UNIVERSITY FOR DEVELOPMENT STUDIES

CLIMATE-SMART AGRICULTURE TECHNOLOGY ADOPTION AND IMPACT IN THE EAST GONJA DISTRICT OF GHANA

MICHAEL AYEAH ISRAEL

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THESIS SUBMITTED TO THE DEPARTMENT OF AGRICULTURAL AND RESOURCE ECONOMICS, FACULTY OF AGRIBUSINESS AND COMMUNICATION SCIENCES, UNIVERSITY FOR DEVELOPMENT STUDIES, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF PHILOSOPHY DEGREE IN AGRICULTURAL ECONOMICS

FEBRUARY, 2019

DECLARATION

Student

I hereby declare that this thesis is a result of my original work and has not been in any part presented for another degree in this University or any other elsewhere.

Signature: ________________________ **Date:** _____________________

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Supervisors

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

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ABSTRACT

Climate Smart Agriculture has been introduced as a viable solution to tackling the climate change challenge across the world. It is believed to have the potential of increasing resilience to the impacts of climate change while simultaneously increasing crop yield and incomes of farmers and reducing the emission of Greenhouse Gases. The aim of this study was to determine the factors contributing to the adoption of CSA practices in the East Gonja district of the Northern region of Ghana and the impact of the adoption of these practices on the welfare of farmers and their contribution to GHG emissions. Data was obtained from a sample of 350 maize farmers randomly selected through personal interviews using semi structured questionnaires. Farmers' demographic and socioeconomic characteristics as well as their perceptions on climate change were analyzed descriptively. The study showed that Soil conservation and livelihood diversification practices were highly adopted compared to irrigation and water harvesting. The Multivariate Probit model, Generalized Poisson model and Endogenous Switching Regression model were used in analyzing the determinants of CSA adoption, Farmers' participation in emission practices and the impact of adoption of CSA practices on welfare respectively. Farm size, credit access and production intention were some of the variables found to influence the adoption of CSA practices in the district. Household size, education, production intention and off-farm revenue were also found to significantly influence the participation in emission practices. The study also showed that non-adopters had a better welfare in terms of per capita consumption expenditure compared to adopters from the ESR model. The study concluded that farmers who adopted CSA practices were less likely to contribute to GHG emissions from farming activities although they had a lower welfare compared to non-adopters. The study recommends that, government should consider the integration of CSA practices into the sector's policy and also, further research should be carried out into finding the impact of CSA adoption using alternative welfare proxies and estimation techniques.

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DEDICATION

I dedicate this work to my loving mother Mrs. Grace Avorkliyah Israel. I wouldn’t have made it without your sacrifice and encouragement. I love you.

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LIST OF ACRONYMS

ACRONYM	MEANING
AFOLU	Agriculture Forestry and Other land Use
AIPW	Augmented Inverted Probability weighting
CSA	Climate-Smart Agriculture
LD	Livelihood Diversification
SCP	Soil Conservation Practices
IWh	Irrigation and Water Harvesting
EGD	East Gonja District
ESR	Endogenous Switching Regression
FAO	Food and Agricultural Organization
GHG	Greenhouse Gases
GOG	Government of Ghana
IPCC	Intergovernmental Panel on Climate Change
MESTI	Ministry of Environment, Science, Technology and Innovation
METASIP	Medium Term Agriculture Sector Investment Plan
MOFA	Ministry of Food and Agriculture
NNM	Nearest Neighbor Matching
PSM	Propensity Score Matching
SAP	Sustainable Agricultural Practices
SSA	Sub-Saharan Africa
USAID	United States Agency for International Development
WRI CIAT	World Resources Institute Climate Analysis indicator tool

CHAPTER ONE

INTRODUCTION

1.1 Background

Climate change has become a critical socio-economic as well as environmental issue. It is one of the most essential areas under the Sustainable Development Goals (SDGs) and poses a major threat to food and nutrition security. Climate change occurs as a result of an increase in the concentrations of greenhouse gases such as carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4) (Rosegrant *et al.*, 2008). Land use and land cover change and agricultural practices are believed to contribute to about 20% of the global annual emission of CO_2 (Intergovernmental Panel on Climate Change (IPCC), 2001).

The IPCC (2007a) defined climate change as "a change in the state of the climate which can be observed by changes in the mean of its properties, its variability or both and that spans for an extended period, typically decades or more".

Climate change negatively affects the production and productivity of livestock, crops and fisheries (FAO, 2016) as well as threatening various sectors of economic development including natural resources, forestry, tourism, manufacturing, and health (IPCC, 2007b). The adverse effects of climate change go a long way to affect the state of food and nutrition security as well as the livelihood of farmers who solely rely on agriculture for their sustenance.

Climate change is a major challenge to agricultural production worldwide with both direct and indirect impacts. Indirectly, climate change affects agriculture by altering the growth and distribution of incomes (Schmidhuber and Tubiello, 2007). The impacts of climate change could also be exhibited through changes in the incidences of floods and droughts and this would lead to exacerbated risk events of the suffering of humankind and also become a major barrier to economic development and reduction in poverty (Herrero *et al*., 2010).

The decline in agricultural productivity accompanied by food price increases has serious implications for food security (FAO, 2016) especially in developing countries where the vulnerability to the impact of climate change is high.

Climate change and variability give rise to a new development challenge, particularly in Sub-Saharan African (SSA) countries where the bulk of the population rely on climate-sensitive activities, particularly, agricultural production (Thompson *et al*., 2010; IFPRI 2010; FAO 2010).

With an agricultural sector dominated by smallholder farmers, the welfare and food security status of SSA countries are vulnerable to climate change and its effect (Barrios *et al*., 2008). SSA still remains the world's most food-insecure region with high levels of Child mortality and poverty as well as low stages of human and physical capital, in addition to poor infrastructure. Although the Agricultural sector in SSA is economically important, it has performed generally poor relative to other developing countries (Barrios *et al*., 2008).

Agricultural production in SSA is characterized mainly by low yields and this is mostly as a result of agro ecological features, lack of inputs and knowledge, poor access to service and low levels of infrastructure investment and irrigation. SSA's vulnerability to the impacts of climate change can largely be attributed to the social, economic, and political constraints that determine the ability of human systems to adapt to external stressors such as climate change (Gregory *et al*., 2005). In Ghana, climate change is predicted to affect the country's crop production, food security, water resources and energy supply (Bodegom *et al*., 2015).

The Ghanaian economic sector is dominated by agriculture in terms of labor with a majority of the farming population coming from rural households (GLSS, 2014). Agriculture is principally a smallholder activity in Ghana with about 90% of farm holdings less than 2 hectares in size (MoFA, 2015). The sector is faced with numerous challenges which hinder the growth of the sector including limited access to credit, heavy reliance on rain-fed agriculture, low level of mechanization, high post-harvest losses as a result of inadequate storage and marketing facilities, poor agricultural extension services and climate variability and change (GoG, 2010).

Vulnerability to climate change in Ghana is mostly concentrated in the Northern, Upper East, and Upper West regions of the country, especially in the agricultural sector (Stanturf *et al*., 2011). The challenges faced in these regions are amplified given the harsh climate and distance from the nation's administrative capital (Sova *et al*., 2014). Majority of the farmers in these locations are dependent on agriculture as their main source of livelihood and welfare. Due to the marginal locations of these rural smallholder farmers coupled with their low level of technical know-how and barriers to access to essential farming resources, these farmers become particularly prone to the effects of climate change (Thamanga-Chitja and Morojele, 2014).

In reducing the negative impacts of climate change, the most efficient way seems to be adaptation (Füssel *et al*., 2006). Adoption of climate change adaptation strategies, however, is dependent on several factors. Socio-economic factors such as education, age, gender, and supply-side policy variables like access to extension and credit as well as agro-ecological settings and temperature all influence farmers' choices of adaptation strategies (Deressa *et al*., 2009). Farmers are, however, usually constrained in their efforts to adopt climate-smart adaptation strategies to offset the negative impacts of climate change. The major barrier to adaptation by most farmers is the lack of access to credit (Gbetibouo, 2009). Although adaptation is believed to offset the negative effect of climate change, it fails to sometimes meet the sustainability criteria. Generally, recommended practices which aim to increase productivity have been found to contribute to net greenhouse gas emissions. Agricultural practices such as tillage, irrigation and the use of agro-chemicals like fertilizers have been discovered to contribute significantly to emissions (Lal, 2004). In 2010, the estimated total non-carbon-dioxide (CO_2) Greenhouse Gas (GHG) emission as a result of agriculture was 10-12% of the global anthropogenic emissions (Smith *et al*., 2014).

According to World Resources Institute Climate Analysis Indicators Tool (WRI CAIT), in 2011 Ghana contributed 0.13% of the world's GHG emissions with 59Mt CO_2e with a per capita emission of 2.37tCO_2e (WRI CAIT 2.0, 2015). Agriculture emissions grew by 32% during 1990-2011 (WRI CAIT 2.0, 2015) and this increase in emissions were attributed to the frequent burning of biomass during land clearing and growth in the number of livestock (MESTI, 2015). The Agriculture Forestry and Other Land Use (AFOLU) sector was the largest source of emissions followed by the energy sector in 2012 constituting 45.1% (15.17 MtCO2e) of total net emissions (MESTI, 2015).

CSA has been introduced in recent times as an approach to battle climate change while concurrently addressing the issues of GHG emissions. CSA seeks to sustainably increase agricultural productivity and incomes as well as building both the resilience and the capacity of agricultural food systems to adapt to climate change. CSA also pursues opportunities to reduce and remove GHGs so as to meet the development goals of countries (FAO, 2016).

Climate-smart agriculture is an approach or pathway for the transformation and reorientation of agricultural development taking into consideration the new realities of climate change (Lipper *et al*., 2014). CSA has the potential of sustainably increasing productivity and resilience while reducing GHG emissions altogether enhancing the achievement of food security and developmental goals of the region (Managa and Nkobole-mhlongo, 2016). Generally, CSA places emphasis on increasing resilient food production systems that lead to food and income security under progressive climate change and variability (Vermeulen *et al*., 2012; Lipper *et al*., 2014). At the core of CSA lies sustainable agriculture and sustainable intensification while accounting for greenhouse gas emissions through mitigation. The need for climate smart agricultural methodologies and technologies as a remedy for the negative impacts of climate change has been clearly outlined in the agricultural sector plan, METASIP II.

Smallholder farmers in northern Ghana are faced with numerous challenges hindering optimal productivity and are also vulnerable to climate change impact while at the same time contributing to GHG emissions through their agricultural production. It is, therefore, imperative to ensure improved welfare and general well-being of farmers through the implementation of programs and projects targeted at improving yields and improving their resilience in the face of climate change while simultaneously reducing emissions. CSA is believed to hold the key to concurrently tackling these challenges and meeting the productivity, resilience, and emission standards.

1.2 Problem Statement

The negative impact of climate change on agricultural production, especially on the global food security situation continues to be a major concern to the world today, particularly in developing countries where the majority of the population depends on food crop production for their livelihoods. Climate change is expected to have damaging impacts on agricultural livelihoods, especially in the tropics and Sub-Saharan Africa. This is because a large majority of individuals in these areas solely depend on agriculture for their livelihoods.

In Ghana, the over-dependence of farmers on rain-fed agriculture and the lack of adequate measures to mitigate climate change effects have been identified as some of the production risks in the agricultural industry (MoFA, 2015). The impacts of climate change are as a result of high climatic sensitivity and a lower flexibility to adaptation which results in the low productivity in the agricultural sector (Dhakal *et al*., 2013).

The government of Ghana took steps to address the climate change problem in 2008 through the National Climate Change Strategy. However, its implementation was not very effective. In order to mainstream climate change into its policy, government partnered with the Climate Change, Agriculture and Food Security to aide in developing CSA Action plan (MoFA, 2015).

Several studies (Chalinor *et al*., 2006; Amikuzuno and Donkoh, 2012; Blanc, 2012) have been carried on how crop yields and productivity are affected by climate change and variability. Studies have also shown that the semi-arid regions of the world are the most likely to suffer from reduced yields in crops like maize, rice and wheat as a result of increasing temperatures and declining levels and distribution of rainfall (Lobell *et al*., 2009). Empirical analysis carried out in the Northern region of Ghana has shown that increase in the average annual temperature would cause a significant reduction in the yield of rice (Mabe *et al*., 2014).

Moreover, farm-level studies in some parts of northern Ghana have revealed that net farm incomes and poverty rates are sensitive to climate change, and livelihood outcomes will be adversely affected by high temperatures and reduced rainfall (Amikuzuno and Hathie, 2013).

The focus of climate change studies have mainly been in the areas of impact, vulnerability and adaptation, especially in the field of agriculture in SSA and Ghana. Though farmers are adapting to the changing climatic conditions, the actual adoption of possible beneficial practices is often low (Arslan *et al*., 2013). Little focus has been placed on farmer contribution to emissions and mitigation. CSA, has therefore, become a more attractive approach in tackling the current climate issues since it deals with increasing productivity and adaptation and reducing mitigation.

Climate Change and its impact poses an imminent threat to farmers, especially smallholder resource constrained farmers. The situation appears to be much dire in SSA and for that fact farmers in Ghana, particularly the Savannah zone where farmers are limited to just one planting season due to the mono-modal rainfall pattern and relatively marginalized lands. Poverty rates in these areas have already been reported to be the highest in comparison to other regions of the country and there is a threat of the situation further worsening unless farmers' resilience to climate change impact is improved (FAO, 2016).

Despite the fact of climate change impact vulnerability being highest in the Savannah zone, in terms of GHG emissions from the agricultural sector, Savannah burning has also been identified to be the major contributor in terms of anthropogenic sources. It is therefore imperative to simultaneously tackle both issues to ensure sustainability of agricultural production in the region.

Smallholder agricultural systems have the potential to adapt to climate change through the adoption of climate-smart practices (FAO, 2016) while at the same time reducing emissions. Despite the possible potentials of CSA, very little has been done in terms of CSA adoption in the savannah zone in terms of research to establish the adoption and possible impacts on the livelihood of farmers and contribution to GHG mitigation. This study therefore, seeks to fill the gap in research by attempting to establish CSA adoption in the East Gonja district of the Northern region of Ghana and its impact on farmers' welfare.

The research questions that guide the study are as follows:

1.3 Research Questions

- What are farmers' knowledge and perceptions on climate change?
- What are the determinants of adoption of climate-smart practices by farmers?
- How does climate-smart technology adoption impact farmers' welfare outcomes?

- Does farmers' knowledge of climate change affect their emission/mitigation practices?

The following objectives emanate from the research questions

1.4 Research Objectives

- General objective
    - To examine the determinants of adoption of CSA technologies, welfare impacts, and farmers' contribution to GHG emission/mitigation
- The specific research objectives are to;
    1. Identify farmers' knowledge and perception on climate change in the study area.
    2. Identify the determinants of adoption of climate-smart practices in the study area.
    3. Estimate the impact of CSA adoption on farmers' welfare.
    4. Determine the factors influencing farmers involvement in emission activities

1.5 Justification

Climate change poses a major challenge to resource constrained farmers across the globe. The situation however, appears to be more severe in SSA and in Ghana, the three northern regions are believed to be the most susceptible to the negative impacts of climate change.

The government already has assessment on the GHG emission status of the country through the National Greenhouse Gas Inventory, establishing the AFOLU sector being the major contributor to emissions in the country however, farmers' participation in the practices leading to GHG emissions is yet to be determined.

In finding out the factors which determine contribution to greenhouse gas emissions or mitigation at the farm household level, this study will be able to help in developing policies targeted at reducing direct greenhouse gas emissions from the agricultural sector which will help in reaching the country's greenhouse gas emission goals as part of the Paris agreement.

The findings of this research will help improve knowledge on the CSA practices used by farmers in northern Ghana and also the factors which help in the uptake of the technologies to help in the implementation of such programs in other parts of the country to help to increase productivity of crops while at the same time increasing the resilience of farmers to the impacts of climate change as well as reducing GHG emission from the agricultural sector which will ultimately lead to sustainability of the country's agricultural sector.

Considering the prevailing poverty conditions in the three Northern regions and their dependence on agriculture largely for their livelihood, it is imperative to develop policies targeted at improving their welfare. This research will provide useful information to help government to develop policy to help in the fight against climate change and stabilizing farmers' welfare.

CHAPTER TWO

LITERATURE REVIEW

2.1 Chapter outline

The chapter presents a review of literature related to study. It covers topics related to climate change in terms of the definition, causes and impacts. The review also covers Greenhouse gas emissions and mitigation as well as climate-smart Agriculture. The review finally concludes with an in-depth review of technology adoption.

2.2 Climate Change

2.2.1 Definition and Causes

Climate is the average state of atmosphere of a location or an area over a defined period of 30 years and climatic change represents a significant variance between two average climatic conditions or climatic normal which impacts the ecosystem significantly (Ayoade, 2003).

Climate change refers to a change in the state of the climate that can be identified statistically by tests by changes in the average and the variability of its properties, and that continues for an extended period, typically 10 years or longer (IPCC, 2011).

The term 'Climate' refers to the average weather conditions, of any given geographic region, estimated over a long period of time, from a few weeks to infinite years, but generally for as long as 30 years or more (NASA, 2008).

According to the IPCC (2014), Climate change may occur naturally as a result of internal processes or external acts like variations of the volcanic eruptions, solar cycles, and persistent anthropogenic changes in the composition of the atmosphere or in land use. Although there are natural forces that also contribute to climate change; human activity is largely the prevailing force (Government of Canada, 2010).

In a study on how crop yield variability is impacted by climate, Chi-Chung *et al*. (2004) presented that precipitation and temperature have opposite effects on the yield levels and variability of maize. They further rationalized that more rainfall could result in yield levels rising, while reducing yield variance and that temperature again has an opposite effect on maize production.

Climate change has been and continues to be, the major source of fluxes in global food production, especially developing countries of the world where production is highly climate dependent (Oseni and Masarirambi, 2011). It is projected to intensify the challenges already faced by SSA smallholder farmers. Changes in rainfall levels and its distribution, increasing temperatures and variations in soil carbon utilization by crops due to climate change are expected to have a negative effect on growing conditions and the possible yields of many crops in SSA (Amikuzuno and Hathie, 2013).

In Ghana, agricultural production is mainly rain-fed with the arable lands under irrigation being less than 2% (MoFA, 2003; GIDA, 2010). As climate change progresses with recurrent droughts and floods, lives and incomes are threatened and sometimes destroyed. In fact, huge production losses have already been a formidable component of the livelihoods of resource-poor rural farm households in SSA (Hodson *et al.,* 2002).

Agriculture is innately sensitive to climate conditions and is one of the most vulnerable sectors to the risks and impact of global climate change (Parry *et al.*, 1999).

2.2.2 Impact of Climate Change on Agriculture

Globally, agriculture is highly responsive to variations in climatic variables, especially temperature and rainfall (precipitation) because they are key components of the whole production process. The effects of climate as a result of predicted accumulation in the earth's atmosphere includes: loss of land area, loss of species and forest area, disruption of water supplies, spread of diseases and loss of agricultural outputs.

Climate change is expected to impact on various sectors of the economy, however, few sectors are as vital as the agriculture sector (Mendelsohn and Dinar, 2009). It is believed that the impacts on people's livelihoods will be greatest in the tropical and subtropical regions, and particularly in Africa, owing to the fact that many poor smallholders depend on agriculture and have few alternatives (IPCC, 2001).

As climate change causes temperatures to rise and precipitation patterns to change, more weather extremes will potentially reduce global food production (IPCC, 2007; Nelson *et al.*, 2010). It is believed that the negative effects of climate change on agricultural productivity are due to increased temperatures and decreased rainfall. A report by IPCC cautioned that Africa was not taking action quickly enough to curtail the dreadful economic and environmental implications of greenhouse gas emissions (IPCC, 2007).

There are studies which show that the recent global warming has affected agricultural productivity leading to declining food production (Kurukulasuriya *et al.*, 2006; Lobell et.

al., 2008). Climate change is likely become a major limiting factor on economic development in developing countries that rely on agriculture for a considerable share of gross domestic production and employment (Rosegrant *et al*., 2008) further worsening the poverty situation in such countries.

According to Ackerman and Stanton (2013), as there will be a change in precipitation patterns as the world continues to warm, with some areas becoming wetter, but some leading agricultural areas becoming drier. However, these patterns are difficult to predict and current droughts in several parts of the world throw more light on the important role of changes in rainfall (Ackerman and Stanton, 2013).

Climatic condition variability has been argued to be a major stumbling block to attaining food security in most developing countries and especially those in SSA (Codjoe and Owusu, 2011). This is mainly because SSA already experiences high temperatures and low (and highly variable) precipitation; second, because the economies are highly dependent on agriculture and; third, because there is low adoption of modern technology (IPCC 2001; Jones and Thornton, 2003; Kurukulasuriya and Rosenthal, 2003; Kurukulasuriya *et al*., 2006; Pearce *et al*., 1996; Rosenzweig and Parry, 1994).

If climate variation adversely affects agriculture, human effects are probable to be more severe in a poorer world. In the long run, rising demand for food over the next century, due to population and real income growth, will lead to increasing global food scarcity, and a worsening of hunger and malnutrition problems particularly in developing countries (Wolfe *et al.*, 2005; Stige, 2006, and Orindi *et al*., 2006).

The possible impacts of climate change on food production are not limited to crops and agricultural production only. In fact, a study by IFAD (2009), shows climate change will have extensive consequences for dairy, meat and wool production, particularly as a result of its impact on grassland and rangeland productivity

Changes in climate and climate variability will affect livestock production systems in all parts of the world, and will inevitably impact the 1.3 billion poor people whose livelihoods are wholly or partially dependent on livestock (Thorton *et al.,* 2013).

2.2.3 Climate Change and Maize Production

Maize is produced on nearly 100 million hectares in developing countries, with almost 70% of the total maize production in the developing world coming from low and lower middle income countries (FAOSTAT, 2010). It is the third most cultivated field crop after wheat and rice in the world. Jaliya *et al*. (2008) reported that, maize is the most popular due to its high yield, ease of processing and low cost of production

Maize is the most important cereal crop in most parts of West Africa (Fosu *et al*., 2004). It is one of the most relevant food crops and very common in all parts of SSA. In 2010, 53 million tons of maize was produced in SSA on about a third of the total harvested cropland area (~33 million ha). (Waha *et al.,* 2003).

In large parts of Africa maize is the principal staple crop accounting for up to 51% of consumed calories. The crop has been increasing in production since 1965 (Morris *et al.,* 1999; FAO, 2008). Maize is the most important cereal crop on the domestic market in Ghana, However, it is only the 7th largest agricultural commodity in terms of value of production over the period 2005-2010 accounting for 3.3 percent of total agricultural production value (FAOSTAT, 2012).

Maize production plays a vital role in food security for many poor households in Ghana (MoFA, 2011) with a per capita consumption of over 100 kg while also serving as a cash crop (FAO, 2008). In Ghana, maize is cultivated in all the agro-ecological zones, but recurrent droughts has been considered among the major constraints limiting the production of maize in the Guinea Savanna of West Africa (Badu-Apraku *et al.*, 2005) and Ghana. It is produced mostly by smallholder farmers who are also resource poor mostly under rain-fed conditions (Altieri and koohafkan, 2008).

Based on the most recent domestic production data, it is estimated that the shortfall between domestic production and domestic consumption would reach 267 000 Mt by 2015 in case there is no productivity improvement (MOFA, 2011).

Researchers earlier found that maize and maize-based food accounted for 10.8% of the total food expenditure in almost all households in Ghana (Boateng *et al*., 1990). It is the number one crop in terms of area planted and accounts for 50-60% of total cereal production. Additionally, maize represents the second largest commodity crop in the country after cocoa (Millennium Development Authority, 2010).

Maize production forms 45% of agricultural production which remains the main source of livelihood for most Ghanaians, providing employment to more than 60 percent of the population and contributing about 30% of gross domestic product (ISSER, 2011) and its production contributes over 20% of incomes earned by smallholder farmers in Ghana (Acquah *et al.*, 2012). Browne Klutse *et al*. (2013) also reported that maize accounts for more than 20% of smallholder farmer incomes. It is believed that by 2050 demand for maize will double in the developing world, and maize is predicted to become the crop with the greatest production globally, and in the developing world by 2025 (Rosegrant *et al.*, 2008).

Maize yields remain low and highly variable between years across SSA at 1.6 t ha^{-1}, only just enough to reach self-sufficiency in many areas (Bänziger and Diallo, 2001; FAOSTAT, 2010) the average yield registered by the Ministry of Agriculture in 2010 was 1.9 Mt/ha against an estimated achievable estimated yield of 2.5 to 4 Mt/ha (Ministry of Food and Agriculture, 2010).

Previous research strongly suggests maize growing regions of SSA will encounter increased growing season temperatures and frequency of droughts (IPCC, 2007). An estimated 80% of the maize crop suffers periodic yield decline as a result of drought stress (Bolonos and Edmeades, 1993). An estimated 40-90% yield loss may occur at flowering and grain filling stages as a result of drought (Nesmith and Ritchie, 1992; Menkir and Akintunde, 2001).

2.2.4 Perception and Adaptation to Climate Change

Perception about climate change determines the social mental picture of climate change. But a number of other factors like socio-demographic and socio-economic factors or even ideological orientations influence perception and the mental picture of climate change (Stedman, 2004).

It is reasonable to argue that the first step towards adaptation is the perception of the problem (Fakali *et al*., 2013). Some researchers are of the opinion that perception is important because a misconception of a risk has undesirable consequences. In fact, misconceptions can lead to maladaptation, which increases the costs of climate change (Peters, 1997). According to Bryant *et al*. (2000), adaptation to climate change in agriculture is usually how the perception of climate change is converted into a process of decision making.

Studies have shown that farmers in both developing and developed countries both perceive that the climate is changing and also take steps to adapt to it (Thomas *et al.*, 2007; Ishaya and Abaje 2008; Mertz *et al.*, 2009).

Adaptation to climate change refers to modifications to practices, processes and systems to reduce the current and potential future negative effects of climate change taking advantage of obtainable prospects to maximize benefits (Eriksen *et al*., 2011; Pouliotte *et al*., 2009; Smithers and Smit, 2009). It is the ability to respond and adjust to the potential impacts of changing climatic conditions in ways that cause moderate harm and take advantages of any positive opportunities that climate may afford (IUCN *et al*., 2004) it is evolutionary and occurs in the context of climatic, economic, technological, social, and political forces which are not easily separated, with most practices serving multiple purposes (Smit and Skinner, 2002).

Adaptation to climate change is necessary both in the short run and long run basis (Adger *et al.*, 2003; Eriksen *et al.*, 2011; Pittock and Jones, 2009) and it does not occur without influence from other factors such as socio-economic, cultural, political, geographical, ecological and institutional that shapes the human-environment interactions (Eriksen *et al.*, 2011). Adaptation measures are therefore important to help these communities to better face extreme weather conditions and associated climatic variations (Adger *et al*., 2003).

Adaptation measures generally were predominantly designed towards agricultural productions primarily through irrigation and cultivating crop resistant species, most local farmers are aware that the stress on their local environment and livelihoods has increased and low capacity for adaptation is a serious issue (Jones *et al*., 2011).

Adaptation has the potential to significantly contribute to reductions in negative impacts from changes in climatic conditions as well as other changing socioeconomic conditions, such as volatile short-term changes in local and international markets (Kandlinkar and Risbey, 2000). It has been shown through various studies that in the absence of adaptation, climate change has a detrimental effect on the agricultural sector but, vulnerability is significantly reduced with adaptation (Rosenzweig and Parry, 1994; Smith, 1996; Mendelsohn, 1998; Smit and Skinner, 2002).

A clearer understanding of the perceptions of farmers on climate change and present adaptation measures together with the factors behind farmers' decision to adapt farming practices is necessary in the developing of policies and programs targeted at promoting successful adaptation in the agricultural sector (Bryan *et al*., 2009). According to Thomas *et al*. (2007) the perceptions farmers have on climate change are crucial in determining the management style these farmers adopt. Also, farmers' appreciation of the relevance and urgency of climate change, how troubled they are as a result of climate change impact and personal opinions on the individual responsibilities in tackling the impacts of climate change also play a significant role in taking climate action (Klöckner, 2013).

Several studies have established a link between climate action and farmers' perceptions on climate change and further pushed for the incorporation of farmers perception of climate variabilities in climate change adaptation planning (Wiid and Ziervogel, 2012; Mert *et al*., 2009; Stringer *et al*., 2009; Arbuckle *et al*., 2013). According to Makate *et al*. (2017), a coherent understanding of smallholder farmers' perception on climate change and how it relates to sustainable agricultural practices, could provide workable and sustainable strategies in improving the linkage between the strategies meant to promote the broader adoption of climate adaptation practices and the actual rate of adoption.

2.3 Greenhouse Gas Emission and Mitigation

Gases that absorb infrared radiation that are found in the atmosphere resulting in trapping heat and leads to warming the surface of the earth are generally referred to as greenhouse gases (Snyder *et al*., 2009). The major GHGs from agriculture are; Carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4) (Snyder *et al*., 2009). According to Denman *et al* (2007), the rate of CH_4 emissions more than doubled over the past 25 years largely because of human activities. Combustion of fossil fuel accounted for more than 75% of anthropogenic CO_2 emissions while land use change comprising mostly of deforestation was responsible for the remainder (Snyder *et al*., 2009).

Greenhouse gases such as carbon dioxide (CO_2) have been shown to contribute to changes in climate conditions such as temperature, precipitation, soil moisture, and sea level (Houghton *et al*., 1996). These gases stay in the atmosphere for extended periods of time. With fossil fuels constantly being burned, the concentration of the greenhouse gases continue to rise, trapping increasing amounts of heat in the earth's atmosphere and resulting in an increase of the earth's temperature over time (Mendelsohn and Dinar, 2009). From Hirsch *et al*. (2006) there has been an increase of about 40%-50% of N_2O emissions from the earth surface as a result of human activities.

It is believed that the agricultural sector is the greatest contributor in terms of global anthropogenic non-CO_2 GHGs, responsible for about 56% of the emissions in 2005 (U.S. EPA, 2011).The agricultural sector contributes significantly to the proportion of GHG emissions which results in climate change – directly, agricultural activities contributes 17% to emissions and 7-14% additionally via land use change and it also contributes to indirect emissions through land use changes like deforestation and land clearing (OECD, 2015). Agricultural production is next to industry and transportation as major contributor to emissions with several activities, like clearing land, burning of biomass or wood, some tillage activities or indiscriminate use of agro-chemicals all magnify the effects of climate change by releasing GHG (FAO, 2015).

It is estimated that agriculture in developing countries in the tropics account for 7-9% of anthropogenic greenhouse gas emissions annually (Smith *et al*., 2014). Smallholder agricultural systems are believed to have contributed significantly to GHG emissions over the past decades due to their highly dynamic and heterogeneous nature (Berry, 2011). Despite global proportions of GHG emissions in Africa being relatively low, a major concern is that major parts of these emissions originate from the agriculture sectors with significant growth rates (FAOSTAT, 2015).

Marland *et al*. (2003) also submitted that in the adoption of some recommended practices for agriculture, there is the involvement of off-farm inputs or external inputs which are mostly carbon based products and operations. In the producing, formulating, storage, distribution and application of these inputs, there is the use of mechanized equipment which also contribute to GHG emissions through the combustion of fossil fuels as well as the use of other energy sources which also contributes to GHG emission (Lal, 2004).Vegetation burning is responsible for the release of CO_2, CH_4, N_2O aerosols and ozone precursors into the atmosphere (Smith *et al*., 2014).

From Gifford (1984), agricultural practices may be classified into primary, secondary and tertiary sources with respect to emissions. According to him, the primary sources include either stationary or mobile operations that contribute to emissions like; tillage, sowing, harvest, transport and grain drying. While the secondary emission sources comprise activities like manufacturing, packaging and storing fertilizer and finally the tertiary sources comprises acquiring raw materials, fabricating equipment and farm buildings. In terms of non-CO_2 emissions, the agricultural sector is expected to remain the major source (OECD, 2015).

As African economies such as Ghana’s expand, it becomes imperative to initiate procedures in reducing emissions from the agricultural sector while simultaneously adapting the sector to the impacts of climate change (Akrofi-Atitianti *et al*., 2018). From the World Resources Institute Climate Analysis Indicators Tool (WRI CAIT), emissions from Land use change and forestry dominates Ghana’s GHG profile as shown in Figure 2.1.

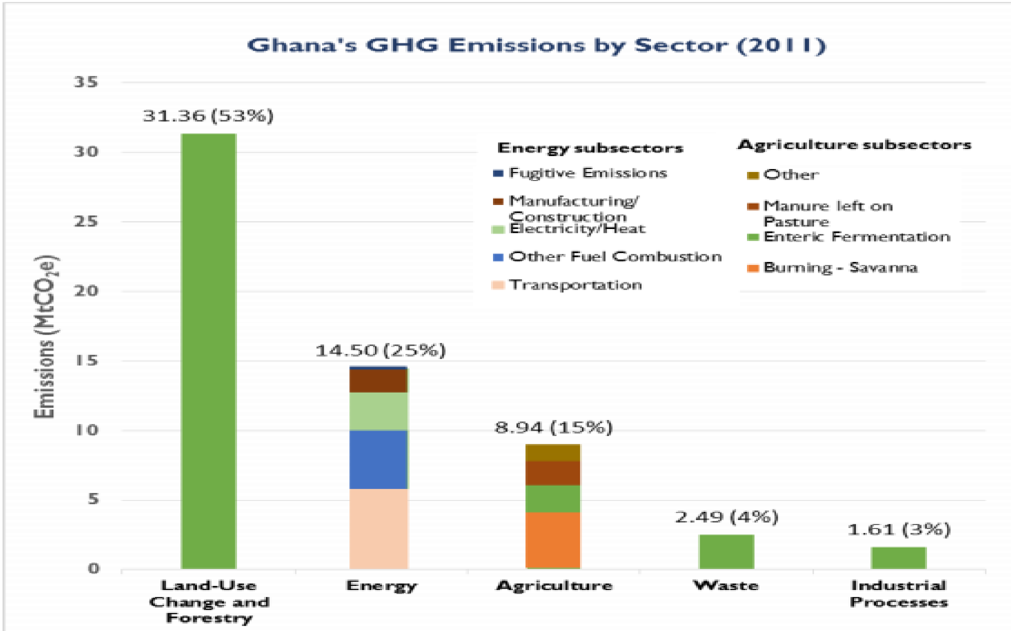


Figure 2. 1 GHG emissions from different sectors of the Ghanaian economy
Source WRI CIAT 2.0, 2015 and FAOSTAT, 2015

In Ghana, the total GHG emission increased by 20% between the period of 1990-2011(WRI, 2015). The contribution of the AFOLU sector to GHG emissions is illustrated in Figure 2.2 below.

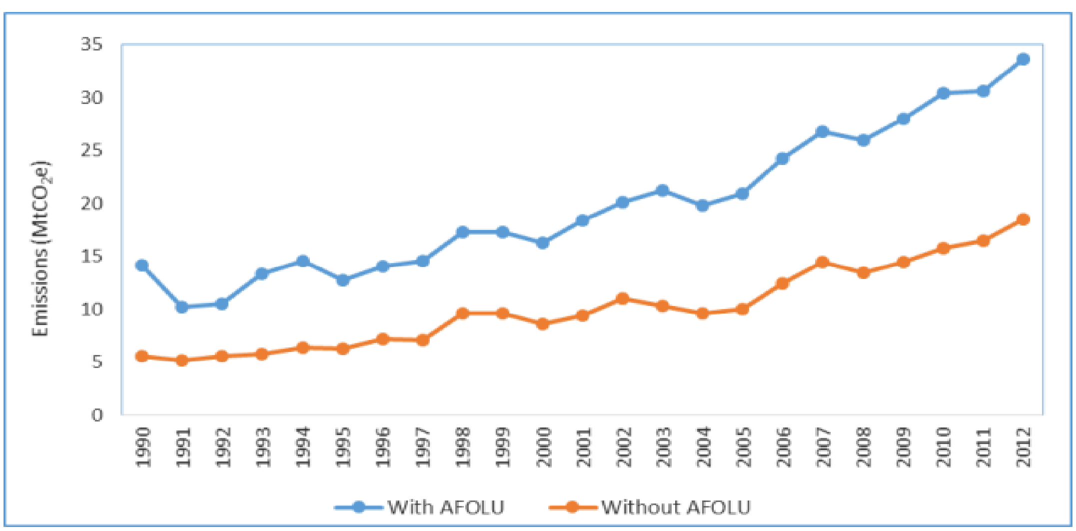


Figure 2. 2 National GHG emission trend with and without AFOLU
Source: MESTI, 2015

With the exception of emissions from industrial processes, total GHG emissions across all sectors have been on the rise in the country with the growth in emissions dominated by the AFOLU sector followed by the Energy sector (MESTI, 2015) as shown in Figure 2.3. According to the Ministry of Environment, Science, Technology And Innovation (MESTI), the increasing emission trend in the AFOLU sector since 1990 is as a result of the conversion of forests to cropland and Grassland, increase in the population of animals, biomass burning through wildfires, the production of crops and the use of fertilizer as well as other associated emissions (MESTI, 2015).

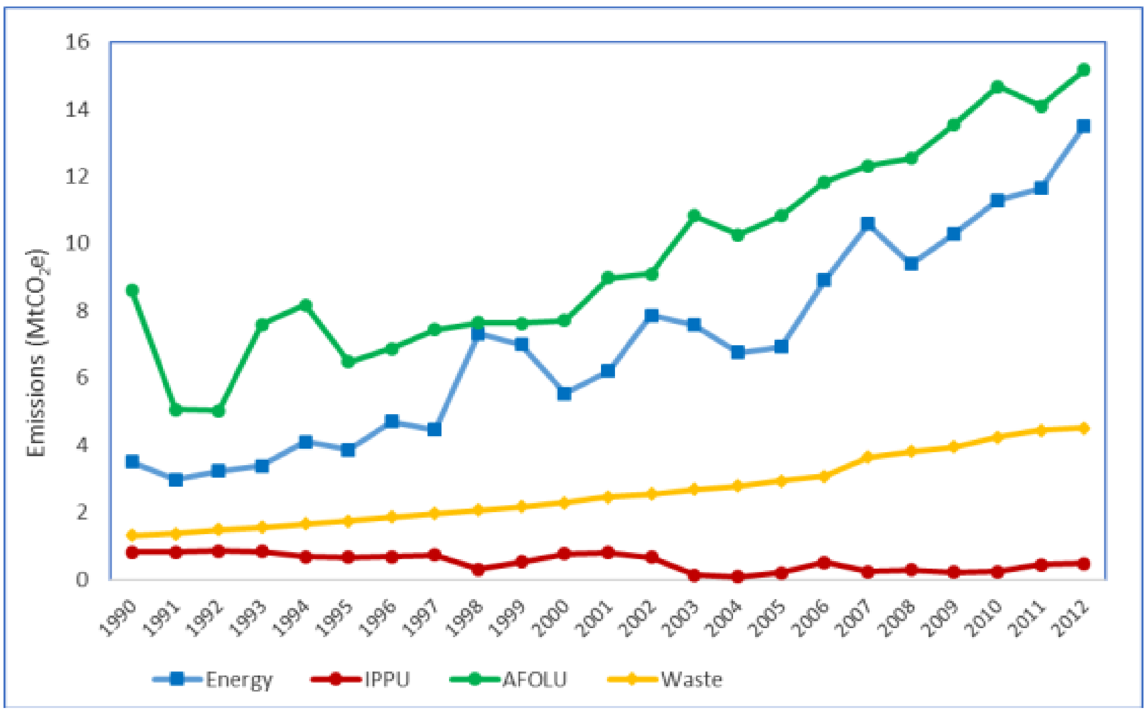


Figure 2. 3 Trends of Total GHG emissions by sectors
Source: MESTI, 2015

Various methods have been proposed in trying to mitigate GHG emissions. Robertson (2004) outlined four strategies which could significantly reduce net CO_2 from the Agriculture sector:

1. Improving farm operations which consume fuel leading to gains in energy efficiency
2. Soil carbon sequestration through changes in tillage, crop residue and animal waste management and the use of cover crops among others
3. Producing and using biofuels and bio-based materials technology to counterbalance fossil fuel use for producing energy
4. Agricultural production and yields efficiency for livestock and crops to offset the need to expand lands for agricultural production resulting in carbon losses.

Dyer and Desjardins (2003) concluded after assessing the impact of farm machinery management GHGs in Canada that reductions in fossil fuel emissions from agriculture in Canada can be obtained by:

1. Reducing summer fallow as a means of controlling weeds
2. Converting to minimum tillage or no-till system as against conventional ploughing
3. Convert marginal agricultural lands to pasture rather than crop lands
4. Switching tillage implements like the Chisel plough for moldboard ploughs

Most of these recommendations are best suited for developed countries rather than developing ones.

Smith *et al*. (2007) categorize GHG mitigation potentials into three, namely;

I. Reducing emissions
II. Enhancing removals
III. Avoiding emissions

In reducing emissions, the instabilities of GHGs are potentially reduced by the efficient management of the flows of carbon and Nitrogen in the agro-ecosystem is crucial (Smith *et al*., 2007).Many developing countries have viewed the move to focus on emissions from agriculture as a threat to stifle their growth and dump the burden of mitigation on developing countries (Chandra *et al*., 2016).

2.5 Climate Smart Agriculture (CSA)

According to the FAO during the 2010 Hague conference on Food Security and climate change, Climate-smart Agriculture (CSA), contributes to the achievement of sustainable development goals. It integrates the three dimensions of sustainable development (economic, social and environmental) by jointly addressing food security and climate challenges (FAO, 2013).

As part of solving Africa's climate change issues with respect to agriculture, CSA has been identified and promoted as a potential solution (Sullivan *et al*., 2012). Strategies aimed at agricultural development have migrated from the promotion of one-size-fits-all technologies with the aim of improving productivity to the recent push for improved agricultural practices which takes into account livelihood and environmental outcomes (Defries *et al*., 2010). The CSA approach develops technical, policy as well as investment conditions in achieving sustainable agricultural development for food security given the changing climate (FAO, 2013).

The term "climate smart" was first used in the Journal of Development in 2008 in framing adaptation efforts, proposing that, in order to manage long term climate change, place based climate change futures and development risks should be taken into consideration in development (Someshwar, 2008). The term "Climate Smart" has however commonly been used in the context of agriculture (WWF, 2016). The CSA concept was developed by the FAO and "identifies interactions and trade-offs among food security, adaptation and mitigation as a grounds for informing and reorienting policy in response to climate change" (Lipper *et al*., 2014). "CSA calls for a set of actions by decision-makers from the farm to the global level" in transforming agriculture toward "climate-smart pathways" (Lipper *et al*., 2014). The CSA term has developed to represent strategies addressing climate change challenges by increasing resilience to extreme weather conditions, climate change adaptation and the reduction of greenhouse gases from agricultural sources which contribute to global warming (Steenwerth *et al*., 2014).

CSA practices are not or must not be necessarily new, in fact according to Schaller *et al*. (2017), any agricultural practice or technique contributing to achieving the three pillars can be considered as climate smart. The different techniques employed in CSA often perform differently over the pillars and as a result have to be combined as an integrated approach to complement each other in in order to maximize the benefits (World Bank 2015; FAO 2015)

The CSA concept combines multiple conventional agricultural practices and approaches such as conservation agriculture, agro ecology and agro forestry, soil management, sustainable agriculture and sustainable intensification as well as climate-smart landscapes (Chandra *et al*., 2016). CSA and Conservation Agriculture (CA) are related in the sense that, CA supports adaptation by reducing risks of soil erosions as a result of rainfall run-off and mitigation through carbon sequestration despite the benefits not being massive on a global scale (Richards *et al*., 2014). CSA interventions are knowledge-intensive and location-specific as well as requiring substantial capacity development (Neufeldt *et al*., 2013).

Numerous factors limit the adoption and effectiveness of CSA policies. According to Sudjen (2015), governmental and non-governmental stakeholder views on CSA are divided raising questions on how the approach meets food security issues of smallholder farmers. McCarthy *et al*. (2011) also argue that institutional barriers limit the adoption and upscaling of CSA practices and technologies. For policymakers, a key challenge in operationalizing CSA is the identification and prioritization of CSA portfolios and options and its valuation in terms of cost-benefit and trade-off analysis (Sogoba *et al*., 2016).

2.6 Technology Adoption

2.6.1 Definition of Technology Adoption

Technology adoption in Agriculture is a subject area that has been studied extensively. Technology has been defined in several ways by different authors. Lavison (2013) defined it as knowledge or information that allows for the accomplishment of certain tasks more easily, allowing for some service to be executed or the manufacturing of a product. Loevisohn *et al*. (2013) also defined technology as the means and methods used in the production of goods and services which includes the methods of production and also the physical technique. The aim of technology is to ideally improve a given situation or change the norm to a more appropriate level (Mwangi and Kariuki, 2015). According to Bonabana-Wabbi (2002), Technology helps save time and labor and it supports in accomplishing tasks more easily than it would have been in the absence of technology. New technology is only new to a particular group of farmers or a given place (Mwangi and Kariuki, 2015) meaning what might be regarded as new technology in one place or among a group of farmers may not necessarily be new in another location or among a different group of farmers.

Just like technology, adoption has been defined in several different ways by various authors. Bonabana-Wabbi (2002), defined it as a mental process individuals go through from when they hear of the technology for the first time to the actual utilization. For Kabir and Raini (2013), it is the outcome of the decision taken on a given innovation while Loevinshohn *et al*. (2013) define it as integrating of new technology and some level of adaptation into an already existing practice after a trial period and a level of adaptation. Donkoh and Awuni (2011) also define adoption as the extent an innovation or new technology is used.

Adoption can be put in two categories; the rate and intensity of adoption (Mwangi and Kariuki, 2015). According to the same authors, the rate of adoption focuses on the relative speed with which an innovation is adopted by farmers which is pillared on the time element whereas Bonabana-Wabi's (2002) definition of intensity refers to the level a given technology is being used at a specific time period.

Several stages precedes adoption of a new technology. According to Rogers (2003) it begins with awareness of a need, followed by, the interest, evaluation, the acceptance and trial before the final adoption. Mercer and Pattanayak (2003) also submitted that, in adopting new technologies there are normally two stages involved: the decision to adopt or not and the extent to which the new technology is adopted. In implementing the adoption decision, a series of individual decisions have to be made which are based on making comparisons between the uncertain costs to be incurred and benefits of the new technology (Hall and Khan, 2002).

The definition of technology adoption is complex, especially because it differs with the technology to be adopted. The primary thing to take into consideration when defining adoption is if the decision is a discrete state with a binary response (Doss, 2003). As Challa (2013) puts it, the definition of adoption is based on the fact that the farmer is an adopter or non-adopter taking values zero and one or if the response is continuous in nature. As such, determining the appropriate approach depends on the specific context (Doss, 2013).

The innovation-diffusion paradigm, economic constraint paradigm and adopter perception paradigm mainly guide technology adoption (Nyanga *et al*., 2011). Information dissemination is identified as a major factor influencing the decision to adopt or not in Rogers' innovation-diffusion paradigm (Rogers, 2010; Prager and Posthumus, 2010) while the economic constraint paradigm submits that utility maximization behavior and economic constraints as a result of uneven distribution of resources is the main influence of technology adoption (Deressa *et al*., 2008; Prager and Posthumus, 2010)

2.6.2 Measuring Agricultural Technology Adoption

Research into agricultural technology adoption over the years generally falls into two main categories. Dorfman (1996) classifies them as; the branch focusing on building models of economic decision units facing the possibility of adopting a new technology and the branch which focuses on the identification of the factors correlated with the decisions to adopt a given technology. This study is founded in the framework of the latter.

In measuring technology adoption, researchers such as Philip *et al*. (2000) and Maiangwa *et al.* (2010) provide some insight on how to go about it. Phillip *et al.* (2000) note that the adoption of any technology is following a logistic curve and as a result the adoption rates can be predicted over time along the curve.

Choice modelling is the general approach used by most modern studies in measuring agricultural technology adoption especially in situations where the dependent variable is measured as a "yes" or "no" response. In certain situations also count models have been employed in the analysis of technology and this is particularly the case in situations where the aim of the study is to find out the intensity of the technology adoption. In modelling technology adoption, the major decision in the model adopted is the consistency with the underlying theory (Besley and Case, 1993).

Time series analysis however, have been used in times past in the empirical analysis of technology adoption. According to Besley and Case (1993), only the aggregate measure of adoption is observed in the data such as the percentage of farmers who adopt the technology of farmers at a given date. A classic example of such a study is by Griliches (1975) in his study of hybrid corn in the United States. These studies model the adoption pattern over time as a logistic-shaped function with the equation in the form

$$p_{it} = f(p_{it-1}) + \varepsilon_{it}. \qquad (2.1)$$

Where p_{it} is the fraction of adopters in the region *i* at date *t.* The limitation of this approach is in what it shows with respect to the dynamic underlying process (Besley and Case, 1993).

In most adoption studies, the adoption variable is simply categorized as adoption or non-adoption. However this categorization is limited in information given that the extent of actual adoption may be between 1%- 100% of his total farm size (Feder *et al*., 1985). As Schutjer and Van der Veen (1977) conclude "the major technology issues relate to the extent and also intensity of use at the individual farm level rather than to the initial decision to adopt the new practice."

Some studies chose the use of *Chi square* contingency tables in performing non parametric hypothesis testing in of the significance of some explanatory variables on adoption (RoChin and Witt, 1975; Parthasarathy and Prasad, 1978) although the outcome of these tests may be significant, the quantitative and economic importance of the results are questionable.

In trying to establish the quantitative relevance of explanatory variables econometrically on adoption, other studies resorted to the use of ordinary least squares (OLS) regressions. A negative outcome of this approach is that where the dependent variable is of a categorical form as is often the case, the parameter estimates from the model presented tend to be biased (Pinyck and Rubinfeld 1998; Shultz and Salvador, 2000) making the OLS regression inappropriate in the investigation of the role and relevance of the different factors in the process of adoption.

From literature, the appropriate estimation method has been developed for the investigation of the explanatory variable on discrete variables. The most common used qualitative response models are the logit and probit models, which assume the logistic and normal underlying distribution respectively. The functional relation between the probability of adoption and various explanatory variables are specified by these models (Feder *et al*., 1985). Agricultural technologies are typically introduced in packages that include a number of components. These components may complement each other, or may be adopted independently (Feder *et al*., 1985). The adoption of agricultural technologies by smallholder farmers in developing countries is not always a direct process (Shultz and Salvador, 2000). According to Shultz and Salvador (2000), the technologies are comprised of several practices that are designed to work together but can at the same time be implemented individually. In order to use binomial models in such situations, economists cluster automatically, the adoption levels into two groups which leads to undesirable statistical measurement errors (Judge *et al*., 1985).

In a multiple adoption setting, McFadden (1984) presents Multinomial, ordered, and multivariate responses as the possible alternative responses. Multinomial choice modelling operates with the assumption of independence of the dependent variables whereas multivariate models assume that there is interdependence of the alternatives.

In adoption studies such as (Hassan and Nhemachena, 2008; Deressa *et al.*, 2009) involving multiple choices, the analytical approach used are the multinomial logit (MNL) where the choices are independent or made jointly. The MNP and MNL approaches are appropriate also in the evaluation of alternative combination of different technologies (Hausman and Wise, 1978; Wu and Babcock, 1998)

However, according to Tekleworld *et al*. (2013) smallholder farmers tend to adopt a combination technologies to manage multiple agricultural production limitations making the decision to adopt a multivariate one inherently. According to Dorfman (1996), any attempt to model a multivariate decision as a univariate one is likely to exclude useful as well as related economic information which is confined in the simultaneous and interdependent decision. Smallholder farmers in the adoption of CSA practices are expected to follow the same.

The underlying theory for the choice modelling for the adoption decisions is usually the random utility theory. According to Walker and Ben-Akiva (2002), the random utility model is built on the idea that an individual is faced with an alternative or alternatives to choose from. The utilities are latent variables assumed to be a function of certain explanatory variables X, which describe the decision maker and the alternative *i*. The utility equation can be written as;

$$U_{in} = V(X_{in}; \beta) + \varepsilon_{in} \qquad (2.2)$$

where U_{in} is the utility of alternative $i[i = 1, \ldots, J_n]$ for decision-maker $n[n = 1, \ldots, N]$ (U_n is a vector of utilities for decision-maker *n*); X_{in} is a vector of explanatory variables describing alternative i and decision-maker *n* (X_n is a matrix of explanatory variables describing all alternatives and decision-maker *n*); β is a vector of unknown parameters; *V* (called the systematic utility) is a function of the explanatory variables and unknown parameters β; and ε_{in} is a random disturbance for *i* and *n* (ε_{in} is the vector of random disturbances, which is distributed $\varepsilon_{in} \sim D(\theta_\varepsilon)$, where θ_ε are unknown parameters)

2.6.3 Determinants of Agricultural Technology Adoption

In trying to find out the factors contributing to the adoption of agricultural technology, the innovation-diffusion paradigm, economic constraint paradigm and adopter perception paradigm are found to mainly guide technology adoption (Nyanga *et al*., 2011).

Information dissemination is identified as a major factor influencing the decision to adopt or not in Rogers' innovation-diffusion paradigm (Rogers, 2010; Prager and Posthumus, 2010) whereas the economic constraint paradigm submits that utility maximization behavior and economic constraints as a result of uneven distribution of resources is the main influence of technology adoption (Deressa *et al*., 2008; Prager and Posthumus, 2010).

The adopter perceptions paradigm postulates that the whole adoption process begins with the perception of the adopter with respect to the problem and the particular technology proposed (Adesina and Zinnah, 1993). It maintains that the adopters' perceptions play a major role in influencing the decision of adoption (Prager and Posthumus, 2010). Perceptions generally are contextual and specific to locations due to variations in factors influencing them such as gender, education, sex, culture, some institutional factors and resource endowments (Posthumus *et al*., 2010).

Institutional and human capacities through the years have been considered as key determinants of adoption decisions. Household size, gender, education and age of household heads according to Feder *et al*. (1985) are some important characteristics of households influencing the adoption of modern agricultural technologies. Generally, technology adoption is related positively to farmers' wealth and schooling as well as the adoption of that same technology by their neighbors (Foster and Rosenzweig, 2010) and as a result the variable is usually included in many adoption studies. Households with better education are expected to have more awareness of the potential benefits of modern technologies and as a result exhibit more efficiency in their farming activities (Pender and Gebremedhin, 2007).

Again, according to Pender and Gebremedhin (2007), the size of the household can be influential in adoption of new technology especially considering that it can be a proxy of a household's labor endowment. Farm size, used as a proxy for wealth or capital as well as scale of economy also tends to influence adoption decisions (Norris and Batie, 1987: Caswel *et al*., 2001; Daberkow and McBride, 2003: Khanna, 2001).

In summary, the adoption of new agricultural technology is largely dependent on personal, cultural, social and economic factors together with the features of the technology being considered itself (Prokopy *et al*., 2008; Shiferaw *et al*., 2008; Eze *et al*., 2008; Kassie *et al*., 2009; Yesuf and K¨ohlin, 2008; Owusu and Donkor, 2012; Challa and Tilahun, 2014).

When a new technology is being adopted by farmers, risks and uncertainty especially about yields can result in low rates of adoption (Dethier and Effenberger, 2011). Other reasons for non-adoption has to do with non-adopters failing to recognize the profitability of the technology under consideration to them. Credit constraints were also recognized as an impairment to technology adoption in developing economies (Feder *et al*., 1985).

2.7 Welfare

2.7.1 Definition and measurement

Historically, welfare has been related to prosperity and happiness, with its current understanding emerging first in the 20th century (Williams, 1976). While welfare encompasses GNP and the total societal spending on resources, it has to do more with a subjective feeling of happiness and the number of individuals living in poverty at the micro level (Greve, 2008).

In measuring and analyzing welfare of households there are several indicators to help in the accomplishment of the task. Two main measures are usually employed in measuring household welfare, namely, asset indices (wealth index) and money metric measures that is, using income or consumption (Moratti and Natali, 2012). Asset indices or wealth index has in recent years been considered as a superior measure of welfare theoretically and practically to income and consumption (Rutstein and Johnson, 2004) and is also found to be less intensive with respect to the data and simpler to calculate and report (Sahn and Stifel, 2000; Azzarri *et al*., 2006).

The wealth index is rarely used as a result of several theoretical and practical reasons as a proxy for welfare in place of income or consumption (Moratti and Natali, 2012). The choice of the best indicator for measuring individual or household welfare has been discussed extensively in economic literature, mostly between income and consumption (Gradín *et al*., 2008).

The choice of the appropriate proxy is dictated by theoretical as well as practical considerations. Income appears to be a good measure of welfare where there is the belief that the income difference between households are driven by life cycle events (Gradín *et al*., 2008). But considering the fact that information on incomes spanning long periods is rarely available in survey information, several authors have resorted to considering current consumption as an accurate proxy (Slesnick, 1993).

Individuals are also believed to gain material well-being from the consumption of goods and services more than they gain from receiving income (Citro and Michael, 1995), making consumption a much better measure of household welfare. Again for self-employed households like smallholder farming households, it becomes quite difficult to measure household income (Moratti and Natali, 2012). The challenge for measuring farm household income is further exacerbated in situations where there is poor record keeping.

2.7.2 Agriculture technology adoption and welfare

Majority of the world's poor and hungry are rural individuals who earn meager livings from agriculture (FAO, 2016). In 2010, almost 900 million of the estimated 1.2 billion extremely poor lived in rural areas and an estimated 750 million of them worked in agriculture, mainly as smallholder family farmers (Olinto *et al*., 2013).

It is believed that agricultural technology has the potential of reducing poverty through both direct and indirect effects (de Janvry and Sadoulet, 2002), especially in the situations of smallholder farmers who depend largely on agriculture for their livelihoods. Across time, few subjects have captured consideration of economists as has the role of agriculture in economic development and poverty reduction, resulting in vast literature of both theoretical and empirical studies (Cervantes-Godoy, 2010).

A close correlation has been established between variations in poverty rates and that of agricultural production, especially the growth rate of productivity over the past 40 years (DFID, 2010). The authors further established a link between agriculture and poverty via four transmission mechanisms:

1) Direct impact of improved agricultural performance on rural incomes

2) Impact of cheaper food for both urban and rural poor

3) Agriculture's role to growth and the generation of economic prospect in the non-farm sector;

4) agriculture's fundamental role in stimulating and sustaining economic transition, as countries shift away from being primarily agricultural towards a broader base of manufacturing and services.

Recent studies on agriculture and welfare (poverty) focus directly on quantifying the relationship between the two parameters. Bresciani and Valdes (2007) captured three key channels they believe link agricultural growth and poverty; 1) labor market, 2) food prices, and 3) farm income.

The above listed are mostly at the macro level, at the micro level however, especially in SSA where smallholder farmers are faced with various challenges leading to high rates of poverty. Apparently, the adoption of new technologies gives opportunity for the increase substantially in production and incomes (Nweke and Akorhe, 2002) as well as lead to improved food security (Nata *et al*., 2014).

Several authors have reported a positive impact of the adoption of improved agricultural technologies on either poverty or welfare. Example, Hossain *et al*. (2003) reports that the adoption of improved varieties of rice had a negative impact on the poor but a conversely positive impact on richer households in Bangladesh. Kijima *et al*. (2008) and Diagne (2006) study on the impact of NERICA in Uganda and Cote d'Ivoire also realized that the adoption of NERICA has appositive effect on poverty reduction and also yields respectively. With the aid of the local average treatment effect, Adeoye *et al*. (2012)

discovered a positive impact on household wellbeing stemming from the adoption of agricultural technologies on rural households in Nigeria and Mendola (2007) also found similar result in Bangladesh using the PSM method. El-Shater *et al*. (2015) also reports an increase in income and net per capita wheat consumption using the ESR and PSM in evaluating the impact of Zero tillage on livelihoods in Syria.

Not all studies show a positive impact of adoption on welfare however. Di Falco and Veronesi (2013) found a negative impact of implementing climate change adaptation strategies on revenues using ESR and Manda *et al*. (2016) who found that the full adoption of SAPs had a negative effect on income using the Multinomial endogenous treatment effects model.

CHAPTER THREE

METHODOLOGY

3.1 Chapter outline

This chapter focuses on the study area, sampling techniques employed in the data collection as well as the type and sources of data collected and the techniques used in the statistical and econometric analysis of the data.

3.2 Study area

The study area comprises communities in the East Gonja district of the Northern region of Ghana. The District was created in 2007 under the Legislative Instrument (LI 1938). East Gonja District lies in the Northern region covering an area of about 8340.1 square kilometers and a total population size of 134,450 from the 2010 census (GSS, 2014). The district is found within Latitude 8^0 N and 9.29^0 N and, Longitude 0.29^0 E and 1.26^0 W. The district is bounded to the north by the Tamale Metropolitan Assembly and Mion districts, Nanumba-North, Nanumba-South and Kpandai Districts to the East, Central Gonja District to the West, and to the south Brong-Ahafo Region. Figure 3.2 below shows a map of the East Gonja District.

The District lies in the tropical continental climatic zone. The district has partly high temperatures which range between 29^0C and 40^0C maximum temperatures are recorded usually in April towards the end of the dry season and minimum temperatures recorded during the Harmattan season, from December to January. It experiences a unimodal rainfall pattern spanning between May to October and an extended dry spell between 112.7mm and 1734.6 mm. The average annual rainfall and minimum and maximum temperature recorded in the East Gonja District spanning the 2008 and 2015 period.

The main economic activity of the people of the East Gonja district is agriculture with yam, maize, millet rice, cassava and groundnuts being some of the common crops being cultivated in the district.

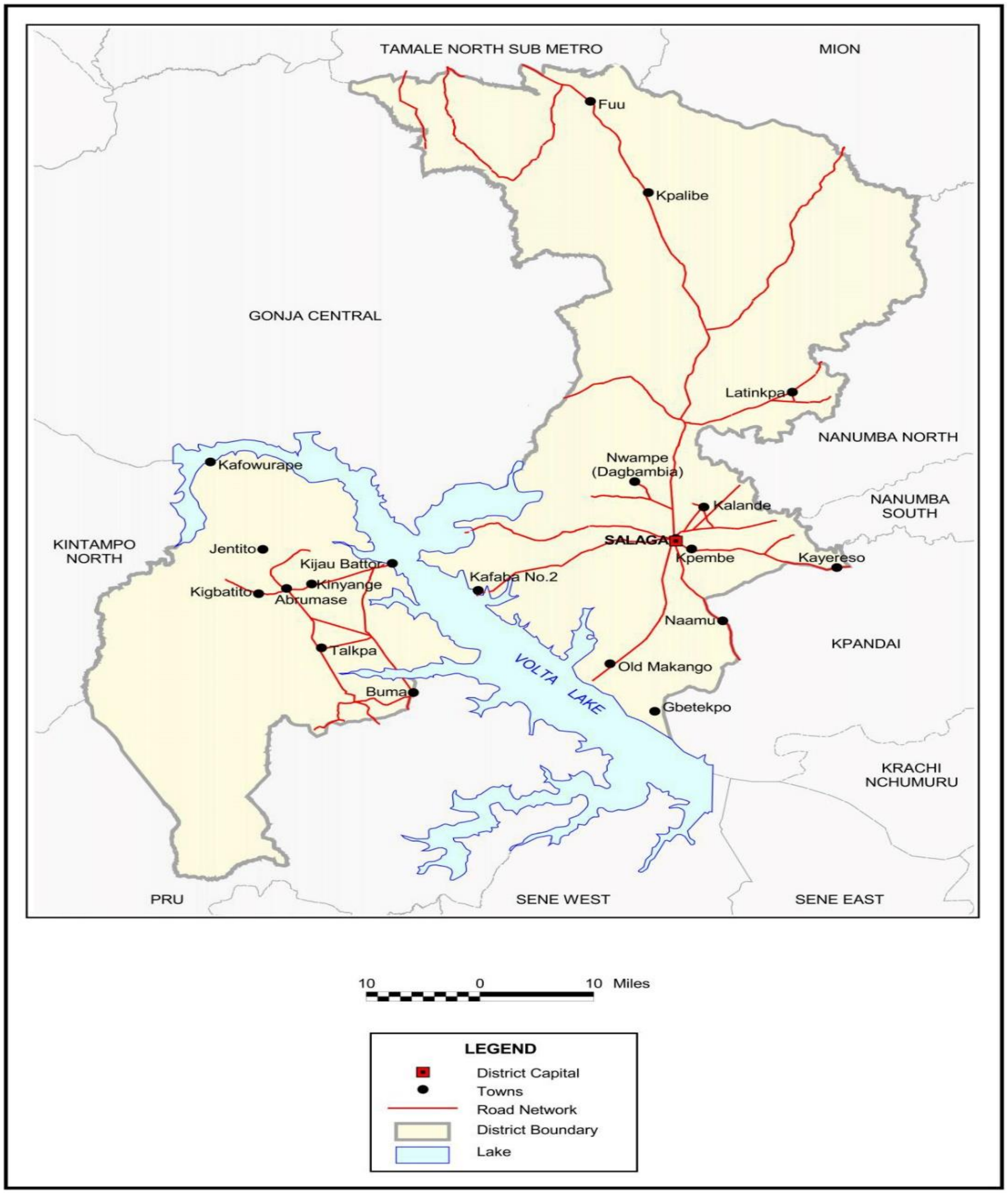


Figure 3. 1 Map of East Gonja district
Source:GSS,2014

3.3 Research Design

The cross-sectional design was used to establish the determinants of adoption of Climate-smart Agricultural technologies in the study area. Semi-structured questionnaires were administered via personal interviews to gather primary data from the respondents.

For this research, descriptive analysis was used to expound the different types of maize-soya production systems employed by farmers as well as the perceptions and knowledge of respondents with respect to climate change, its impact and its causes and also socio-demographic characteristics of respondents.

Quantitative analysis was used in examining the decision to adopt any of the climate-smart agricultural technologies and its relationship to certain exogenous variables which relates to their socio-economic and demographic factors as well as farmers knowledge and perception about climate change. Quantitative analysis was also used to estimate the effect of adoption of Climate-smart agricultural practices on the welfare of respondents.

3.4 Data Sources and Types

The study mainly used primary data and this was obtained from a cross-sectional survey of maize farmers in the East Gonja District. Data on the socio-demographic and economic characteristics, farmers' perception of climate change effect and causes were also collected for the purpose of this research. The variables were measured in both continuous and discrete scales and both quantitative and qualitative data were used in this study.

3.5 Sample Size Determination

In order to draw conclusion from the study which reflects the general population under consideration it is important to determine the appropriate sample size for the study. According to Saunders *et al*. (2009), drawing conclusions on larger sample sizes results in a high likelihood of accurately reflecting the actual population under review. However, there are several limitations barring the selection of adequately large sample sizes. As noted by Hair (2006) and Saunders *et al*. (2009), availability of funds, limited time and the type of statistical analysis among other reasons make it necessary for the selection of a sample from a population.

In selecting the sample size for this study, the study adopted Yamane's (1967) simplified formula for calculating sample sizes given as:

$$n = \frac{N}{1 + N(\mathrm{e})^2} \qquad (3.0)$$

Where n is the sample size to be estimated and N is the population size of the study area and e is the confidence level. Applying the above formula to the study, the sample size was estimated as follows:

$$n = \frac{134450}{1 + 134450(0.05)^2}$$

$$n = \frac{134450}{1 + 336.125} = n = \frac{134450}{337.125}$$

n=398

The estimated sample size for the study was 398 but 375 was collected which was further reduced to 350 for the study as a result of missing responses and incomplete questionnaires.

3.6 Sampling Technique

A multistage sampling procedure was employed for this study. In the first stage, the district was stratified into beneficiary and non-beneficiary communities. A beneficiary community is a community where the CSA technologies have been directly introduced to while a non-beneficiary community is one where the technologies were not directly introduced to. In the second stage, simple random sampling was used to select 15 communities, 10 and 5 communities from the pool of beneficiary and non-beneficiary communities, respectively. In the final stage, 25 households from each of the selected communities were selected randomly for the study. In all, a minimum of 350 households were sampled for this study.

3.7 Data Collection Methods

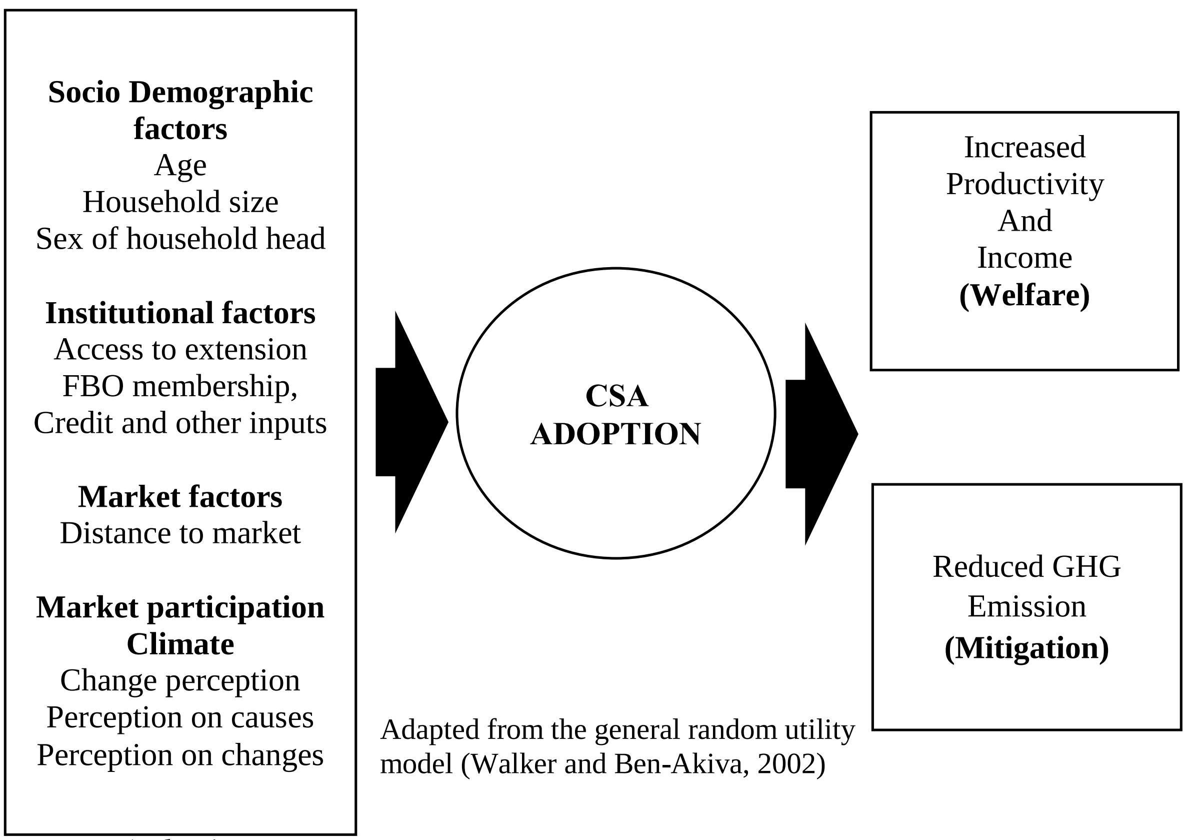
In order to meet the objectives of this study, personal interviews with the aid of semi-structured questionnaires were used in a survey to gather relevant information. To be able to capture as much information as possible in achieving the objectives of the study, the questionnaire was designed with both open and close ended questions. The information gathered was treated with strict confidentiality and as such the names of the respondents did not appear in the research or anywhere else with respect to this study. Translators were employed to assist enumerators where respondents could only communicate in Gonja or Kokomba.

3.8 Conceptual Framework and Theoretical Framework

The adoption of a given technology is based on farmers' decision of a choice at a given time and space. Given the information available, some farmers may choose to adopt a particular technology or not. As indicated earlier, there are three components of CSA technologies and farmers are more likely to simultaneously adopt a mix of the components as mitigation strategies against the negative effects of climate change/variability than to adopt a single component. Recent studies (Asfaw and Lipper, 2015; Makate *et al.*, 2016) have suggested farmers consider a set of adaptive strategies and choose a particular bundle that maximizes their expected benefits, while accounting for interdependency and simultaneous adoption decisions. Wu and Babcock (1998) noted that neglecting such interrelationships may lead to biased estimates of the factors affecting the adoption of the CSA technologies.

From literature (Prokopy *et al*., 2008; Shiferaw *et al*., 2008; Eze *et al*., 2008; Kassie *et al*., 2009; Yesuf and K¨ohlin, 2008; Owusu and Donkor, 2012; Challa and Tilahun, 2014.) documented that socioeconomic and demographic characteristics, farm household, institutional and policy factors among others play significant roles in the decision to adopt a certain technology including CSA technologies (Figure 3.3). Moreover, it is expected that adoption of CSA technologies may enhance farmers' productivity and, will in turn have a spill-over effects on their welfare. Farmers' knowledge on climate change is also expected to help them build resilience against climate change which affects their contribution to GHG emissions. Finally, the study hypothesized that maize-soya production systems adopted by farmers as a way of climate change mitigation strategies is likely to improve crop yield.

The study employed three econometric techniques to achieve its objectives. First, farmers' decision to adopt CSA was modelled using multivariate probit model (MVP) to jointly identify factors that influence the probability of adopting each of the CSA practices, while accounting for interdependency. Second, endogenous switching regression was used to estimate the causal effects of CSA on farmers' welfare outcomes. Finally, the study employed the count data regression to assess the determinants of farmers' contribution to emission. The decision of a farmer/ farm household to adopt or not to adopt is expected to influence the productivity and resilience of the farmer which in turn is expected to influence the welfare of the farmer.



Source: Author's conception

Figure 3. 2 Conceptual framework

3.8.1 CSA Technology Adoption

This study is founded on the random utility model of microeconomic consumer theory. According to Walker and Ben-Akiva (2002), the random utility model is built on the idea that an individual choosing an alternative will choose the alternative he believes maximizes his utility. The utilities are latent variables and assumed to be a function of certain explanatory variables, X, which describe the decision maker and the alternative *i*. The utility equation can be written as;

$$U_{in} = V(X_{in}; \beta) + \varepsilon_{in} \qquad (3.1)$$

where U_{in} is the utility of alternative $i[i = 1, \ldots, J_n]$ for decision-maker $n[n = 1, \ldots, N]$ (U_n is a vector of utilities for decision-maker *n*); X_{in} is a vector of explanatory variables describing alternative i and decision-maker *n* (X_n is a matrix of explanatory variables describing all alternatives and decision-maker *n*); β is a vector of unknown parameters; *V* (called the systematic utility) is a function of the explanatory variables and unknown parameters β; and ε_{in} is a random disturbance for *i* and *n* (ε_{in} is the vector of random disturbances, which is distributed $\varepsilon_{in} \sim D(\theta_\varepsilon)$, where θ_ε are unknown parameters)

Random utility model assumes utility maximization:

$$\text{Decision-maker } n \text{ chooses } i \text{ if and only } U_{in} \geq U_{jn} \text{ for all } j \in C_n, \qquad (3.2)$$

Where C_n is the set of J_n alternatives faced by *n*.

The choice probability equation is then:

$$P(i \mid X_n; \beta, \theta_\varepsilon) = \text{Prob}[U_{in} \geq U_{jn}, \forall j \in C_n] \quad (3.3)$$

Applying the concept of random utility to CSA technology adoption, a farmer will adopt any of the CSA technologies if the expected utility is greater than zero and fail to adopt any of the technologies if the expected utility is less than zero (Negative). The utility derived from adoption can be increased yield and income or reduced risk as a result of increased resilience.

Following Asfaw *et al*. (2012), the utility among adoption (U_{AI}) and non-adoption (U_{NI}) of the climate-smart agricultural technologies may be noted as G^*, such that a utility-maximizing farm household, *i*, will make the decision to adopt a CSA technology if the utility gained from adopting is greater than that of non-adopting

$$(G^* = U_{AI} - U_{NI} > 0) \quad (3.4)$$

$$G_i^* = \beta X_i + u_i \text{ with } G_i = \begin{cases} 1 \text{ if } G_i^* > 0 \\ 0 \text{ otherwise} \end{cases} \quad (3.5)$$

Where G is a binary indicator variable that equals 1 if a farmer adopts CSA and zero otherwise; β is a vector of parameters to be estimated; X is a vector of explanatory variables; and u is the error term.

The assumption of this study is that, the adoption decision of farmers is voluntary and the response variations can be attributed to the fact that farmers have different demographic, socioeconomic and institutional factors.

3.9 Definition of Concepts and Description of Variables

3.9.1 Adopter

A farmer was classified as an adopter for this study if he or she was found to be practicing at least one of the technologies under the scope of Climate-smart agriculture in the study area for a period of at least one season prior to the time of data collection. This approach was adapted from Rogers (2003) definition of adoption. As a result, a farmer who practices only soil conservation practices is still considered to be an adopter of CSA practices. The adoption or use decision for this study will therefore be discrete or binary with values of one if the farmer practices CSA and zero if otherwise.

3.9.2 Welfare

In this study, household consumption expenditure was used as a proxy for welfare. This approach is more favored in the context of developing countries like Ghana. Consumption appears to be more stable in agrarian communities (Moratti and Natali, 2012). The study captured consumption based on a household's food expenditure and non-food expenditure.

3.9.3 Climate–smart agricultural practices

Table 3. 1 List of CSA practices

Climate Smart Agric. Practice/Technology
Soil conservation practices(SCP)
Creation of swales
Compost application
Making contours
Bush burning control
Ploughing crop residues into soil
Livelihood diversification(LD)
Commercial livestock production
Soya cultivation
Soya processing
Dry season gardening
Bee keeping
Irrigation and water harvesting(IWH)
Water Harvesting
Manual pump irrigation

As shown in Table 3.1 above, the CSA practices were classified into 3 main categories namely: soil conservation practices, livelihood diversification and irrigation and water harvesting. These practices were introduced to certain communities in the study area through SEND-GH, a non-profit organization operating in the East Gonja district.

Soil conservation practices comprises activities aimed at improving and enhancing soil fertility and structure with a reduced risk of negative environmental impacts.

Creation of swales which are helpful in checking erosion by slowing and spreading water contrary to the water rushing down and creating gullies and in the processing washing away the top soil and nutrients. Swales also are beneficial on lands that are relatively flat or have gentle slopes. Composting or application of decayed organic domestic waste and crop residues improves soil fertility and increases yield at the same time improving soil structures, retaining soil moisture and also reducing emissions as raw animal manure is applied. Making contours is another way of checking soil erosion where the land is ploughed following the elevation of the land to prevent run-off water and allowing water to settle rather than running off. Bush burning control limits emissions by checking wildfires as well as preserving soil fauna which contribute to improving the soil structure. Ploughing crop residues back into the soil also helps in improving the organic matter content of the soil, the soil fertility especially when done with legumes and the yields of crops

Livelihood diversification strategies are aimed mostly at minimizing weather-induced losses and also stabilize incomes of farmers. The strategies considered in this study include the livestock for commercial purposes, beekeeping, soya cultivation as an alternative to the cultivation of traditional crops like maize, millet, cassava and yam and the processing of the soya into other forms like "tom brown" and tofu for sale and dry season gardening of vegetables under irrigated production systems. The varieties of soybean introduced to the farmers are the early maturing, high yielding and anti-shattering varieties like Afayak, Sompumgum and Jenguma.

Irrigation and water harvesting strategies target improving farmers' resilience to climate change induced challenges at both the farm and household levels. The use of manual pumps were introduced to the farmers to support the continuous cultivation of crops in the face of droughts as a result of climate change and water harvesting to help farmers harness water which can be used in irrigation and also domestic activities for the same reason.

It must be noted that all the practices mentioned above are strategies to be implemented at the farm household level. Other strategies like the establishment of woodlots were introduced at the community level to reduce the indiscriminate cutting of trees and to serve as a source of fuel wood for women and at the same time reducing the emissions of GHG through carbon sequestration.

3.9.4 Emitters

Ideally, an emitter should be classified based on an individual's participation in any practice that contributes to the emission of GHGs. However, seeing that the study's scope of Agriculture, emitters will be limited to Agriculture and Land-use and Forestry sources and further focus on activities of tree cutting and burning in cognizance of the fact that burning of Savannah is the major source of emission in the Agricultural sector (WRI CAIT 2.0, 2015; FAOSTAT, 2015).

3.9.5 Independent Variables

Several variables drawn from economic literature are included in the different models as explanatory variables for the adoption of CSA practices and technologies and its impact on mitigation and welfare. The description of the variables are presented in the subsequent sections below.

3.9.5.1 Socioeconomic Characteristics

Age of farmer: the age of the farmer, measured in years has been used by several authors in adoption studies. The effect of this variable is undefined across several studies as a result of several factors. Some studies have found older farmers more likely to adopt as a result of experience accumulated over years of farming (Nkamleu *et al*., 1998) while others have found the opposite attributing it to the conservative nature of older farmers (Tiamiyu *et al*., 2009). This study also hypothesized an indeterminate effect of the effect of age on the adoption of CSA practices as well as its impact on emission.

Education: this variable is also measured in years and hypothesized to increase the likelihood of adoption of CSA practices and also reduce farmers' participation in GHG emission practices. According to Feder *et al*. (1985) farmers with better education are earlier adopters when it comes to modern technologies and are able to apply more efficiently modern inputs. With respect to mitigation it is expected that farmers who have a level of education would at least be exposed to knowledge on the causes and effects of climate change so would take steps not to contribute to emissions. As such the sign in the emissions model should be negative while that of the adoption model, positive.

Household size: household size was measured as number of people who live in the same house and share the same pot, acknowledging one head (either male or female) adopted from the GLSS 6 (2014). Improved technologies are expected to be adopted by households with large numbers (Adeoti, 2008). Larger household sizes could also be a barrier considering the allocation of resources amongst members which means limited reserves for adoption. In terms of mitigation by not participating in emission practices the contribution of family size is also undetermined.

Farm size: for this study, farm size refers to the total acreage cultivated by respondents in the study area. Farm size can be a proxy for wealth and as a result larger farm sizes are expected to adopt improved technologies. However, when it comes to participation in burning, larger farm sizes might be compelled to burn in land clearing or from the angle where large farm sizes are being equated to wealth, burning might not be the case given that wealthier farmers may be able to hire more labor. The sign for farm size in both adoption and emission models hence are not truly defined.

3.9.5.2 Institutional Characteristics

FBO Membership: Respondents' membership to a social organization such as a credit union or any other organization focused on any aspect of the agricultural production was recorded and this variable was recorded as a dummy with 1= member, 0= non-member. The expectation here is that farmers who are members of such organizations would be more likely to adopt CSA practices. This is because there is an increased likelihood of farmer to farmer information dissemination relating to improved technologies. Also, farmers in groups are more likely to get access to credit to supplement their production.

Extension Access: this variable was also measured as a dummy with 1= access and 0= no access. Here also, the expectation is that farmers who gain access to extension services whether from MoFA or any other source will be more likely to adopt improved technologies and in the context of CSA, farmers who get access to extension are more likely to learn about climate change, its impact and causes. As a result, extension access should have a positive influence on CSA adoption and a negative influence on participation in GHG emission practices.

Farm Training: this variable has to do with establishing whether farmers have participated in any seminar or workshop or conference in terms of farming in general. Farmers are exposed to new technologies from these training and as a result become receptive to any new technology introduced to them. It is also measured as a dummy and is expected to have a positive influence on the adoption of new technology and also a negative effect on the participation of farmers in emission practices.

CSA training: farmers in some communities in the study area and communities considered in this study were exposed to CSA training. The difference between the former variable and this variable has to do with the purpose of the training. Farmers who partook in the CSA training were introduced to CSA technologies specifically as well as gaining knowledge into climate change causes and impacts. This variable was measured as a dummy and is expected to increase the probability of adopting CSA technologies and in line with the objectives of CS, lead to a reduction in emissions visible in the reduced likelihood of participating in emission practices.

3.9.5.3 Climate Change Perception

According to Niles and Mueller (2016), the perceptions of individuals on climate change is connected to their support of climate policies and their alteration of their climate-related behaviors. In effective adaptation to climate change and in its mitigation, there is the need to understand the causes and the impacts of climate change and individual's willingness to change their behaviors which either contribute to GHG emissions or are insolvent unsustainable considering future climate impacts (Niles and Mueller, 2016). This study therefore tried to measure the perception of individuals on the observed changes as well as the causes of climate change and tried to determine how they relate to the adoption of CSA technologies as well as its influence on respondents participation in emission practices.

Perception on changes: Respondents' perception on changes in some climatic parameters were solicited. These perceptions were measured as a scale; 1= increase, 2= no change, 3=decrease. The perception of the variables on the adoption on different CSA technologies will vary based on different factors as such the sign for all the perception causes in both models will be undefined.

Perception on causes: the perception of respondents on the causes of climate change was also recorded. This variable was measured on a Likert scale with -2= strongly disagree, -1 = disagree, 0= no idea 1= agree 2= strongly agree. A positive coefficient relates to individuals who agree on climate change being caused by either deforestation, bush burning, or gods. These variables are expected to be significant in the emission models with the perception on anthropogenic causes having a negative sign while the others have a positive.

3.10 Determinants of Adoption of CSA Technologies – MVP

To find out the determinants of farmers' adoption of CSA practices, a multivariate Probit (MVP) model was used. Considering the discrete nature of the dependent variables for this study, using the OLS technique to model the determinants of farmers' adoption of CSA practices will lead to inefficient estimates. A probit or logit model may be more appropriate using the maximum likelihood estimation since the decision to adopt the use of the technology is binary, whether to adopt or not adopt. However, in modelling the adoption of multiple technologies several factors should be carefully taken into consideration. The decision to adopt could be dependent on previous adoption decisions informing the successive future practices.

Contrary to other models which analyze technology adoption separately, MVP models simultaneously analyze the effect of explanatory variables on multiple technologies, while allowing for the potential correlation between unobserved disturbances, as well as the relationship between the adoptions of different practices. The MVP model estimates the influence of exogenous factors simultaneously on the adoption of CSA technologies, allowing the error terms of each of the technologies to be correlated freely. Failure to account and correct for those interrelationships can lead to the estimation of biased results (Kassie *et al.*, 2013; Lin *et al.,* 2005).

Considering an i^{th} farm household ($i = 1 \ldots. N$) facing a decision on whether or not to adopt the available CSA portfolio on its plot *p* (p = 1 …P) .We can let $U_0 = Z_a$ represent the benefits to the farmer for no adoption and let U_k represent the benefit of adopting the K^{th} technology: *(k = LD, SCP, IWℏ)* denoting the various choices, livelihood diversification (LD), soil conservation practices (SCP), and irrigation and water harvesting (IWH). The decision of the farmer to adopt the k^{th} technology can be expressed as;

$$Y_{ik}^{*} = X'_{ik}\beta_k + U_{ik}, \quad \text{where}(k = \text{LD,SCP\& IWh}) \tag{3.6}$$

The net benefit Y_{ik}^{*} that is derived by the farmer from the K^{th} technology is a latent variable determined by observed characteristics (X_{ip} and unobserved characteristics U_{ip}

The unobserved preferences in the above equation translates into observed binary outcome equations for each choice as follows:

$$Y_k = \begin{Bmatrix} 1\, if\ Y_{ik}^{*} > 0 \\ 0\, if\ otherwise \end{Bmatrix} \tag{3.7}$$

Where $k = 1\ldots.3$ represents the type of CSA practice. The assumption is that the rational farmer has a latent variable, Y^*_{ik} which accounts for the unobserved preference associated with the k^{th} choice of CSA practice. U_{ik} are the error terms having a multivariate normal distribution with mean vector zero and a covariance matrix $\sum$ with a unit diagonal matrix as shown in (3.8)

$$\sum = \begin{bmatrix} 1 & \rho_{12} & \rho_{13} & \rho_{14} & \cdots & \rho_{1m} \\ \rho_{12} & 1 & \rho_{23} & \rho_{24} & \cdots & \rho_{2m} \\ \rho_{13} & \rho_{23} & 1 & \rho_{34} & \cdots & \rho_{3m} \\ \rho_{14} & \rho_{24} & \rho_{34} & 1 & \cdots & \rho_{3m} \\ \vdots & \vdots & \vdots & \vdots & 1 & \vdots \\ \rho_{1m} & \rho_{2m} & \rho_{3m} & \rho_{4m} & & 1 \end{bmatrix} \tag{3.8}$$

The parameters of the MVP model are estimated using the maximum likelihood procedures. Where $M = 3$, the log likelihood function for a sample of N independent observations is given by

$$L = \sum_{i=1}^{N} \omega_i \log \Phi_3(\mu_i, \Omega) \quad (3.9)$$

Where w_i is an optional weight for observation $i = 1. . . N$, and $\Phi_3(.)$ is the multivariate standard normal distribution with arguments μ_i and Ω where

$$\mu_i = (K_{i1}\beta_{i1}^{'}, K_{i2}\beta_{i2}^{'}, K_{i3}\beta_{i3}^{'}) \quad (3.10)$$

with $K_{ik} = 2y_{ik} - 1$, for each i, k = 1, . . . , 3. Matrix **Ω** has constituent elements **Ω***jk*, where

$$\begin{aligned} \Omega_{jj} &= 1 \; for \;\; j = 1, ..., 3 \\ \Omega_{21} &= \Omega_{12} = K_{i1}K_{i2}\rho_{21} \\ \Omega_{31} &= \Omega_{13} = K_{i3}K_{i1}\rho_{31} \\ \Omega_{31} &= \Omega_{22} = K_{i3}K_{i2}\rho_{32} \end{aligned} \quad (3.11)$$

The log likelihood function depends on the multivariate standard normal distribution function $\Phi_3(.)$. The Geweke–Hajivassiliou–Keane (GHK) smooth recursive conditioning simulator is the most common simulation method for evaluating multivariate normal distribution functions.

3.11 Farmer contribution to Greenhouse gas emissions

The ordinary least square (OLS) estimation approach is the most commonly used method used in econometric analysis. However, this approach limits the analysis when dealing with relationships between socio-economic, institutional and bio-physical variables and adoption and use of various technology or in the case of this study, practices. The key limitation of OLS in these kinds of estimation is centered on the nature of the dependent variables which are seldom continuous. This renders the OLS model inefficient.

Conversely, for dependent variables which are discrete in nature, the binomial probit or logit model using the maximum likelihood approach seems to be more desirable but limited to only two options while the study deals with more than two. Artificially lumping the practices into two categories where (1= full participation and 0= no participation) could be a possible solution but according to Judge *et al*. (1985) this would lead to statistically detrimental measurement errors.

This study adopts the use of count modelling in the analysis of participation in emission practices. The objective is to analyze the participation of farmers in the East Gonja district in various practices that contribute to agricultural sector emissions. The practices under consideration are bush burning as part of hunting, bush burning as part of land preparation, burning crop residues after cultivation and tree cutting for fuel wood. The explanatory variables for this model are the socioeconomic characteristics of the farmer, knowledge and perception on climate change and institutional variables. Intensity of participation in emission practices can be modelled using the standard Poisson because at any given y_i , an integer of counts can be said to come from a Poisson distribution and as such can be modeled using the standard Poisson model (Greene, 2008).

The standard Poisson model is specified in equation 3.12.

$$f\left(y_i,\theta_i\right)=\frac{\theta_i^{y_i}e^{-\theta_i}}{y_i\,!},y_i=0,1,\ldots..\theta_i>0 \qquad (3.12)$$

The assumption of equidispersion (equal variance of the dependent variable and its mean) is a major shortcoming of the Poisson model since most empirical studies on count data have been shown to exhibit overdispersion with the variance being greater than the mean as a result of zero observations in the dependent variables of data sets (Nkegbe and Shankar, 2014). This raises the need to model such situations with more appropriate and suitable models. The count dependent variable of this study showed that the variance is less than the mean resulting in underdispersion which can be attributed to the fact that only 6% of the information on the dependent variable was zero. It is therefore imperative to find a model capable of handling under dispersion. The Generalized Poisson Regression (GPR) is a flexible count data approach capable of handling count data of any nature, thus, under, over or equidispersion. The GPR has been studied by Famoye (1993) and has been used in modelling the number of accidents and some covariates by Famoye *et al*. (2004).

Given a random variable Y, it is said to have a generalized Poisson distribution (GPD), if its probability mass function is given by;

$$f\left(y_i,\theta_i,\delta\right)=\frac{\theta_i\left(\theta_i+\delta y_i\right)^{y_i-1}e^{-\theta_i-\delta y_i)}}{y_i\,!},y_i=0,1,2,3,4 \qquad (3.13)$$

Where $\theta_i > 0$ and max (-1, θ_i/4)<δ,1. y_i is the various emission practices.

The variance and mean of the random variable $Y_i$are given by the following

$$\mu_i = E\left(Y_i\right) = \frac{\theta_i}{1-\delta}, \text{Var}(Y_i) = \frac{\theta_i}{\left(1-\delta\right)^3} = \frac{1}{\left(1-\delta\right)^2} E(Y_i) = \phi E(Y_i) \tag{3.14}$$

The term $\phi = 1/(1-\delta)^2$ acts as the dispersion factor. Thus, when $\delta=0$, we have the case of equidispersion and the generalized Poisson distribution reverts back to the normal Poisson distribution with parameter θ_i. Also, in the situation where $\delta > 0$, overdispersion prevails and conversely, $\delta < 0$ indicates underdispersion which is the case for this study's data set.

The log likelihood ($\mathcal{L}$) associated with the Generalized Poisson model is given by

$$\text{L} = \sum_{i=1}^{n} \text{L}\left(\theta_i, \delta; y_i\right) = \sum_{i=1}^{n} InL\left(\theta_i, \delta; y_i\right) \tag{3.15}$$

$$= \sum_{i=1}^{n} \left\{ In\theta_i + \left(y_i - 1\right) In\left(\theta_i + \delta y_i\right) - \left(\theta_i + \delta y_i\right) - In\, y_i! \right\} \tag{3.16}$$

It has also been illustrated that covariates can be introduced into a regression model (Consul and Famoye, 1992) via the relationship

$$log \frac{\theta_i}{1-\delta} = \sum_{r=1}^{p} x_{ir} \beta_r \tag{3.17}$$

Where x_{ir} is the ith observation of the rth covariate, the number of covariates in the model is represented by p and the rth regression parameter is represented by β_r.

3.12 Endogenous Switching Regression Model

The impact of adoption of CSA on farmers' welfare was measured using the endogenous switching regression (ESR) model following Dubin and McFadden, (1984). In examining the impact of the adoption and use of CSA practices on the welfare of farming households, the simplest approach would be to include a dummy for the adoption or use of CSA practices as a variable into an OLS model. But according to Di Falco *et al.*, (2011), that approach might lead to the estimation of biased estimates because the model assumes that the decision to adopt CSA practices is determined exogenously whereas it might actually be endogenous. Farmers self-select themselves endogenously into adopters/non-adopters, therefore, there is a probability that decisions are influenced by certain unobservable characteristics correlated with the outcome under consideration. There is the need for selection of the correct estimation method, and the ESR treatment effect approach was applied to correct for the selectivity bias. ESR accounts for self-selection bias and the interaction between choices of individual practices (Mansur *et al.*, 2008).

The ESR technique first of all models the selection into adoption with a binary model, and the equations for outcome which in this case is the welfare of farmers, modelled for both adopters and non-adopters conditional on the selection.

Theoretically, a farmer makes the decision to adopt CSA practices when the expected utility gained from adoption (D_1^*) is greater than the expected utility derived from the non-adoption of CSA practices (D_0^*). Given that expected utility is unobserved but adoption of CSA practices is, the adoption decision (*D*) is treated as a dichotomous choice:

$$D=1 \text{ if } D_1^* > D_0^* \text{ and } D=0 \text{ if } D_0^* > D_1^* .$$

Using the underlying latent variable model, the adoption model can be modelled as;

$$D_i^* = \alpha Z_i + \varepsilon , \qquad (3.18)$$

Where Z represents an $n \times m$ matrix of the independent variable, α is an $m \times 1$ vector of the parameters to be estimated with ε also being $n \times 1$ vector which represents a normally distributed error term with mean zero and variance σ_{ε}^{2}.

The expectation is that, farmers' decision to adopt CSA practices will lead to better welfares. With the premise of this assumption, we specify separate outcome models for CSA adopters and non-adopters such that:

$$y_1 = X_1\beta_1 + \mu_1 \qquad if\ D = 1 \tag{3.19}$$

$$y_0 = X_0\beta_0 + \mu_0 \qquad if\ D = 0 \tag{3.20}$$

Where y_j with $j = 1, 0$ is an $n \times 1$ vector of dependent variables representing household welfare proxied by the consumption expenditure per capita of households. y_1 and y_0 represent the welfare for CSA adopters and CSA non- adopters respectively. X_j is an $n \times k$ matrix of independent variables and β_j is a $k \times 1$ vector of parameters to be estimated. In the situation where the error term ε in equation 3.18 correlates with the error terms μ_1 in μ_0 from the outcome equations (3.19 and 3.20), then a selection problem arises (Huang *et al.*, 1991). Failure to account for unobserved farmer characteristics will lead to biased parameter estimates, β_j.

The error terms ε, μ_1 and μ_0 are assumed to have a trivariate normal distribution with a mean vector zero and a covariate matrix stated as:

$$\operatorname{cov}(\varepsilon, \mu_1, \mu_0) = \begin{bmatrix} \sigma_{\mu_0}^2 & \sigma_{\mu_1\mu_0} & \sigma_{\mu_0\varepsilon} \\ \sigma_{\mu_1\mu_0} & \sigma_{\mu_1}^2 & \sigma_{\mu_1\varepsilon} \\ \sigma_{\mu_0\varepsilon} & \sigma_{\mu_1\varepsilon} & \sigma_{\varepsilon}^2 \end{bmatrix}, \quad (3.21)$$

Where σ_{ε}^2 represents the variance of the binary selection equation (3.18) disturbance term ε while $\sigma_{\mu_1}^2$ and $\sigma_{\mu_0}^2$ are the variance terms from the outcome equations (3.19 and 3.20) while $\sigma_{\mu_0\varepsilon}$ and $\sigma_{\mu_1\varepsilon}$ represent the covariance between ε, μ_1 and μ_0.

The full estimation maximum likelihood (FIML) estimator presents an efficient method of fitting the endogenous switching regression model (Kim *et al*., 2000; Lokshin and Sajaia, 2004). The FIML approach simultaneously estimates the adoption and welfare equation to produce consistent estimates. For the model to be properly identified, at least one of the independent variables included in the selection model is excluded from the outcome equation, in this case the welfare equation (Maddala, 1983). A requirement for selecting instruments is that it must directly have an effect on the decision to adopt but not on the outcome (welfare) equation (Anang, 2017). Extension access was selected as the instrument for the ESR in this study. The variable regressed on the adoption decision was found to be significant at 10% while it was found to be not significant when regressed against the outcome variable.

The ESR can be used in examining the Average treatment effects (ATT) by comparing the expected outcomes of CSA adopters and that of Non-adopters. This can be achieved by the comparison of the expected values of the outcomes of the adopters (treated) and that of the non-adopters (untreated) under actual scenarios and counterfactual scenarios. Following

Carter and Milon (2005) and Di Falco and Veronesi (2011) the average treatment effect is computed as follows:

Adopters with adoption (actual adoption observed in the sample):

$$\begin{cases} E(Q_{i2} \mid I = 2) = Z_i\alpha_2 + \sigma_2\lambda_2 \\ \vdots \qquad\qquad\qquad \vdots \\ E(Q_{ij} \mid I = j) = Z_i\alpha_j + \sigma_j\lambda_j \end{cases} \tag{3.22}$$

Adopters, had they decided not to adopt (counterfactual):

$$\begin{cases} E(Q_{i1} \mid I = 2) = Z_i\alpha_1 + \sigma_1\lambda_2 \\ \vdots \qquad\qquad\qquad \vdots \\ E(Q_{i1} \mid I = j) = Z_i\alpha_1 + \sigma_1\lambda_j \end{cases} \tag{3.23}$$

The ATT is defined as the difference between Eqn. (3.22) and Eqn. (3.23) given as:

$$ATT = E[Q_{i2} \mid I = 2] - E[Q_{i1} \mid I = 2] \tag{3.24}$$

As a check for the robustness of the estimates, the study employed the Augmented Inverse Probability Weighting (AIPW) and Nearest Neighbor Matching (NNM) of the Propensity Score Matching (PSM) estimator for ATT. According to Caliendo and Kopeinig (2005), the general form of the PSM estimator for ATT can be written as:

$$\tau_{ATT}^{PSM} = E_{P(X)|D=1}\left\{E\left[Y(1) \mid D=1, P(X)\right] - E\left[Y(0) \,||= 0, P(X)\right]\right\} \tag{3.25}$$

The PSM estimator is the mean difference in outcomes which is appropriately weighted using the propensity score distribution of participants. NNM (Rubin, 1973) is one of the most common matching methods and easier to implement and understand methods. NNM estimates the ATT by matching control individuals to the treated groups and discarding controls unselected as matches. AIPW estimators generally use aspects of regression adjustments and inverse probability weighting in combination to estimate potential outcome means and ATT. AIPW have the doubly robust property (Tsiatis, 2007).

AIPW estimators utilize a three-step method in estimating treatment effects. First, the parameters of the treatment model are estimated and the inverse-probability weights computed. Then, separate regression models of the outcome for each treatment level is estimated to find the treatment specific outcomes for individual subjects. Finally the weighted means of the treatment specific predicted outcomes are computed using the weights computed in the first step. The ATE estimates is the differences of the weighted averages.

3.9.5 Climate Change Knowledge and Farmers' Emission Practices

Farmers were interviewed to assess their perceived knowledge on climate change, its effect and causes. The assumption here is that, a farmer who believes climate change is as a result of anthropogenic activities which largely causes the increase in GHGs in the atmosphere leading to the negative impacts of climate change will take steps to reduce the emissions at the farm household level. The emission practices and not the amount of GHGs emitted were sought from the farmers. Tree cutting, burning of crop residues after harvesting and burning of farm lands before cultivation are some of the major practices that farmers were interviewed on.

Farmers' perceived knowledge and their emission practices were analyzed independently using descriptive statistical methods and the results are presented in charts and frequency tables. Contingency tables or Cross tabulations were used to establish the relationship between farmers' perception on climate change and their emission practices and tested for significance using the *Chi Squared* test.

CHAPTER FOUR

RESULTS AN DISCUSSIONS

4.0 Chapter outline

The results from the field survey are presented and discussed in this chapter. The demographic characteristics of farm household heads, their perception on the changes in certain climatic parameters and the causes of climate change and their practices which contribute to greenhouse gas emissions are discussed The chapter also presents the results of the various econometric analysis employed in analyzing the determinants of farmers' decision to adopt the various climate-smart technologies, the intensity of emission practices by farmers in the study area and the effect of adaptation of the various climate-smart technologies on the welfare of farm households.

4.1 Socio-Economic Attributes of Respondents

4.1.1 Sex of Farm Household Head

The sex of the household head was measured as a dummy, a value of 0 was assigned to female while male were assigned 1. From the results 328(93.71%) out of the 350 respondents were male headed households while 22(6.21%) were female headed households. This result appears to be in line with figures from the 2010 population and housing census for the district which reported that majority of households in the East Gonja district are male headed (GSS, 2014). Table 4.1 below shows a summary of the gender of the interviewed respondents.

Table 4. 1 Sex of Household heads

Household head	Frequency	Percentage
Male	328	93.71
Female	22	6.29
Total	350	100

Source: Author's computation from field survey (2018)

Age of Respondents

The mean age of respondents interviewed in the study area is 42.34 years with a minimum age of 20 years and a maximum age of 85 years. The mean age of 42 years signifies that crop farming and livestock production in the east Gonja district is mainly carried out by economically active members of the population. The mean age of 42.34 is close to findings by Adams and Ohene-Yankyera (2014) who reported a mean age of 47.29 for the Northern region in their study and also that of Baidoo *et al.* (2016). Table 4.2 below provides a summary of the age of respondents interviewed in the survey.

Table 4. 2 distribution of respondents by age

Category	Frequency	Percentage
16-25	32	9.14
26-35	111	31.71
36-45	82	23.43
46-55	66	18.86
>55	59	16.86
Total	**350**	**100**

Source: Author's computation from field survey (2018)

4.1.2 Marital Status of Respondents

Marriage is a significant component in the culture of most traditional communities. It was revealed from the study that the majority of the respondents were married. About 92% of the sampled population were married, out of which, 12 were female and 309 male. About 4% of the respondents were single, 2% of the respondents were divorced; and members of the population who were widowed too were also about 2% of the total sample. Although the figure from the study for the marriage and single population do not conform to that recorded by the Ghana Statistical service (49% and 43% respectively), however, the figures for widowed and divorced were quite similar to their findings (GSS, 2014).

Table 4. 3 Marital status of household heads

Marital Status	Female	Male	Pooled (%)
Single	4	11	15 (4.29)
Married	12	309	321 (91.71)
Divorced	4	3	7 (2)
Widowed	2	13	7 (2)
Total	**22**	**328**	**350(100)**

Source: Author's computation from field survey (2018)

4.1.3 Educational Status of Household Heads

For this study, education was categorized into primary, junior high school, senior high school, tertiary and no formal education for respondents who have never been to school. Again, the study revealed that about 58% of the sample had no formal education. Out of the 350 farm households, only 147 had farm household heads with some level of formal education; about 9.71% of the total population had attained at least primary education, 15.43% of the sampled population had attained up to JHS level of education, 14.29% of the sample population had reached the SHS level and finally, about 3% of the sampled population attained tertiary education. Table 4.4 below shows a summary of the educational status of respondents in the study area.

Table 4. 4 Educational status of household heads

Education Level	Frequency	Percent
Primary	34	9.71
Junior High School	54	15.43
Senior High School	50	14.29
Tertiary	9	2.57
No Formal	203	58.00
Total	350	100

Source: Author's computation from field survey (2018)

4.1.4 Religion of Respondents

The study collected data on the religion of respondents. Generally, East Gonja district is mostly dominated by members of the Islam religion (GSS, 2014), however, from the field survey, it was realized that majority of the respondents were Christians with 50.86%, followed by Islam with an estimated 26.29% and traditionalist making up 20.29% of the sampled population. About 2.57% of the respondents claimed they did not belong to any of the listed religion. Table 4.5 below shows the distribution of the various religions of the respondents in the study area.

Table 4. 5 Distribution of religion

Religion	Frequency	Percentage
Islam	92	26.29
Christian	178	50.86
Traditional	71	20.29
Other	9	2.57
Total	350	100

Source: Author's computation from field survey (2018)

4.1.5 Main Occupation of Respondents

From the field survey, the major occupation of respondents in the study area was crop farming. An estimated 96.29% of the sample population were engaged in crop farming. This was followed by civil servants who accounted for about 2.57% and trading which accounted for 0.86% of the total number of respondents. This finding is in line with that of the Ghana Statistical Service which found that agriculture, forestry and fishery employed the greatest proportion of the employed population in the East Gonja district (GSS, 2014). Table 4.6 shown below gives a summary of the main occupations of respondents interviewed in the study area.

Table 4. 6 Major occupation of Household heads

Occupation	Frequency	Percentage
Crop Farming	337	96.29
Civil servant	9	2.57
Trading	3	0.86
Other	1	0.29
Total	350	100

Source: Author's computation from field survey (2018)

4.1.6 Household Size

The average household size from the study is 8.46 with a minimum household size of 2 and a maximum of 30. This finding deviates slightly from that of the Ghana Statistical Service for the district with an average household size of 7.1 for the district and 7.7 for the Northern region (GSS, 2014). In terms of structure and composition, the average number of Children in a household in the district is about 6 with a minimum of 0 and a maximum of 24. The average for male and female Children for households in the district were 3 each. Table 4.7 shows a summary of the household size and distribution across the Children and their sexes in the study area.

Table 4. 7 Household size and distribution

Variable	Mean	Std. dev	Minimum	Maximum
Household size	8.46	4.42	2	30
Children(both)	5.76	3.79	0	24
Male Children	2.89	2.19	0	16
Female Children	2.98	2.28	0	14

Source: Author's computation from field survey (2018)

4.2 Descriptive Results of Farm and institutional attributes of farmers

4.2.1 Farm Size (Land Holding)

From the study, it was discovered that the average farm size cultivated by farm households in the study area was 8.15 acres (3.23 Hectares) with a minimum of an acre to about 70 acres. Land holding or ownership in the East Gonja district communities however is not private as revealed through some key informant interviews; all members of the communities in the district have access to land for farming without any form of restriction for the Gonja people however, the Konkomba's cultivate land released to them by the Gonja Chiefs. Essentially farm lands are not owned out rightly by the farmers but are held in usufruct.

The average maize farm size in the study area was 3.17 acres with a minimum of 0.5 acres and a maximum of 50 acres. For farmers cultivating soybeans the average farm size was 2.47 acres with a minimum of 1 acre and a maximum of 14 acres. The average farm size for all other crops cultivated in the district is 5.35 acres with an acre and 50 acres as the minimum and maximum farm plot sizes. Figure 4.1 below is a chart showing the average farm size for the crops of interest in the study area.

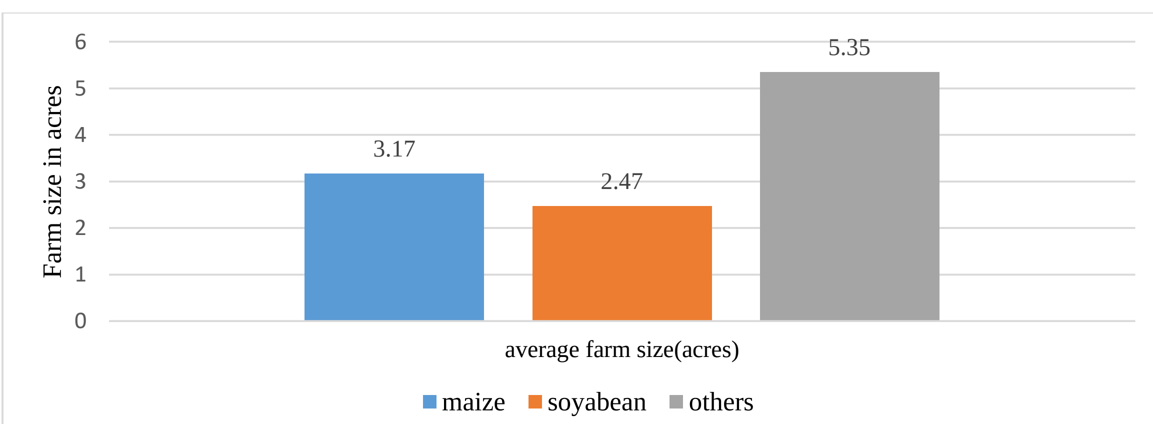


Figure 4. 1 Average farm size for maize, soybean and other crops cultivated
Source: field survey (2018)

4.2.2 Farming Experience

Farming years or experience of farmers interviewed in the district ranged from 2 years to 60 years. The average years of farming for farmers interviewed in the study area was found to be 20.21. For maize, the average number of years farmers interviewed had been farming in the East Gonja district was 15.6 years with the least being a year and a maximum of 60 years. Soybean had been cultivated on the average for 9.9 years by farmers in the district with a minimum of a year and a maximum of 23 years. The number of years a farmer has been farming for is important in determining their likelihood of adopting new technology. Table 4.8 below gives a summary of farming experience in the district.

Table 4. 8 Summary of farming experience by maize and soybean farmers

Variable	Obs.	Mean	Std. dev.	Minimum	Maximum
Farming exp.	350	20.22	13.31	2	60
Maize exp.	350	15.62	13.16	1	60
Soybean exp.	56	9.88	5.85	1	23

Source: field survey (2018)

4.2.3 Farmers' Production Intention

As part of the study, the main purpose for farmers' engagement in farming was required. The purpose for which farmers engaged in farming were mainly for family consumption and commercial purposes. It must be noted however that a given farmer is likely to engage in farming for all the reasons stated at a given time, however a farmer may gravitate towards just one of the above listed more than the others. From the field survey it was realized that majority of the farmers produced mainly for family consumption. About 61% of the interviewed farmers produced mainly for family consumption while an estimated 39% farmers produced for commercial. Figure 4.2 below gives an illustration of farmers' production intentions in the study area.

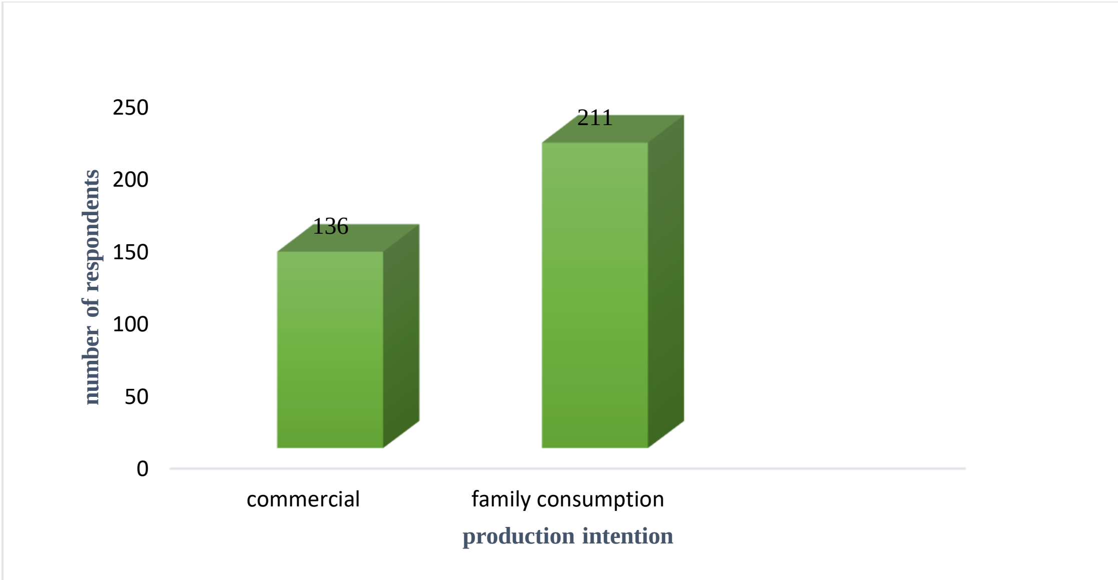


Figure 4. 2 Farmers' production intention in the study area
Source: field survey (2018)

4.2.4 Farm Output

Another important farm attribute of farmers considered in the study was the output of the main crops under consideration for this study; maize and soybean across two seasons (2016 and 2017). It was revealed from the study that an average of approximately 0.6 Mt/Ha was realized by interviewed farmers in the study area with respect to maize in 2016 and 0.5 Mt/Ha in 2017, both years falling short of the countries average for rain-fed maize yield of 1.9Mt/Ha (MOFA, 2016). Majority of the maize farmers interviewed recorded yields less than 0.3-0.6 Mt/Ha (30.6%), 6% of respondents recorded yields of more 1.2Mt/Ha in 2016. In 2017, 30% of the respondents recorded yields of between 0.3-0.6Mt/Ha of maize, 29.71% reported yields of less than 0.3Mt/Ha and 9.43% reported yields of more than 1.2Mt/Ha.

Generally, the average yields for maize reduced during the 2017 cropping season compared to the 2016 season. Most farmers attributed the drop in output to the poor rainfall and cases of fall army worm attacks which were widespread across the nation.

4.2.5 Livestock Ownership and Housing by Farmers

Respondents also, were interviewed to find out if they owned livestock. Approximately 71% of the respondents kept animals while 29% did not. The average years in livestock rearing by a respondent was 10.96 years. With a minimum of a year and a maximum of 60 years. The average revenue gained by farmers from the sale of their livestock in the study area was 709.64 GHS/month with a minimum revenue of 40 GHS and a maximum value of 3,600 GHS/month. Information on housing system for the livestock/animals employed by the respondents were also collected. The animals were either kept under the extensive, semi-intensive or intensive system of rearing animals. From the study, it was revealed that, majority of the farmers kept their farm animals and livestock under the semi-intensive system of rearing farm animals, where the animals are housed by the farmer or individual mostly at night but are left during the day to roam and forage for their own feed. Almost 69.6% of the respondents kept their animals using the semi-intensive system. Approximately 24% of animal-rearing respondents interviewed kept their animals strictly under the extensive system. About 6% kept the animals under the intensive system. Table 4.9 show a summary of animal rearing in the study area.

Table 4. 9 Summary of animal rearing in the study area.

Variable	Response	Freq.	Percent	Mean	Std. Dev.	Min	Max
Livestock Rearing	Yes	247	70.57				
	No	103	29.43				
Livestock Housing	Intensive	13	5.99				
	Semi-Intensive	151	69.59				
	Extensive	53	24.42				
Livestock Exp.(yrs.)				10.96	11.12	1	60
Livestock Rev. (GHs)				709.64	735.80	40	3600

Source: Author's computation from field survey (2018)

Animals kept by farmers in the study area include; cattle, sheep, goats and pigs as well as various kinds of poultry (figure 4.3). In all, the poultry was the highest accounting for about 45% of the total animal kept in the study area, followed by goats and sheep which made up for about 29% and 13% of the animal kept respectively then pigs making up for almost 8% of the population and finally cattle with 5% of the animal kept. While rearing of livestock presents an option for farmers against the negative impact of climate change, the kind of animals kept by farmers play a crucial role in GHG emissions. Ruminants like cattle, sheep and goats have been shown to contribute to the emissions of GHGs like methane through enteric fermentation.

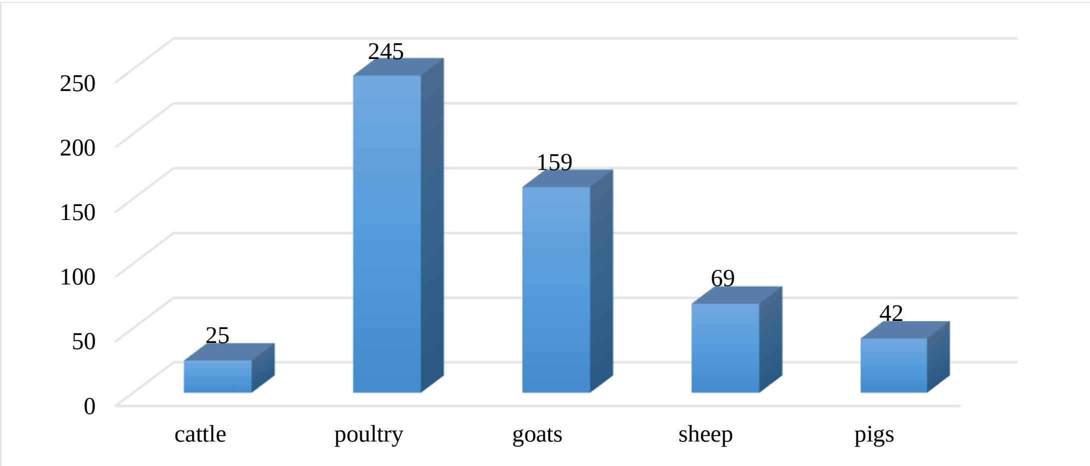


Figure 4. 3 livestock reared in the study area
Source: field survey (2018)

4.3 Institutional Characteristics of Farmers

On access to extension services, approximately 36% of the sampled population claimed not to have access to extension services while 64 % responded yes to having access to extension services (Table 4.10). Majority of the yes respondents stated they got access to the service on a monthly basis with the major provider of the service being the Ministry of Food and Agriculture (MoFA).

With respect to FBO membership, an estimated 26% of the respondents were found to be members of an FBO or a farmer group while 74% members of the respondents had no affiliation to any farmer group. It must be noted that the use of communal labor is common in the communities during some basic farming activities like land clearing and weeding. FBOs created by non-profit organizations in these communities create the avenue for the efficient dissemination of new innovations in agricultural productions as well as the mobilization of funds through the “susu” system and the access of external credit and other resources necessary for their agricultural production.

Respondents were queried on whether they got access to credit or not. Majority of the respondents, about 67% of those interviewed responded no while an estimated 33% responded yes to credit access. Of the respondents who had no access to credit, some 68% attributed it to the fact that credit was unavailable followed by 26.5% of the respondents who stated that they did not get access to credit simply because they had no need for it. High interest and no collateral were the other reasons given by respondents who did not get access to credit and they were reasons given by 2.1% and 3.4% of the respondents without access to credit respectively. The major source for respondents who had access to credit was the family, with approximately 44% of the respondents followed by about 26%

of the respondents having access through various credit unions and approximately 16% having access through their FBOs. Friends and commercial banks each accounted for about 4% of the respondents as sources of credit and finally rural banks and other sources each corresponding to approximately 3% of the respondents. According to majority of the farmers interviewed the credit was used primarily to support farming activities.

A summary of the institutional characteristics of farmers is shown in table 4.10 below.

Table 4. 10 Institutional characteristics of farmers

Institutional variable	Response	Frequency	percentage	Total
Extension access	Yes	225	64.29	350
	No	125	35.71	
Extension frequency	Weekly	2	0.90	223
	Monthly	160	71.75	
	Yearly	61	27.35	
Extension source	FBO	10	5.88	170
	MOFA	156	91.76	
	NGO	4	2.35	
FBO Membership	Yes	91	26	350
	No	259	74	
Credit Access	Yes	116	33.14	350
	No	234	66.86	
Credit source	Family	51	43.97	116
	Rural bank	3	2.59	
	Credit union	30	25.86	
	FBO	19	16.38	
	Friends	5	4.31	
	Commercial Banks	5	4.31	
	Others	3	2.59	
Reasons for no credit	Not needed	63	26.47	238
	Not available	162	68.07	
	No collateral	8	3.36	
	High interest	5	2.10	

Source: Author's computation from field survey (2018)

4.4 Knowledge and perception on climate change

4.4.1 Farmers' Knowledge on Climate Change

On farmers' knowledge about climate change, about 72% of the respondents claimed they knew or had heard of climate change and 28% of the respondents claimed they did not know about climate change. Figure 4.4 shows the farmer knowledge of climate change.

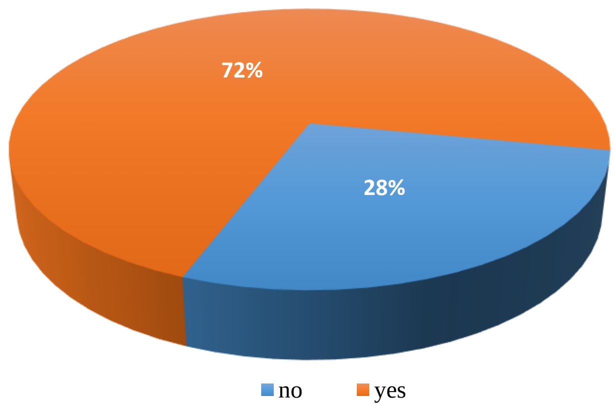


Figure 4. 4 Farmers' Knowledge on Climate Change
Source: field survey (2018)

4.4.2 Respondents' perception on changes in climatic variables

Respondents were probed to find out what they perceived to be the changes they had observed in the climate over time. They were interviewed on the changes they had observed with respect to rainfall amount and predictability, temperature, drought, winds, harmattan and flooding. About 85% of the sampled farmers believed that the amount of rainfall had decreased over the years. Approximately 9% of the respondents asserted that rainfall over the years has been on the rise. About 4% of the respondents believed that there was no change in rainfall while 2.9% had no idea of the changes in rainfall over time.

Also, 87.8% of the respondents believed that there had been an increase in temperature over the years while 5.4% of the respondents were of the view that temperatures had actually reduced and not increased over time. Approximately 4% and 3% of the respondents claimed they had observed no change in the temperature and had no idea of changes in the temperature across the years, respectively.

On the unpredictability of rainfall, 35.7% and 35.4% of the respondents claimed it had increased and decreased, respectively. Majority of the respondents again believed that the occurrence of droughts had increased in the study area. About 71% of the respondents believed that droughts had increased with only 16.9% of the respondents claiming a decrease in the incidence of droughts observed over the years. Also, an estimated 8% of respondents reported no change in the unpredictability of rainfall while 20.6% reported they had no idea when it comes to changes in rainfall unpredictability over the years.

Moreover, 70.6% of the sampled farm households asserted that droughts had increased over time, 16.9% claimed droughts had reduced while 8.9% and 3.7% of the respondents reported they had no idea on the changes in drought and that there was no change in incidents of droughts over the years, respectively.

With respect to the incidence of wind intensity and strength observed by respondents, 52.3% reported an increase while 29.7% reported a decrease in winds. However, 11.1% of the respondents claimed there has been no change in the strength and intensity of winds over the years while 6.9% had no idea with respect to the changes in winds.

Finally, on respondents' views concerning changes in the harmattan over time, 2% of the respondents claimed there has been an increase in the harmattan while about 33% of the respondents actually claimed there had been a decrease in the harmattan over the years. Again, 10.3% of the respondents reported no change and 3.1% said they had no idea when it comes to changes in harmattan over the years.

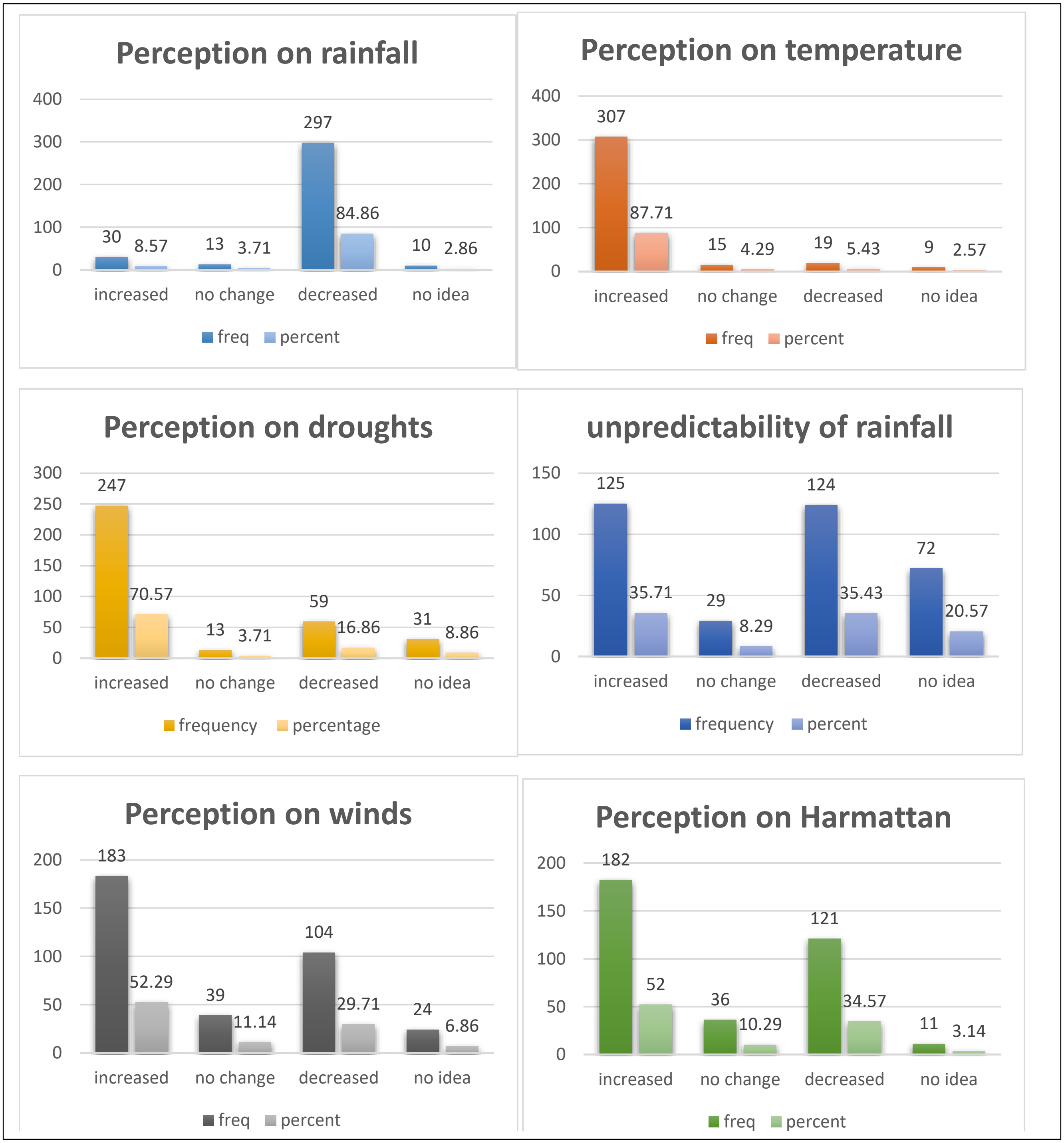


Figure 4. 5 Perception of changes in climatic variables
Source: field survey (2018)

4.4.3 Respondents' Perception on Causes of Climatic Change

The study tried to identify respondents' perception on climate change, specifically in relation to the causes and changes observed over time. Respondents' perception on the causes of climate change were measured on a Likert scale with responses of; strongly agree, agree, no idea, disagree and strongly disagree. These responses were assigned scores ranging from -2 to 2 against their perception on whether climate change is as a result of natural causes, caused by gods, as a result of deforestation or as a result of bush burning.

The study revealed a higher positive response on the perception of natural causes (1.03) as the cause of climate change followed by deforestation (0.75) and then bush burning (0.33). Perceptions of climate change being caused as a result of gods were the lowest with negative mean score (-0.37) which is an indication that on the average respondents disagreed to climate change occurring as a result of acts of gods . From the mean scores as indicated in Table 4.11, it can be concluded that respondents in the communities mostly attributed the change in the climate to natural causes and least to the action of gods.

From Figure 4.5, 169 respondents strongly agreed that climate change occurred as a result of natural causes, with only 9 of the respondents strongly disagreeing to the perception of climate change being as a result of natural causes. On climate change occurring as a result of deforestation, 145 of the respondents strongly agreed that climate change was as a result of deforestation. Also, 178 of the respondents disagreed that the occurrence of climate change was by actions of gods with only 25 of the respondents strongly agreeing. The result with respect to the attribution of climate change being caused as a result of an act of gods is dissimilar to findings by Yaro (2013) who submitted that in Ghana, farmers tend to attribute the changes in the climate to moral, social and religious reasons. Figure 4.5 below gives a graphical representation of respondents' perception of the causes of climate change.

Table 4. 11 Mean scores of perception on climate change

Cause	Obs	Mean	Std. dev.	Min	Max	Skewness	Coeff. Var.
Gods	350	-0.37	1.15	-2	2	0.75	-3.11
Natural	350	1.04	1.14	-2	2	-0.94	1.10
Deforestation	350	0.75	1.32	-2	2	-0.54	1.75
Bush burning	350	0.33	1.38	-2	2	-0.83	4.12

Source: Author's computation from field survey (2018)

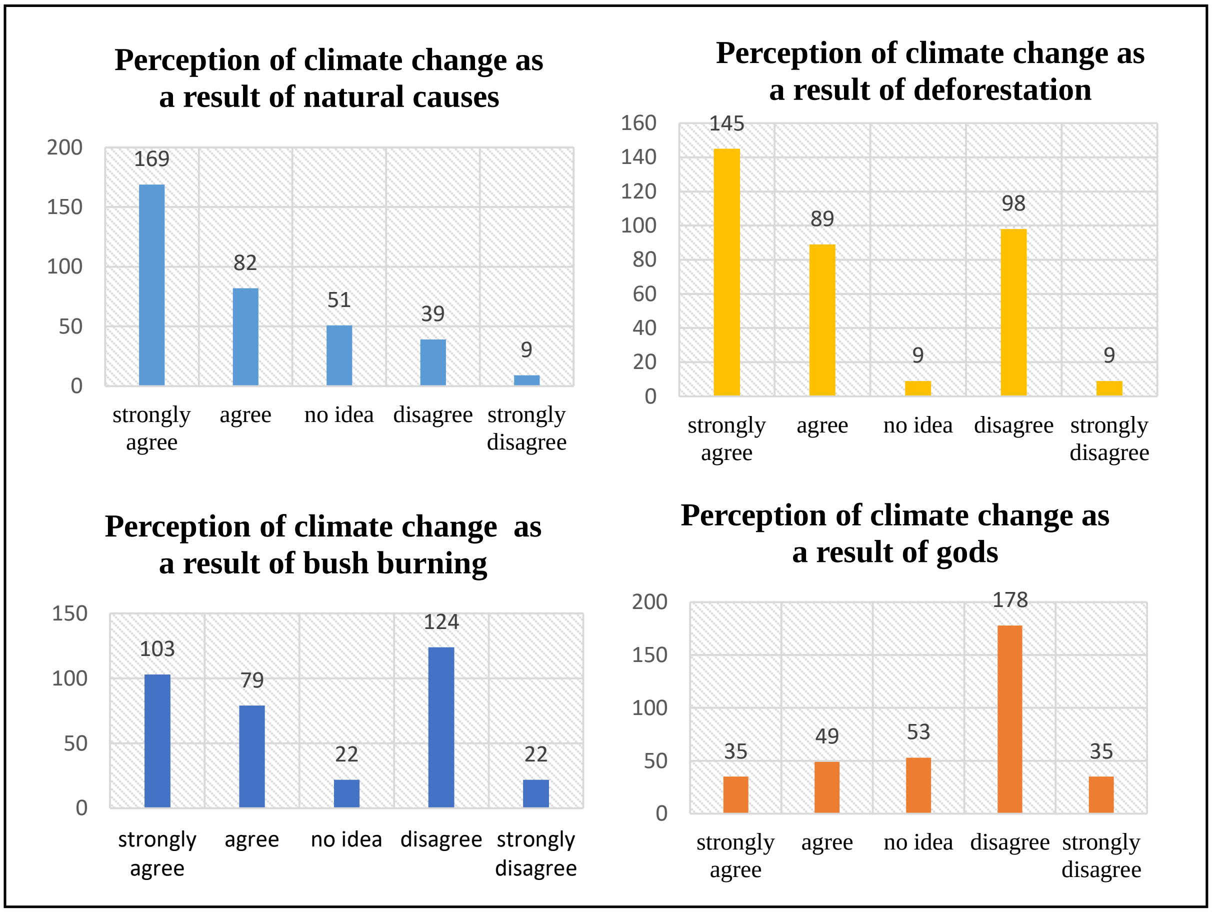


Figure 4. 6 charts showing farmers' perception on causes of climate change.
Source: Field survey (2018)

4.4.4 Knowledge of Climate Change and Perception on Climate Change Causes

The study further tried to establish if there was any difference between respondents who had knowledge of climate change and those who did not and their perception on the causes of climate change. The study again employed a cross tabulation analysis with a Pearson *Chi square* test to explore if there was any relationship between the respondents' perceived knowledge and their perception on the causes of climate change.

Results from the cross tabulation revealed that 75.7% of the farmers who strongly agreed that climate change was as a result of natural causes had knowledge of climate change while the remaining 24.5% of them did not know what climate change is (Table 4.13). Respondents who disagreed with the perception that climate change was caused by gods had 77.1% of them knowing about climate change and the remaining 22.9% not knowing what climate change is.

With respect to climate change being attributed to deforestation activities, 82.8% of the respondents who strongly agreed that climate change was as a result of deforestation had knowledge of climate change while the remaining 17.2% did not know about climate change. Also, 89.3% of respondents who strongly agreed that climate change was caused as a result of bush burning had knowledge of climate change whereas 10.7% of them had no knowledge.

The result of the Pearson *Chi square* test for the perceived causes attributed to natural, gods were not statistically significant. This is an indication that there is no difference between respondents who have knowledge of climate and those who do not have knowledge of climate change in the study area with respect to attribution of causes of climate change to non-anthropogenic factors. The result of the Pearson *Chi square* test for causes of climate change from anthropogenic activities; deforestation and bush burning were significant at 1% implying that there is actually a difference between respondents who have knowledge on climate change and those who did not. As such it can be concluded that knowledge of climate change influenced respondents' perception on climate change, specifically when considering anthropogenic factors as major causes of climate change. Table 4.12 gives a detailed outlook of how farmers' knowledge of climate change relates to their perception on the causes of climate change.

Table 4. 12 Relation between farmers' knowledge on climate change and perception on causes

Knowledge On CC	Response						
	Strongly Agree	**Agree**	**No Idea**	**Disagree**	**Strongly Disagree**	**total**	X^2
	Perception of Climate change from natural causes						
No	41(24.26)	25(30.49)	13(25.49)	14(35.90)	4(44.44)	97(27.71)	
Yes	128(75.74)	57(69.51)	38(74.51)	25(64.10)	5(55.56)	253(72.29)	4.01
total	169(100)	82(100)	51(100)	39(100)	9(100)	350(100)	
	Perception of climate change being caused by gods						
No	5(14.29)	17(34.61)	16(30.19)	51(28.65)	8(22.86)	97(27.71)	
Yes	30(85.71)	32(65.31)	37(69.81)	127(71.35)	27(77.14)	253(72.29)	4.99
Total	35(100)	49(100)	53(100)	178(100)	35(100)	350(100)	
	Perception of climate change being caused by deforestation						
No	25(17.24)	39(43.82)	5(55.56)	21(21.43)	7(77.78)	97(27.71)	
Yes	120(82.76)	50(56.18)	4(44.44)	77(78.57)	2(22.22)	253(72.29)	**36.14*****
Total	145(100)	89(100)	9(100)	98(100)	9(100)	350(100)	
	Perception of climate change being caused by bush burning						
No	11(10.68)	24(30.38)	13(59.09)	36(29.03)	13(59.09)	97(27.71)	
Yes	92(89.32)	55(69.62)	9(40.91)	88(70.97)	9(40.91)	253(72.29)	**36.93*****
Total	103(100)	79(100)	22(100)	124(100)	22(100)	350(100)	

Source: Author's computation from field survey (2018)

4.5 Adoption of Climate Smart Agricultural practices

4.5.1 Distribution of Adopters and Non-Adopters of CSA

Respondents' adoption of the various CSA practices is shown in Table 4.13. The Table indicates that about 68% of the respondents adopted soil conservation practices. Majority (88.57%, 89.14% and 74.57%) of the respondents failed to adopt the application of compost, creation of swales and making of contours under the soil conservation practices. Also, 55% of respondents adopted bush burning control and 38.8% adopted ploughing of crop residues back into the soil.

Livelihood diversifications was adopted by 66% of the respondents while 58.8 adopted commercial livestock production. Soya cultivation, processing, dry season gardening and bee keeping had less than 15% of the respondents each with bee keeping having the lowest with 2% of adoption.

Irrigation and water harvesting was the least adopted among the three categories of CSA technologies under consideration. About 42% of the respondents adopted at least one of the technologies under the category while 39% of respondents adopted water harvesting and only 2.8% adopted the use of manual pump irrigation. The use of manual pumps had less adoption rate. This, according to the respondents was due to inadequate availability of the pumps as well as the high cost of renting if available.

Table 4. 13 Adoption of CSA practices

Climate Smart Agric. Practice/Technology	Adopters (%)	Non-Adopters (%)
Soil conservation practices(SCP)	**67.7**	**32.29**
Creation of swales	10.86	89.14
Compost application	11.43	88.57
Making contours	25.43	74.57
Bush burning control	55.14	44.86
Ploughing crop residues into soil	38.86	61.14
Livelihood diversification(LD)	**66.00**	**34.00**
Commercial livestock production	58.86	41.14
Soya cultivation	13.71	86.29
Soya processing	9.71	90.29
Dry season gardening	7.43	92.57
Bee keeping	2.29	97.71
Irrigation and water harvesting(IWH)	**41.71**	**58.29**
Water Harvesting	39.14	60.86
Manual pump irrigation	2.86	97.14
Total=350		

Source: Author's computation from field survey (2018)

4.5.2 Determinants of Adoption of CSA Practices by Farmers

With the aid of the multivariate probit regression model, the effect of various explanatory variables on the likelihood of farmers' decision to adopt climate-smart practices were evaluated. Twenty-eight explanatory variables were included in the MVP model to identify their effects on farmers' decision to apply the climate-smart agricultural technologies. The results from the MVP are reported in Table 4.14.

A *Chi square* value of 23.19 was estimated from the likelihood ratio test and was statistically significant at 1%, rejecting the null hypothesis that the error terms among the three CSA technologies are not correlated. This further indicates the error term of the different CSA practices are not fully independent of each other. The use of the MVP model is thus justified over the use of separate univariate models for each technology, which would have led to bias and inconsistent results.

Again, the *Wald Chi Square* value for the model of 330.66 which is significant at 1% level, shows the coefficients of the explanatory values in the model are significantly different from zero, suggesting that at least one of the explanatory variables included in the model influences the likelihood of a farmer choosing any of the CSA practices or technologies.

The pairwise correlation coefficients show a positive relation among some of the different CSA practices which indicates complementarity between the practices. Soil conservation practices and livelihood diversification are positively correlated implying that farmers who employ the use of soil conservation practices do so in conjunction with livelihood diversification practices. Also, soil conservation practices (SCP) and irrigation and water harvesting (IWh) practices are positively correlated which also implies that soil conservation practices and irrigation and water harvesting are practiced in conjunction with each other by the farmers. However, the correlation coefficient for livelihood diversification and irrigation and water harvesting was negative signifying those two practices are substitutes though, the p-value for the correlation coefficient was not statistically significant even at 10%.

From the MVP model, age squared was found to have a negative coefficient significant at 10% on IWh. The implication of this result is; holding all other variables constant, older farmers are less likely to adopt irrigation and water harvesting practices. This finding is consistent with Baiyegunhi (2015) in his study on the determinants of rainwater harvesting technology in South Africa where he also discovered a negative relationship between age and the adoption of rainwater harvesting. The result also fits in the theory of human capital; younger farmers in a community have a greater chance of taking up new technology and applying relatively new technologies and knowledge (Sidibe, 2005).

Tractor service was also shown to have a positive significant relation to the adoption of IWh technologies. This result could be attributed to the fact that in the study area, tractor operated activities (specifically ploughing) is the first to be carried out before any other farm operation is carried out. In the light of this, farmers who access tractor services to complete this first phase of farming activities are more likely to go ahead and carry out other activities like on-farm rain harvesting.

The perception of respondents on the changes in climatic variables were found to be significant in all three equations. The perception of temperature had a negative correlation to the adoption of SCP. This result indicates that respondents who perceived temperature to have increased over the years were more likely to adopt SCP. This finding was in line with the *a priori* expectation of the study. Perception on drought was positive in LD and negative in IWh significant at 10% and 5% respectively. The result means that, respondent who perceived a decrease in droughts were more likely to adopt LD practices and respondents who perceived an increase in the occurrence of droughts were more likely to adopt IWh practices. The result for the IWh equation is line with the *a priori* expectation of the study. Farmers who perceived that there is water scarcity as a result of droughts increasing are more likely to take steps to offset the negative impacts both domestically and at the production level.

The variable farm size was found significant at 5% with a negative coefficient in the SCP equation. This implies that as farm sizes increased, farmers were less likely to adopt SCP. The cost of implementing SCP practices increase as the size of the farm increases. This could likely account for the negative coefficient reported.

Several studies (Hassan *et al.*, 1998; Kandlinkar and Risbey, 2000; Tizale, 2007) have shown credit as a vital determinant which improves the adoption of diverse technologies. Findings of this study are no different as credit access was found to be positive and significant at 1% in all the equations except IWh. The findings are in line with the *a priori* expectation and similar to that of Nonvide (2017) and also that of Mulwa *et al.* (2017) who found using the MVP model that farmers who are credit constrained have a lower probability of adopting soil and water conservation practices in his study on the determinants of climate change adaptation in Malawi.

Farmers' production intention was also found significant in both SCP and IWh equations with negative coefficients being significant at 1%. Indicating that, all other variable being constant, farmers who produce or cultivate crops with commercial intentions are less probable to adopt SCP and IWh practices compared to those who produce mainly for household consumption. Farmers with commercial intention primarily seek to make profit before focusing on household consumption as compared to farmers who are more subsistence oriented. This is backed by Morton (2007) who opined that soil and water conservation practices are more relevant to subsistence and smallholder farmers given that they are more vulnerable to the impacts of climate change than commercial driven producers.

The distance to farm was significant in the SCP and IWh equation and the distance to market was also significant in the IWh equation only. Distance to farm showed a positive coefficient significant at 1% in the SCP equation and negative relation significant at 10% in the IWh equation. As the distance from the farmers household to the farm increases, farmers are more likely to adopt SCP and less likely to adopt IWh practices. This finding is similar to that of He *et al*. (2007). Irrigation and water harvesting received more attention and supervision from farmers and household members when they are closer to the home as such households with farms farther away were less likely to adopt. The result also showed that, as the distance to the market increased, farmers were more likely to adopt IWh practices.

Farmers who had knowledge about climate change were found to be more likely to adopt LD practices as compared to farmers who did not. The variable was significant at 1% level and in line with the *a priori* expectation of the study. Farmers who have knowledge of climate change especially in terms of its impacts are more likely to take steps to offset the negative impacts through production and livelihood diversifications.

Access to climate information was also significant in all three equations. However, the coefficient for this variable was negative in SCP and LD significant at 5% in both cases but positive in the case of IWh and significant at 1%. The results suggest that, for SCP and LD, farmers who got access to information were less likely to adopt than those who did not. While for IWh practices, farmers who had access to climate information were more likely to adopt IWh practices. For IWh, This finding is similar to that made by Deressa *et al*. (2009) who found a positive significant relationship between information on climatic variables and adoption of adaptation practices and that of Mulwa *et al*. (2017) who found a positive relationship between access to climate information and adoption of soil and water conservation practices. In rationalizing the negative relationships, Nyamisi *et al*. (2017) showed that although farmers had access to climate information, the accuracy and timeliness as well as its lack to suggest relevant additional information with regards to practices make the access to climate information usually irrelevant to farmers hence the negative relationship.

An important variable which played a significant role in the adoption of SCP and LD was the participation in CSA training which was found to be positive and significant at 1%. Ideally, farmers who participated in CSA training had a higher probability of adopting CSA practices than those who did not, *ceteris paribus*. The simple reason for this being that, farmers who are trained on CSA practices have firsthand exposure to the benefits of the practices as well as practical and technical knowledge on how to implement the technologies. This makes it easier for these farmers to take up the soil conservation practices than those who do not.

Land ownership also had a significant negative coefficient variable which was found to be significant at 1%. The results is interpreted as; farmers who own lands or are natives of the community are less likely to adopt to IWh technologies. This finding is contrary to findings by Shikur and Beshah (2012), who discovered land security to be a significant contributing factor in the adoption of rainwater harvesting technologies.

The individual perception variables on causes of climate change were found significant in only SCP and IWH equations. Individuals who agreed that climate change occurred as a result of acts of gods were more likely to adopt SCP with the variable significant at 5%. Individuals who agreed climate change occurred naturally were also more likely to adopt both SCP and IWh practices. Farmers who disagreed that deforestation caused climate change were found to be less likely to adopt IWh with the coefficient significant at 10%. Also, farmers who agreed that climate change was as a result of bush burning were also more likely of adopting IWh practices.

Table 4. 14 Maximum likelihood estimates of Multivariate probit model

Variable	Soil Conservation Practices		Livelihood Diversification		Irrigation and Water Harvesting	
	Coeff.	SE	Coeff.	SE	Coeff.	SE
Intercept	-0.249	0.942	-0.730	0.999	-0.779	1.108
Age	-0.0005	0.032	0.024	0.034	0.042	0.035
Age squared	0 .00005	0.0003	-0.0001	0.0004	-0.0006*	0.0004
Education(Years)	-0.01	0.02	-0.01	0.02	-0.01	0.02
Household size	0 .02	0.02	-0.01	0.02	-0.02	0.02
Tractor service	0.30	0.20	-0.31	0.19	0.72***	0.23
Perc on drought	0.10	0.11	0.21*	0.11	-0.41***	0.14
Perc on temperature	-0.32**	0.16	-0.23	0.17	-0.26	0.23
Perc on rainfall	0 .14	0.15	0.13	0.15	-0.12	0.18
Farm size	-0.03**	0.13	0.01	0.01	0.01	0.02
Experience	-0.005	0.01	-0.01	0.01	0 .01	0.01
FBO membership	-0.06	0.27	0.43	0.43	-0.17	0.28
Extension Access	-0.30	0.20	0.03	0.21	-0.37	0.22
Credit access	0 .92***	0.21	0.52***	0.19	0.26	0.21
Farm training	-0.03	0.25	0.08	0.24	-0.80***	0.29
Production Intention	-0.63***	0.19	-0.008	0.18	-0.56***	0.21
Distance from farm	0.12***	0.04	0.02	0.03	-0.08*	0.04
Distance from input shop	0 .005	0.09	-0.004	0.10	-0.14	0.11
Distance from market	0.03	0.07	-0.03	0.06	0.21**	0.08
Off-farm revenue	-0.10	0.20	-0.10	0.20	-0.12	0.27
Climate change knowledge	-0.05	0.23	0.64***	0.20	0.27	0.28
Climate info	-0.63**	0 .24	-0.57**	0.22	1.28***	0.27
CSA training	1.30***	0.39	0.95**	0.44	0 .05	0.31
Input support	-0.23	0.24	0.30	0.25	-0.08	0.29
Land ownership	-0.07	0.21	-0.23	0.14	-0.97***	0.27
Perception on causes						
Gods	0.15**	0.07	0.04	0.08	-0.10	0.08
Natural	0.19**	0.08	-0.06	0.08	0.25**	0.10
Deforestation	0.15	0.09	0.12	0.08	-0.17*	0.10
Bush burning	-0.01	0.90	0.07	0.08	0.20**	0.10
Rho21	0.432***	0.087		Number of obs = 333		
Rho31	0.246**	0.108		Wald $Chi^2(84) = 321.04$		
Rho32	-0.156	0.107		Prob > $Chi^2 = 0.0000$		
Likelihood ratio test of rho21 = rho31 = rho32 = 0: Chi2(3) = 23.91 Prob > $Chi^2 = 0.0000$						

*;**;*** significant at 10%; 5%; and at 1%, respectively

Source: Author's computation from field survey (2018)

4.6 Participation in Emission Activities

4.6.1 Respondents' Contribution to GHG Emissions

There are four main farming activities which have been identified to contribute to greenhouse gas emission in Ghana, namely; bush burning before cultivation, bush burning as part of hunting small game, tree cutting for fuel, and burning of crop residue after production. Farmers, were therefore, ask of their participation in any of the practices and the results are presented in Table 4.15. Their responses were further cross-tabulated against their knowledge on climate change and tested with the Pearson *Chi square* to determine if there is a relationship between knowledge and contribution to greenhouse gas emissions at the household level.

The results indicate that 300 of the sampled farm households resorted to bush burning before cultivation of their crops as part of land clearing activities and 50 of the respondents did not burn before cultivation. Out of the 300 respondents engaging in bush burning, 74.67% had knowledge of climate change and 25.33% did not. The *Chi square* value was significant at 5% indicating a relationship between farmers' knowledge on climate change and their engagement in GHG emission activities through bush burning.

Tree cutting for fuel wood was also practiced among 304 of the respondents in the study area with 74.01% of those respondents having knowledge of climate change and 25.99% having no knowledge on climate change. Moreover, 60.87% of farmers who did not engage in trees cutting for fuel had knowledge of climate change while 39.13% did not know of climate change. The Pearson *Chi square* value of 3.45 was significant at 10%. This also indicates that there is a relationship between climate knowledge and contribution to GHG emission through tree cutting for fuel wood in the study area.

Burning of crop residues after cultivation was practiced by 199 of the sampled respondents in the East Gonja district while 151 of the respondents did not practice burning of crop residues after cultivation. Respondents who had knowledge of climate change constituted 75.38% and 68.21% of those who participated in GHG emission practices and those who did not, respectively. Respondents without knowledge of climate change constituted about 24.62% and 31.79% of the emitters and non-emitters, respectively. However, the *Chi square* statistic for the relationship between knowledge of climate change and burning crop residues was not significant. Therefore, it can be concluded that there is no difference between individuals who know about climate change and the practice of burning crop residues in the study area.

Hunting for game is a common activity in most communities in the Northern region and is undertaken communally by hunting parties at least once every week in the dry season, especially in the East Gonja district primarily to meet their nutritional requirements. The study showed 193 respondents took part in hunting for game and 157 did not. Respondents who knew what climate change was yet took part in hunting activities were 77.72% of the group while those who had no knowledge of climate change were 22.28% of the group. The *Chi square* value was significant at 10%, therefore, the null hypothesis is rejected and the conclusion that there is a difference between respondents who know about climate change and those who burn for hunting.

Table 4. 15 Relation between climate knowledge and emission practices

Farmer Knowledge On Climate Change	Emission Activity		Total	Chi^2
	Yes (%)	No (%)		
	Bush Burning Before Cultivation			
No	76(25.33)	21(42.00)	97	**5.94****
Yes	224(74.67)	29(58.00)	253	
Total	**300**	**50**	350	
	Tree Cutting For Fuel Wood			
No	79(25.99)	18(39.13)	97	
Yes	225(74.01)	28(60.87)	253	**3.45***
Total	**304**	**46**	350	
	Burning Crop Residues			
No	49(24.62)	48(31.79)	97	
Yes	150(75.38)	103(68.21)	253	2.20
Total	**199**	**151**	350	
	Bush Burning During Hunting			
No	43(22.28)	54(34.39)	97	
Yes	150(77.72)	103(65.61)	253	**6.34****
Total	**193**	**157**	350	

*;**;*** significant at 10%; 5%; and at 1%, respectively
Source: Author's computation from field survey (2018)

From Table 4.16, it was revealed that 6% of the sampled households did not participate in any of the GHG emission practices under consideration and as such they have zero counts while 41.14% of the households sampled were into all 4 emission contributing practices. Further, about 8% participated in at least one of the practices found to contribute to GHG emissions from the agricultural sector in Ghana. An estimated 22% and 22.57% of sampled households were into at least 2 and 3 of the practices contributing to GHG emissions in the study area, respectively.

Table 4. 16 Distribution of counts of emission practices farmers participated in

Emission Practice(Counts)	Frequency	Percent
0	21	6
1	29	8.29
2	77	22.00
3	79	22.57
4	144	41.14
Total	350	100

Source: Author's computation from field survey (2018)

4.6.3 Maximum Likelihood Estimation of Participation in Emission Activities

The generalized Poisson regression model results are shown in table 4.17. The estimated dispersion parameter from the generalized Poisson regression model is negative, indicating under dispersion. The likelihood ratio test of delta gave a *Chi square* value of 141.61 which is significant at 1%, suggesting that the generalized Poisson model rather than the Basic Poisson model is the appropriate model for the estimation. Also, the *Wald Chi square* value of 153.84 was found to be significant at 1% implying that at least one of the explanatory variables included in the model influences the likelihood of participation in emission practices.

The parameter estimates from the generalized Poisson model revealed that 13 of the explanatory variables under consideration in the model are significant determinants of participating in GHG activities.

Household size has a negative coefficient and significant at 10%. This implies that larger household sizes are less likely to participate in emission practices in the study area considering all other variables constant. The incidence rate ratio estimated for the household size variable is 0.993 indicating an increase in household size by one person leads to a decrease in the rate of participation in emission practices by 0.99 holding all other variables constant. Larger household size means more labor for manual land clearing over burning.

Respondents with higher level of education tend to reduce their rate of participating in GHG emission activities by 0.99 as indicated by the result. This result is in line with the *a priori* expectation of the study given that education has a positive influence on the adoption of modern and sustainable agricultural practices. Being educated allows households in understanding the threats and risks posed by the emission practices and its overall impacts on the climate and environment. This finding corroborates that of Manda *et al.* (2016) who also found a significant positive relationship between education and the adoption of sustainable agricultural practices in rural Zambia.

The religion variable in the GPR model was categorical, thus, Islam, Christian, Traditional and no religion. All the religions were found to have positive significant coefficients. Christian and traditional religions were both significant at 1% significant level with incidence ratios of 1.149 and 1.262, respectively. Respondents who belong to no religion also had a positive coefficient but significant at 10% and with an incidence rate ratio of 1.211. This implies that, the rate for participation in emission practices for Christians and traditionalist are 1.149 and 1.262 times, respectively more than members of Islam in the study area.

Farm size also had a positive significant coefficient at 5% with an incidence rate ratio of 1.041 which indicates an increase in the rate of participation in emission practices by 1.041 as the farm size increases by an acre. This finding is consistent with the *a priori* expectation given that larger farm sizes may require more labor to clear before and after production. Most farmers would rather resort to burning the crop residues after production or during clearing without any form of control because of the farm sizes. It is relatively easier to clear smaller farms using limited labor and even employ fire management practices where burning is practiced.

FBO membership and Extension access both had negative coefficients significant with incidence rate ratios of 0.944 and 0.901, respectively. Implying members of FBOs have 0.944 reduced rate of participating in emission practices than those who are not members of FBOs and farmers who get access to extension services have a drop in the rate of participating in emission practices by 0.901 compared with farmers who do not have access to extension services. These findings are also in line with the expectation and consistent with findings in the literature. For instance, Kim *et al.* (2005) reported a positive effect of extension services on the adoption of best management practices among beef cattle producers in Louisiana. Similarly, Nkegbe and Shankar (2014) also established a positive relationship between extension contact and adoption of soil and water conservation practices in northern Ghana. Being a member of an FBO exposes farmers to mutual labor sharing engagements. This enables farmers in groups to access labor for land clearing and preparations. FBO membership also exposes farmers to knowledge on modern agricultural practices since most aid agencies prefer to work with farmers in groups, which was the case in the East Gonja district.

Households whose main purpose of production is for family consumption tend to contribute less to emission practices as compared to those producing with commercial intention. Thus, the incidence ratio of 1.086 suggests the households who produced for commercial purposes were 1.086 times more likely to participate in emission practices than those who were producing for family consumption, holding all other variables constant. This result could be attributed to the fact that households producing for family consumption tend to cultivate on small farmlands which makes land clearing easier and burning unnecessary.

Surprisingly, access to climate information had a positive and significant effect on emission with IRR of 1.262. Individuals with access to climate information were participating in emission practices 1.262 times more than those with no access to climate information. This finding was contrary to the study's *a priori* expectation. This phenomenon could be because climate information was inaccessible and unreliable as cited by some of the respondents and also recorded by Nyamisi *et al*. (2017) on their work on "adoption and dissemination pathways for Climate-Smart Agriculture technologies and practices in Lushoto, Tanzania".

Off-farm revenue was also found to have a positive coefficient significant at 1% implying, individuals with alternate source of income streams tend to participate more in practices leading to emissions in the study area considering all other variable constant. The IRR value of 1.122 goes to show that respondents with off-farm revenue sources contributed 1.122 times more than farmers who had no other source of revenue apart from farming taking all other variables to be constant.

Farmers who participated in CSA training were also found to be less likely to contribute to GHG emissions through participation in emission practices than those who did not. The coefficient was found to be significant at 10% with an incidence rate ratio of 0.896, indicating that, individuals who participated in CSA training were 0.896 times less likely to participate in burning and tree cutting than individuals who have not participated in CSA practices.

The CSA adoption variable was found to be negative and significant at 1% with a corresponding incidence risk ratio of 0.908. This means respondents who practiced CSA are 0.908 times less likely to contribute to GHG emissions through participation in the practices under consideration holding all other variables constant. Considering that one of the objectives of CSA is the mitigation of GHG emission, this result actually conforms to the expectations and confirms that the adoption and practice of CSA is a way of positively addressing the climate change issues through reducing emission.

Also, results from the generalized Poisson model showed that land ownership had a negative and significant coefficient with an incidence rate ratio of 0.905. This result is interpreted as individuals with land ownership titles contributed less at a rate of 0.905 to GHG emissions than those without, holding all other variable constant. Farmers who own lands do not tend to cultivate on the same piece of land seasonally unlike those who do not and have to perennially rotate the land and resort to slash and burn operations in preparing the land for cultivation.

In terms of farmers' perceptions on the causes of climate change and how they influence their contribution to climate change, only the anthropogenic causes; deforestation and bush burning was shown to have a significant effect on GHG emissions. The perceived cause of deforestation as the cause of climate change had a negative coefficient with an associated incidence rate ratio of 0.948 and that of bush burning with a positive coefficient and incidence rate ratio of 1.03. Thus, individuals who generally disagreed that climate change was as a result of deforestation were likely to contribute more to GHG emission than those who agreed. The result conforms to the *a priori* expectation. It indicates that farmers are sensitive to environmental issues and are likely to desist from certain activities which could have a negative impact on the environment.

The result for the bush burning also showed that as individuals agreed more that bush burning was one of the contributing factors of climate change, the more likely they were to contribute to emissions through the practices, holding all other variables constant.

Table 4. 17 Maximum likelihood estimates of Generalized Poisson model

Variable	Coefficient	SE(Robust)	IRR	SE(robust)
Intercept	0.957***	0.116	2.605***	0 .301
Household size	-0.006*	0.004	0.993*	0.004
Education(Years)	-0.006*	0.004	0.994*	0.003
Religion				
Christian	0.139***	0.052	1.149***	0.059
Traditional	0.233***	0.055	1.262***	0.070
No religion	0.181*	0.104	1.199*	0.124
Main occupation	0.042	0.066	1.043	0.069
Farm size	0.007**	0.003	1.007**	0.003
Experience	0.00002	0.0013	1.0002	0.0013
FBO membership	-0.057*	0.048	0.944*	0.046
Extension Access	-0.103***	0.036	0.902***	0.032
Credit access	0.027	0.041	1.023	0.042
Production Intention	0.083	0.038	1.087**	0.041
Distance from farm	-0.012	0.007	0.988	0.007
Climate change knowledge	0.024	0.043	1.024	0.044
Climate info	0.233***	0.046	1.262***	0.058
Off- farm revenue	0.118***	0.036	1.125***	0.041
CSA training	-0.110*	0.0619	0.899*	0.056
CSA adopter	-0.098***	0.034	0.907***	0.031
welfare	-0.0001	0.0001	0 .999	0.0001
Land ownership	-0.103***	0.037	0.903***	0.034
Perception on causes				
Gods	-0.004	0.016	0.996	0.016
Naturally	-0.003	0.017	0.997	0.017
Deforestation	-0.054***	0.020	0.948***	0.019
Bush burning	0.030*	0.017	1.031*	0.018
Dispersion = -0.74		Number of obs = 350		
Log pseudo likelihood= -501.52		Wald Chi2(26) = 152.09		
		Prob > Chi2 = 0.0000		
		Pseudo R2 = 0.1122		
Likelihood-ratio test of delta=0: Chi2(1) = 141.86		Prob>=Chi2 = 0.0000		

*;**;*** significant at 10%; 5%; and at 1%, respectively

Source: Author's computation from field survey (2018)

4.7 Impact of Climate-Smart Agriculture Practices on Welfare of Households

The econometric model results for the impact of climate-smart agriculture practices using the full information maximum likelihood estimation of the Endogenous Switching regression are presented in Table 4.18 including results for both the adoption and use decision and the outcome model

For this study, the household consumption expenditure per capita is used as a proxy for welfare. Farmers who practiced either Soil conservation practices, livelihood diversification or irrigation and water harvesting or all of them were considered as adopters while those who did none of them were categorized as non-adopters. The result from the probit model is used to analyze the determinants of adoption of CSA practices.

4.7.1 Determinants of CSA Adoption

The variables considered to influence the adoption of CSA are twenty, out of which five are found to be significant. These include livestock rearing, off-farm revenue, production intention, credit access and CSA training. Farmers who reared livestock were found to have a higher probability of adopting CSA practices as compared to those who did not, the coefficient for this variable was positive with a significance level of 1%. This could be as a result of the fact that these farmers had a diversified income stream from the sale of livestock to invest in the implementation of CSA practices as compared to farmers who solely relied on crop production as their income source considering all other variables constant. The off-farm revenue also has a significant effect and positively signed. Farmers producing for commercial reasons were found to be more likely to adopt CSA practices than those producing for household consumption and this variable was found to be significant at 10%. Access to credit also showed to increase the probability of adoption of

CSA practice. This finding is consistent with Di Falco *et al*. (2011) who also found in their study in Ethiopia on farmers' decision to adapt to climate change and how it affects food security that adoption of new technologies usually comes at an additional cost to farmers who are usually credit constrained, which is particularly the case of most farmers in the East Gonja district. As such farmers without access to credit would find it more difficult to implement CSA practices.

Finally, farmers who participated in CSA training were also more probable to adopt CSA practices than those who did not, holding all other variables constant. The variable was found to be significant at 10% and it can be attributed to the reason that farmers who participate in CSA training are exposed to the potential benefits of the practices over traditional non-CSA practices making them more likely to adopt than farmers not exposed.

4.7.2 Adoption Effects of CSA Practices

This section reports and discusses the findings from the Full Information Maximum Likelihood (FIML) estimates of the endogenous switching regression and conditional expectation of the farm household welfare. Table 4.18 reports the estimates of the FIML from the ERS that account for the unobserved heterogeneity for the adoption of CSA practices regarding the consumption expenditure per capita. The results of the outcome model showed that livestock rearing, age, climate knowledge and access to climate information had significant effects on welfare for both adopters and non-adopters of CSA. Off-farm revenue was a significant determinant of welfare among the CSA adopters. However, the finding of this study is contrary to that of Nonvide (2018) who found off-farm income to have a positive effect on the yield of irrigated farmers. The result suggests that off-farm income does not improve the welfare of non-adopters.

Livestock rearing was also estimated to have a positive and significant effect on welfare for both CSA adopters and CSA non-adopters. The impact of livestock rearing on the welfare of non-adopters was higher than that of CSA adopters in magnitude, *ceteris paribus*. Similarly, as age of the farmer increases, the welfare of both adopters and non-adopters also increases. The impact on welfare is much higher in non-adopters than that of adopters.

Climate change knowledge and climate information were also both significant in both adopters and non-adopters at 5% and 10% for the two variables, respectively. Non-CSA farmers with knowledge on climate change had negative welfare compared with those who knew holding other variables constant. Farmers with access to climate information in both the CSA adopter and non-adopter model were shown to have better welfare than farmers who did not but the impact of climate information on welfare was more in the non-adopters than the adopters. The correlation coefficients ρ_1 and ρ_0 are both significant at 5% significant level, however, the coefficient for ρ_1 is negative and that of ρ_0 is positive. The negative coefficient for the correlation between CSA adoption equation and the consumption expenditure (welfare) equation (ρ_1) suggests that both unobserved and observed factors are influential in the decision to adopt CSA practices and the welfare outcomes given the adoption decision. The significance of the coefficient of correlation between the two equations is an indication of self-selection in the adoption of CSA practices. The log likelihood-ratio test of independence of the three equations is also found to be significant at 5% significant level.

Table 4. 18 Full information maximum likelihood estimates of ESR model

Variable	Adoption model	Outcome model(OLS)	
		CSA adopters	CSA Non-adopter
Household size	-0.003(0.02)	5.88(3.87)	-14.45(15.27)
Income	0.02(0.26)	74.17(39.27)*	-51.63(171.02)
Extension	-0.08(0.21)	9.01(33.63)	-24.82(137.34)
Livestock rearing	0.69(0.23)***	67.22(37.80)*	341.35(156.44)*
Off farm revenue	0.73(0.32)**	-79.43(45.24)*	-320.97(263.87)
Age squared	-0.0002(0.00013)	0.04(0.02)**	0.17(0.09)*
Production intention	0.39(0.22)*	-37.50(33.58)	-72.11(114.03)
Farm experience	0.01(0.01)	-1.80(1.85)	-15.23(9.33)
Input support	-0.41(0.27)	63.51(42.20)	-107.28(149.14)
Market access	-0.42(0.33)	-54.32(46.61)	142.17(237.31)
Credit access	0.56(0.28)*	24.44(38.09)	-62.38(201.46)
Climate change knowledge	0.20(0.25)	-38.92(43.03)*	262.61(140.95)*
Climate information	0.03(0.27)	76.22(43.85)**	344.39(164.15)**
Farm size	-0.02(0.01)	-	-
Main occupation	-0.28(0.36)	-	-
Distance from input shop	0.03(0.10)	-	-
CSA training	2.56(1.49)*	-	-
TV ownership	0.27(0.21)	-	-
Perception on drought	-0.10(0.16)	-	-
religion	-0.31(0.26)	-	-
constant	0.80(0.78)	207.80(96.50)**	271.47(454.57)
$\sigma_{\varepsilon 1}$	265.79(14.12)***		
$\sigma_{\varepsilon 0}$	403.31(81.97)***		
ρ_1	-0.467(0.276)**		
ρ_0	0.560(0.324)**		
LR test of independent eqns. : Chi2(**1**) = **4.17** Prob > Chi2 = **0.0412**			

*;**;*** significant at 10%; 5%; and at 1%, respectively

Source: Author's computation from field survey (2018)

4.7.3 Conditional Expectations of the Effects of CSA

In determining the causal effect of CSA practices on household welfare, the consumption expenditure per capita of the farm households that did adopt CSA are compared with the same households had they decided otherwise. This is called average treatment effect on the treated. Similarly, the consumption expenditure of the households that did not adopt was compared with same households had they adopted. This is also known as the average treatment effect on the untreated. The results from the ESR indicated that participation in CSA practices reduces household's consumption expenditure per capita by GH¢419. For farm households who did not adopt, their consumption expenditure would have increased by GH¢ 417 if they did adopt. The result does not conform with the expectation of the study considering that CSA adoption was expected to lead to an improvement in yields and possibly lead to better households' welfare. However, Di Falco and Veronesi (2013) reported similar findings showing that in executing climate change adaptation strategies, more inclusive strategies do not always translate to higher net revenues. The negative impact of CSA household as indicated in Table 4.19 does not necessarily mean that CSA leads to a lower welfare in real life. The consumption expenditure proxy fails to account for scenarios where households may have saved most of the income earned and especially in the context of the study area consumption of own food as opposed to purchased food. In other words, adopting households might actually record higher yields in their production coupled with livestock diversification making the adopting households sufficient in terms of food access. As such, non-adopting households would be spending more in terms of consumption expenditure but may not be exactly better off in terms of welfare (per capita consumption expenditure). Again, the adoption of new technologies is believed to possibly lead to reduced welfare in the short term but lead to realization of improved outcomes in the long run.

Table 4. 19 Average Treatment effects of CSA adoption after ESR

Welfare indicator	Adoption type	Decision stage		
		Adoption	**Non-Adoption**	**Treatment effect**
Consumption expenditure (Per capita)	ATT	288.19**	707.20**	-419.01
	ATU	287.95**	705.15**	-417.20
	HE	BH1=0.24	BH2=2.05	TH=-1.81

*;**;*** significant at 10%; 5%; and at 1%, respectively

Source: Author's computation from field survey (2018)

The study also estimated the heterogeneity effects of the outcome variable. The transitional heterogeneity effect is negative confirming that the impact of the CSA practices on the welfare of households that did not adopt is greater than those that did adopt.

Table 4.20 shows the average treatment effect of CSA adoption on welfare of households. Multiple estimation procedures were used to ensure robustness of the estimates. Results from the AIPW and NNM were significant at 5% and 10% respectively with the coefficients from both estimation procedures having negative signs. The results supplement the estimates from the average treatment effect of the ESR model; non-adopters had a better welfare than CSA adopters.

Table 4. 20 Average treatment effect using different estimation approaches

Treatment effect estimation method	Coefficient	Robust SE	P-value
Augmented Inverse probability weighting	-127.17	63.87	0.046
Nearest neighbor matching	-97.89	57.69	0.090

Source: Author's computation from field survey (2018)

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Chapter outline

The summary of the key findings of the study are presented in this chapter. Based on the key findings, conclusions are made and followed by recommendations for policy implications. Suggestions for further studies are also captured in this chapter.

5.2 Summary of Key Findings

The aim of the study was to determine the main factors influencing the adoption of CSA technologies in the East Gonja District of the Northern Region of Ghana and how the adoption of these technologies impact the welfare of farmers as well as the contribution of farmers to GHG emission or mitigation. Specifically, the study aimed at determining farmers' decision to adopt CSA practices, contribution to GHG emissions and the impact of adoption on welfare.

The study made use of data obtained from a random sample of 350 maize farmers collected through personal interviews using semi structured questionnaires.

Descriptive statistics were employed in the analysis of farmers' demographic and socioeconomic characteristics as well as their perceptions on climate change. The Multivariate probit model was used in evaluating the determinants of CSA adoption while the generalized Poisson model was adopted for the estimation of farmers' contribution to GHG emission. The Endogenous switching regression model was used in estimating the impact of adoption on farmers' welfare.

Results on the perceptions on climate change showed that most of the farmers interviewed attribute the incidence of climate change to natural causes. Also, majority of the farmers interviewed perceived an increase in temperature and a decrease in rainfall over time.

On the adoption of CSA practices, the study revealed that soil conservation practices and livelihood diversification practices were highly adopted in the study area with 68% and 66% adoption levels respectively with irrigation and water harvesting being the least adopted with 42% adoption rate.

Empirical results from the multivariate probit model show that for soil conservation practices, credit access and participation in CSA training increased the probability of adopting. Farmers who had the perception that climate change was as a result of deforestation were likely to adopt soil conservation practices. The same applies for farmers who perceived an increase in temperature and decrease in rainfall. For livelihood diversification practices, the result from the model showed that farmers who perceived that temperature was increasing were more likely to adopt as well as farmers who got access to credit. Farmers who were members of FBOs also had a higher likelihood of adopting and same applies to farmers who had knowledge on climate change. The likelihood of adopting livelihood diversification increased as welfare of households increased. The model also showed that irrigation and water harvesting adoption was more likely for farmers who got access to tractor services, climate/weather information and homestead was farther from markets.

On participation in emission practices, most of the farmers were found to participate in bush burning as a land clearing activity and tree cutting as fuel wood with 300 and 304 of the respondents respectively. The *Chi Square* test for the relationship between farmers' climate knowledge and emission practices was significant for all except burning of crop residues. Around 41% of the respondents participated in all 4 of the emission practices under consideration with only 6% not participating in any of the practices.

The empirical results from the generalized Poisson model showed that, household size, education of household head, FBO membership, extension access, CSA training and CSA adoption were all found to reduce the participation in practices contributing to GHG emissions. While larger farm sizes, off-farm revenue and climate revenue increased farmers' participation in GHG emission practices.

Estimates from the Endogenous Switching regression showed that the general adoption of CSA practices was influenced by livestock rearing, off-farm revenue, credit access and CSA training. Welfare of both adopters of CSA and Non-adopters of CSA was influenced by livestock rearing and the age of the farmer. The same applies for both climate knowledge and climate information. The average treatment effect after ESR as well as the Augmented Inverse Probability Weighting and Nearest Neighbor Matching showed that non-adopters had a better welfare (per capita consumption expenditure) compared to adopters.

5.3 Conclusions

The following conclusions were made based on the findings from the study.

- Credit access and FBO membership are important factors which influence the adoption of CSA practices and technologies
- The perception of farmers on climate change also contributed to the decision to adopt the use of CSA practices.

- The study showed that majority (94%) of the respondents interviewed participated in at least one of the GHG emission activities.
- Majority of the farmers interviewed in the study area could be said to be contributing to GHG emission through cutting trees down to be used for fuel in domestic activities and also burning as part of land preparation.
- The adoption of CSA practices reduces the participation of households in the activities which lead to GHG emissions.
- Farmers perception on deforestation and bush burning as a cause of climate change also contributed to whether or not they participated in emission activities, farmers who agreed that deforestation and bush burning are causes of climate change contributed less to emissions at the household level.
- The adoption of CSA practices reduced emissions, however adopting CSA practices had a negative impact on the welfare (household consumption expenditure) of adopters compared to that of non-adopters in the short term.

5.4 Recommendations

The following recommendations are made based on the conclusions of this study

- Farmers should be encouraged to form cooperatives and FBOs to help in the dissemination and implementation of new technologies which are more sustainable and beneficial.
- There should be credit facilities and policies specially designed to meet the needs of the farmers to help them easily access credit and payback easily.

- Education on climate change should be intensified for smallholder farmers and their households especially on the causes and impacts given that farmers whose perceptions on climate change were right had a higher probability of adopting CSA practices and also contributed less to GHG emissions and also taking into consideration the fact that most of the farmers interviewed contributed to emissions through burning and tree cutting for fuel wood.
- Government, through MoFA, should consider integrating CSA practices in the sector's policy comprehensively since it resulted in a reduction of GHG emissions. By doing so, the government gets a step closer to meeting their emission reduction targets.
- Research should be carried out into developing sustainable alternative energy sources like biogas which can be used in domestic activities in households in order to reduce the reliance on tree species for fuel. Government could also intensify and spread their Gas Cylinder Distribution Programme to cover agrarian communities.
- Further research should be carried out into the impact of CSA adoption to see its impact on farmers' welfare using different welfare proxies and estimation techniques as well as using panel data to examine the long run effect.

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APPENDICES

UDS – FACS

Climate Smart Agriculture Technology Adoption in the Northern Region of Ghana.

Research Questionnaire

Enumerator number______________ Enumerator code________ questionnaire code_____________

Community____

Introduction and Consent
My name is__________________________, an enumerator collecting data on behalf of Mr. Michael Israel, an Mphil. Student with UDS, who is carrying out a research on Climate smart Agriculture technology adoption in the Northern region. The responses will be strictly used for academic purposes and would be treated with the utmost confidentiality and anonymity. You may seek clarification at any point in the interview process and are at liberty to call the principal researcher on +233209376551/+233241564961 for clarification at any time

Respondent Name______________________________________ contact_________________

A. DEMOGRAPHIC and SOCIO ECONOMIC CHARACTERISTICS

A.1 Sex of respondent	[ ] Male [ ] Female
A.2 Age of respondent	
A.3 Are you the household head	[ ] Yes [ ] No
A.4 Role of the respondent	[ ] head [ ] spouse [ ] in-law [ ] child [ ] other
A.5 Marital Status	[ ] single [ ] married [ ] divorced [ ] widowed
A.6 Highest Educational level of HHH	[ ] primary [ ] JHS [ ] SHS [ ] Tertiary [ ] no formal
A.7 Number of years of education of HHH	
A.8 Religion	[ ] Islam [ ] Christian [ ] traditional[ ] other
A.9 Household size	Total________ Male _____________Female_______
A.10 Number of children	Total_______ Male _____________Female_______
A.11 Educational level of children	Primary_____JHS___SHS___Tertiary___Voc.___
A.12 HH composition by age	<15years___16-35years___36-65years___65+years___
A.13 Nationality of respondent	
A.14 Residency status	[ ] Native [ ] Migrant

A.15 Main occupation [ ] crop farming[ ] civil servant[ ] trading [ ] other specify_______________

A.16 Do you have any other source of income? [ ] Yes [ ] No

A.17 Farm size in Acres___________________________

A.18 Do you own the land? [ ] Yes [ ] No

A.19 How long have you been farming for? _______________________

A.20 Are you a member of any FBO? [ ] Yes [ ] No

A.21 Name of the FBO__________________________________

A.22 How long have you been a member of the FBO? ___________________

A.23 Do you get access to extension? [ ] Yes [ ] No

A.24 How often do you get extension visits? ____________[ ]Weekly [ ]Monthly
A.25 Source of extension [ ] MOFA [ ] FBO [ ] others, Specify_______________________________
A.26 Do you get access to credit? [ ] Yes [ ] No
A.27 If no why [ ] not needed [ ] not available [ ] no collateral [ ] high interest
A.28 Source of credit? [ ] Family [ ] Rural Banks [ ] credit union [ ] FBO [ ] Friends [ ] commercial banks
A.29 What was the credit used for?____
A.30 Do you participate in training/workshop on farming? [ ] Yes [ ] No
A.31 Source of the training___________________________
A.32 Was the training beneficial? [ ] Yes [ ] No
A.33 Do you participate in training/workshop on capacity building? [ ] Yes [ ] No
A.34 Source of the training___________________________
A.35 Was the training beneficial? [ ] Yes [ ] No
A.36 How often do you go for trainings in a year?__________________________________
A.37 Is your farm insured? [ ] Yes [ ] No
A.38 Do you get access to market for your produce? [ ] Yes [ ] No
A.39 Do you get access to tractor service? [ ] Yes [ ] No

B. CROP PRODUCTION

B.1 What is the main Purpose of production? [ ] commercial[ ] family consumption [ ] security [ ] other specify __________________
B.2 Which Maize-Soya production system do you use[ ] intercropped[ ] crop rotation [ ] none [ ] other specify __________________
B.3 What other crops do you cultivate ____
B.4 Do you practice fallowing? [ ] Yes [ ] No
B.5 How long have you farming maize for?______________
B.6 How long have you been farming soya for?______________
B.7 Do you get input support for your production? [ ] Yes [ ] No
B.8 Do you get price information? [ ] Yes [ ] No
B.9 Do you cultivate on irrigated land? [ ] Yes [ ] No
B.10 Do you cultivate in the dry season? [ ] Yes [ ] No
B.11 How do you sell your maize? [ ] individuals[ ] retailers [ ] aggregators [ ] processors [ ] others specify __________________
B.12 How do you sell your soya? [ ] individuals[ ] retailers [ ] aggregators [ ] processors [ ] others specify __________________

B.13 Which of the following inputs do you use in the production of your maize

input	maize		soya		Other crops	
	Qty.	Unit cost	Qty.	Unit cost	Qty.	Unit cost
Farm size						
Family labor						
Hired labor						
fertilizer						
Seeds(improved)						
Seeds(Local)						
Other inputs						
Other Agrochemicals						

B.14 What output did you get from the last production season

crop	Land/Size		Name of Variety		Output		price	
	2016	2017	2016	2017	2016	2017	2016	2017
maize								
soya								

B.15 How long does it take you to travel to the following places?
Home to farm ………..miles………..hours by foot…………hours by bicycle
Home to input shop ………..miles………..…hours by foot…………hours by bicycle
Home to market ………..miles…………..hours by foot…………hours by bicycle
Home to clinic ………..miles…………..hours by foot…………hours by bicycle

B.16 How much revenue did you get from the sale of other crops?_________________

B.17 How much revenue did you get from off-farm activities?_____________________

B.18 Which of the following activities do you or HH members do? (Tick where applicable

Activity	Tick	Reason
Bush burning before cultivation		
Tree cutting for fuel		
Burning crop residues after production		
Bush burning when hunting small game		

C. CLIMATE CHANGE PERCEPTION

C.1 Do you know what climate change is? [ ] Yes [ ] No

C.2 Do you think the climate has changed over time? [ ] Yes [ ] No

C.3 Where did you learn about climate change from?________________________________

C.4 Do you get access to climate information? [ ] Yes [ ] No

C.5 What is your source of climate information?______________________________

C.6 In your own view what do you perceive to be some of changes in the climate you have observed?

Climatic event	Increased	No change	Decreased	No idea
Temperature				
rainfall				
droughts				
flooding				
Unpredictable rainfalls				
winds				
Harmattan				

C.7 What are the causes of climate change in your opinion?
[1] Strongly Agree [2] Agree [3] No Idea [4] Disagree [5`] Strongly Disagree

Possible cause	Enter code
They are as a result of natural causes	
They are caused by the gods	
They are caused by deforestation	
They are as a result of bush burning	
Caused as a result of indiscriminate use of chemicals	

D. CLIMATE-SMART AGRICULTURE

D.1 Were you part of the SENDGhana CSA training? [ ] Yes [ ] No
D.2 How long have you known about the CSA technologies?_________
D.3 Do you think the cost of adopting is high? [ ] Yes [ ] No
D.4 Which of the following practices have you adopted?

	Technology	tick	period
SCP	Creation of swales		
	Compost application		
	Making contours		
	Bush burning control		
	Ploughing crops into the soil		
LD	Animal rearing		
	Soya cultivation		
	Soya processing		
	Dry season gardening		
	Bee keeping		
IWh	Water harvesting		
	Manual pump irrigation		

C.8 Did you face any challenges which made the adoption of any of the above difficult? [ ] Yes [ ]No
C.9 Did you use any of the above technology at any time and discontinue? [ ] Yes [ ]No
C.10 If yes why? ______________________________
C.11 What are some of the challenges faced ;
____

E. ANIMAL PRODUCTIONS

E.1 Do you keep animals? [ ] Yes [ ] No
E.2 How long have you been keeping the animals for?___________
E.3 Do you keep the animals for commercial purposes? [ ] Yes [ ] No
E.4 Reasons for not keeping animals?
____
E.5 How much revenue do you get from the sale of your animals?__________________
E.6 Under what system do you rear the animal? [ ] intensive[ ] semi-intensive [ ] extensive
E.7 What kind of animals do you keep?

Animal	**number**	**value**	**Animal**	**Number**	**value**

F. HOUSEHOLD WELFARE MEASUREMENTS

F.1 Food expenditure

Item	Quantity/week	Amount/Week(GHs)	Amount/Season(GHs)
Beans			
Bread			
Rice			
Fruits and vegetables			
Fish/egg/poultry/meat			
Sugar/salt			
Oil/butter			

Spices			
Soft drinks/Alcohol			
Milk			

F.2 Non-food expenditure

Item	Amount/month(GHs)
Health care	
Transport /fuel	
Utility (electric bills/airtime)	
Clothing	
Education	
Social events	
entertainment	
Remittances/gifts	
rent	

F.3 Household assets

Asset	**tick**	**number**	**Condition**	**value**
Television				
Radio				
Mobile phone				
Bicycle				
Motorbike				
Tricycle				
Boats				
Personal computers/laptops				
Knapsack sprayer				
Hoe				
Cutlass				
Donkey cart				
tractor				

F.4 How satisfied or dissatisfied are you with the following

Item	Very dissatisfied	Dissatisfied	Neither	Satisfied	Very satisfied
Quality of your environment					
health					
Current job					
Current safety					
Personal relationships					
Housing					
Future security					
Personal achievements					

Thank you for your time!!