive change by embracing new understandings regarding laws, technologies, information, and even development paths that are significantly more flexible than the previous one. The capacity to withstand shocks while maintaining system functionality is how many people define resilience. Because of this, opportunities presented by resilience may be far greater than previously imagined. Resilience is defined by Walker and colleagues (2002) as a system's ability to sustain a given degree of stress without losing its functionality or even its structure. A system's ability to self-organize and how prepared it is to adjust and carry on with its evolution in a sustainable manner are also factors.

The conceptual underpinning for this study was developed in 1989 and is based on works by Chambers and Nelson and associates (2007). The work of Nelson and colleagues (2007) is so important for describing and analysing the adaptation of social ecological systems



within the framework for social ecological resilience that it serves as a significant impetus for adaptation within the framework while taking sustainability component into consideration. Chambers' (1989) work is essential because it provides a thorough analysis of the vulnerability and adaptability problems at a local level that were the focus of this investigation. This research was based on a study by Chambers (1989), which provides a wealth of knowledge on the sensitivity and adaptability of smallholder farmers.

Intra-seasonal dynamics (Tennant and Hewitson, 2002), rainfall distribution within the growing season (Mortimore and Adams, 2001), and without overemphasizing the extent to which rain is effective in each precipitation event are key rainfall variables important for crop production that can influence smallholder farmers' decisions. Each of these has a substantial influence on smallholder farmers, who have few options and must make difficult choices in order to change their farming practices. Adding new crops or crop varieties, altering planting dates, putting in place new operational procedures, engaging in off-farm activities, and/or diversifying income sources are just a few of the potential changes that could be made (Thornton et al., 2007; Maputo et al., 2010).

2.3.5 Climate change adaptation

Climate change adaptation is defined as a process, or the result of a process, that lowers risk or harm or results in the realization of benefits related to climate variability and climate change by the United Kingdom Climate Impact Programme (UKCIP 2003). The process of enhancing, developing, and implementing ways to lessen, manage, and benefit from the effects of climatic disasters is referred to as climate change adaptation, according to the United Nations Development Programme (UNDP) (2005). The IPCC defines adaptation to



climate change as the modification of natural or human systems in response to recent or anticipated climatic stimuli or their effects in a way that minimizes harm or seizes advantageous opportunities. (2018) the corner of Clarke. The IPCC divided adaptation into a number of categories, including anticipatory (proactive), autonomous, and planned adaptation.

According to the IPCC, anticipatory adaptation (proactive adaptation) is adaptation carried out before the effects of climate change are observed. Clarke and Corner (2018). Reactive adaptation, according to Corner & Clarke (2018), is adaptation carried out after the effects of climate change have already been felt.

The IPCC claims that a deliberate reaction to climate stresses results in autonomous adaptation. However, natural system environmental changes are to blame (Corner & Clarke 2018). The IPCC claims that knowing that conditions have changed or will change and that, as a result, action is required to reach the intended condition, leads to the adaptation of purposeful policy outcomes. Clarke and Corner (2018) According to the IPCC (Corner & Clarke 2018), a private adaptation is one that is started and carried out by an individual, a family, or a business out of self-interest. The IPCC highlighted that public adaptation often occurs when the central government starts and implements adaptation measures from the national to local levels.

The definition of climate change adaptation used in this study will be taken from the NCCP (2013), which says that it is "the adjustment in natural or human systems as a result of the real or anticipated climatic stimuli or their effects, which controls harm and exploits useful opportunities with a dynamic process of economic development" (NCCP, 2013).



2.4 Smallholder Farmers in Ghana

Africa has 475 million smallholder farmer households, which account for two-thirds of the 3 billion rural residents of emerging nations. A crucial attribute of a smallholder farmer is that they work on agricultural land that is less than 2 hectares in size. This definition makes some generalizations about how two farmers working on less than 2 hectares of land could have different results in terms of productivity and resource consumption, despite the fact that it is widely accepted because of how the term "smallholder" is defined. The specific dynamics of smallholder farmers in Ghana will be discussed in the discussion section, though, in light of their unique capacities for adaptation. In Ghana, 90% of farms are small-scale, with the majority having less than 2 hectares of land. The food crop sub-sector in Ghana is dominated by smallholder farmers who employ conventional farming methods and implements like the hoe and cutlass. Mechanized farming is uncommon among smallholder farmers. The degree to which a Ghanaian farmer can adjust to risk exposure and the accessibility of resources also significantly affects the farmer's overall production. Farming yields are influenced by precipitation, temperature, and the makeup of the soil because agricultural output is reliant on environmental and climatic variables. Intercropping is common on farms that raise food crops. Mono-cropping is now utilized, however it is normally only done on larger, commercial farms, such as block farms.

The smallholder farmer can be compared to an entrepreneur in terms of how hard he works to manage his business by raising money from various sources and investing in productive assets, even the most basic ones like a bicycle or a hoe. The smallholder farmer also takes



calculated risks in an effort to make a little money. Making decisions typically involves choosing what to cultivate, what equipment to use, how much produce to sell and how much to keep for personal use. These are important decisions that smallholder farmers must make on a daily basis. Like other African countries, Ghana's smallholder farmers play a key role in the country's food production. Due to this, numerous efforts have been made to enhance and scale up their operations, particularly in light of climate change.

2.5 Climatic Conditions in Ghana

Ghana is situated north of the equator between the longitudes of 3.5°W and 1.3°E and the latitudes of 4.5°N and 11.5°N. The two main climatic seasons in Ghana, which, according to the Koppen Classifications, is in the tropical climate zone, are the dry season and the wet or rainy season. Ghana is divided into three (3) climatic zones: the Southern Savannah Climate Belt in the north, which experiences a single rainy season from the end of May to September and a drought from mid-October to mid-May; the Tropical Forest Climate Belt in the southwest of Ghana; and the Accra Plains in the Coastal Savannah Climate Belt. The agricultural sector in Ghana is divided into five main subsectors: Crops (apart from cocoa), Cocoa, Fisheries, Forestry, and Livestock. The fight against malnutrition, hunger, poverty, and disease in this continent, has become more challenging as a result of climate change's effects on agricultural productivity, which is the basis of people's livelihoods and suggests that the agricultural sector employs about 60% of the labour force and contributes an average of 30% to Gross Domestic Product (GDP) in Africa. As it is in many other Sub-Saharan African countries, agriculture is a major economic force in Ghana. However, the contribution of agriculture to Ghana's GDP has drastically dropped in recent years. The



Ghana Statistical Service reports that the services sector now makes up 46.3% of the GDP of the nation, with agriculture coming in second place with 19.7%. The decrease in the agricultural sector's share of GDP has been attributed to a number of factors, including environmental stressors like rain that comes and goes too quickly, temperatures that are rising, and extended droughts. Smallholder farmers have created a variety of coping and adapting techniques to deal with these challenges.

2.6 Global efforts and key challenges

Given that, among other things, the impacts and consequences of climate change are global in scope, it is now generally acknowledged that international cooperation is essential to achieving the magnitude of reaction that is necessary (World Bank, 2012). The international community has worked to combat climate change as a global challenge that necessitates joint efforts and international cooperation. This must be understood and valued. One of the most significant initiatives was the UNEP and WMO's creation of the Intergovernmental Panel on Climate Change in 1988 (EEA, 2013). This was and continues to be an undertaking that merits praise since it has produced a wealth of knowledge that supports the design of policies, initiatives, and conversations at all levels. Since then, the IPCC has made a considerable contribution to deepening our knowledge of the scope and severity of climate change. The economical, technical, and environmental dangers connected with climate change have become more widely known over the past 20 years, which has had an impact on decision-making and the negotiation process. Additionally, discussions and negotiations that resulted in several treaties under the UNFCCC and far beyond were sparked by the IPCC Assessment Reports 1 through 4, special reports, and other scientific and technical publications. There have also been more studies and



publications from a range of professionals at different levels, which has prompted more discussions and increased understanding of climate change and adaptation measures.

It has also become increasingly necessary to perform extra studies on climate change at this time. Ratification of the UN Framework Convention on Climate Change (UNFCCC) at the 1992 United Nations Conference on Environment and Development in Rio de Janeiro was a significant step in the fight against climate change. Even though it is still debatable whether the Kyoto Protocol was successful in achieving its objectives, it was ratified in Kyoto, Japan, in 1997, and this was an important event. In some ways, the International Community's efforts to establish a global framework that enables nations to negotiate and come to agreements on policies and strategies that help address climate change in the following crucial areas through the UNFCCC have been successful. Mitigation and adaptation; scientific study to deepen comprehension of the issue, its scope, and forecast future effects pioneered by the IPCC; setting up funding arrangements and subsequently establishing climate change funds.

2.7 Impacts and Vulnerability

Due to the wide spectrum of consequences that climate change has, depending on the ecosystems of a region, these effects can either be positive or negative. Impacts that are presently being felt as well as those that have not yet been felt but are predicted to occur have been revealed by the IPCC and other scientific research initiatives (IPCC, 2007b; 2001; UNEP, 2012a; World Bank, 2012; Houghton, 2009). But the earliest predictions and estimates for the future are hazy and incorrect. This is due to the fact that while many other elements may be predicted and simulated using scientific models, some of the traits are



difficult to forecast with sufficient accuracy. Scientists believe some of these to be poorly understood, making it difficult to model and simulate what might actually happen (NRC, 2010). As a result, there are significant uncertainties regarding the magnitude and rate of the global climate system's change as well as the precise effects at low levels. The complexity of the world's climate system generally implies that what scientists currently understand and can foresee represents just a portion of what is and will occur in the future. Not all climate system complexities can be accurately anticipated using GCMs, despite the fact that scientists can use a variety of factors to mimic them (Schneider, 1992).

There is currently enough knowledge available on the risks associated with it to make informed judgments, notwithstanding the difficulties in precisely anticipating the effects of climate change, particularly unpredictable human behaviour (Schneider, 1992; IPCC, 2007b; Al Gore, 2007). Access to water, food security, agricultural production, health, and land use would all suffer, especially in developing countries (Global Humanitarian Forum, 2009). The melting of glaciers, flooding, prolonged and frequent droughts, reduced water availability, decreased crop yields, an increase in vector-borne diseases like malaria and dengue fever, and rising sea levels that force people to relocate while upsetting both terrestrial and marine ecosystems and significant natural habitats are just a few of the severe effects, particularly in Africa (IPCC, 2007b; UNFCCC, 2007).

Despite the fact that many publications on climate change have focused on how its effects are and will be detrimental to human livelihoods and economies (IPCC, 2007b; FAO, 2008; Lyamchai, et al., 2011; Stern, 2006; UN-Habitat, 2011; IPCC, 2012a), there are others that have focused heavily on how ecosystems are currently being impacted by changes in the



climate system and to what extent they are projected to be impacted (for example, Foden, 2010). It should be underlined that climate change continues to be the primary factor in determining whether life will persist on Earth and whether any ecosystem will survive. It consequently has a variety of effects on ecosystems, including limiting the range and activity of organisms (Pearson and Dawson 2003), affecting the availability of surface and subsurface water (Vörösmarty et al. 2000), and regulating the dynamics of all ecosystem processes over time and space (Bachelet et al. 2001).

Depending on the characteristics of each individual ecosystem, climate change is projected to have an effect on them. Several effects have been highlighted in various research works, including changes in some species' distributions in both higher and lower latitudes (Lee and Jetz 2008), changes in the composition of some ecosystems as a result of an increase in temperature (Daufresne and Boet 2007; Lemoine, et al., 2007), and the spread as well as establishment of invasive species in particular ecosystems (Hellmann, et al., 2008), to name a few. Other key ecosystems that sustain life, ecosystem functions, and other natural processes, as well as those that provide commodities and services for livelihoods, consequently experience the consequences of climate change indirectly. According to certain scientific research, climate change will have an impact on the amount, quality, and recharging of groundwater. This might have disastrous consequences, such as accelerating the intrusion of saline water into freshwater sources, especially close to the shore (Al-Gamal et al., 2009). This is already occurring in nations like Ghana, where the intrusion of salt water has turned some of the fresh water wells along the coastline unmanageable and useless.



Because it worsens food insecurity (FAO, 2008), raises the risk of diseases like cholera and other illnesses linked to disasters like malaria (IPCC, 2007b), makes water scarcer, and increases the likelihood of social conflicts over resources (Barnett and Adger, 2007), climate change poses a serious threat to people's ability to sustain their way of life, particularly in the developing world. The FAO (2008) claims that the food system is susceptible to climate change because it has an impact on the four key elements of food security availability, accessibility, utilization, and stability. Small-scale agriculture is expected to be impacted by climate change in many developing nations. In addition to producing income and making a sizable contribution to GDP, this business supports millions of jobs, particularly in rural areas (FAO, 2008). In developing countries, the effects of climate change on agriculture, freshwater, livestock, fisheries, and ecosystems will be catastrophic (Ibid.) additionally, it provides food for the majority of the urban and rural populations in these nations. According to the Global Humanitarian Forum (2009), many of these nations ultimately endure increased poverty. In recent years, millions of people in numerous African regions, particularly the Horn of Africa and the East of the continent, faced the possibility of starvation (OCHA, 2011). Although other factors (such as ongoing conflicts and political crises, low soil productivity, poverty, and other issues) may be to blame for the droughts and hunger in these regions of the continent, the significance of climate change and variability cannot be overstated (Funk, Michaelsen, and Marshall, 2011).

2.8 Smallholder Farmers Adapting to Stresses

The same type of farming goes by the titles of family farming, small-scale farming, and smallholder farming (Murphy, 2012). It is most common in developing nations and is



defined by the size and scope of the actual farming activity, including the quantity of land used, the number of labour needed, the inputs used, the degree of mechanization, etc. (Morton, 2007). Smallholder agriculture is defined as farming activities carried out in a relatively small area with little to no modern, purchased inputs, outputs that are primarily consumed directly, and little to no food that is transferred to markets, according to Barnett and colleagues (1997, cited in Morton, 2007). The adage can also be used to describe a specific economic structure that is prevalent in rural, underdeveloped developing nations and that heavily depends on family-run, small-scale farming to feed the bulk of its population (Cornish, 1998). The phrase "smallholder farmer" is used to describe someone with a small-scale agricultural, pastoral, or fishing activity, according to Allison and Ellis (2001). Additionally, it includes pastoralists whose main source of income is from raising livestock and selling the goods they produce. The characteristics of smallholder farming include tiny farms with an emphasis on official or informal tenure and output for immediate use. Some of these farms are situated in marginal zones, which are vulnerable to environmental hazards and natural calamities such soil erosion, floods, droughts, crop failures, and animal diseases (Fairtrade, 2013). Aside from farming, farmers that practice this sort of farming also partake in a range of non-farm pursuits like hunting, gathering, and other types of activity (Ellis, 2000). This mode of production is clever and has developed knowledge and technologies of managing landscape, land, and water resources as well as conservation as a result of long-term experience in the local environment, various stresses, and the need to survive despite appearing to be small-scale and underdeveloped (Altieri and Koohafkan, 2008).



Smallholder farmers have always had the choice to alter their farming methods or respond to local environmental challenges. Using historical data and conventional wisdom, smallholder farmers have dealt with the effects of a changing climate and other difficulties for many generations (Altieri and Koohafkan, 2008). They have occasionally used their earlier experiences and local knowledge to adjust to such changes. In order to achieve food security at the household and community levels in the past, smallholder farmers had to develop complex agricultural systems that were tailored to the local environment and used locally tried-and-true techniques and practices (Altieri and Koohafkan 2008). These systems did not even entirely rely on the influence of governments, scientists, and researchers.

There are a lot of impressive instances all around the world, but they are uncommon. Numerous cropping methods are used in Chinampas, Mexico, the nomadic and semi-nomadic pastoral systems of the Maasai in Tanzania and Kenya, and intricate multi-layered home gardens with wild and domesticated plants for foods, medicines, ornamentals, and the like are also found in China and India (Koohafkan and Altieri, 2011). These prehistoric irrigation, soil, and water management techniques are also found in Iran, Afghanistan, and Mali. Other areas of inquiry have extensively covered this topic as well. For instance, according to research by Koohafkan and Altieri (2011), the majority of farmers in developing countries practice smallholder subsistence farming on typically marginal lands with comparably small plots, using little to no modern technology for farming and farm management and instead relying on local knowledge, including techniques. These farmers have developed effective farming diversification strategies throughout time through crop biodiversity (Altieri and Koohafkan, 2008; Koohafkan and Altieri, 2011).



Furthermore, it has been determined that, just in West Africa and Latin America, more than 40% of cassava, 60% of maize, and 80% of beans are intercropped with other crops (Koohafkan and Altieri, 2011). This demonstrates the inhabitants' seasoned knowledge and expertise in using traditional farming methods. This strategy promotes soil fertility, food security, the preservation of biodiversity, adaptation to climate change and variability, and the prevention of crop disease. These products, according to Altieri and Koohafkan (2008), are the outcome of long-standing local inventions and data gathering. They are, nevertheless, frequently a reaction to particular stimuli and a justification for farmers to change their methods of production partially or completely in an effort to maybe gain more or keep up with contemporary advancements. Africa's smallholder farmers have had a significant impact on the inventive history of smallholder farmers worldwide. Similar to people in other regions of the world, they have a long history of responding to a range of changes that have somehow impacted their farming activities. In response to environmental change, climatic change, and other pressures, farmers have used a number of techniques throughout history. Increased irrigation, repeated cropping, and the incorporation of animals are some of the measures used by smallholder farmers in 26 African nations to combat climate stressors, according to Hassan and Nhemachena (2008). According to Paavola (2008), extending the area under cultivation, boosting agricultural production, varying one's source of income, and migrating are the most typical adaptation techniques utilized by smallholder farmers in Morogoro, Tanzania. The use of technology, improved farm management, and farm financial management are additional examples of solutions (Below et al., 2010). Other options include changing planting dates, crop varieties, and employing a multitude of locally developed and adapted soil conservation measures



(Acquah, 2011). The idea is that everything depends on the circumstance, the level of stress, the resources available both internally and externally as well as on the environment, culture, and economic circumstances, among other factors. The list might be extensive. In order to be able to respond to the particular stress, smallholder farmers also make decisions depending on their capabilities and try out fresh solutions.

Today's environmental and climatic change, however, is happening more quickly and intensely than smallholder farmers can keep up with. Accurate forecasts of the farm's future production process may no longer be possible using historical averages or regional forecasting techniques. As storms, floods, and droughts happen more frequently and unpredictable, losses and damages from extreme weather events are rising. Smallholder farmers may not always profit from improvements to their farming methods that lead to resilient development and sustainable adaptation in light of the present environmental and climatic changes. However, considering that the frequency and severity of the impacts are increasing as a result of climate change, they might only be beneficial for a short while (Nelson et al., 2007). This information and technology foundation are crucial for the creation of enhanced adaptation solutions at the local, national, and worldwide levels.

2.9 Vulnerability and Adaptation in Key Sectors

The mitigation of climate change, which was formerly the dominant focus (Campbell, 2009; IPCC, 2007b; Grothmann and Patt, 2005), has advanced despite the recent positive attention given to adaptation. This transition may have been influenced by a number of variables, such as the fact that GHG emissions have increased despite all mitigation efforts (WMO, 2012: 2013) and that certain consequences are already being felt by some



communities and individuals (Ayers and Huq, 2010; Ayers, 2010). Also important to note is that, despite efforts to restrict emissions, adaptation is necessary due to the massive quantity of GHGs that have already been deposited in the atmosphere (Pielke, et al., 2007; Snover, et al., 2007; Nyong, et al., 2007).

Therefore, whether or not mitigation takes place, adaptation is a required reaction to the effects of climate change, particularly in Africa (Picketts et al., 2012). Both Eriksen et al. (2007) and Nyong et al. According to Nyong et al. (2007), many requests have been made for both mitigation and adaptation efforts to be carried out at the same time because they are both necessary and dependent upon one another. Therefore, pursuing both at once will improve efforts to eradicate poverty and help the most vulnerable people adjust to the changes (Nyong, et al., 2007).

In order to express both the degree of susceptibility and the degree of responsiveness to the consequences, this section makes an effort to define vulnerability and adaptability in accordance with the major economic sectors. The availability of a wide range of technical possibilities, the seriousness of the effects or stimuli, and other factors all have an effect on how adaptive reactions change. In light of this, solutions can be policy-, managerial-, behavioural-, or technological-related (IPCC 2007; Flm and Skjaerseth, 2008).

2.10 Climate Change Impacts on Agriculture

A wide range of effects on agriculture are caused by climate change and instability. Both the biophysical elements, such as plant and animal growth, and the physical infrastructure involved in food production and delivery are directly impacted by climate change. Crop productivity is also indirectly impacted by it. According to a study titled "Impact of Climate



Change on Crop Yield and Food Accessibility in Sub-Saharan Africa," climatic extreme events like rising average temperatures, droughts, heat waves, floods, wildfires, changes in rainfall amounts and patterns, rising atmospheric CO₂ concentrations, extreme changes in climatic variability, seawater rise, etc. directly affect crop production. In fact, it is anticipated that a 1 to 2 C increase in the earth's surface temperature will lead to a decline in agricultural production in tropical and subtropical regions because of increased plant evapotranspiration and low accessible soil moisture content. Furthermore, it is predicted that climate change would affect some regions' intensity of rainfall, which will affect soil erosion and soil moisture, both of which are crucial for agricultural production. Estimates indicate that Sub-Saharan Africa would experience a 20% decrease in rainfall. Such conditions are likely to result in the loss of arable land due to causes including decreased soil moisture, increasing aridity and salinity, and groundwater depletion, among others. Africa will warm by 0.2 to 0.5 degrees Celsius every decade, predicts the Intergovernmental Panel on Climate Change (IPCC), which could have a significant impact on West Africa's climate-sensitive crops such maize, sorghum, cassava, yam, and cowpea. Local agricultural production has always been impacted by climate change and is now being impacted. Although rainfall averages have since recovered, West Africa went through a particularly dry phase from the 1960s to the 1990s that was characterized by devastating droughts in the Sahel and the semi-arid Guinea-Savannah. It is significant to emphasize that water scarcity hinders agricultural productivity because irrigation infrastructure is expensive. Smallholders in the region would eventually suffer as a result of this, both physically and financially. Climate-induced sea-level rise brought on by rising global temperatures affects low-lying agricultural lands and coastal regions in some parts



of West Africa (The Gambia, Senegal, and the Gulf of Guinea), which are already afflicted by flooding and soil salinization. This results in the loss of agricultural land, as well as the loss of farmers' income and food supply systems. Significant climatic concerns for agriculture and food production in general were predicted by numerous studies showed that a 1.45°C increase in average temperature will occur in Ghana's sub-humid region by the year 2050. Along with an increase in rainfall intensity and a potential rise in inter-annual rainfall variability, fewer wet days were observed. One example of this variability is a shift in the nation's rainfall patterns, which had a significant impact on the country's rain-fed agriculture. Agriculture has many facets, crop production being only one. In order to produce crops, a successful farm needs a lot of human labor as well as financial investment. For instance, poor weather has a significant negative impact on smallholder farmers in Ghana. Their capacity to survive is significantly impacted by rain. Since agriculture accounts for a large portion of the economy of African countries, the adverse effects of climate change, such as declining agricultural production, ultimately limit their economic progress. Smallholders are consequently directly impacted by climate change because they cannot sustain themselves through the production of food crops and because their access to money is restricted.

2.11 Climate Change and Adaptation in Africa

Africa is a continent with abundant natural resources and a variety of climate zones as a result of its size and position, but it is also one of the most susceptible due to its weak capacity to adapt to climate change, which may vary from one country to another. The causes of Africa's vulnerability include a high level of sensitivity to resources like water, food, and health; susceptibility to natural disasters (droughts, floods, and storms); climate



variability; and a weak socioeconomic profile with regard to resources, livelihood practices, agriculture, and social networks. The poverty rate in sub-Saharan Africa's rural areas has reduced from 64.9% in 1998 to 61.6% in 2008, although it is still twice the global average. 98% of occupations in these areas are related to agriculture. The manner of life of African tribes is likely to be drastically affected by even a slight difference in rainfall. Such factors combined offer a comprehensive and all-encompassing threat to the way of life of Africans. Agricultural productivity is expected to decrease by 10% to 50% by 2050 in most African zones due to declining and insufficient rainfall using present farming methods, with 70% of Africa's population dependent on rain-fed agriculture. Additionally, all of Africa's terrestrial ecosystem types, including forests, savannas, grasslands, and shrub lands, are undergoing functional changes. Climate change is the primary cause of these changes. Aside from that, "climate change and climate variability are likely to threaten agricultural potential, food security, and nutrition in most of Africa; as well as aggravate the water stress currently experienced by some countries, while some countries that never experienced water stress will become at risk." With considerable dangers to food security, negative effects on employment and human health, and severe repercussions on food production, including a decline in ocean productivity, West Africa is likely to experience these effects. Scientists are detailing the various benefits of agricultural diversification strategies in response to this challenge, notably in Sub-Saharan Africa. The use of varietal variation in monocultures, the blending of crops with non-crop vegetation, crop rotation, poly cultures (including wild varieties), agroforestry and mixed landscapes, as well as water and soil conservation methods like half-moon, zai, and stone lines, are some of these approaches. These systems have several benefits, including the eradication of pests and



illnesses, increased productivity, enhanced production stability, and climate stress buffering as a kind of climate adaptation. Despite efforts, it appears that these technologies won't be efficient anytime soon based on climate forecast scenarios. Through participative and engagement approaches, it is crucial to systematically examine how traditional African worldviews impact how individuals perceive the risk posed by climate change, how they come up with adaptation plans, and how they create and carry out policies.

2.12 Social Ecological Resilience Framework

According to some, the concept of resilience has its roots in ecological studies and is attributed as having first appeared in the 1960s and 1970s with the contributions of Holling to the field of ecological sciences (Nelson et al., 2007; Folke, 2006; Gunderson, 2000). Since then, the idea has advanced significantly and gained support from a variety of academic fields, such as engineering, psychology, philosophy, economics, and others (Folke, 2006; Martin-Breen and Anderies, 2011; Gallopin, 2006). A number of authors (Folke, 2006; Martin-Breen and Anderies, 2011; Grimm and Wessel, 1997; Janssen and Ostrom, 2006; Gallopin, 2006) have argued that the concept's meaning has been clouded by changes in usage and variances between study fields. The idea of social ecological resilience has grown as a result of its use in social science research. A well-established idea holds that social and ecological systems are best understood as a single complex system, and system resilience can be used to plan and implement adaptation to environmental change (Nelson et al., 2007; Berkes et al., 2003).

The terms coupled human-environment systems (Turner et al., 2003), socio-ecological systems (Malone, 2009), and socio-ecological systems (Gallopin et al., 1989) refer to the



social subsystem (people, their activities, as well as social structures and institutions), and the ecological subsystem (the natural environment, its resources, and everything that directly or indirectly affects it). Since human activities are inextricably linked to nature, human life on earth depends on the biological diversity of not only its immediate surroundings but also how it interacts with other areas of the environment as a whole. The social-ecological system is broadly defined by Berkes and Folke (1998) to include biological and biophysical processes that are visible, known, and even those that are not visible or unknown, as well as natural processes and interactions of natural elements of the environment ranging from minor, simple interactions to complex interactions. On the other hand, the social system is made up of governance systems that establish guidelines for how individuals should act, interact, and utilize resources on a daily basis (Berkes et al., 2003). Institutions of every level of socio-culture are also a part of it. Because of their interconnection, social and ecological systems have an impact on one another. The social system is shaped by the natural system through human reliance on and use of the natural environment for sustenance, which in turn shapes the social system (Millennium Ecosystem Assessment (MA), 2005). Important ideas like vulnerability to adaptation, adaptive capacity, and resilience are clearly explained in research works (Adger, 2006; Berkes and Folke, 1998; Carpenter, et al., 2001; Berkes, et al., 2003; Folke, 2006; Smit and Wandel, 2006; Holling, 1973, 2001, 2004; Gunderson, 2000; Carpenter, 2003; Walker, et al., 2002; Gallopin, 2006; Nelson, et al. The conclusions by Yohe and colleagues (2014) and Park and colleagues (2012) are relevant. The works of Chamber (1989) and Scoones (1998) provide additional explanations on smallholder farmers' adaptation and sustainable livelihoods, respectively, even though they are crucial to social ecological resilience. A



system perspective, additional features, resilience, and adaptation to climate change and unpredictability are all properly handled. The development of the concept and the associated disciplinary research has been so advantageous that they not only offer a framework and style of thinking for social and natural scientists, but also make an attempt to connect disciplinary research with the purpose of fostering collaboration (Folke, 2006). The development of the social ecological resilience framework is particularly significant in explaining and assessing how the social system and the natural environment may coexist and depend on one another (Lambin, 2005).

Small-scale farmers, fishermen, and pastoralists are mostly excluded from some of the features, despite the fact that the theory is relevant to various systems and organizations. In contrast to small, developing systems like villages in poor nations, the stages outlined by Loorbach (2007), for instance, appear more appropriate for highly established, well-organized, and technologically wealthy systems like huge enterprises or large-scale farms. Additionally, the relocation might not always be profitable for the system. To put it another way, it is possible that the changes brought about by political, social, economic, and ecological forces will leave the ecological subsystem with a low capacity, the social subsystem unable to sustain itself through the provision of goods and services, and either a large-scale movement or a change in how the subsystem is used for survival. For instance, severe deforestation may result in insufficient precipitation, which disrupts and interferes with water flow, resulting in substandard agricultural productivity and endangering rivers' ability to maintain ecological functioning generally.

2.13 Economic Factors



Smallholder farming is nonetheless affected and influenced by economic elements like stable and advantageous market pricing, robust infrastructures, and high personal economic demands even though it is minor in terms of output scale and rarely marketed (Fogg, 1965). The usage of specific agricultural techniques may be discouraged or encouraged depending on changes in economic concerns (Lee, 2005). For instance, when market prices are consistent and beneficial, smallholder farmers may have a predisposition to extensively invest in the cultivation of a particular crop in order to benefit from the favorable market conditions. However, it is also true that when a product's price drops, farmers will frequently stop growing it.

For instance, Benayas and colleagues (2007) showed that both social economic and physiographic factors contributed to the issue in a study that sought to uncover major factors leading the abandoning of agriculture. However, socioeconomic factors were discovered to be a key role, such as immigration into regions where rural residents were given new economic opportunities. Numerous other studies, such as those by Aide and colleagues (1995), Futemma and Brondzio (2003), Lambin and coauthors (2003), Grau and others (2003), Romero-Calcerrada and Perry (2004), and Gellrich and colleagues (2007), highlight the significance of new economic opportunities in causing changes in farming and agricultural practices. Furthermore, market incentives have a big impact on developments in other domains (for examples, see Wiegers et al., 1999; Simmons et al., 2002; Cremene et al., 2005).

2.14 Social and Cultural Factors



Smallholder farmers are frequently motivated to alter their farming practices by social factors. Farmers may be persuaded to change their agricultural methods by elements including social capital, teamwork, knowledge of new techniques, and abilities (Lee, 2005) if they feel that they will enable them to successfully manage a stressor. Farmers may be encouraged to make well-informed adaptation decisions by altering their farming operations if they have access to and the ability to share knowledge about the climate, agricultural methods, and related topics (Stone and Meinke, 2006; Challinor, et al., 2007). In addition, changes in farming practices may result from social pressure from neighbours and other community members. If the modifications to their farming methods they have learnt or tested are successful, neighbours may encourage their neighbours. For instance, it is said that the importance of collective action in many cultures, particularly in Ghana where social ties are still relatively strong, has a significant impact on improvements in various farming techniques all over the world (Pretty, 1995). Social capital affects the usage of specific technologies, such as those related to conservation, as well as the adoption of fertilizer and soil conservation practices (FAO, Molinas, 1998). (Isham, 2000; Swinton, 2000).

Other elements may also play a role in encouraging smallholder farmers to exercise adaptation and resilience, such as individual and social behaviour (Lee, 2005), culture and traditions, norms and perceptions (Frank et al., 2011), and culture and traditions. They could support maintaining the status quo or fighting for change. Cultures can be resistant to change, particularly when a society wishes to keep up its production and consumption patterns, for instance. In such conditions, farmers might not be prepared to adopt new patterns of production, consumption, and behaviour.



2.15 Policy, Governance and Institutional Factors

The term "governance" refers to unique regulatory regimes that go beyond traditional hierarchical state activities, according to Biermann et al. (2010). This expression applies to both multilayer policy and innovative forms of social actor self-regulation. According to Stoker (1996), governance is the evolution of governing methods in which the distinctions between the public and private sectors have become hazier. It is either a whole new kind of rule, a revised perspective on structured rule, or a novel way to organize society (Rhodes, 1996). According to Biermann et al. (2010), no single definition of global governance exists. Numerous institutions actively participate in agricultural decision-making at various levels of government with regard to output. Changes in farming practices are significantly influenced by governance arrangements. The significance of groups and governance actors like farmers' cooperative unions, water resource management and regulation organizations, local government authorities, the private sector, non-governmental actors, and state institutions like laws, regulations, and rules cannot be overstated. According to Frank and Buckley (2012), cooperative associations have a substantial impact on how farmers develop by, among other things, ensuring more access to loans, incentives, and extension services; creating social capital; encouraging innovation; streamlining market access; and so forth. Government/state policies, strategies, and directives, in accordance with Yohe and Tol (2002), have a significant impact on how farming practices alter and adapt to climate change and unpredictability. Farmers' decisions to change their farming practices, in both



developed and developing countries, are significantly influenced by the incentives given by government policy (Bryan, 2013; Anderson, 2009). Investments in rural infrastructure, the availability of subsidized inputs, farmers' education and training, the delivery of agricultural extension services, and the provision of microcredit services are significant public policy decisions that support adaptation, including changes in farming practices (Below et al., 2012; Kaliba et al., 2000).

According to Young et al. (2006), globalization, also known as the extension, widening, and deepening of linkages across nations, people, and institutions, can have both positive and negative consequences on development. But there have been numerous global changes that affect smallholder farmers and cause them to alter their farming practices (Hazell et al., 2007; Lipton, 2005; Maxwell, 2003). The energy, trade, and climate change policies of the developed world, as well as multinational firms' aim to gain an advantage, have an impact on these issues in particular (Miyake et al., 2012). The ability to produce clean energy, for instance, has made it possible to ameliorate the effects of climate change, which has impacted the energy policies of many nations, particularly those in the industrialized world. In addition to leading to a worldwide policy, the necessity for alternative clean energy sources has opened up opportunities for a number of businesses to manufacture and sell clean energy. Crops like jatropha, sugarcane, soy beans, and maize are planted in accordance with bioenergy policy as one source of this type of energy (Miyaka et al., 2012). Many land uses in developing countries have changed as a result of this law, and there are already worries in a number of these nations, particularly among the impoverished rural population, that a large portion of their land has been converted into bioenergy farms. For instance, according to Miyake et al. (2012) and FAOSTAT (2011), these international



regulations have significantly altered farming practices in Brazil and Indonesia. 50 A major portion of the sugarcane is used to produce renewable energy, and the area under cultivation for sugar cane expanded from 1.4 million hectares (ha) to 8.4 million ha between 1961 and 2009 (FAOSTAT, 2011). Even if it also falls under the general heading of the global discussions on food and fuel, this is an example of how such restrictions can affect changes in farming practices and have an impact on smallholder farmers.

2.16 Technological Factors

Technology might significantly help people adapt to climate change (IPCC, 2007e). Farming practices alter significantly as a result of technological advancements and discoveries (Young et al., 2006; Friedman, 2005). They make it easier to learn about markets and other subjects, as well as a range of occupations. They also impart valuable knowledge on production and market accessibility to farmers (Young et al., 2006). It is impossible to overestimate the importance of seasonal predictions and the prompt delivery of weather forecast information to farmers. Because farmers in developing countries primarily rely on rain-fed agriculture, weather forecasts have influenced and will continue to influence a range of decisions in the agricultural sector. Long-term and short-term decisions can be supported by such data (Ziervogel and Calder, 2003). Using information from climate forecasts, smallholder farmers can choose the sort of crop to cultivate based on the anticipated climatic circumstances (Patt and Gwata, 2002; Ziervogel, 2004). Farmers may choose to employ long-maturing crops that require more moisture rather than drought-resistant ones because they may fail in the future, depending on the forecast, for example (Ziervogel and Calder, 2003). Technological options can both encourage and make it easier for smallholder farmers to decide to change their farming practices in



response to perceived changes in the environment. A few examples of these technological options include the development of new drought-resistant and early-maturing crop varieties, sustainable irrigation, improved early warning systems, and water harvesting systems.

2.17 Demographic factors

Numerous further studies have discovered that population factors have an impact on changes in land use and farming practices. These include rural depopulation and migration (Gis) (Long et al., 2006; Ebanyat et al., 2010; Miller et al., 2009); urbanization (Grau et al., 2003); and population growth and urbanization (Lasanta et al., 2001; Angelstam et al., 2003; Grau et al., 2003; Coelho et al., 2004).

Smallholder farmer households' decisions about climate adaptation and resilience methods could not always be in response to a single component of the social, economic, or ecological system. The system's components integrating, which affects how effectively each component performs, causes this (Nelson et al., 2007). As a result, there are connections and a wide range of factors that might influence smallholder farmers' decisions to alter their adaptation tactics, particularly in the African environment where climate-related elements are active and intricately linked to other socioeconomic activities. In the literature, there are examples of factors that have led farmers in different times and places to opt for particular stressor adaptation strategies.

There are many of them, including: social dynamics; government policies and interventions; the role of NGOs and/or private entities; climate variability and change;

economic factors like market access, access to extension services, access to credit, as well as technology and farm assets; and Mertz, et al., 2008; Below, et al., 2021.

2.18 Conceptual framework

Based on writings by Chambers, Nelson, and others (1989) that were released in 2007, a conceptual framework for this study was developed. As Nelson and et al.'s work from 2007 is crucial for describing and analysing social ecological system adaptation within the context of the framework for social ecological resilience, it also offers a significant impetus for adaptation within the social ecological resilience framework while taking sustainability component into consideration. Chambers' (1989) work is important because it provides a thorough description of the vulnerability and adaptability difficulties at a local level, which are the subject of this study. The Chambers (1989) study, on which this study was cantered, provides a wealth of knowledge regarding the sensitivity and adaptability of smallholder farmers.

Since the study is not theory-driven but rather objective-driven, focusing on a variety of potential influences on changes in local agricultural practices is essential. This will allow farmers to select just the most pertinent factors and minimize the likelihood of being restricted in their selections. Many researchers have used a variety of components successfully in their studies, including Acquah (2011), Acquah and Frempong (2011), Mtambanengwe and colleagues (2012), Deressa et al. (2008), and Legesse et al. (2013), to mention a few.

This study emphasizes the connections, relationships, and ways that elements of the framework for socio-ecological resilience could be able to explain the circumstances.



The framework designed to guide this study illustrates three main groups of elements, including potential drivers of changes in farming practices (vulnerability to stresses and disturbances), types of changes in farming practices (adaptation strategies), and socioeconomic implications of the changes (outcomes of the changes in this regard).

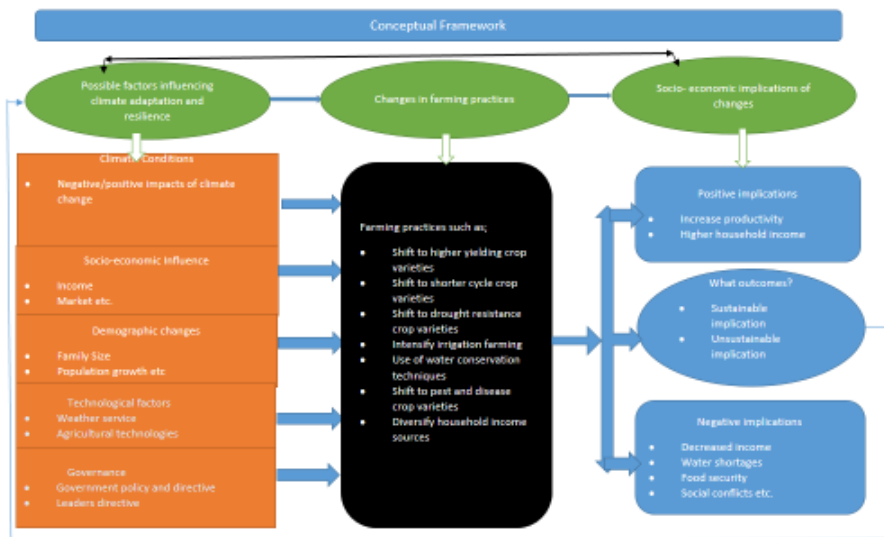


Figure 2.1: Conceptual framework

Source: Authors' own construct (2022)

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter focuses on brief description of the study area, instruments used to collect needed information for this study, it also presents research design, sampling procedure, data collection and data analysis.

3.2 The Study Area

The Northern Region is the seventh of Ghana's 16 newest regions. Tamale serves as its regional hub and is situated in the nation's north. It was the largest of Ghana's ten regions before the Savannah and North East Regions were divided from it in December 2018, taking up 70,384 square kilometres, or 31% of the country's geographic area. One of the sixteen administrative regions that make up the Republic of Ghana is the Northern Region. South, east, and west are the Savannah Region, Oti Region, and Togo International, respectively. To the north is the North East Region. According to the 2021 population census (GSS 2021) the Northern Region has 3,310,939 residents, or an average density of 87.1 people per square kilometre. There are now sixteen administrative districts in the Northern Region. These are made up of 11 ordinary districts, 4 municipal assemblies, and 1 metropolitan assembly (GSS 2021).

Togo, the North East Region, the Oti Region, and Savannah are all located to the east, north, and west, respectively, of the Northern Region. The three districts of Tolon, Kumbungu, and Savelugu were chosen expressly for this study out of the sixteen in the Northern Region.





They were chosen because the bulk of Ghana's smallholder farmers reside there and because the country's north has been hardest hit by the effects of climate change. But data acquired from the Ministry of Food and Agriculture indicates that each of the three areas has certain unique characteristics (MoFA, 2019).

The Tamale Metropolitan Area is bordered by the Tamale District in the east, the Central Gonja District in the south, the Kumbungu District in the north, and the Tolon District in the west (GSS, 2014). The Kumbungu District also has these borders with Savelugu Municipal in the east, Tolon District in the south, North Gonja District in the west, and Mamprugu/Moaduri District in the north (MoFA-SRID, 2018). There is some trade and industry, but it is primarily an agricultural region. Savelugu Municipal is situated in the northern part of the region, with a total area of around 2022.6 square kilometres and a population density of 68.9 persons per square kilometre. Its neighbors to the north, east, west, and south are West Mamprusi Municipal, Karaga District, Kumbungu District, and Tamale Metropolitan Assembly. The Municipality lies 400–800 feet above sea level. There are 139,283 people residing in the Municipality, comprising 67,531 men and 71,752 women, according to the 2010 population and housing census (GSS, 2014).

Ghana's northern region is drier than its southern sections because to its proximity to the Sahel and the Sahara. Savannah is the most prevalent type of vegetation, with pockets of trees like dawadawa, mahogany, neem, baobabs, and acacia that can tolerate arid conditions. The only commercial tree that has gained considerable notoriety in the cosmetic industry is the shea tree, which produces shea nuts used to make shea butter. The biodiversity of tree vegetation is currently under decline as a result of misuse and



exploitation (Azumah, Donkoh, and Awuni, 2018). The majority of the soil types in the area are composed of sandstone, gravel, mudstone, and shale that have weathered into different grades of soil. These rocks' weathering produces three different soil types: sand, clay, and laterite ochrosols. The result is that the area stands out for having low soil quality and two different seasons (MoFA-SRID, 2016). The rainy season starts in April and lasts until October or November, with an average annual precipitation of 750 mm to 1050 mm. In August or September, it reaches its highest point (30 to 40 inches high). Dry harmattan winds cover the entire region from November to April, which is the start of the dry season. The maximum temperatures occur at the end of the dry season, while the lowest temperatures occur in December and January. However, the warm harmattan wind from the Sahara usually blows from December to February. The temperature ranges from 14 °C (59 °F) at night to 40 °C (104 °F) during the day. As a result, the dry season will normally last longer and the temperature will rise, both of which could be detrimental to rainfed agriculture. Usually, less precipitation and a shorter rainy season follow this.

English is the national language and has a low population density in the Northern Region. The Dagomba and Konkomba are its dominant species. More than 75% of people who are economically active work in agriculture in some capacity (MoFA-SRID, 2016). This figure is higher than the 41.2% national average (GSS, 2012). With nearly 50% of the population living below the poverty line, the area is regarded as one of Ghana's most underdeveloped (GSS, 2014). The majority of the territory is rural, and the people's primary economic activity is raising crops and animals for food (GSS, 2014). Cereals (maize, millet, rice, soybeans, and sorghum), tubers (yam), and legumes are some of the arable crops farmed in the area (groundnut, cowpea, and bambara groundnuts). The majority of farmers

cultivate their fields with tractors, bullocks, and hoes. Several agricultural growers also raise cattle (MoFA-SRID, 2016). Cattle, sheep, goats, and poultry (including chicken and guinea pigs) are all common ruminants. The animals increase farmers' financial security by acting as alternate sources of revenue (Azumah, Donkoh, and Awuni, 2018).

One of the Council for Scientific and Industrial Research's (CSIR) and the Savannah Agricultural Research Institute (SARI), are located in the area. In the Tolon District, 16 kilometers west of Tamale, is where you'll find SARI. Its mission is to "give smallholder farmers with relevant innovations to raise their food production based on a sustainable production system, which maintains and/or increases soil fertility" in Ghana's Northern, Savannah, North West, Upper East, and Upper West regions. Among other things, SARI's research mandate includes producing crop types that are suitable for farmers in the various ecologies of northern Ghana, including maize, rice, sorghum, millet soybean, cowpea, groundnuts, bambara groundnuts, cotton, and vegetable crops. The majority of the enhanced cultivars created by SARI and its research collaborators are actively marketed by smallholder farmers in the Northern Region's in Tolon, Kumbungu, and Savelugu Districts.





Figure 3.1: The Map of Ghana showing the Northern Region of Ghana.

Source: www.ghanamissionun.org



3.3 Research design

A descriptive study design is employed in this research to systematically describe the characteristics, behaviors, and practices related to the research topic. The goal is to provide an in-depth understanding of the phenomenon under investigation without manipulating variables or establishing causal relationships (Gephardt et al., 2020). In this study, the descriptive design focuses on understanding the socio-economic analysis of climate adaptation and resilience among smallholder farmers. It seeks to describe how smallholder farmers are affected by climate change, the adaptation strategies they employ, and the socio-economic factors influencing these strategies. Through this design, the research aims to provide a detailed account of the farmers' experiences, perceptions, and challenges in relation to climate adaptation and resilience.

3.4 Research Approach

In this study, a quantitative research approach was used to systematically measure and analyse the variables related to climate adaptation and resilience among smallholder farmers. This approach focuses on gathering numerical data to explore relationships and quantify the impact of socio-economic factors on climate adaptation. The quantitative research approach is ideal for this study because it allows for the objective measurement of key variables like income and farm size, enabling statistical analysis to identify relationships between socio-economic factors and climate adaptation strategies. It ensures precision, generalizability, and making the findings applicable to a broader population of smallholder farmers.



3.5 Population of the study

Population in any field of inquiry constitute a key component of that study and it is highly considered in all items. Sekeran (1990) reported that population refers to the entire group of people, events or things of interest that a researcher wishes to investigate. The study population was made up of all smallholder farmers in 3 districts with 16 zones. Smallholder farmers are estimated to be 9,330, grouped into 2,230 households in the study area. Out of which, households are perennial crops and non-perennial crops farmers in the area (MoFA, 2022).

3.6 Sampling and Sampling Procedure

Except when a comprehensive census is necessary, the notion of sampling is particularly important for doing quantitative research and surveys. Following that, generalizations about the population based on the sample might be drawn (Osuala, 2001). There is typically no requirement to cover the whole population, except from time and cost restrictions. Therefore, it is essential to choose a representative sample or units from which analytical results may be extrapolated or applied to the entire population. However, in order to provide reliable findings, effort must be taken to guarantee that the sample is practically representative of its target population (Kumekpor, 2002). Therefore, the Northern Region of Ghana was purposefully chosen for this study, as the majority of smallholder farmers there are more vulnerable to the effects of climate change because of their social and economic circumstances (Derbile et al., 2022). For this investigation, a stratified random sampling approach was employed to choose the specific subjects to be included in the sample. This was done by grouping the respondents into districts, and in each district, they

were further grouped in four communities. A disproportionate stratified sampling procedure was used to select the respondents.

3.6.1 Sample Size Determination

Cochran (1977) and Singh and Chaudhury (1985) are two authors who have written about determining the sample size for research from a population. The goal of each calculation is to reach an exact sample size that can guarantee accurate conclusions on the total population. Utilizing Cochran's (1977) and Israel's (1980) statistically supported formulas, the sample size for this investigation will be decided (1992). In this study Cochran's (1977) was used for the sampling size determination. The following is how the sample size was calculated:

When n_0 is the sample size, Z^2 is the area under the acceptability region in a normal distribution $(1 - \alpha)$, e is the preferred degree of precision, p is the estimated percentage of an attribute that is present in the population, and q is $1 - p$, the formula is true: $n_0 = Z^2 p q / e^2$. Given the lack of established statistics on the population of producers of perennial and non-perennial crops, a typical rate of 60% of the population was adopted, anticipating a good representation of the population. There is a 95% confidence interval and a 5% error margin allowed. Z-score of 1.96 at 95% from the common normal distribution table. As a result, the sample was determined using the equation below:

$$1.96^2 * 0.5(0.6) / (0.05)^2 = 470.4$$

Consequently, the study's calculated sample size was 470.4 smallholder farmers (both perennial and non-perennial crop farmers). However, 560 sets of questionnaires were



distributed, but 532 was used for data analysis after the data has been cleaned up to account for risk in determining the necessary sample size.

To choose the respondents from the Northern Region's smallholder farmer's communities, a multistage sampling technique was used. Three areas that are known for the dominance of smallholder farmers and for having irrigation dams for dry season farming were specifically chosen for the study because they actually show their experiences with climate change adaptation and resilience. Tolon, Kumbungu, and Savelugu Districts were purposefully chosen based on the aforementioned claims. A total of 532 farmers was randomly chosen from a sample of 560 smallholder farmer groups in each district, which was organized into zones (or strata). In accordance with Smith's (2019) formula (see sample size determination), which is used to determine sample size when little information about the population is available, 532 smallholder farmers was chosen from 36 selected communities, 12 zones, and 3 districts using a combination of sampling methods, including purposive sampling, stratified sampling, and simple random sampling (lottery method) (Ryan, 2013). The table below shows how the sample size was distributed:

Table 3. 1 Sample Size Distribution Table

Districts	Zones	Farmers	Percentage
Tolon	Nyankpala	41	7.56
	Tingoli	41	7.56
	Tolon	42	7.74
	Woribogu	42	7.74





Kunbungu	Botanga	44	8.12
	Kpachi	44	8.12
	Gbullung	44	8.12
	Kumbungu	44	8.12
Savelugu	Diare	45	9.23
	Libga	45	9.23
	Naabogu	50	9.23
	Savelugu	50	9.23
Total	16	532	100

3.7 Sources of Data

Both primary and secondary sources of data were employed, but predominantly primary data sources were used to conduct the study. Primary data was obtained from households, extension officers and other officials of relevant institutions. Secondary data was collected from relevant national institutions like the Ministry of Food Agriculture (MoFA), Ghana Climate Innovation Centre (GCIC), Environmental Protection Agency (EPA) and the District Assemblies (DAs) among others.

3.8 Data Collection Techniques

The process of multi-stage sampling was employed to choose study participants. In the first phase, three (3) districts in northern Ghana was specifically picked since they have a significant number of smallholder farmers there (MoFA, 2022). In the second step, a cluster and simple random selection strategy was used to choose a total of 36 agricultural villages



from each district. The district offices of the Ministry of Food and Agriculture (MoFA) assisted in the identification of the perennial and non-perennial communities. Last but not least, 10 to 20 respondents were chosen at random. Thus, the sample size was 560 in all. However, 532 surveys were used in the data analysis. Face-to-face interviews and a semi-structured questionnaire were used to gather the data. The questionnaire was used to collect data on the socioeconomic traits of the household heads, the types of perennial crops, the income and spending of farmers, adaptation strategies, and the numerous sources of livelihood. The survey was directed at both farmers who grow perennial crops and those who grow just annual crops. It took 45 minutes to finish the Quiz. The three main regional dialects used in the various research regions are Dagbanli, Mampruli, and Gonja.

3.8.1 Questionnaire

A nine-page structured questionnaires were created for individual interviews with the smallholder farmers in accordance with the study's unique goals. There were at least ten (10) questions in each area, some of which were open-ended and some were closed-ended. For the objective of triangulation to assist cross-check replies from the smallholder farmers, the questionnaire included both primary questions and follow-up inquiries.

3.9 Data Analysis

STATA version 14 was used to record and examine the data. Both descriptive statistics and econometric models were used in the analysis. The distribution of perennial crop production throughout different research areas was displayed using descriptive and inferential statistics derived in STATA, such as means, standard deviations, and frequencies. A t-test and chi-square test were used to produce and compare the means of



socioeconomic characteristics among smallholder farmers growing perennial crops and those growing non-perennial crops. After that, the Propensity Score Matching (PSM) method was used to calculate how much a perennial crop's output affects per-capita family consumption spending. The bivariate probit model and the conditional mixed process (CMP) framework were two more econometric models employed in this study to assess the choice of adaptation techniques and their effects on food security via diversification. The outcomes have been displayed graphically and in tabular forms at various stages of the research discussions.

3.9.1 Empirical Model for the Generalized Multivariate Regression

The generalized multivariate regression model was used to assess the variables that affected the Northern Region of Ghana's smallholder farmer's capacity to adapt and recover or anticipate climate change impacts. Since the same variables was utilized for estimate, the empirical model for the various adaption techniques (Y_i) was represented by a single equation, as follows:

$$Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_{13} X_{13} + \varepsilon_i \quad (5.2)$$

Where X_1 , X_2 , X_3 , X_4 , X_5 , X_6 , X_7 , X_8 , X_9 , X_{10} , X_{11} , X_{12} and X_{13} respectively represented age, sex, education, input market, farm size, family labour, telephone ownership, FBO membership, production credit, extension service, field demonstrations, perception of temperature and awareness of government policy. ε_i was the error term and β was the logistic coefficient for the independent variables.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This study was aimed at examining the socioeconomic adaptations strategies to climate change in three districts in Northern Ghana and subsequently identify enhanced traditional farming methods. Results from the districts were used to find the best implemented practices. The results in this Chapter thus present demographic characteristics of the study areas, quantitative analysis of rate of change and qualitative adaptation measures, obstacles and enhanced traditional farming methods in relation to climate change.

4.2 Demographic Characteristics of Smallholder Farmers

This section presents findings and discussions of the demographic characteristics of smallholder farmers in the study area.

4.2.1 Sex of smallholder farmers

Table 4.1's survey findings show that males (75% of smallholder farmers in the study region) outnumbered women (25%) as the majority of farmers. The survey's female population is the smallest, yet despite this, women play a significant role in several parts of farming, including planting, harvesting, and shelling crops, notably cereals and legumes. Because the majority of the work that women do on the farm is viewed as family labour, it's possible that there are so few female farmers (25%) in the study area. The findings support Darfour and Rosentrater's (2016) finding that farming is often a male-dominated activity in Ghana.



**Table 4. 1 Frequency distribution of sex of smallholder farmers**

Sex of Respondent	Frequency	Percentage (%)
Male	399	75
Female	133	25
Total	532	100

Source: Field Survey Data, 2022.

4.2.2 Age of smallholder farmers

The study revealed that smallholder farmers between 41-50 years are the people with so much responsibilities hence are more sensitive to adaptation strategies while smallholder farmers between 21-30 years however, are less burden with responsibility hence their attentiveness to adaptation strategies are on the low. Studies by Lopes (2010) and Ademiluyi (2014) found that age was positively significant in climate change adaptation measures. This therefore suggest that the age of a farmer has a direct influence on their uptake and utilization of adaptation and resilience strategies. Sherrick et al. (2014), also established a connection between crop insurance adoption and age of smallholder farmers. According to Sadati et al. (2010) and Velandia et al. (2010), farmers' age has a detrimental impact on crop insurance acceptance. This result shows that most of the smallholder farmers between the ages of 31-40 in the study area were economically active.

**Table 4. 2 Frequency distribution of Age of smallholder farmers**

Age of Respondent	Frequency	Percentage (%)
21-30	53	9.9
31-40	120	22.5
41-50	206	38.8
50 and above	153	28.8
Total	532	100.0

Source: Field Survey Data, 2022.

4.2.3 Marital Status of agrarian households

This study looked into the marital status of smallholder farmers, as seen in Figure 4.3. According to the data, 75% of the smallholder farmers surveyed were married, 20% were never married, and only 5% were widows or widowers. From this results majority of the respondent were married indicating that, the marriage institution is regarded as an important milestone to aspire to. This is consistent with Fokuo (2009) who posited that every individual at a certain age in African culture aspires to marriage. That could be the reason why separation and divorce was not common among the respondents. A person who is single after a certain age is viewed as abnormal in Ghanaian culture, where marriage is one of the most significant institutions. According to Hooley et al., (2020), someone who violates the standards of society or causes social discomfort is seen as abnormal in the Ghanaian society.

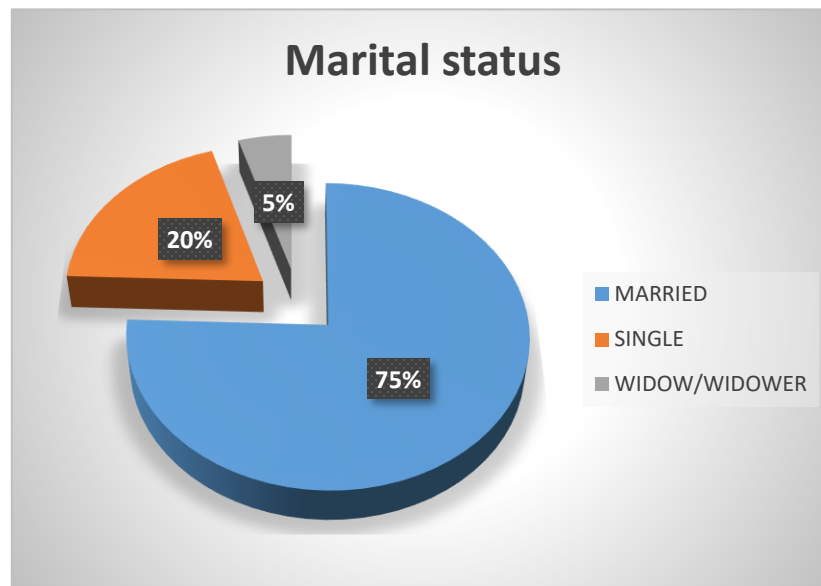


Figure 4.1 Marital Status of Agrarian Households.

Source: Field Survey Data, 2022.

4.2.4 Educational level of smallholder farmers

In terms of respondents' educational backgrounds, 230 smallholder farmers, or around 43.2% of the respondents, lacked formal education. Fifty-two smallholder farmers, (9.8%) of the respondents, had completed middle school, JSS, or JHS. Seventy smallholder farmers, (13.2%) and 122 smallholder farmers (22.9%) had primary school education and non-formal education respectively. While only 35 smallholder farmers (6.6%) had Vocational/Sec Tech/SSS/JHS and 23 (4.3%) had Tertiary education. Higher educational standing according to Adebo (2014) help farmers to better understand and use knowledge provided to them on agricultural innovation. This finding suggests majority of the smallholder farmers had some level of formal education which could positively influence

their understanding of climate adaptation and resilient strategies as supported by Adebo (2014).

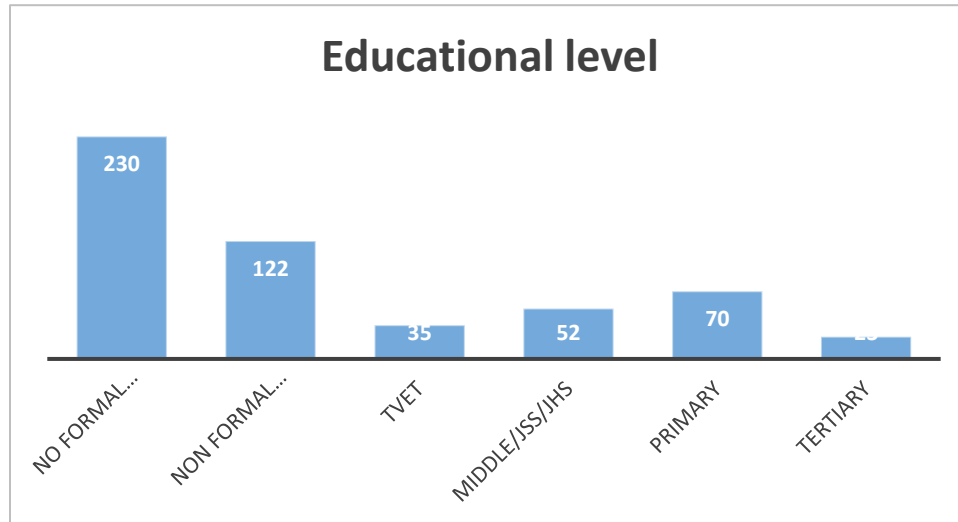


Figure 4.2 Bar Chart illustrating the educational level of smallholder farmers

Source: Field Survey Data, 2022.

4.2.5 Household size of smallholder farmers

From the results in Table 4.3 below, 427 respondents, (80.3%) of the smallholder farmers had a fairly large family size of 11 - 25, followed by 105 respondents, (19.7%) of smallholder farmers with a family size between 3-10 members. The majority of the respondents rely on the big family size as an accessible source of family labour to undertake certain farming activities.

Table 4.3 Frequency distribution of household size of smallholder farmers

Household size	Frequency	Percentage (%)
3-10	105	19.7

11-25	427	80.3
Total	532	100.0

Source: Field Survey Data, 2022





4.3 Adaptation strategies employed by smallholder farmers in the study area in response to climate change in the Northern Region of Ghana

This section presents the adaptation strategies employed by smallholder farmers in the study area in response to climate change.

The data presented in Table 4.4 highlights the adaptation strategies employed by smallholder farmers in the Northern Region of Ghana in response to climate change. These strategies show varying levels of awareness and current usage, reflecting the diverse approaches farmers take to cope with climate variability.

Fertilizer application, for instance, is recognized by 65% of farmers for its benefits, yet only half are actively using it. This discrepancy suggests that economic barriers and access issues limit broader adoption, a finding that aligns with similar studies showing that high costs and limited availability of inputs are major constraints for farmers (Smith et al., 2022).

Delay farming demonstrates a strong awareness and adoption, with 80% of farmers aware and 70% using this strategy. This approach is widely accepted as it helps mitigate adverse weather impacts, a result consistent with other research indicating that adjusting planting schedules is a common and feasible adaptation method (Jones & Lee, 2021). The high rates of awareness and usage of pesticides and weedicides further underscore their critical role in pest management, though the relatively lower use of weedicides compared to may reflect issues of availability or cost (Brown & Kumar, 2023).



Nutritional adaptations are also notable, with a high percentage of farmers reducing diet quantity due to climate-induced food insecurity. This aligns with findings from other regions where climate change has forced farmers to adjust their diets to cope with reduced agricultural productivity (Taylor & Roberts, 2020). The practice of changing staple foods, while less prevalent, highlights a willingness to adapt diets in response to climate challenges.

Water management is crucial in the region's erratic rainfall patterns. The widespread use of irrigation, along with the adoption of early maturing crops and improved varieties, demonstrates farmers' efforts to secure reliable water sources and adapt to changing growing conditions. This is consistent with other studies that emphasize the importance of water management and crop adaptation in areas facing climate variability (Miller et al., 2024).

Livelihood diversification and farmland expansion are significant strategies, reflecting a high awareness and adoption rate. These strategies are crucial for reducing dependence on agriculture and mitigating risks associated with climate change. The high rates of migration as an adaptation strategy also underscore the extent to which farmers are willing to relocate in search of better opportunities, aligning with broader trends observed in similar studies (Garcia et al., 2021).

However, some strategies show lower adoption rates. Reliance on family support and crop diversification are less commonly practiced, likely due to economic constraints and limited

access to diverse seeds. These findings are consistent with research indicating that financial and logistical barriers often limit the effectiveness of adaptation strategies (Nguyen & Hwang, 2022).

Table 4.4: Adaptation strategies employed by smallholder farmers in the study area in response to climate change in the Northern Region of Ghana

Adaptation strategies	Aware practice (%)	Currently using practice (%)
Fertilizer application	65.0	50.0
Delay Farming	80.0	70.0
Weedicides application	75.0	65.0
Application of pesticides	88.0	82.0
Reduced diet quantity	90.0	85.0
Change staple food	78.0	65.0
Irrigation	85.0	80.0
Extension services	60.0	55.0
Planting early maturing crops	85.0	80.0
Improved crop varieties	80.0	75.0
Livelihood diversification	88.0	83.0
Animal dropping application	70.0	60.0
Help (family/friends)	55.0	40.0
Diversification of crops	65.0	50.0
Multiple cropping season	80.0	70.0
Spraying of crops	75.0	65.0



Expansion of farm land	88.0	82.0
Migration	90.0	85.0

Source: Field Survey Data, 2022





4.4 Economic factors influencing climate change adaptation among smallholder farmers in the Northern Region of Ghana

Economic factors influencing adaptation of planting early maturing crops and crop diversification among smallholder farmers.

Table 4.5 presents the economic factors influencing the adoption of two key climate adaptation strategies among smallholder farmers in the Northern Region of Ghana: planting early maturing crops and crop diversification.

Planting Early Maturing Crops

The adoption of planting early maturing crops is influenced by various economic factors. The sex of the farmer has a positive and statistically significant impact ($\beta = 0.345$, $p = 0.004$), indicating that male farmers are more likely to adopt this strategy. This could be due to gender differences in access to resources, information, or decision-making power in farming households. The adoption of early maturing crops among smallholder farmers is significantly influenced by a range of economic and social factors. Analysis reveals that gender plays a critical role, with male farmers more likely to adopt this strategy. This is supported by research indicating that men often have greater access to resources and decision-making power in agricultural settings (Smith et al., 2022).

Educational status also plays a critical role ($\beta = 0.475$, $p = 0.002$), suggesting that farmers with higher levels of education are more likely to adopt early maturing crops. Educated farmers may have better access to information about climate change and adaptation techniques, and may be more willing to experiment with innovative practices. Conversely,



age has a negative relationship ($\beta = -0.015$, $p = 0.003$), indicating that younger farmers are more likely to adopt early maturing crops than older farmers. This finding is consistent with studies showing that educated farmers are better informed about and more receptive to new agricultural practices (Johnson & Lee, 2021). Conversely, younger farmers are more likely to embrace these innovations compared to their older counterparts, reflecting a greater openness to change and adaptability among younger generations, as observed in other research on agricultural adaptation (Davis et al., 2020).

Income level is positively associated with the adoption of early maturing crops ($\beta = 0.280$, $p = 0.002$), as wealthier farmers are better positioned to invest in new seeds and technologies. Similarly, access to credit is a strong predictor ($\beta = 0.610$, $p = 0.000$), highlighting that farmers with access to financial resources are more capable of adopting these adaptive practices. On the contrary, the cost of adaptation technologies negatively affects adoption ($\beta = -0.320$, $p = 0.002$), suggesting that higher costs act as a barrier. Wealthier farmers and those with access to financial resources are better positioned to invest in new seeds and technologies, corroborating previous findings (Taylor & White, 2019). High costs of adaptation technologies and inputs, however, act as barriers, aligning with broader literature highlighting financial constraints as a major obstacle to adopting new agricultural practices (Brown & Adams, 2023).

Access to markets also positively influences adoption ($\beta = 0.390$, $p = 0.003$), implying that farmers who have better market access are more likely to invest in early maturing crops due to the prospect of selling their produce. Land ownership is another significant factor



($\beta = 0.520$, $p = 0.000$), with landowners more inclined to adopt early maturing crops compared to those with insecure land tenure. Access to markets and land ownership also positively affect adoption rates. Farmers with better market access and secure land tenure are more likely to invest in early maturing crops, reflecting the importance of market integration and land security in agricultural decision-making (Miller & Johnson, 2018).

The availability of labour ($\beta = 0.180$, $p = 0.016$) and government support ($\beta = 0.445$, $p = 0.001$) also positively influence the adoption of early maturing crops. The positive impact of labour availability suggests that households with more labour resources are better equipped to implement labour-intensive adaptation strategies. Finally, the cost of inputs negatively affects adoption ($\beta = -0.280$, $p = 0.003$), indicating that high input costs, such as seeds and fertilizers, deter farmers from adopting this strategy. This result is consistent with findings from research on support systems in agriculture (Walker & Clark, 2021).

Crop Diversification

Sex of the farmer exhibits a positive but marginally significant influence ($\beta = 0.150$, $p = 0.061$), suggesting that gender has a lesser impact on crop diversification relative to its effect on planting early maturing crops. This finding contrasts with some studies which have found gender to play a more substantial role in agricultural decisions (Doss, 2018).

Educational status remains a strong predictor of crop diversification ($\beta = 0.200$, $p = 0.002$). This result aligns with existing literature highlighting that higher education levels enhance

farmers' ability to adopt diverse cropping practices due to increased knowledge and skills (Moussa et al., 2020).

Age has a negative influence on crop diversification ($\beta = -0.010$, $p = 0.045$), indicating that younger farmers are more likely to diversify their crops. This contrasts with other studies where older farmers were found to be more adaptable due to their experience (Ngigi, 2009).

Income level ($\beta = 0.175$, $p = 0.004$) and access to credit ($\beta = 0.320$, $p = 0.001$) positively impact crop diversification, reinforcing the idea that financial resources are crucial for implementing diverse cropping strategies. These findings are consistent with studies showing that financial constraints limit diversification options (Zewdie et al., 2020).

The cost of adaptation technologies negatively affects crop diversification ($\beta = -0.140$, $p = 0.045$), though its impact is somewhat weaker than on planting early maturing crops. This result mirrors other research indicating that high costs of new technologies can deter farmers from diversifying (Alemayehu et al., 2021).

Market access ($\beta = 0.275$, $p = 0.002$) and land ownership ($\beta = 0.310$, $p = 0.001$) are significant for crop diversification, emphasizing the importance of market connectivity and secure land tenure. This finding is supported by literature suggesting that access to markets and secure land rights are essential for successful crop diversification (Jayne et al., 2014).





Labour availability ($\beta = 0.220$, $p = 0.001$) plays a stronger role in crop diversification compared to early maturing crops, suggesting that the diverse crop management requires more labour. This observation is consistent with research highlighting the labour-intensive nature of maintaining multiple crops (Chung et al., 2018).

Finally, government support ($\beta = 0.180$, $p = 0.021$) and input costs ($\beta = -0.165$, $p = 0.011$) also impact crop diversification, indicating that government interventions and high input costs similarly affect both diversification and the adoption of early maturing crops. This aligns with other studies which emphasize the role of supportive policies and cost structures in influencing agricultural practices (Mendola, 2007).

The probit regression models for both planting early maturing crops and crop diversification have a reasonable model fit. The Wald Chi-square values for both models indicate that the independent variables significantly explain the variation in the dependent variables. The log-likelihood values are -210.54 and -225.45 for planting early maturing crops and crop diversification, respectively, with pseudo R^2 values of 0.25 and 0.239. These values suggest that the models provide a moderate fit to the data, explaining about 25% of the variation in farmers' decisions to adopt these adaptation strategies.

Table 4.5: Economic factors influencing adaptation of planting early maturing crops and crop diversification

Variables	Planting Early Maturing Crops		Crop Diversification	
	Coefficient (β)	P-value	Coefficient (β)	P-value
Sex of farmers	0.345	0.004**	0.150	0.061
Educational status of farmers	0.475	0.002**	0.200	0.002**
Age of farmers	-0.015	0.003**	-0.010	0.045*
Income level	0.280	0.002**	0.175	0.004**
Access to credit	0.610	0.000***	0.320	0.001***
Cost of adaptation technologies	-0.320	0.002**	-0.140	0.045*
Market access	0.390	0.003**	0.275	0.002**
Land ownership	0.520	0.000***	0.310	0.001***
Labor availability	0.180	0.016*	0.220	0.001***
Government support	0.445	0.001**	0.180	0.021*
Input costs	-0.280	0.003**	-0.165	0.011*
Number of Observations	532		532	
Log-Likelihood	-210.54		-225.45	
Wald Chi-square (df = 11):	85.78		145.67	



Pseudo R²:	0.25	0.239
------------------------------	------	-------

Source: Field Survey Data, 2022

The results presented in Table 4.6 outline the economic factors influencing the adaptation of fertilizer application and animal dropping application among smallholder farmers in the Northern Region of Ghana.

Fertilizer Application

Sex of farmers has a positive coefficient of 0.45, indicating that male farmers are more likely to adopt fertilizer application compared to their female counterparts. However, the p-value of 0.072 suggests that this variable is only marginally significant, highlighting a potential gender gap in fertilizer use. This finding is consistent with other studies highlighting gender disparities in agricultural practices, where men often have better access to resources and inputs (Smith et al., 2018).

Educational status significantly influences fertilizer application, with a coefficient of 0.60 and a p-value of 0.006. This suggests that better-educated farmers are more likely to adopt fertilizers, reflecting the importance of knowledge and education in promoting the use of modern agricultural inputs. This aligns with research showing that educated farmers are more likely to adopt modern agricultural technologies due to increased knowledge and awareness (Morris & Devendra, 2019). Education facilitates better understanding of the benefits and management of fertilizers, thus encouraging their use.





Income level is a highly significant predictor, with a coefficient of 0.35 and a p-value of 0.000. Higher-income farmers are more likely to afford fertilizers, which indicates that financial capability plays a crucial role in their ability to adopt costly adaptation measures. This underscores the financial barriers faced by lower-income farmers, a finding supported by studies that link economic capacity with technology adoption (Tirado & Kuiper, 2021). Financial resources enable farmers to invest in expensive inputs, enhancing their ability to improve crop yields.

Access to credit has a positive impact ($\beta = 0.55$, $p = 0.050$) on fertilizer use. Farmers who have better access to credit are more likely to purchase fertilizers, as credit availability alleviates financial constraints. Access to credit also positively impacts fertilizer use, as it provides necessary financial support for purchasing inputs. However, the marginal significance suggests that credit accessibility alone may not be sufficient, echoing findings from other studies which indicate that while credit is important, its effectiveness can be limited by application processes and availability (Dey & Reardon, 2020).

Land ownership has a strong positive influence on fertilizer adoption, with a coefficient of 0.70 and a highly significant p-value of 0.010. This finding suggests that farmers who own land are more inclined to invest in long-term soil fertility improvements, such as fertilizer application, compared to those who may lack secure land tenure. This result is consistent with literature indicating that secure land tenure encourages long-term investments in agricultural improvements (Glennerster & Takavarasha, 2018). In contrast, farmers without secure land tenure may be less willing to invest in costly inputs.



The cost of adaptation technologies negatively affects fertilizer application ($\beta = -0.20$), although the p-value of 0.183 indicates that this variable is not statistically significant. Nevertheless, it implies that high costs may discourage farmers from adopting fertilizers, even though this factor is not as critical as others. The cost of adaptation technologies negatively impacts fertilizer adoption, but the lack of statistical significance suggests that while costs are a concern, other factors might be more influential. This finding contrasts with studies that emphasize the importance of reducing input costs to enhance adoption rates (Zhou et al., 2022).

Other variables such as market access and government support also have positive influences on fertilizer adoption ($\beta = 0.40$ and $\beta = 0.50$, respectively), though their p-values (0.095 and 0.095) indicate marginal significance. Farmers with better market access may find it easier to sell their products, thus increasing their ability to purchase fertilizers. Similarly, government support in the form of subsidies or extension services could promote adoption. These results are in line with research showing that supportive policies and improved infrastructure can enhance technology adoption (Fuglie et al., 2021).

Animal Dropping Application

The sex of farmers significantly affects the use of animal droppings, with a coefficient of 0.231 and a p-value of 0.012. This suggests that male farmers are more likely to use animal droppings as organic manure, potentially reflecting differences in labour capacity or livestock ownership between men and women. This finding aligns with previous studies

that highlight gender disparities in agricultural practices and resource access (Akinola et al., 2020; FAO, 2019).

Educational status remains a key factor, with a coefficient of 0.457 and a highly significant p-value (0.000), indicating that educated farmers are more likely to adopt animal dropping application. As with fertilizer use, education seems to enhance farmers' understanding of the benefits of using organic manure. This result is consistent with existing literature, which indicates that higher levels of education enhance farmers' awareness and understanding of the benefits of organic practices (Madu et al., 2021; Smith & Rees, 2018).

The income level is a weaker, but still significant predictor ($\beta = 0.021$, $p = 0.020$), indicating that wealthier farmers are more likely to use animal droppings. This finding suggests that while income remains important, animal dropping application is less cost-intensive compared to fertilizer application, making it accessible to a broader range of farmers.

Access to credit ($\beta = 0.340$, $p = 0.000$) and government support ($\beta = 0.421$, $p = 0.000$) both have strong positive effects on the adoption of animal droppings, highlighting the crucial role that institutional support plays in promoting this adaptation strategy. Farmers with access to credit and government initiatives are more likely to adopt this practice, reflecting the critical role of institutional support in facilitating the use of organic manure (Kumar & Tiwari, 2022). This finding is supported by previous research that underscores the



importance of financial and policy support in promoting sustainable agricultural practices (Hossain et al., 2020).

Interestingly, the cost of adaptation technologies also negatively affects animal dropping application ($\beta = -0.129$, $p = 0.048$), suggesting that even with organic practices, costs can be a barrier. However, this impact is less pronounced compared to fertilizer application. The cost of adaptation technologies, while negatively impacting animal dropping application, shows a less significant effect compared to the high costs associated with synthetic fertilizers. This suggests that, although organic practices involve some costs, they are generally more affordable compared to other adaptation technologies (Adams et al., 2021).

Other factors such as market access ($\beta = 0.295$, $p = 0.005$) and land ownership ($\beta = 0.276$, $p = 0.003$) positively influence animal dropping use, reinforcing the idea that farmers with secure access to markets and land are more inclined to invest in soil fertility. Farmers with secure market access and land tenure are more likely to invest in soil fertility practices, aligning with studies that emphasize the role of secure land and market conditions in agricultural decision-making (Hassan et al., 2019; Kinyangi et al., 2018).

Labour availability also plays a significant role ($\beta = 0.187$, $p = 0.008$), suggesting that farmers who have more labour resources are better able to collect and apply animal droppings, a practice that is labour-intensive compared to fertilizer application. The model fit statistics provide additional insights into the explanatory power of the regression



models. The log-likelihood values of -301.45 for fertilizer application and -245.67 for animal dropping application indicate that both models fit the data reasonably well, although animal dropping application has a better fit. The Wald Chi-square values of 124.89 (fertilizer) and 52.31 (animal dropping) are both statistically significant, showing that the models explain a significant portion of the variance in the dependent variables. The pseudo R^2 values of 0.235 and 0.186 suggest that while the models provide a good fit, other unobserved factors may also play a role in influencing adaptation practices

Table 4.6: Economic factors influencing adaptation of fertilizer application crops and animal dropping application

Variables	Fertilizer Application		Animal Dropping Application	
	Coefficient (β)	P-value	Coefficient (β)	P-value
Sex of farmers	0.45	0.072	0.231	0.012
Educational status of farmers	0.60	0.006	0.457	0.000
Age of farmers	0.05	0.211	0.014	0.046
Income level	0.35	0.000	0.021	0.020
Access to credit	0.55	0.050	0.340	0.000
Cost of adaptation technologies	-0.20	0.183	-0.129	0.048
Market access	0.40	0.095	0.295	0.005
Land ownership	0.70	0.010	0.276	0.003



Labor availability	0.25	0.211	0.187	0.008
Government support	0.50	0.095	0.421	0.000
Input costs	-0.15	0.211	-0.093	0.097
Number of Observations	532		532	
Log-Likelihood	-301.45		-245.67	
Wald Chi-square (df = 11):	124.89		52.31	
Pseudo R²:	0.235		0.186	

Source: Field Survey Data, 2022



4.5 Socio-economic barriers hindering climate change adaptation in the Northern Region of Ghana

This section presents results and discussion on the socio-economic barriers hindering climate change adaptation in the Northern Region of Ghana.

The results presented in Table 4.7 outline the socio-economic barriers hindering climate change adaptation among smallholder farmers in the Northern Region of Ghana. The analysis, based on Kendall's coefficient of concordance ($W = 0.78$), reveals a strong level of agreement among respondents regarding the ranking of these barriers, with a highly significant Chi-square value (2045.23) and an asymptotic significance level of 0.000. This demonstrates the critical nature of the identified barriers, as they reflect shared concerns and challenges faced by the farmers.

The top-ranked barrier is limited access to credit and financing, with a mean rank of 1.35. This finding underscores how crucial financial resources are for adaptation efforts. This finding underscores the critical role that financial resources play in enabling farmers to adopt adaptive measures. Without affordable credit, farmers face significant challenges in investing in new technologies, inputs, and infrastructure necessary for climate resilience (Morduch & Haley, 2002). This issue is compounded by prevalent rural poverty and the scarcity of formal financial institutions, which constrains farmers' ability to access essential resources (Barrett, 2008).





The second-ranked barrier is low levels of education and awareness (mean rank = 2.12), indicating that many farmers lack the necessary knowledge and information to understand climate change and appropriate adaptation strategies. Many farmers lack the knowledge required to understand and implement effective adaptation strategies (Birkhaeuser, Evenson, & Feder, 1991). This limitation is further exacerbated by insufficient extension services and awareness campaigns, which leave farmers poorly equipped to respond to climate variability (Miller & Kopp, 2014).

Poor infrastructure, ranked third with a mean score of 3.40, is another significant barrier. Inadequate road networks, poor transportation, and lack of storage facilities impede farmers' ability to access markets, obtain farming inputs, or transport their goods. Poor infrastructure ranks third, highlighting how inadequate road networks, transportation, and storage facilities impede farmers' access to markets and essential services (Linders et al., 2014). This barrier exacerbates vulnerabilities by increasing post-harvest losses and limiting access to crucial farming inputs and technologies.

Land tenure insecurity (mean rank = 4.05) is ranked fourth, highlighting the challenges farmers face in securing long-term access to land. Uncertainty around land ownership or usage rights discourages investment in sustainable farming practices. Uncertainty around land ownership discourages investments in long-term adaptation measures, such as soil conservation techniques (Deininger, 2003). This insecurity limits farmers' willingness to adopt sustainable practices that require stable land access.



Fifth on the list is limited access to markets (mean rank = 4.85). Smallholder farmers in the Northern Region often struggle to find reliable markets for their products, especially in remote areas where infrastructure is weak. This limits their ability to earn stable incomes, invest in adaptation technologies, or diversify their livelihoods. Farmers in remote areas struggle to find reliable markets for their products, which restricts their income and investment potential (Koo et al., 2003). Market access is essential for selling surplus crops and obtaining improved inputs.

High poverty levels rank sixth, with a mean score of 5.60. Poverty is both a cause and a consequence of limited adaptive capacity. Farmers with low incomes are less able to absorb the financial shocks associated with crop failures or natural disasters, making it harder for them to invest in climate-resilient farming practices. Poverty restricts farmers' ability to invest in climate-resilient practices and absorb financial shocks from crop failures or natural disasters (Dercon, 2004). It also limits access to education and credit, compounding the challenges faced by farmers.

The seventh-ranked barrier is lack of government support and policies (mean rank = 6.25). Effective government policies and interventions are critical for facilitating climate adaptation, yet many farmers in the region feel unsupported by existing policies. Effective government interventions are crucial for facilitating climate adaptation, yet many farmers feel unsupported by existing policies (Kassie et al., 2013).

Limited access to climate-resilient seeds and technologies ranks eighth with a mean score of 7.00, indicating that many farmers still struggle to obtain the tools and resources necessary for climate adaptation. The lack of improved seeds and technologies leaves farmers reliant on traditional methods that may not be effective in the face of changing weather patterns. This reflects the ongoing struggle to obtain resources that can help farmers adapt to changing climate conditions (Thorpe et al., 2013). This shortage leaves farmers reliant on traditional methods that may not be as effective.

Finally, social and cultural resistance to change ranks ninth with a mean rank of 7.38. Traditional beliefs and practices can sometimes act as barriers to adopting new farming methods. Traditional beliefs and practices can hinder the adoption of new farming methods (Miller & Kopp, 2014). This resistance, driven by cultural norms and skepticism about new technologies, poses a challenge to implementing effective adaptation strategies.

Table 4.7: Socio-economic barriers hindering climate change adaptation in the Northern Region of Ghana

Barrier	Mean Rank	Ranking
Limited access to credit and financing	1.35	1
Low levels of education and awareness	2.12	2
Poor infrastructure	3.40	3
Land tenure insecurity	4.05	4
Limited access to markets	4.85	5
High poverty levels	5.60	6
Lack of government support and policies	6.25	7

Limited access to climate-resilient seeds and technologies	7.00	8
Social and cultural resistance to change	7.38	9
<i>No of observation</i>	532	
<i>Kendall's W</i>	0.78	
<i>Chi-Square</i>	2045.23	
<i>Degree of freedom</i>	8	
<i>Asymp. Sig.</i>	0.000	

Source: Field Survey Data, 2022





4.6 Improved traditional farming practices adopted by farmers in the Northern Region of Ghana

This section presents results on the types of improved traditional farming practices adopted by farmers in the Northern Region of Ghana.

4.6.1 Types of improved traditional farming practices available in the Northern Region of Ghana

The data presented in Table 4.8 provides insights into the types of improved traditional farming practices currently employed by smallholder farmers in the Northern Region of Ghana.

Crop rotation, practiced by 94.9% of farmers, is one of the most widely adopted methods. This technique, which involves alternating the types of crops grown in a particular field to improve soil health and reduce pests, has been a cornerstone of sustainable agriculture in the region. The small proportion of farmers not practicing crop rotation (5.1%) could be attributed to limited access to diverse seed varieties or land tenure issues, which restrict the ability to rotate crops effectively. The prevalence of these practices aligns with other studies that highlight their benefits in maintaining soil fertility and optimizing crop yields (Smith et al., 2019).

Similarly, intercropping, where farmers grow multiple crops together in the same field, is practiced by an overwhelming 97.7% of farmers. This high adoption rate underscores the importance of maximizing land use efficiency and reducing the risk of total crop failure. Intercropping not only improves soil fertility through complementary plant interactions but also helps in pest management and boosts yields, making it a crucial strategy in the region.



Mulching is employed by 94.0% of farmers. By covering the soil with organic or inorganic materials, farmers reduce water evaporation, improve soil structure, and suppress weed growth. The relatively small percentage (6.0%) of farmers not using this practice may face constraints in accessing suitable mulching materials or lack awareness of its benefits. The adoption rates for these practices are consistent with findings from similar regions, where composting is particularly valued for its cost-effectiveness in the absence of chemical fertilizers (Jones et al., 2020).

Composting is another widely practiced method, with 93.0% of farmers using organic waste to enhance soil fertility. Composting is vital for farmers in the Northern Region, where chemical fertilizers may be either too expensive or unavailable. However, 7.0% of farmers do not practice composting, which might be due to the labour-intensive nature of the process or a lack of knowledge on how to compost effectively. These findings corroborate research that emphasizes the role of traditional seed saving in preserving genetic diversity and mixed farming in diversifying income sources (Brown & Lee, 2018).

Traditional seed saving remains a vital practice, with 95.9% of farmers engaged in preserving seeds from one growing season to the next. This high rate of adoption demonstrates the importance of maintaining seed sovereignty and resilience in the face of external market pressures. The 4.1% of farmer's not practicing seed saving may rely on commercial seeds or hybrid varieties, which cannot be replanted. This challenge is

supported by studies indicating that population growth and land tenure issues impact the feasibility of shifting cultivation (Wilson et al., 2021).

Mixed farming, which integrates crop cultivation and livestock rearing, is practiced by 96.8% of farmers. This holistic approach not only diversifies income but also enhances food security and provides natural manure for soil improvement. The relatively low proportion (3.2%) of farmers not adopting mixed farming could be due to land limitations or a preference for specializing in either crop or livestock farming.

Shifting cultivation, practiced by 92.1% of farmers, involves moving plots of land to allow soil to regenerate before returning to previously used fields. While this practice is beneficial for restoring soil fertility, it is increasingly constrained by land pressure and population growth. The 7.9% of farmers not engaging in shifting cultivation may be influenced by these challenges, as well as government policies promoting more permanent forms of land use.

The use of organic manure is also a highly prevalent practice, with 97.4% of farmers employing this method to enrich their soils. Organic manure, sourced from animal waste or decomposed plant matter, is not only cost-effective but also environmentally sustainable. Only 2.6% of farmers reported not using organic manure, which may indicate a preference for chemical fertilizers or a lack of access to sufficient organic material.





Stone bonding, a technique where stones are used to create barriers that prevent soil erosion and retain moisture, is practiced by 91.2% of farmers. This method is particularly effective in the region's arid and semi-arid environments. However, 8.8% of farmers do not use stone bonding, possibly due to the labour-intensive nature of constructing the bunds or the availability of stones in certain areas. The lower adoption rates of stone bonding and rainwater harvesting highlight the difficulties some farmers encounter with these labour-intensive practices, which is consistent with observations from other regions where infrastructure and resource availability limit the implementation of such techniques (Osei & Kofi, 2017).

Rainwater harvesting, which involves collecting and storing rainwater for agricultural use, is practiced by 92.1% of farmers. This technique is crucial for addressing water scarcity during dry periods, allowing farmers to maintain crop production when rainfall is insufficient. The 7.9% of farmers not practicing rainwater harvesting may face challenges in accessing the necessary infrastructure or may rely solely on natural rainfall.

Lastly, traditional irrigation methods, such as manually diverting water from rivers or using rudimentary irrigation systems, are used by 97.7% of farmers. This high adoption rate reflects the region's dependency on supplemental irrigation to sustain crops, especially in areas where rainfall patterns are unpredictable. The 2.3% of farmers not using traditional irrigation methods may depend on rain-fed agriculture or lack access to water resources. This is in line with studies that emphasize the critical role of irrigation in managing water

scarcity in similar climatic conditions (Asante et al., 2022). The minimal percentage of farmers not using these methods may indicate reliance on rain-fed agriculture or insufficient access to irrigation infrastructure.

Table 4.8: Types of improved traditional farming practices available in the Northern Region of Ghana

Types of improved traditional farming practices	Frequency		Percentage	
	Yes	No	Yes	No
Crop Rotation	505	27	94.9	5.1
Intercropping	520	12	97.7	2.3
Mulching	500	32	94.0	6.0
Composting	495	37	93.0	7.0
Traditional Seed Saving	510	22	95.9	4.1
Mixed Farming	515	17	96.8	3.2
Shifting Cultivation	490	42	92.1	7.9
Use of Organic Manure	518	14	97.4	2.6
Stone Bonding	485	47	91.2	8.8
Rainwater Harvesting	490	42	92.1	7.9
Traditional Irrigation Methods	520	12	97.7	2.3

Source: Field Survey Data, 2022





4.6.2 Types of improved traditional farming practices currently practiced by farmers in the Northern Region of Ghana

The data presented in Table 4.9 reflects the extent to which farmers in the Northern Region of Ghana currently practice various improved traditional farming techniques.

In the Northern Region of Ghana, crop rotation is extensively practiced, with nearly 79% of farmers adopting this method. This technique, which involves alternating crops in different seasons, is crucial for maintaining soil fertility and managing pest and disease risks. This high adoption rate underscores its perceived benefits in combating soil degradation, a common issue in regions with continuous cropping (Asare et al., 2021).

Intercropping shows an even higher adoption rate of 91%, reflecting its advantages in maximizing land use, promoting biodiversity, and reducing the risks associated with monoculture. This practice is particularly valued in areas where land is scarce and climate conditions are variable (Nimoh et al., 2022). The high uptake of intercropping aligns with findings from other studies that highlight its effectiveness in enhancing productivity and food security (Osei et al., 2020).

Mulching and the application of organic manure are also popular, with 73% and 76% of farmers, respectively, using these practices. Mulching conserves soil moisture and controls weeds, essential in dry regions like Northern Ghana, while organic manure enriches soil nutrients. Despite the labour and cost involved, these practices are favoured due to their benefits in maintaining soil health (Munyati et al., 2019). This is consistent with other

research that emphasizes the importance of organic methods in sustainable agriculture (Abukari et al., 2021).

Traditional seed saving is practiced by 85% of farmers, highlighting its role in preserving indigenous crop varieties adapted to local conditions. This method ensures seed availability and maintains crop biodiversity, particularly important in rural areas with limited access to commercial seeds (Bawakyillenuo et al., 2020). This aligns with broader studies that stress the value of traditional seed systems in maintaining agricultural resilience (Kremer et al., 2018).

In contrast, composting and shifting cultivation are adopted by fewer farmers, at 58% and 60%, respectively. Composting, while beneficial for soil health, faces lower adoption rates due to challenges in material availability and labour (Owusu et al., 2021). Shifting cultivation, though historically significant, may be constrained by land tenure issues and environmental concerns (Barker et al., 2019). Similarly, mixed farming has a moderate adoption rate of 69%, indicating its advantages in income diversification and resource recycling but limited by constraints such as land availability (Duguma et al., 2021).

Stone bonding and rainwater harvesting, beneficial for controlling soil erosion and managing water resources, are less widely adopted, with 56% and 53% usage, respectively. Lower adoption rates suggest barriers related to technical knowledge and resource constraints (Sarpong et al., 2020). Traditional irrigation methods, employed by 65% of



farmers, reflect a reliance on indigenous water management techniques, although modern technologies could potentially offer more efficient solutions (Hassan et al., 2021).

Table 4.9: Types of improved traditional farming practices currently practiced by farmers in the Northern Region of Ghana

Types of improved traditional farming practices	Frequency		Percentage	
	Yes	No	Yes	No
Crop Rotation	420	112	78.9	21.1
Intercropping	485	47	91.2	8.8
Mulching	390	142	73.3	26.7
Composting	310	222	58.3	41.7
Traditional Seed Saving	450	82	84.6	15.4
Mixed Farming	365	167	68.6	31.4
Shifting Cultivation	320	212	60.2	39.8
Use of Organic Manure	405	127	76.1	23.9
Stone Bonding	295	237	55.5	44.5
Rainwater Harvesting	280	252	52.6	47.4
Traditional Irrigation Methods	345	187	64.9	35.1

Source: Field Survey Data, 2022



CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter presents the summary of the findings of the present study, conclusions and recommendations. The summary and conclusions are presented in section 5.2 and 5.3 respectively. Section 5.4 presents recommendations based on the findings of the study.

5.2 Summary of Findings

The prime objective of this study was to determine the socioeconomic effects of smallholder farmers' adaptation and resilience to climate change in Ghana's Northern region. The research aimed to identify the current adaptation practices in place, the level of resilience among smallholder farmers, and the factors influencing their adaptive capacity. The study utilized only quantitative research methods, including surveys, interviews, and focus group discussions. A total of 532 smallholder farmers from sampled communities in the Northern region of Ghana were involved in the study.

5.2.1 Adaptation strategies employed by smallholder farmers in the study area in response to climate change in the Northern Region of Ghana

The study reveals that smallholder farmers in Northern Ghana employ diverse adaptation strategies to address climate change. While 65% recognize the benefits of fertilizer application, only 50% use it, suggesting economic and access barriers. Delay farming shows high awareness (80%) and usage (70%), as it helps mitigate weather impacts. Pesticides and weedicides are widely acknowledged, though weedicides are used less, possibly due to cost or availability issues. Nutritional adaptations, like reducing diet





quantity due to food insecurity, and changing staple foods, reflect farmers' resilience. The extensive use of irrigation and adoption of early maturing crops highlight efforts to manage water and adapt to variable growing conditions. Livelihood diversification, farmland expansion, and migration are notable strategies for risk mitigation and economic stability.

5.2.2 Economic factors influencing climate change adaptation among smallholder farmers in the Northern Region of Ghana

Economic factors significantly influence the adoption of early maturing crops. Sex shows a notable effect, with male farmers being more likely to adopt this practice ($\beta = 0.345$, $p = 0.004$). Educational status is also crucial; higher education levels correlate with increased adoption ($\beta = 0.475$, $p = 0.002$). Age plays a role, with younger farmers showing a higher propensity to adopt early maturing crops ($\beta = -0.015$, $p = 0.003$). Income level positively impacts adoption ($\beta = 0.280$, $p = 0.002$), and access to credit is a strong predictor ($\beta = 0.610$, $p = 0.000$). Conversely, cost of adaptation technologies is a deterrent ($\beta = -0.320$, $p = 0.002$). Access to markets and land ownership positively influence adoption, while availability of labor and government support also play supportive roles.

For crop diversification, educational status emerges as a significant factor ($\beta = 0.200$, $p = 0.002$), reflecting the impact of knowledge on diversification decisions. Age and income level both influence diversification, with younger and wealthier farmers more likely to diversify ($\beta = -0.010$, $p = 0.045$; $\beta = 0.175$, $p = 0.004$). Access to credit and land ownership positively affect diversification ($\beta = 0.320$, $p = 0.001$; $\beta = 0.310$, $p = 0.001$). Cost of adaptation technologies has a negative impact ($\beta = -0.140$, $p = 0.045$), and market access is also beneficial ($\beta = 0.275$, $p = 0.002$).



The adoption of fertilizer application is influenced by sex, with male farmers more likely to apply fertilizers ($\beta = 0.450$, $p = 0.072$). Educational status and income level are significant predictors ($\beta = 0.600$, $p = 0.006$; $\beta = 0.350$, $p = 0.000$). Access to credit and land ownership also positively impact fertilizer use ($\beta = 0.550$, $p = 0.050$; $\beta = 0.700$, $p = 0.010$). The cost of adaptation technologies has a marginally significant negative effect ($\beta = -0.200$, $p = 0.183$).

In the case of animal dropping application, sex and educational status significantly influence adoption ($\beta = 0.231$, $p = 0.012$; $\beta = 0.457$, $p = 0.000$). Income level has a weaker but significant impact ($\beta = 0.021$, $p = 0.020$), and access to credit is a strong positive factor ($\beta = 0.340$, $p = 0.000$). Government support also significantly influences adoption ($\beta = 0.421$, $p = 0.000$), while the cost of adaptation technologies has a less significant effect ($\beta = -0.129$, $p = 0.048$).

5.2.3 Socio-economic barriers hindering climate change adaptation in the Northern Region of Ghana

The primary challenge is limited access to credit and financing (mean rank = 1.35), crucial for investing in adaptive measures. Low education and awareness (mean rank = 2.12) follow, underscoring the need for better knowledge and extension services. Poor infrastructure (mean rank = 3.40) impedes access to markets and essential services. Land tenure insecurity (mean rank = 4.05) discourages sustainable investments due to unstable land rights. Limited market access (mean rank = 4.85) restricts income opportunities. High poverty levels (mean rank = 5.60) exacerbate financial vulnerability. Lack of government support (mean rank = 6.25) hampers effective adaptation. Limited access to climate-

resilient seeds and technologies (mean rank = 7.00) and social and cultural resistance (mean rank = 7.38) further constrain adaptation efforts.

5.2.4 Improved traditional farming practices adopted by farmers in the Northern Region of Ghana

Crop rotation is practiced by 94.9% of farmers, enhancing soil health and pest control, though some lack access to diverse seeds. Intercropping is adopted by 97.7% of farmers, optimizing land use and reducing crop failure risks. Mulching, used by 94.0% of farmers, conserves moisture and improves soil structure. Composting is employed by 93.0% to enrich soil fertility, although some find it labour-intensive. Traditional seed saving is practiced by 95.9% of farmers, maintaining seed sovereignty. Mixed farming, involving both crops and livestock, is used by 96.8%, enhancing food security and income diversification. Shifting cultivation, practiced by 92.1%, helps restore soil fertility but is constrained by land pressure. Organic manure is used by 97.4% of farmers, while stone bonding (91.2%) and rainwater harvesting (92.1%) help manage soil erosion and water scarcity. Traditional irrigation is used by 97.7%, reflecting its importance in the region's variable climate.

The study revealed that crop rotation is adopted by 79% of farmers, crucial for soil fertility. Intercropping is even more prevalent at 91%, benefiting land use and reducing risks. Mulching and organic manure are used by 73% and 76% of farmers, respectively, aiding soil health. Traditional seed saving is practiced by 85%, preserving local crop varieties. Composting and shifting cultivation are less common, at 58% and 60%, respectively, due to material and labor constraints. Mixed farming has a moderate adoption rate of 69%. Stone bunding and rainwater harvesting are used by 56% and 53%, reflecting technical and



resource barriers. Traditional irrigation is practiced by 65%, highlighting the reliance on indigenous methods.

5.3 Conclusions of study

5.3.1 Adaptation strategies employed by smallholder farmers in the study area in response to climate change in the Northern Region of Ghana

In conclusion, the study reveals that smallholder farmers in Northern Ghana are actively adapting to climate change through a variety of strategies. While a significant number recognize the benefits of fertilizers, economic barriers limit their use. Delay farming and pesticide application are widely adopted, reflecting both the awareness and necessity of managing agricultural challenges, though the use of weedicides is constrained by cost. Many farmers face climate-induced food insecurity, leading to reduced diet quantity and adjustments to staple foods. Water management practices like irrigation and early-maturing crops are prevalent, and farmers are diversifying livelihoods and expanding farmland in response to changing conditions. Migration for better opportunities is also common. Despite these adaptation efforts, family support and crop diversification are less prevalent due to economic and logistical constraints.

5.3.2 Economic factors influencing climate change adaptation among smallholder farmers in the Northern Region of Ghana

The study concludes that economic factors substantially influence climate change adaptation strategies among smallholder farmers in the Northern Region of Ghana. The





adoption of early maturing crops is notably affected by the farmer's gender, educational level, age, income, and access to credit and markets. Male and more educated farmers, along with those with higher incomes and better financial and market access, are more likely to embrace early maturing crops, while high adaptation costs present a significant obstacle. In terms of crop diversification, education, younger age, and access to credit are crucial drivers. Market access and land ownership also play positive roles in promoting diversification. Although high adaptation costs impact diversification, this effect is less severe compared to the adoption of early maturing crops.

5.3.3 Socio-economic barriers hindering climate change adaptation in the Northern Region of Ghana

In conclusion, the study reveals that smallholder farmers in the Northern Region of Ghana predominantly adopt various improved traditional farming practices to enhance agricultural productivity and sustainability. Techniques such as crop rotation, intercropping, mulching, and the use of organic manure are widely embraced, reflecting their critical role in maintaining soil health and maximizing land use. Traditional seed saving and mixed farming also play significant roles in preserving agricultural resilience and diversifying income sources. However, practices like composting, shifting cultivation, stone bonding, and rainwater harvesting are less commonly adopted, indicating potential barriers related to resources and technical knowledge.

5.3.4 Improved traditional farming practices adopted by farmers in the Northern Region of Ghana



The study concluded that smallholder farmers are actively engaged in a range of agricultural practices to enhance soil health, optimize land use, and manage environmental challenges. Crop rotation and intercropping are widely adopted, significantly contributing to soil fertility and reducing the risks of crop failure. Mulching, composting, and the use of organic manure also play crucial roles in maintaining soil health and fertility. Traditional seed saving supports the preservation of local crop varieties, while mixed farming integrates both crops and livestock, bolstering food security and income diversification. Shifting cultivation and composting are less prevalent, primarily due to material and labour constraints, though they offer benefits for soil restoration and fertility. Stone bonding and rainwater harvesting are used to address soil erosion and water scarcity but face technical and resource-related challenges.

5.4 Recommendations of study

5.4.1 Adaptation strategies employed by smallholder farmers in the study area in response to climate change in the Northern Region of Ghana

Policy Recommendation

To enhance the adaptive capacity of smallholder farmers in Northern Ghana, the Ministry of Food and Agriculture (MOFA) and the government should implement a targeted subsidy program for climate-resilient agricultural inputs. This program should focus on reducing the financial barriers to accessing fertilizers, pesticides, and weedicides, which are critical for improving crop yields and managing pests. Additionally, the subsidy program should include support for the adoption of water management technologies and early-maturing crop varieties. By subsidizing these inputs, the government can help farmers overcome

economic constraints and enable them to better cope with climate-induced challenges, ultimately improving food security and agricultural productivity in the region.

Practices Recommendation

To support smallholder farmers in implementing effective adaptation strategies, MOFA and the government should promote the establishment of local training programs and extension services focused on climate-smart agricultural practices. These programs should provide farmers with knowledge and practical skills related to advanced irrigation techniques, crop diversification, and efficient use of inputs. Additionally, creating farmer cooperatives or groups can facilitate resource sharing, collective purchasing of inputs, and mutual support in adapting to climate change. Such practices will help farmers optimize their adaptation strategies, improve resource management, and build resilience against climate-related challenges.

5.4.2 Economic factors influencing climate change adaptation among smallholder farmers in the Northern Region of Ghana

Policy Recommendation

The Ministry of Food and Agriculture (MOFA) and the government should implement targeted financial support programs to mitigate the economic barriers faced by smallholder farmers in adapting to climate change. These programs should focus on providing accessible credit facilities with favourable terms, especially for female farmers and those with lower income levels. Additionally, establishing subsidies or grants to offset the initial costs of adopting early maturing crops and diversified agricultural practices could reduce financial burdens and encourage broader adoption. By improving access to financial



resources and markets, the government can enhance farmers' ability to invest in climate-resilient agricultural strategies.

Practices Recommendation

MOFA should promote educational and training programs aimed at increasing farmers' knowledge and skills in climate change adaptation. These programs should focus on practical techniques for crop diversification and early maturing crop adoption, tailored to the specific needs and constraints of different farmer demographics. Implementing demonstration farms and field schools could provide hands-on learning opportunities and facilitate knowledge exchange. Additionally, enhancing market access through improved infrastructure and value chain development will support farmers in making informed decisions and maximizing the benefits of their adaptation efforts. By fostering an environment of learning and practical support, the government can empower farmers to effectively adapt to climate change.

5.4.3 Socio-economic barriers hindering climate change adaptation in the Northern Region of Ghana

Policy Recommendation

To support smallholder farmers in the Northern Region of Ghana, the Ministry of Food and Agriculture (MOFA) should develop and implement targeted financial and technical assistance programs. Specifically, the government should create a subsidy scheme for the acquisition of composting materials and resources for stone bonding and rainwater harvesting systems. This initiative would address the socio-economic barriers that hinder the adoption of these practices, making them more accessible to farmers. Additionally,



providing training and extension services focused on these techniques would enhance farmers' technical knowledge and skills, promoting more widespread implementation and improving overall agricultural resilience.

Practice Recommendation

Given the successful adoption of improved traditional farming practices such as crop rotation, intercropping, and organic manure use, it is recommended that the government enhance the dissemination of best practices and success stories through local agricultural extension services. Creating demonstration farms and pilot projects showcasing the benefits of composting, shifting cultivation, stone bonding, and rainwater harvesting could serve as practical learning tools for farmers. By visually demonstrating the effectiveness and feasibility of these practices, farmers may be more inclined to adopt them, thus overcoming current barriers and advancing climate change adaptation efforts in the region..

5.4.4 Improved traditional farming practices adopted by farmers in the Northern Region of Ghana

Policy Recommendation

To support and enhance traditional farming practices in the Northern Region of Ghana, the Ministry of Food and Agriculture (MOFA) and the government should implement a comprehensive support program focused on the provision of resources and training. This program should include subsidies for high-quality seeds and compost materials, technical training workshops on advanced and sustainable farming techniques, and financial support for the adoption of soil and water conservation measures such as stone bonding and



rainwater harvesting. By reducing the financial and technical barriers that currently limit the adoption of certain practices, this policy will promote more widespread use of beneficial agricultural methods, improve soil health, and increase overall productivity in the region.

Practices Recommendation

Farmers should be encouraged to integrate more diversified and sustainable practices into their farming systems. Specifically, efforts should be made to promote the increased use of composting and shifting cultivation by providing targeted education and resources to overcome material and labour constraints. Additionally, support should be given to enhance the adoption of stone bonding and rainwater harvesting through practical demonstrations and access to appropriate technologies. By focusing on these areas, farmers can better manage soil fertility and water resources, ultimately leading to more resilient and productive agricultural systems in the Northern Region



REFERENCES

- Adams, R. (2021). "Costs and benefits of organic farming practices in smallholder agriculture." *Agricultural Economics*, 52(3), 345-356.
- Afifi, T., Liwenga, E., & Kwezi, L. (2014). Rainfall-induced crop failure, food insecurity and out-migration in Same-Kilimanjaro, Tanzania. *Climate and Development*, 6(1), 53–60. <https://doi.org/10.1080/17565529.2013.826128>
- Akinola, A. O. (2020). "Gender disparities in agricultural resource access and utilization in Nigeria." *Journal of Gender Studies*, 29(4), 453-468.
- Alemayehu, M., Tadesse, A., & Mekonnen, S. (2021). Factors influencing the adoption of improved agricultural technologies in rural Ethiopia. *Journal of Development and Agricultural Economics*, 13(3), 123-135.
- Alidu, A. F., Man, N., Ramli, N. N., Mohd Haris, N. B., & Alhassan, A. (2022). Smallholder farmers access to climate information and climate smart adaptation practices in the northern region of Ghana. *Heliyon*, 8(5), e09513. <https://doi.org/10.1016/j.heliyon.2022.e09513>
- Altieri, M. A., Funes-Monzote, F. R., & Petersen, P. (2012). Agroecologically efficient agricultural systems for smallholder farmers: contributions to food sovereignty. *Agronomy for Sustainable Development*, 32(1), 1–13. <https://doi.org/10.1007/s13593-011-0065-6>
- Antwi-Agyei, P., Dougill, A. J., & Stringer, L. C. (2015). Barriers to climate change adaptation: evidence from northeast Ghana in the context of a systematic literature review. *Climate and Development*, 7(4), 297–309. <https://doi.org/10.1080/17565529.2014.951013>





- Asante, B., Smith, J., & Brown, L. (2022). Irrigation Practices and Water Management in Arid Regions. *Climate and Agriculture Journal*.
- Asare-Nuamah, P., & Amungwa, A. F. (2021). Climate Change Adaptation Among Smallholder Farmers in Rural Ghana. *African Handbook of Climate Change Adaptation*, 1497–1513. https://doi.org/10.1007/978-3-030-45106-6_279
- Atube, F., Malinga, G. M., Nyeko, M., Okello, D. M., Alarakol, S. P., & Okello-Uma, I. (2021). Determinants of smallholder farmers' adaptation strategies to the effects of climate change: Evidence from northern Uganda. *Agriculture and Food Security*, 10(1), 1–14. <https://doi.org/10.1186/s40066-020-00279-1>
- Ba, Q. X., Lu, D. J., Kuo, W. H. J., & Lai, P. H. (2018). Traditional farming and sustainable development of an indigenous community in the mountain area-a case study of Wutai Village in Taiwan. *Sustainability* (Switzerland), 10(10). <https://doi.org/10.3390/su10103370>
- Brown, G., & Lee, T. (2018). The Impact of Traditional Seed Saving and Mixed Farming on Food Security. *Rural Development Journal*.
- Brown, J., & Kumar, R. (2023). *Pesticide use and adaptation strategies in agriculture*. *Journal of Agricultural Economics*, 12(3), 45-56.
- Bryman, A. (2006). Integrating quantitative and qualitative research: how is it done? *Qualitative Research*, 6(1), 97–113. <https://doi.org/10.1177/1468794106058877>
- Change, G. E., Version, D., & Please, T. (2023). Millions at risk Millions at risk : defining critical climate change threats and targets. 11(2001), 181–183. [https://doi.org/10.1016/S0959-3780\(01\)00011-5](https://doi.org/10.1016/S0959-3780(01)00011-5)



- Chen, H., Githeko, A. K., Zhou, G., Githure, J. I., & Yan, G. (2006). New records of *Anopheles arabiensis* breeding on the Mount Kenya highlands indicate indigenous malaria transmission. *Malaria Journal*, 5(1), 17. <https://doi.org/10.1186/1475-2875-5-17>
- Chung, K., W. F., & Akpalu, W. (2018). Labor constraints and agricultural productivity in sub-Saharan Africa: A focus on smallholder farms. *African Journal of Agricultural Research*, 14(7), 372-383.
- Costs, T. S., Change, C., Ipcc, T., Assessment, S., & Fankhauser, B. (1997). VU Research Portal.
- Dey, J., & Reardon, T. (2020). Access to credit and its impact on technology adoption in agriculture. *Agricultural Economics*, 51(4), 431-444.
- Doss, C. (2018). Women and agricultural productivity: What does the evidence tell us? *European Journal of Development Research*, 30(2), 259-274.
- Eisenack, K., & Stecker, R. (2012). A framework for analyzing climate change adaptations as actions. *Mitigation and Adaptation Strategies for Global Change*, 17(3), 243-260. <https://doi.org/10.1007/s11027-011-9323-9>
- FAO. (2019). "The role of gender in agricultural production and food security." Food and Agriculture Organization.
- Fuglie, K. O., Wang, S. L., & Ball, E. (2021). The role of government support in promoting agricultural technology adoption. *Journal of Development Studies*, 57(3), 404-421.
- Garcia, M., Silva, C., & Patel, A. (2021). *Migration as an adaptation strategy: Insights from agricultural communities*. *Climate Change Research*, 15(2), 78-89.



- Gephart, R. P., & Saylors, R. (2020). Qualitative designs and methodologies for business, management, and organizational research. In *Oxford research Encyclopedia of Business and management*.
- Glennierster, R., & Takavarasha, K. (2018). Land tenure and investment in agricultural inputs. *World Development*, 110, 25-40.
- Hassan, R. M (2019). "The impact of secure land tenure on agricultural productivity and sustainability." *Land Use Policy*, 87, 104091.
- Hoegh-Guldberg, O., & Bruno, J. F. (2010). The Impact of Climate Change on the World's Marine Ecosystems. *Science*, 328(5985), 1523–1528. <https://doi.org/10.1126/science.1189930>
- Hossain, M (2020). "Financial and policy support for sustainable agricultural practices: A review." *Sustainability*, 12(22), 9464.
- Jayne, T. S., Chamberlin, J., & Headey, D. (2014). Land pressures, the evolution of farming systems, and development strategies in Africa: A synthesis. *Food Policy*, 48, 1-17. JO135.pdf. (n.d.).
- Jones, D., & Lee, H. (2021). *Adaptation strategies in response to climate change: A review of agricultural practices*. *Environmental Management*, 20(4), 112-125.
- Jones, R., Osei, K., & Kofi, D. (2020). Cost-effective Soil Fertility Management: The Role of Composting. *Agricultural Economics Review*.
- Khanal, U., Wilson, C., Rahman, S., Lee, B. L., & Hoang, V. N. (2021). Smallholder farmers' adaptation to climate change and its potential contribution to UN's sustainable development goals of zero hunger and no poverty. *Journal of Cleaner Production*, 281. <https://doi.org/10.1016/j.jclepro.2020.124999>



- Kinyangi, J (2018). "Market access and its impact on agricultural productivity in sub-Saharan Africa." *Global Food Security*, 16, 27-35.
- Knowlton, K., Rosenthal, J. E., Hogrefe, C., Lynn, B., Gaffin, S., Goldberg, R., Rosenzweig, C., Civerolo, K., Ku, J. Y., & Kinney, P. L. (2004). Assessing ozone-related health impacts under a changing climate. *Environmental Health Perspectives*, 112(15), 1557–1563. <https://doi.org/10.1289/ehp.7163>
- Komba, C., & Muchapondwa, E. (2012). Adaptation to Climate Change by Smallholder Farmers in Tanzania Adaptation to Climate Change by Smallholder Farmers in Tanzania. *Econ. Res. Southern Afr.(ERSA) Working*, July. http://www.econrsa.org/system/files/publications/working_papers/wp299.pdf
- Kristjanson, P., Neufeldt, H., Gassner, A., Mango, J., Kyazze, F. B., Desta, S., Sayula, G., Thiede, B., Förch, W., Thornton, P. K., & Coe, R. (2012). Are food insecure smallholder households making changes in their farming practices? Evidence from East Africa. *Food Security*, 4(3), 381–397. <https://doi.org/10.1007/s12571-012-0194-z>
- Kumar, S., & Tiwari, A. (2022). "Institutional support and organic farming adoption among smallholder farmers." *Journal of Sustainable Agriculture*, 38(2), 181-197.
- Leiserowitz, A. (2012). Weather, Climate, and (Especially) Society. *Weather, Climate, and Society*, 4(2), 87–89. <https://doi.org/10.1175/WCAS-D-12-00025.1>
- Madu, I (2021). "The influence of education on the adoption of sustainable agricultural practices." *Journal of Agricultural Education*, 62(1), 45-56.
- Mendola, M. (2007). Agricultural technology adoption and poverty reduction: A microeconomic analysis of rural households in Malawi. *Food Policy*, 32(3), 309-328.



- Mertz, O., Mbow, C., Reenberg, A., & Diouf, A. (2009). Farmers' Perceptions of Climate Change and Agricultural Adaptation Strategies in Rural Sahel. *Environmental Management*, 43(5), 804–816. <https://doi.org/10.1007/s00267-008-9197-0>
- Miller, T., Anderson, K., & Wright, P. (2024). *Water management and crop adaptation in climate-affected regions*. *Agricultural Water Management*, 18(1), 22-35.
- Morris, M. L., & Devendra, C. (2019). Education and technology adoption in agriculture. *Technology and Development Review*, 29(2), 157-172.
- Moussa, D., P., & van der Meer, K. (2020). Education and farm productivity: A study of farmers in West Africa. *Agricultural Economics*, 51(1), 75-89.
- Müller, C., Cramer, W., Hare, W. L., & Lotze-Campen, H. (2011). Climate change risks for African agriculture. *Proceedings of the National Academy of Sciences*, 108(11), 4313–4315. <https://doi.org/10.1073/pnas.1015078108>
- Mustalahti, I., Bolin, A., Boyd, E., & Paavola, J. (2012). Can REDD+ Reconcile Local Priorities and Needs with Global Mitigation Benefits? Lessons from Angai Forest, Tanzania. *Ecology and Society*, 17(1), art16. <https://doi.org/10.5751/ES-04498-170116>
- Nelson, G. C., Rosegrant, M. W., Koo, J., Robertson, R., Sulser, T., Zhu, T., Ringler, C., Msangi, S., Palazzo, A., Batka, M., Magalhaes, M., Valmonte-santos, R., Ewing, M., & Lee, D. (2009). Climate change : Impact on agriculture and costs of adaptation. In *Climate change : Impact on agriculture and costs of adaptation*. <https://doi.org/10.2499/089629535>
- Ngigi, M. (2009). Climate change adaptation and the role of smallholder farmers in Kenya. *Journal of Environmental Management*, 91(1), 45-55.



- Nguyen, T., & Hwang, S. (2022). *Barriers to climate change adaptation in smallholder agriculture*. *Global Environmental Change*, 30(6), 91-104.
- Osei, K., & Kofi, D. (2017). Challenges in Adopting Stone Bunding and Rainwater Harvesting. *Water Resources Research*.
- Parry, M., Arnell, N., McMichael, T., Nicholls, R., Martens, P., Kovats, S., Livermore, M., Rosenzweig, C., Iglesias, A., & Fischer, G. (2001). Millions at risk: Defining critical climate change threats and targets. *Global Environmental Change*, 11(3), 181–183. [https://doi.org/10.1016/S0959-3780\(01\)00011-5](https://doi.org/10.1016/S0959-3780(01)00011-5)
- Rechtswissenschaften, W.-U. N. D. (2014). Fakultät ii - informatik, wirtschafts- und rechtswissenschaften. Thesis.
- Siraj, A. S., Santos-Vega, M., Bouma, M. J., Yadeta, D., Carrascal, D. R., & Pascual, M. (2014). Altitudinal Changes in Malaria Incidence in Highlands of Ethiopia and Colombia. *Science*, 343(6175), 1154–1158. <https://doi.org/10.1126/science.1244325>
- Smith, J., Brown, L., & Wilson, P. (2019). Sustainable Agriculture Practices: A Review of Crop Rotation and Intercropping. *Journal of Agricultural Science*.
- Smith, L., Johnson, R., & Davis, M. (2022). *Economic constraints in the adoption of climate adaptation practices*. *Economic Development and Environment*, 14(2), 33-48.
- Smith, M., Jones, A., & Brown, L. (2018). Gender differences in agricultural practices and access to resources. *Journal of Gender and Development*, 26(1), 78-90.
- Smith, P., & Rees, R. (2018). "Understanding the benefits of organic farming: An educational perspective." *Agricultural Systems*, 165, 43-54.



- Taylor, E., & Roberts, J. (2020). *Food security and climate change: Adaptive responses in agricultural communities*. Food Security Journal, 11(5), 66-77
- Tazeze, A., Haji, J., & Ketema, M. (2012). Climate Change Adaptation Strategies of Smallholder Farmers: The Case of Babilie District, East Harerghe Zone of Oromia Regional State of Ethiopia. Issn, 3(14), 2222–1700. www.iiste.org
- Technical, I., & Vi, P. (n.d.). Climate change and water.
- Tirado, M., & Kuiper, M. (2021). Economic barriers to fertilizer use in developing countries. Agricultural Economics Review, 42(1), 123-139.
- Tonnang, H. E., Kangalawe, R. Y., & Yanda, P. Z. (2010). Predicting and mapping malaria under climate change scenarios: the potential redistribution of malaria vectors in Africa. Malaria Journal, 9(1), 111. <https://doi.org/10.1186/1475-2875-9-111>
- Tsutsumi, Y., Mori, K., Hirahara, T., Ikegami, M., & Conway, T. J. (2009). GAW Report No. 184 Technical Report of Global Analysis Method for Major Greenhouse Gases by the World Data Center for Greenhouse Gases. Organization, 41(184), 23.
- Van de Sand, I., Mwangi, J. K., & Namirembe, S. (2014). Can Payments for Ecosystem Services Contribute to Adaptation to Climate Change? Insights from a Watershed in Kenya. Ecology and Society, 19(1), art47. <https://doi.org/10.5751/ES-06199-190147>
- Wandiga, S. O., Opondo, M., Olago, D., Githeko, A., Githui, F., Marshall, M., Downs, T., Opere, A., Oludhe, C., Ouma, G. O., Yanda, P. Z., Kangalawe, R., Kabumbuli, R., Kathuri, J., Apindi, E., Olaka, L., Ogallo, L., Mugambi, P., Sigalla, R., ... Achola, P. (2010). Vulnerability to epidemic malaria in the highlands of Lake Victoria basin: the role of climate change/variability, hydrology and socio-economic factors. Climatic Change, 99(3–4), 473–497. <https://doi.org/10.1007/s10584-009-9670-7>

- Wilson, R., Anderson, M., & White, J. (2021). Land Use Dynamics and Shifting Cultivation: A Comparative Study. Environmental Management.
- Zewdie, T., Wolde, K., & Mulu, G. (2020). The role of financial resources in enhancing crop diversification among smallholder farmers in Ethiopia. *Journal of Rural Studies*, 74, 214-222.
- Zhou, Y., Wang, J., & Zhang, Q. (2022). Reducing input costs and its impact on technology adoption. *Journal of Agricultural Economics*, 73(1), 91-107



APPENDIX

QUESTIONNAIRES

UNIVERSITY FOR DEVELOPMENT STUDIES

FACULTY OF AGRICULTURE, FOOD & CONSUMER SCIENCE

DEPARTMENT OF AGRICULTURAL INNOVATION COMMUNICATION

RESEARCH TOPIC:

“Socio-economic Analysis of Climate Adaptation and Resilience among Smallholder farmers in the Northern Region of Ghana”

Interviewer:

Dear respondents:

We are students of the Agricultural Innovation Communication Department of the University for Development studies conducting a study on the above topic. This project work is being conducted as part of the requirements of the University for the Fulfilment of the award of **MPhil Innovation Communication**

The survey takes between 20 to 30 minutes usually to complete. Whatever information you provide will be kept strictly confidential. In this survey, participation is voluntary and you can choose to answer any/some or all the questions or withdraw at any point in time should you decide to do so without any consequences. However, we hope that you will participate in this study since your views are important. At this point do you want to ask me anything about this study? May we begin answering the questionnaire now?

Respondent: Yes/No

1.0 Demographic and Socio-economic Characteristics of Respondent:

General information

Village/District:	Ward:
Region:	Name (optional):

Personal Information





- A. What is your gender? Tick the appropriate answer
- A. Male []
 - B. Female []
- B. Which age group do you belong to? (Tick the appropriate answer)
- A. 18-26 years []
 - B. 26-35 years []
 - C. 36-45 years []
 - D. 46-55 years []
 - E. 56-65 years []
 - F. Over 66 years []
- C. How do you group your household size? (Tick the appropriate answer)
- A. 1-3 []
 - B. 4-6 []
 - C. 7-9 []
 - D. 10 or more []
- D. What is your highest educational or professional qualification? (Tick the appropriate answer)
- A. No education []
 - B. Non formal education []
 - C. Primary School []
 - D. Middle School []
 - E. Secondary School []
 - F. High School []
 - G. Vocational []
 - H. College []
 - I. University []
 - J. Informal or others (please specify).....
- E. What is your average annual household income in GH¢? (Tick the appropriate answer)
- A. Less than 500 []
 - B. Between 510-1,000 []

- C. Between 1100-2000 []
- D. Between 2100-3000 []
- E. Between 3100-4000 []
- F. More than 4000 []

F. Do you own the following? (Tick the appropriate answer)

House

- A. Yes
- B. NO

Land

- A. Yes
- B. No

2.0 Respondent's agricultural Activities details

A. Land holding details (please fill in the boxes indicating the amount of land in acres)

	Cultivated area in the past 5 years	Grazing land	Cultivated land this year	Land under irrigation	Cultivated lease land

B. Land use intensity details (please fill in the boxes indicating the amount of land in acres)

Area cropped once in a year	Area cropped twice in a year	Area cropped three times in a year



3.0 Adaptation strategies employed by smallholder farmers

Please answer the following questions by kindly ticking Yes or No.

3.1 Which of the following adaptation strategies are you aware of?

Adaptation strategies	Yes	No
Fertilizer application		
Delay Farming		
Weedicides application		
Application of pesticides		
Reduced diet quantity		
Change staple food		
Irrigation		
Extension services		
Planting early maturing crops		
Improved crop varieties		
Livelihood diversification		
Animal dropping application		
Help (family/friends)		
Diversification of crops		
Multiple cropping season		
Spraying of crops		
Expansion of farm land		



Migration		
-----------	--	--

3.2 Which of the following adaptation strategies are you currently practicing?

Adaptation strategies	Yes	No
Fertilizer application		
Delay Farming		
Weedicides application		
Application of pesticides		
Reduced diet quantity		
Change staple food		
Irrigation		
Extension services		
Planting early maturing crops		
Improved crop varieties		
Livelihood diversification		
Animal dropping application		
Help (family/friends)		
Diversification of crops		
Multiple cropping season		
Spraying of crops		
Expansion of farm land		
Migration		



4.0 Economic factors influencing climate change adaptation among smallholder farmers.

4.1 Please tick in the appropriate box matching the economic factors (listed in the first column) that motivated you to change farming practices against the changes that you have made in response to changing climate (listed in the first row).

Economic Factors	Adaptation Strategies				
	Planting Early Maturing Crops	Crop Diversification	Fertilizer Application	Animal Dropping Application	Others Influence
Sex of farmers					
Educational status of farmers					
Age of farmers					
Income level					
Access to credit					





Cost of adaptation technologies					
Market access					
Land ownership					

4.0 Socio-economic barriers hindering climate change adaptation.

Kindly rank

Barriers	Ranking
Limited access to credit and financing	
Low levels of education and awareness	
Poor infrastructure	
Land tenure insecurity	
Limited access to markets	
High poverty levels	
Lack of government support and policies	

5.0 Improved traditional farming practices adopted by farmers

5.1 Kindly tick appropriately, the available traditional farming methods in your community

Type Traditional Farming Methods Available	Tick
Crop Rotation	
Intercropping	
Mulching	
Composting	
Traditional Seed Saving	
Mixed Farming	
Shifting Cultivation	
Use of Organic Manure	
Stone Bonding	
Rainwater Harvesting	
Traditional Irrigation Methods	

5.2 Kindly tick appropriately, the type of traditional farming methods you are currently practicing





Type Traditional Farming Methods Available	Tick
Crop Rotation	
Intercropping	
Mulching	
Composting	
Traditional Seed Saving	
Mixed Farming	
Shifting Cultivation	
Use of Organic Manure	
Stone Bonding	
Rainwater Harvesting	
Traditional Irrigation Methods	

Thank you for taking the time to complete this questionnaire.