UNIVERSITY OF CAPE COAST

RICE KNOWLEDGE SYSTEM TOWARDS ADAPTATION TO CLIMATE CHANGE IN THE NORTHERN REGION OF GHANA

FATIMAH ABUBAKARI VON

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BY

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DECLARATION

Candidate's Declaration

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

Signature ………………………….. Date …………………….

Candidate's Name: Fatimah Abubakari Von

Supervisor's Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

Principal Supervisor's Signature ………………. Date ……………………

Name: Prof Festus Annor-Frempong

Co-Supervisor's Signature …………………….. Date ……………………

Name: Dr. Albert Obeng-Mensah

ABSTRACT

Despite the crucial role of knowledge systems in effective technology development and transfer, rice knowledge system for climate change adaptation in Ghana's Northern Region tend to be vague. The study sought to analyze rice knowledge system towards adaptation to climate change in Ghana's Northern Region. Explanatory sequential mixed method design was used to collect data on rice adaptation technologies to climate change from 335 farmers, 38 agricultural extension agents (AEAs) and 33 researchers. Structured interview schedules, questionnaires and interview guides were used as data collection instruments. Data was analysed using descriptive statistics (means, standard deviations, frequencies and percentages), inferential statistics (Correlations, Kruskal-Wallis H tests, Mann-Whitney U test, ANOVA and Ordinary Least Squares stepwise multiple regression) and thematic analysis. The study discovered a mismatch between farmers, AEAs and researchers interactions in knowledge generation, modification, transfer and use of climate change adaptation technologies. Recommended rice varieties and weedicides were not effective in adapting to floods and wild rice respectively. Climate change effect on rice production perceived by AEAs was higher than that of farmers and researchers. In conclusion, there is great disparity in the knowledge system for adaptation of rice production technologies to climate change in the Region. It is recommended that AEAs and researchers conduct informal grass-root planning sessions and field visits to interact with farmers and assess the effectiveness of adaptable technologies. Furthermore, plant breeders at Savannah Agricultural Research Institute and the Council for Scientific and Industrial Research should develop rice varieties that are resistant to floods and the pest wild rice.

KEY WORDS

Adaptation

Agricultural Extension Agents

Climate change

Rice farmers

Knowledge systems

Researchers

Ghana

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DEDICATION

To the memory of my late father, Dunyin Naa Abubakari Von Salifu whose passion for the growth of the rice sector in the Northern Region has partly strengthened my interest to conduct this work.

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LIST OF ACRNOYMS

AEAs	Agricultural Extension Agents
CSIR	Council for Scientific and Industrial Research
FAO	Food and Agriculture Organization
FBOs	Farmer Based Organizations
FGDs	Focus Group Discussions
GSS	Ghana Statistical Service
IIED	International Institute for Environment and Development
IPCC	Intergovernmental Panel on Climate Change
ISNAR	International Service for National Agricultural Research
JICA	Japan International Cooperation Agency
MESTI	Ministry of Environment, Science, Technology and Innovation
MOFA	Ministry of Food and Agriculture
NASA	National Aeronautics and Space Administration
OECD	Organization for Economic Co-operation and Development
RELC	Research Extension Farmer Linkage Committee
SARI	Savannah Agriculture Research Institute
UNFCCC	United Nations Framework Convention on Climate Change

CHAPTER ONE

INTRODUCTION

Background to the Study

Rice is thought to have originated in southern India and spread by trade to China and other areas of the world (Khan, Dar & Dar, 2015). It is by far the most economically important cereal food crop in the world. It provides about two thirds of the calorie intake of more than three billion people in Asia, and one third of the nearly one and half billion people in Africa and Latin America (FAO, 1995; Khan *et al.*, 2015). To meet rising demand, rice production increased by nearly 140 percent worldwide between 1968 and 2010. Within the same period, the area of rice cultivated worldwide increased from 129 million hectares to about 159.4 million ha with the average yield almost doubling from 2.23 t/ha to 4.32 t/ha (Mohanty, Wassmann, Nelson, Moya & Jagadish, 2013).

Rice is a food security crop and used to improve the nutrition of mankind since it contains fat, crude fiber, carbohydrates, calcium, phosphorus, iron, sodium, potassium, riboflavin, niacin, vitamin E acetate, energy and protein needed for growth and development (Gnanamanickam, 2009; Verma & Shukla, 2011). Rice is also known to have been used to prevent diseases such as high blood pressure, Alzheimer's and weak heart conditions, cancer and dysentery (Verma & Shukla, 2011). Aside the nutritional and health benefits for humans, the straw of rice is used to feed cattle and thatch to roof buildings. In the cottage industry, the rice straw is used in the manufacture of hats, mats, ropes, sound proofs, boards and litter material. Rice husk is also used as feed for animals and provides domestic and industrial fuel. The rice bran is used to prepare poultry and cattle feeds, while the fatty acids extracted from the rice bran is used in the preparation of soap by industries (Toungos, 2016). Rice production does not only provide food for the populace but it also serves as source of rural employment for farmers and labourers who have no land for production (Kranjac-Berisavljevic, 2000).

Owing to economic development, increased urbanisation and changes in consumer preferences, rice consumption in Africa is rapidly displacing other staple foods. The increase in rice consumption has resulted in a domestic production deficit and the continent has increased supply through rice imports from Asia. Nevertheless, Africa has seen an expansion rate of 6 percent per annum of rice production, 70 percent of which is due to land expansion and 30 percent credited to increase in productivity (Fagade, 2000; Falusi, 1997; Africa Rice Center, 2007). However, much of local production in Africa is rain-fed (Dingkuhn, Jones, Johnson, Fofana & Sow, 1997) whilst demand continues to outstrip home-grown production (Africa Rice Center, 2007). West Africa as the leading sub-region for rice production has accounted for about 70 percent of Africa's overall production between 2007 and 2016 (Nigatu, Hansen, Childs & Seeley, 2017). However, the comparative progression of demand for rice is still higher in the West African sub-region than any other part of the continent (The United States Agency for International Development (USAID), 2009) due to increase in population, consumer preference and an increase in income (Balasubramanian, Sié, Hijmans & Otsuka, 2007).

In Ghana, rice is grown as a cash crop and is consumed as a staple food. The consumption of rice grew from 35kg per capita in 2016/17 and is estimated to reach 40kg per capita by the end of 2020 (Taylor, 2019). Domestic production of rice in Ghana has increased by about 12 percent between 2016/17 and 2017/18 reducing the pressure on imports modestly (Oxford Business Group, 2018). Rice paddy production rose from 645,000 tonnes in 2013 to 755,000 tonnes in 2018 (FAO, 2019). Even with these numbers, local production is still unable to provide for the growing population as just 34 percent of rice consumed is produced locally in the country (Lamptey, 2018). As a result, the nation generally relies on imported rice to bridge the supply gap (Tanko, 2015). A total of 680,000 metric tonnes of rice was imported in 2018 to supplement domestic rice production, representing 66 percent of Ghana's rice imports (Lamptey, 2018). Ghana, since 2015, has spent over one billion dollars on rice importation annually (Ghana News Agency, 2018). The high importation of rice to meet local consumption has triggered several interventions aimed at boosting local rice production (Addison, Sarfo-Mensah & Edusah, 2015). The Japan International Cooperation Agency (JICA) Sawah Project was aimed to increase rice production in Ghana (Fujimoto, 2011). The Food and Agriculture Sector Development Policy (FASDEP) 1, FASDEP 2, Growth and Poverty Reduction Strategy (GPRS) 1 and 2, Medium-Term Agricultural Development Programme (MTADP), Accelerated Agricultural Growth and Development Strategy (AAGDS) policy documents of the Ministry of Food and Agriculture (MoFA) and Ghana Government for that matter (MOFA, 2009), the Council for Scientific and Industrial Research's (CSIR) quality rice development project (Ghana News Agency, 2014), Rice Development Strategy by the Government of Ghana have made put in place strategies to promote rice production in Ghana. Furthermore, there is fifty percent subsidy on rice seeds and fertilizer to increase affordability and boost domestic production in Ghana (Jeffery, 2011).

The Northern Region of Ghana has had the most share of interventions designed to increase and promote rice production (Martey, Wiredu, Asante, Annin, Dogbe, Attoh & Al-Hassan, 2013). This is because 70 percent of the total area of land under rice production in the Ghana is found in the Northern Region (SRID/MoFA, 2011). Among the prominent interventions are the Rice Sector Support Project (RSSP), Lowland Rice Development Program (LRDP), Gbewa Rice Project (GRP), Northern Rural Growth Program (NRGP), Inland Valley Rice Project (IVRDP), the Multinational Nerica Rice Dissemination Project (MNRDP), the USAID Emergency Rice Initiative, (Martey, Wiredu, Asante, Annin, Dogbe, Attoh & Al-Hassan, 2013; Tanko, Iddrisu & Alidu, 2016). These programmes focused primarily on assisting smallholder rice farmers with technology coupled with best practices to increase production and enhance their livelihoods and welfare status. The Ghana Commercial Agriculture Project (GCAP) seeks to improve rain-fed and irrigation rice production on a 20,000-hectare land in the Nasia-Nabogo valley in the Northern Region.

Despite the interventions of these projects and policy strategies, the productivity of rice is still not encouraging and the average production of the country in 2011 was 2.92Mt/ha compared to the potential yield of 6Mt/ha (MoFA, 2012). This is partly due to low level of engagement of farmers and low technology uptake which has all led to low yields of rice (Wiredu, Gyasi, Marfo, Asuming-Brempong, Haleegoah, Asuming-Boakye & Nsiah, 2010). Moreover, reduced soil fertility, lack of credit access and poor use of improved technologies (SRID/MoFA, 2011), land ownership, the use of traditional farming methods, land degradation, illiteracy, weak agricultural structure, lack of quality seeds, migration, dry spells as a result of climate change all contribute to the low yields of rice (Masood, Ellahi, & Batool, 2012).

Around the world, the evidence of climate change is alarming due to rises in sea levels, changes in precipitation, temperature and retreating glaciers (Adedeji, Reuben & Olatoye, 2014). Accelerated climate change is expected to have negative consequences on the sustainability of the earth due to adverse impacts on the ecology, society and economy (Stern, 2006). Over the last thirty years, climate change has been the most severe menace to crop production (Masood, Ellahi, & Batool, 2012; Saul, 2015). The outcomes of the changes in climate including alterations in precipitation and temperature cause changes in growing seasons, dates of planting and harvesting, and an increase in the population of weeds, pests and diseases. Also, variations in biomass production, evapotranspiration, photosynthesis and land suitability for crop production seems to be a direct impact of climate change (Mark, Mandy, Gary, Lan, Saleemul & Rowena, 2008; Saul, 2015). The change in climate is also expected to negatively affect crop growth, availability of soil water and soil fertility (Adejuwon, 2004). Generally, crop yield is expected to fall to a minimum of 10-20 percent and a maximum of 50 percent by the year 2050 as a result of the change in climate (FAO, 2006a).

Rice is the crop that is very vulnerable to changes in climate (Mohanty, Wassmann, Nelson, Moya & Jagadish, 2013). This is because apart from soil conditions, rice is extremely susceptible to climatic conditions (Furuya & Koyama, 2005; Mabe, Sarpong, & Osei-Asare, 2014). Extremes of climatic conditions affect the critical developmental stages of rice growth. High temperatures, flooding and drought cause submergence and wilting of the rice crop (Mohanty *et al*., 2013). The yield of rice decreases by 0.6 t/ha for every 1 °C increase in temperature (Sheehy, Ferrer, & Mitchell, 2006). For rain-fed rice in drought-prone areas, a decrease of 17 to 40 percent of rice yield has been found to cause enormous production losses and chronic food scarcity (Greenbio, 2011). There is therefore a need to adapt to climate change, especially in Africa, since precipitation is unlikely to increase Christensen *et al*. (2007). The continent is also heavily reliant on agriculture, which is directly impacted by changes in climate. Poor farmers are likely to feel the negative consequences of the change in climate due to limited technological capacity to respond to climate change (Yohe and Tol, 2001).

Currently, global efforts to limit greenhouse gas emissions are inadequate to avoid the risk of climate change and sea-level impacts and hence the need for adaptation (CoastAdapt, 2017). There are several benefits of adaptation which include; adaptation are more immediate compared to mitigation since the impacts of mitigation sometimes takes decades before they are felt. Also, the results of adaptation are not dependent on groups of people but rather on individuals (Jackson *et al*., 2010). Various population groups have different opinions on climate change awareness and the impact of climate change (Haque, Yamamoto, Malik and Sauerborn, 2012; Aoyagi-Usui, 2008; Carew-Reid, 2008). When people are aware of climate change, the effect becomes more evident as a result of risk perception and thus paves the way for the generation and use of effective adaptation technologies (Pennings & Leuthold, 2000). The successful generation, transfer, modification and utilization of rice technologies adaptable to climate change in the Northern Region of Ghana depend on key players such as farmers, extension agents and researchers. Akinnagbe and Ajayi (2010) described the players as knowledge system. Agricultural knowledge systems link people and institutions and promote or stimulate mutual learning, development, sharing and use of agricultural technology, knowledge and information (Anandajayasekeram, Puskur, Sindu, & Hoekstra, 2008). FAO and World Bank (2000) describe knowledge systems as a group of organizations and individuals engaged in knowledge and information processes. Rivera, Qamar and Mwandemere (2005) explain that the agricultural knowledge system seeks to develop and/or enhance contact and knowledge between actors in order to ensure the adoption of technology and innovation in agricultural production and to improve the livelihoods of farmers. Christoplos (2010), on the essence of the knowledge system explains that knowledge systems between farmers, extension agents and researchers should concentrate on best-fit approaches, promote pluralism, use participatory methods, build capacity and ensure long-term institutional support. This in essence indicates that technologies generated by both farmers and researchers should be able to adapt to farmers environment so that farmers can accrue maximum benefits. Also all actors should be seen as working together to generate and test technologies and used extension methods that involve all actors. In the long run, the capacity of farmers, AEAs and researchers should have been built as a result of their interactions. Government and non-governmental institutions' support to actors should be sustainable. Researchers, extension agents and farmers are critical knowledge sharing partners who have important roles to play and must work together in the adaptation of suitable and effective rice technologies to climate change (Davis, 2009; Ozor & Nnaji, 2011; Chukwuma, 2012). Researchers, for example, have the responsibility to develop suitable technologies that reflect agro-ecological and production conditions to help farmers adapt to climate change (Lybbert & Sumner, 2010). Furthermore, researchers implement government policies on scientific investigations, development as well as commercialization of appropriate technologies in partnership with other organizations for various sectors of the economy (Council for Scientific and Industrial Research [CSIR], 2019). There is no doubt that with the vagaries of climate change on rice production, research is being done to address the issue of climate change. In sub-Saharan Africa [SSA], rice growers are guided by researchers to adopt suitable mechanization techniques to improve production (International Rice Research Institute [IRRI], 2009). Agricultural Extension Agents (AEAs) play major roles in the provision of appropriate technologies, information and education to farmers on how to cope with climate change (Singh & Grover, 2013). Agricultural Extension Agents connects farmers to the innovation process involving researchers and other actors (Mustapha, Undiandeye & Gwary, 2012). Farmers, on the other hand, are developers of indigenous technologies and help in disseminating technologies, act as effective feedback mechanisms and are the end users of technologies (Swanson, 1998). Research has shown that farmers are responding the climate crisis by use of various indigenous crops. Linkages and interactions among farmers, extension agents and researchers are thus essential for effective adaptation to climate change. The need for effective linkages and interactions triggered the Ministry of Food and Agriculture (MoFA) and the Council for Scientific and Industrial Research (CSIR) to establish the Research-Extension-Farmer Linkage Committees (RELC) to create demand-driven services to farmers, other stakeholders and address indigenous or local challenges confronting agriculture (CSIR-MOFA, 2013; Ragasa, 2011).

Statement of the Problem

The effect of climate change on agricultural growth is a threat to food security in SSA (Enete & Amusa, 2010). Its overall impact on food production is projected to be undesirable (Nelson, *et al*., 2009) due to weak coping, mitigation and adaptive strategies (Kranjac-Berisavljevic, Blench & Chapman, 2003; Jagtap, 2007). The effect of climate change on rice production is expected to be disastrous as rice yields are predicted to decline, especially with temperature increases of 2ºC-4ºC (Duttarganvi, 2013). The rise in temperature coupled with drought, affect the physiological development and photosynthetic process in rice, thereby leading to a decline in yields.

The detrimental consequence of the change in climate on rice production is a danger to the security of current and future generations. It is also damaging to the achievement of Sustainable Developments Goals (SDGs) 1, 2, 3, 13 and 15 which seeks to achieve no poverty, zero hunger, good health and well-being, climate action and life on land respectively (Korres, Norsworthy, Burgos & Oosterhuis, 2016; Khanal, 2009; Futakuchi, 2005). To alleviate the adverse impact of climate change, there has been increasing advocacy on the use of climate change adaptation technologies (UNFCCC, 2006).

However, effective knowledge system is essential to the effective adoption of adaptation technologies (Akinnagbe & Ajayi, 2010). AEAs serve as liaison between farmers and researchers, promote the transfer and appropriate use of technologies, inform and educate producers to cope with, alleviate and adapt to changes in climate, making AEAs' input into technology generation, modification and utilization vital (Singh & Grover, 2013). Farmers, on the other hand, are developers of indigenous technologies, help disseminate technologies and act as effective feedback mechanisms. They are also end-users of technologies and the ability to use them depends on the suitability, complexity and affordability of the technologies. Therefore, the involvement of farmers in knowledge generation and modification cannot be overemphasized. (Swanson, 2008). Researchers, AEAs and farmers need to develop symbiotic and systematic interactions to ensure that research focuses on priority needs and issues relevant to adaptation of farmers to climate change (International Rice Research Institute, 2009). The knowledge system process for successful linkage between crucial stakeholders in the knowledge system begins with a joint assessment by farmers, extension agents and researchers of the resources, constraints and priorities of farmers vital in the generation, transfer, modification and utilization of rice technologies to ensure that adaptation technologies are relevant to farmers in the face of climate change. Appropriate technologies cannot be developed, modified, transferred and used where coordination between farmers, AEAs and researchers is ineffective.

Despite the important role of knowledge system, inadequate information on the role of knowledge systems in addressing climate change in the Northern Region has left many salient questions unanswered such as; are farmers, agricultural extension agents and researchers aware of climate change issues in the Northern Region? Do they know the effects of the change in climate on rice production? What technologies are recommended by AEAs and researchers to farmers? What technologies are used by farmers? Are technologies effective in adapting to climate change? What linkage activities and interactions occur in the development, modification, transmission and use of technologies? The study therefore sought to provide answers to these critical questions.

Research Objectives

The general objective of the study was to analyze rice knowledge system towards adaptation to climate change in the Northern Region of Ghana.

The specific objectives were to:

1. Examine the socio-demographic and farmer-related characteristics of rice farmers, agricultural extension agents and researchers in relation to level of awareness of climate change on rice production.
2. Describe how farmers, agricultural extension agents and researchers perceived the effect of climate change on rice production.
3. Determine the extent of recommendation/use of rice production technologies in climate change adaptation from AEAs and researchers and farmers.
4. Assess the effectiveness of rice production adaptation technologies in addressing climate change.
5. Examine the nature of linkages and interactions in the generation, modification, transfer and utilization of rice production technologies.
6. Determine the best predictors of effectiveness of climate change adaptation technologies in rice production.

Hypotheses of the Study

Three hypotheses were formulated to guide the study. These hypotheses were tested at 0.05 alpha level and they include:

Hypothesis 1:

H_0: There is no significant differences in the perception of farmers, extension agents and researchers on the level of awareness of climate change in rice production.

Hypothesis 2

H_0: There is no significant differences on perceived effect of climate change on rice production between farmers, extension agents and researchers.

Hypothesis 3

H_0: There is no significant differences in the level of interactions between farmers, AEAs and researchers in the generation, modification, transfer and use of adaptation technologies.

Significance of the Study

The study sought to analyze rice knowledge systems towards adaptation to climate change in the Northern region of Ghana. The study provided policy recommendations on rice knowledge system towards the adaptation of climate change in the Northern Region of Ghana. Governmental organizations, non-governmental organizations (NGOs) and Civil Society Organizations (CSOs) could use them for growth decision making to improve the rice sector in Ghana.

The study provided information on impact of change in climate on rice production and suggested adaptation technologies available along with the extent to which climate change adaptation technologies are used by farmers. This information is useful for the planning and implementation of agricultural extension programmes. Extension agents can reinforce their training and discussion of rarely-used innovations that are essential to productivity increase. Information on the effectiveness of available technologies have also been provided. Researchers can reassess these technologies, improve on them with farmers and extension agents to ensure improved productivity. These findings will further equip farmers, NGOs working in the rice sector, institutes of higher learning, CSIR and MOFA with information on effective adaptation technologies available in the region. The study correspondingly made available information on the best predictors of farmers' extent of use of climate change adaptation technologies which is relevant for AEAs and NGOs in improving farmers' extent of use of adaptation technologies. Additional, details on the level of interactions and effectiveness of extension teaching methods would be vital for improving technology generation, modification, transfer and utilization by famers, AEAs and researchers. The Ministry of Food and Agriculture and the Ministry of Environment, Science, Technology and Innovation could have a look at it to improve on the policy of RELCs in Ghana.

Delimitations

The study was conducted in four of the ten rice growing districts and Metropolis in the Northern Region. The districts and Metropolis randomly selected were Tolon, Savelugu and Nanumba North districts, and Tamale respectively. The study focused mainly on rice farmers, agricultural extension agents from MoFA and researchers from CSIR-SARI in the Northern Region. Furthermore, the concept of agricultural knowledge systems is applicable to the scope of this study, which focuses on interactions between farmers, AEAs and researchers in the generation, modification, transfer and use of adaptation technologies to respond to climate change in rice production and not entirely agricultural production. The indigenous knowledge used by farmers to adapt to climate change was not considered in this study.

Limitations

The data given by farmers was mainly based on recollection. It is therefore likely that farmers might have omitted some vital information due to information overload. However, data collected during the rainy season when farmers experienced climate change, its associated effects, used adaptation technologies and interacted more with researchers and AEAs reduced the likelihood of memory loss. A sample of 10 AEAs and 6 researchers were used for the Cronbach's Alpha coefficient test for reliability. These are less than the minimum requirement of thirty respondents (Yurdugül, 2008). Nevertheless, the researcher was able to ask respondents if the item was unclear, which the researcher explained to them before they replied, thanks to the face to face t approval method. The process did not only give the opportunity to the researcher to address reliability issues but also issues of validity. Of the 381 farmers selected for the sample size, 321 were available and agreed to participate as well as to provide information, resulting in a response rate of 84.2 percent. However, Baruch and Holtom (2008) indicated that the average response rate for studies using data collected from individuals was 52.7 percent, indicating the response rate of the rice farmers was valid.

Definition of Key Terms

Climate: Climate is ta location's average precipitation and temperature for a minimum of thirty years.

Climate change: Climate change is the variation in amount of temperature and rainfall due to human and natural activities over a period of 30years or more.

Rice Knowledge systems: The interactions between farmers, agricultural extension agents and researchers to generate, transmit, modify and use rice technologies to acclimatize to variations in temperature and rainfall in the Northern Region.

Level of Awareness of Climate Change: Knowledge of level of variation in the amount of temperature and rainfall for the past thirty years.

Adaptation: The use of rice technologies to acclimatize to major variations in temperature and rainfall to boost the yield of rice.

Soft adaptation technologies: Information and instructions on how knowledge and skills on rice technologies are used by farmers, AEAs and researchers to deal with significant changes in temperature and rainfall to increase yield. Specifically, these include knowledge and skills on planting dates, row planting, bund construction and crop insurance among others.

Hard adaptation technologies: These are physical objects and machinery used by farmers to manage the significant variations in temperature and rainfall to increase yield in rice**.** They include early maturing varieties, pest resistant varieties, seeds treated with fungicides.

Researchers: Scientists and technologists from the Savanna Agricultural Research Institute (SARI) investigating and finding solutions to challenges of rice and fitting climate change to it.

Effectiveness of adaptation technology: Extent to which rice technologies used by farmers acclimate to major changes in temperature and rainfall can successfully contribute to the increase in yield/output of rice in the face of climate change.

Organization of the Study

The thesis is organized in eight chapters. Chapter One focused on the background to the study, the statement of problem, research objectives, hypotheses, significance of the study, delimitations and limitations of the study, and the definition of terms as used in the study and an outline of the organization of the study.

The second Chapter presented a review of related literature. It highlighted the theoretical framework and the concepts of climate and climate change, awareness, adaptation and agricultural knowledge systems. The empirical review of literature and the conceptual framework of the study were detailed in the Chapter.

Chapter Three comprised of the research design, the study area, population of the study, the sampling procedure, the pretesting of research instruments, data collection instruments, procedures for data collection, the processing of data and its analysis.

Chapter Four presented and discussed the relationship between demographic and farmer/work-related characteristics of rice farmers, agricultural extension agents and researchers to level of awareness of climate change in rice production. The results of the perceived effects of climate change on rice production was presented and discussed in Chapter Five. The recommended climate change adaptation rice production technologies, farmers' extent of use and effectiveness of rice production adaptation technologies in addressing climate change were discussed in Chapter Six. The Seventh Chapter presented the results and discussions of nature, depth and frequency of linkages and interactions among stakeholders in the generation, modification, transfer and utilization of climate change adaptation technologies.

Chapter Eight summarized the main findings, concluded and gave recommendations that were grounded on the findings of the study. Implications for agricultural extension and recommendations for further studies were also presented.

CHAPTER TWO

LITERATURE REVIEW

Introduction

The Chapter sought to bring together existing theoretical conceptual and empirical studies which form the foundation of the research. The Chapter has highlighted the general systems theory, the concepts of climate change adaptation, adaptation technology, agricultural knowledge systems and awareness. Literature was also reviewed on farmers, researchers and AEAs' awareness to climate change, relationship between awareness to changes in climate and demographic characteristics, in addition to the effects of climate change on rice production. This Chapter also reviewed literature on linkages and interactions among farmers, AEAs and researchers, and ends with the conceptual framework that guided the study.

Theoretical Framework

The study was guided by the systems theory posited by Ludwig von Bertalanffy. The choice of system theory was based on the fact that it provides a framework for conceptually examining the components of the system within the context of a relationship with each other and with other systems in order to understand how systems work (Capra, 1997; Drack, 2008; Wilkinson, 2011). The theory states that individual parts and processes of living things are inadequate to give a complete and universal explanation when isolated and studied unless with coordination of the parts and processes (Bertalanffy, 1972). Hence the use of the systems theory.

The systems theory has been applied in the fields of psychology, biological systems, organizational systems and communication (Dekkers, 2017). Systems theory has been used in social work to explain how interrelated factors contribute to unhealthy behavior: the absence of a drug-addicted father was found to influence the use of drugs in a child because the child wanted to feel closer to the father and the only recollection the child had of the father was his use of drugs (Social Work License Map, 2017). In organizational management, Jolly (2015) shows how the system theory is used to explain how everything is interdependent in business and how harmful it can be to management and the whole enterprise to neglect the system theory of organization. In an example, Jolly (2015) explained that management did not know that the remuneration of staff, and indeed the fate of the company as a whole, was intricately linked to the value of the stock price, and the value of the stock price was interlinked or linked to the downturn in the growth of the airline industry as a whole. Had management been aware of these interrelationships, a gradual rise in employee base salaries to compensate employees when stock prices declined would have been the remedy and the once strong airline would still be in operation. Researchers have also applied systems theory to establish effective communication mechanisms for the smooth running of organizations. In applying systems theory, organizations must participate in multiple levels of contact with all kinds of stakeholders and maintain effective internal and external networks with staff, customers or clients and other stakeholders (Scott and Lewis, 2017).

The theory is based on six key principles or elements which all systems must possess. They include holism, hierarchy, self-regulation, openness, adaptability and finally stability and flexibility (Ritzer, 1992). The principle of holism emphasizes the need for a system to be assessed in its entirety rather than assessing the system through its individual parts. This principle helps to understand that successful adaptation to climate change is a collective effort by farmers, AEAs and researchers, and hence the need for them to work together rather than separately. It further explains that each of them has a vital role to play in adapting to climate change but are interdependent on each other and need to work together to ensure that appropriate technologies for adaptation are developed, transmitted, modified and used. The openness principle relays the engagement of systems vigorously with their environment. It helps to examine how farmers, AEAs and researchers actively engage with one another and other relevant stakeholders such as NGOs, government institutions and universities to exchange evidence on climate change, it effects on rice and adaptation technologies. It explains the importance of communication and feedback in the generation and modification of adaptation technologies for increased productivity.

The principle of adaptability places emphasis on the changing nature of systems which helps in responding to challenges due to their engagement with their environment. It gives explanation that farmers, AEAs and researchers can adapt to variations in climate by finding solutions to emerging problems through their continuous interactions with each other and with NGOs and universities. This allows for farmers, AEAs and researchers to improve outdated technologies and develop new ones in response to the variation in temperature and rainfall. Another principle or characteristics of systems is its hierarchical nature. Farmers, AEAs and researchers are usually part of a hierarchy. Although SARI researchers are seen as a system, they are fragment of a bigger system known as the CSIR, which is part of an even larger system known as the

Ministry of Environment, Science, Technology and Innovation. In the same vein, extension agents are a network that is part of a higher structure known as the District Department of Agriculture and an even broader system known as the Regional Directorate of Agriculture and finally the Ministry of Food and Agriculture. Finally, rice farmers may belong to farmer based organizations. This makes decisions taking difficult since the decisions must go through a complex bureaucratic process. Funding and approval of projects for instance must go through the hierarchies, from the top to the bottom. The systems theory principle of self-regulation gives the understanding that each of the actors display a measure of self-regulation. The operations of farmers, AEAs and researchers are guided by their specific goals which are usually pre-determined. These goals ensure that they become focused and not veer away. The theory helps to understand that farmers, AEAs and researchers are constantly re-evaluating themselves to ensure that they are moving towards their set goals. The principle of stability and flexibility helps to understand the role of farmers, AEAs and researchers in maintaining a complex balance between their unchanging efficient performance and their versatile, creative responses to changing climate conditions.

In systems theory, there are the closed and open systems. While the closed system is isolated and has no influence on the environment, the open system is receptive of inputs of the environment and thus, conditions within the system are influenced by conditions from outside (Marais, 1979). The open systems also receives content and energy from its external environment and also gives content and energy to it as well (Littlejohn, 1983). The open system is adapted in this study because farmers, AEAs and researchers do not act in isolation but influences and are also influenced by their external environment. According to Scott (2008), an open system consist to five key elements and they include input, throughput or transformation process, output, feedback and the environment.

The inputs are usually from the system itself and the environment. The inputs may include physical, financial, human and information resources (Lunenburg, 2010). In the throughput or transformation process, these resources are combined to attain the goal of developing technologies that effectively adapts to climate change. The interactions that occurs between farmers, AEAs and researchers is also part of the transformation process. Also, the technical competencies of farmers, AEAs and researchers are important in the transformation process.

Output in the open system are usually the results or outcomes of the transformation process (Lunenburg, 2010). In this study, the expected outcome will be the development, modification, transfer and use of effect adaptation technologies. Feedback is very essential for the success of adaptation to climate change. Negative feedback on a developed technology will lead to its modification so that farmers can use it to effectively adapt to climate change. The environment of farmers, AEAs and researchers may include research institutions, government organizations, non-governmental organizations and processors.

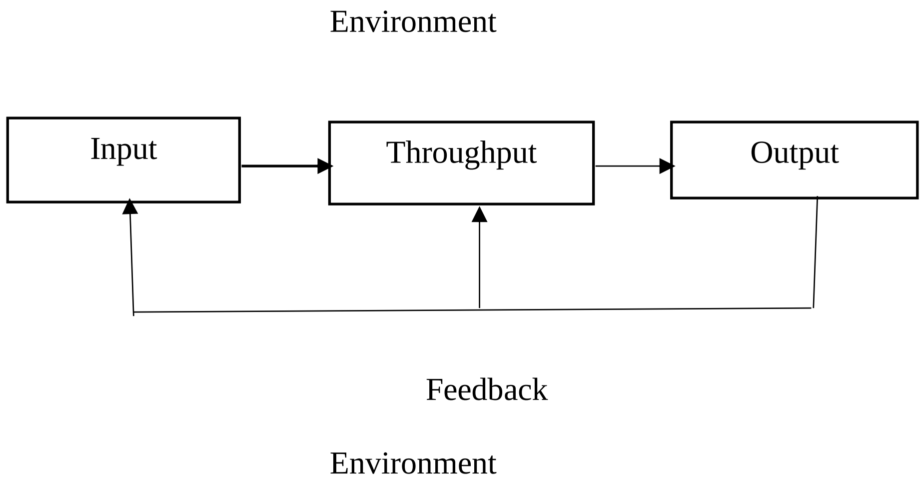

Figure 1: Open Systems Model (Scott, 2008)

The systems theory has a number of advantages in the analyses of rice knowledge systems for adaptation to climate change. It takes a holistic view in dealing with climate change adaptation by looking at farmers, AEAs and researchers as a system rather than independent member parts. Climate change can easily be managed through effective interaction of farmers, AEAs and researchers with each other as well as other important stakeholders along the rice value chain. Furthermore, the systems theory utilizes feedback to develop new adaptation technologies and improve on old ones. Finally, the theory recognizes the importance of greater systems (super systems) in decision making. One disadvantage of the theory is the fact that it leads to delays in decision making since there have to be stakeholders meetings, technology innovations and trials and possible modifications before the approval and release of technologies.

Review of Concepts

The application of systems theory brings to fore the need to review concepts of climate change, awareness, adaptation and adaptation technologies, knowledge systems, climate effects and impacts on rice production.

Concept of Climate Change

Climate is often referred to as the long-term averages of temperature, precipitation, atmospheric circulation and chemistry of a region as measured over a 30year period (Australian Academy of Science, 2015). It is also defined as the averages of weather conditions of a geographic location projected for a long length of time, from a few weeks to as long as 30 years or more (NASA, 2005). The conventional period in contemporary measurement of climate is thirty (30) years (IPCC, 2001a; NASA, 2005). Changes in averages of precipitation, temperature, humidity and sunshine over a thirty-year period can thus result in climate change.

Climate change has also been defined as a long-term shift in the statistics of temperature and precipitation (Le Treut *et al*., 2007). The Inter-governmental Panel on Climate Change [IPCC] (2001b), defines climate change as any change in temperature, precipitation, humidity and sunshine over time as a result of natural causes; such as volcanic activity and human activity; caused by greenhouse gases and carbon dioxide. This definition implies that the change in climate could be as a result of natural developments and or the anthropogenic activities performed by man. Article 1 of United Nation's Framework Convention on Climate Change [UNFCCC] (1992) confirms that a change in climate is attributed directly or indirectly to human activities that alters the composition of the global atmosphere and natural climate variability over an extensive time frame. This study adopted Le Treut *et al.* (2007), IPCC (2001a) and UNFCCC (1992) definition of climate change as the change in the timing and amount of temperature and rainfall as a result of natural processes and anthropogenic causes.

Concept of Awareness

Basically, awareness is this power of pure observation. Awareness is to be mindful about a fact. Climate change awareness is therefore considered as a state of consciousness of the variations in climate over a period of 30 years. Madsen (1996) underscored the fact that the concept of awareness is the critical driving force that motivates knowledge. The change in climate presents a crucial threat not only to the atmosphere, but also to agriculture and food security in many developing countries of which Ghana is no exception. This is primarily attributed to extremely inconsistently changing climatic patterns. Rural farmers in particular, for whom their livelihood depend on using of natural resources are projected to suffer the consequences of the effect of changes in climate (Acquah, 2011). Climate change awareness is therefore crucial. When farmers become aware of the problem, the implications become evident, thus providing a sense of risk (Ohene-Asante, 2015). Accurate risk perception is a requirement for choosing an effective risk-coping or adaptation strategy since research has shown that a farmer who is unaware of any risk will not choose any adaptation strategy (Pennings & Leuthold, 2000).

Concept of Adaptation

Adaptation has constantly been essential to farming, and farmers have been skillful to adapt to a changing environment even before the issue of climate change became a concern (Organisation for Economic Co-operation and Development [OECD], 2012). The decision of farmers to adapt is as a result of the benefits they stand to gain immediately compared to the effects of mitigation which could take several decades (Jackson *et al.*, 2010). Furthermore, an assured amount of climate change is unavoidable because of historical emissions (IPCC 2001). Moreover, adaptation technologies/measures might be used on local or regional levels and their effectiveness is usually less dependent on the actions of other people.

According to De Chavez and Tauli-Corpuz (2008), and Tol (1998), adaptation in climate change is the phenomenon whereby ecological, social, or economic systems alter or modify their ways to actual or expected climatic stimulus and their effects or impacts. Adaptation could also be efforts made by people to amend to current and possible effects of changes in climate (Mani, Markandya & Ipe, 2008). Adger, Huq, Brown, Conway and Hulme (2003), and Kurukulasuriya and Mendelson (2007) view adaptation as any activity that reduces the negative influence of climate change. Maddison (2006) is also of the view that farmers must attest to a change in climate before ascertaining suitable adaptation measures and finally put those measures in use. Adaptation can either be anticipatory or reactive. It is anticipatory when systems adapt before the initial impacts occur, and reactive when the adjustment is implemented after the initial impacts have occurred (IUCN, IISD, SEI, SDC & Intercooperation, 2004).

The responsibility of adaptation in agriculture will lie chiefly with farmers (Berry, Rounsevell, Harrison, & Audsley, 2006). Howden *et al.* (2007) have highlighted the probability of farmers not commencing adaptive actions, if they doubt that the climate is changing or do not recognize it as a threat. Also, the understanding of changes in climate would have a significant impact on farmers' capacity to respond to changes in climate in their localities. Tol (1998) stated that understanding the changes in climate has the potential to encourage farmers to improvise on local technology to aid adaptation.

Climate Change Adaptation Technology

The most widely encouraged strategy for climate change adaptation in the agricultural sector is technology (Houghton, Jenkins, & Ephrams, 1990; Rosenberg, 1992). A technology is defined as any equipment, technique, practical knowledge or skills used for carrying out a specific activity (UNFCCC, 2006a). It is also defined as the ability to practically apply knowledge to accomplish a defined task using mechanical objects and know-how for production and use of objects (IPCC, 2007a).

Any technology that is applied to diminish or decrease helplessness and improve the resilience of a natural system to the consequence of climate change is known as an adaptation technology. An effective adaptation technology would usually combine both 'hard' and 'soft' technologies (UNFCCC, 2006b).

Types of Adaptation Technologies

There are basically two types of adaptation technologies, hard and soft technologies (Christiansen, Olhoff & Traerup, 2011; Sovacool, 2011; UNFCCC, 2006b).

Hard technologies

These are usually technologies that are complicated to manage, expensive, human built infrastructure that involve large scale disturbances to ecosystems. Even though hard technologies can be indigenous in nature, they are mostly owned by foreign firms (Sovacool, 2011). Hard technologies are inventions that are relatively expensive and require help from government and other organizations and institution to implement. Hard technologies also comprise infrastructure that improve the agricultural sector in the face of climate change (Sutton, Srivastava, Neumann, Iglesias & Boehlert, 2013). UNFCCC (2013) describes hard technologies for adaptation as the physical tools as well as resistant varieties of crops used to increase resilience. Hard adaptation approaches generally involve the usage of particular techniques and activities comprising capital products such as drought resistant seeds, seawalls and irrigation technologies (UNFCCC, 2006b).

Elliot, Armstrong, Lobuglio and Bartram (2011) have suggested that since rainfall has become erratic, the digging of boreholes for domestic use in drought prevention, desalination for irrigation, household water treatment and safe storage, improving resilience of protected wells to flooding, increasing the use of water-efficient fixtures and appliances, leakage management, detection and repair in piped systems especially irrigation systems, post construction support for community-managed water systems, rainwater collection from ground surfaces (small reservoirs and micro catchments), rainwater harvesting from roofs, water reclamation and reuse and finally water safety plans is essential. According to the UNFCCC (2006b), farmers would usually use drought resistant seeds and new irrigation systems when adapting to climate change. Mbah and Ezeano (2016) found that the climate change adaptation measures used by farmers in Benue State, Nigeria were zero tillage, early ripening of rice varieties, afforestation/planting of trees, improved land management techniques, mixed crop use, crop rotation, value addition and diversification of crop and livestock production.

Soft technologies

Sovacool (2011) explains that these are technologies that are found naturally in communities, are simple to use, quite easy to understand and are owned by the local people. These technologies are less costly, flexible and involve community specific adaptation measures which is achieved by integrating community-based resources with indigenous knowledge (Ayers & Forsyth, 2009). They are also technologies that concentrate on information, capacity building, strategy creation and institutional arrangements (World Bank, 2011).

Clements, Haggar, Quezada and Torres (2011) further explains that soft technologies are the farming practices that are communicated to and invented by farmers themselves to minimize the impacts of the changes in climate. Soft adaptation measures concentrate solely on capacity building, information, policy and strategy creation and institutional arrangements that sought to adjust to the impact of climate change. Some of these include insurance schemes which is fairly new to farmers in sub-Saharan Africa, crop rotation patterns, intercropping and the change in the time of planting which are common (UNFCCC, 2006b).

Concept of Agricultural Knowledge Systems

The concept of Agricultural Knowledge Systems was devised in the 1970s by extension specialists who emphasized the inaptness of a one way flow of information and knowledge from researchers to farmers (Nagel, 1979). Policy-makers and donor organizations also realized the weak link between researchers and extension agents thus restraining technological change (Crawford, 1982; World Bank, 1985). Extension programmes were often panned for low efficiency and lack of fairness in service provision (Evenson, 1987) while research institutions were incompetent, irrelevant and deficient of sustainability (Beye, 2002). In order to promote agricultural development, there was a need for a strong coordination in the transfer of innovation (Leeuwis & van den Ban, 2004).

It was thus introduced in the agricultural sector to address the inadequacies of mainly, formal, scientific knowledge (Reid *et al.*, 2006). It projected the flow of knowledge among research, education, extension and support services including supply, credit institutions and markets (Rivera & Schram, 1987; Rivera & Gustafson, 1991). Emphasis was however laid on links and information flow to both farmers and the triangle of research, extension and education (Axinn & Thorat, 1972). A study by Eicher in 2001 explained the need for the three entities to be strategic or structured as a system so as to respond to global change, farmers' needs and anxieties.

As time went by however, Agricultural Knowledge Systems (AKS) become known as Agricultural Knowledge and Information System due to the importance placed on information. Well along, it was quietly refined as Agricultural Knowledge and Innovation Systems (AKIS) comprising knowledge and novelty in rural areas (Scar, 2012).

Hartwich *et al.* (2007) are of the view that the absence of information and knowledge exchange between farmers and those who produce farm-relevant knowledge is a crucial concern in pro-poor agricultural development especially in rural areas. This concept therefore takes into consideration the difficulties faced by information and innovation procedures in rural areas. AKIS is anticipated to assist in explaining the flow of knowledge and information as well as strengthening them (Scar, 2012). AKIS is a system that connects farmers and institutions to reciprocal learning whiles generating, sharing and utilizing knowledge, information and agriculture-related technology to improve production (Codjoe, Asuming-Brempong & Mabe, 2012). It has been well-defined as a collection of agricultural organizations or individuals, as well as the linkages and interactions between these organizations or individuals in generating, transforming, transmitting, storing, retrieving, intergrating, diffusing and utilizing of technology, with the goal of collaborating symbiotically to assist appropriate the solving of problems, innovation and agricultural production (Röling & Engel, 1991). It can also be described as one that connects people and institutions as well as encourages or stimulates reciprocal learning, produce, share and use agricultural technology, knowledge and information (Anandajayasekeram, Puskur, Sindu, & Hoekstra, 2008). FAO and World Bank (2000) defines knowledge systems as a collection of organizations and individuals engaged in the process of knowledge and information generation. The main purpose of AKIS is to establish and or reinforce communication and knowledge among actors so as to ensure technology adoption and innovation in agricultural production and improve the livelihoods of producers (Rivera, Qamar & Mwandemere, 2005). Christoplos (2010), on the essence of knowledge system, explains that knowledge systems among farmers, extension agents and researchers should focus on best-fit approaches, embracing pluralism, using participatory approaches, developing capacity and ensuring long-term institutional support.

Two things influence effective agricultural knowledge and information systems. These are the linkage between actors and the utilization of knowledge disseminated. Agbamu and van de Ban (2000) define linkage as the connection between two or more organizations/actors through regular communication as a result of a shared objective. Agriculture research and extension are two subsystems linked by information flow and feed back to promote agriculture development.

For technologies to be relevant, research, agricultural extension agents and farmers must play roles in identifying research problems, adopt the recommendations and provide feedback to research. However, in most developing countries, there exist virtually no working relationships between agricultural research, extension and farmers (Swanson, 1998). The absence of information flow or effective linkage between research and extension or extension and farmers leads to low agricultural productivity (Adesoji & Aratunde, 2012). Communication links are therefore important in transforming or adapting technology recommendations and initiating further knowledge generation. These links enable the new technologies to be developed in a manner that would suit the needs for local conditions (Agbamu, 2000).

The utilization of knowledge disseminated also affects agricultural knowledge and information systems. It is evident that there is growing inability of small scale farmers in Africa to achieve food sufficiency largely due to their inability to adopt agricultural technologies due to weak knowledge systems. This is owing to the fact that the methods used for transferring technologies are not familiar or favourable to farmers and farmers are not able to comprehend these messages (Lado, 1998). From research to extension and finally to farmers, technology transfer is one-way and there is little or no feedback from farmers to extension and research, another indication of weak knowledge systems (Agbamu, 2000). Many of these technologies presented to farmers are either too expensive to implement, difficult or complex and usually do not suit farmers' conditions. Ultimately, farmers are incapable of using these technologies

(Mangombe & Sabiiti, 2013). This problem is not exclusive to farmers as extension agents find it difficult to interpret protocols given to them by researchers.

According to Faborode and Laogun (2008), in order for agricultural technologies to be applicable to the local needs, scientists, extension staff, farmers and agricultural input suppliers should play crucial role in identifying research issues, adapting recommendations to local conditions and providing researchers with feedback on emerging innovations. However, the challenging institutional problems facing agriculture ministries in many developing countries is the absence of strong working relations between national agricultural research and extension organizations and with various groups of farmers as well as farm organisations (Swanson, 2008).

In most cases, research and extension agencies typically contend with the same limited government resources and often do not see themselves as part of a wider system; the Agricultural Technology System (ATS). Rather, they seek to rise the movement of resources to their respective establishments to solve the day-to-day administrative problems rather than to ensure that their organizations contribute to the larger goal of improving agricultural technology for categories of farmers (Adesoji & Aratunde, 2012). Furthermore, the leadership and staff of most research and extension organizations do not recognize the important roles that farmers and farmer organizations play both in the dissemination of technology and in active feedback mechanisms (Swanson, 1998). The definition of linkage means that coordination and working relationships are formed between two or more organizations following commonly shared goals with a view to regular contact and improved productivity (Agbamu, 2000). The Research-Extension-Farmers-Input linkage has been described as a method of communication used by non-university-based scientists to contact Nigerian fish farmers (Ogunremi & Olaniran, 2010). Adesoji and Aratunde (2012) explain that the linking mechanism is not without problems if the flow of information is interrupted, either from research to extension or from extension to farmers, the final product that improves food production would be adversely affected.

Climate Change Impacts on the Agricultural Sector

A favourable climate in Agriculture is said to maintain global food security, and avoid large-scale human suffering in developing countries where agricultural production and rural populations are most vulnerable (Jarvis, Ramirez, Anderson, Lelblng, & Aggarwal, 2010). Climate change is transforming the planet's ecosystems and threatening the well-being of current and future generations (Gerber *et al.* 2013). Sub-Saharan Africa is considered to be among the most vulnerable regions to climate change as a consequence of its low adaptive capacity with accompanying poverty rates, poor infrastructure and a great dependence on rain-fed agriculture (Thornton *et al.* 2006). The IPCC (2009) states that rising temperatures, droughts, floods, desertification and severe weather conditions would have a significant effect on agriculture, especially in the developing world, owing to the fact the climate is the driving force of agriculture in developing countries.

Agriculture is extremely at risk of climate change owing to its heavy reliance on natural factors of climate. Higher temperatures ultimately reduce the yield of most crops while promoting weed and pest spread. The shift in precipitation patterns also raises the probability of short-term crop failures and long-term decreases in production. Although production gains will be experienced in certain crops in some regions of the world, the overall impacts of climate change on agriculture are expected to be negative as the world will experience losses in key staples threatening food security worldwide (Nelson *et al*., 2009; Herrero *et al.*, 2010). Climate change has physiological effects on the quality and quantity of crops, livestock, pasture and on land, soils and water bodies as well (Antwi, 2013). It is also expected that prices of key staples will increase while malnutrition among children will be on the rise due to lower food accessibility and increased prices of commodities (Herrero *et al*, 2010). With the change in climate, it is anticipated that the incidence of crop pest will increase with an increase in the rate of new pest introductions.

Also, the threat of pesticide residues in food will rise due to an increase in pesticides use and resistance (Dinesh *et al.* 2015). Also, under continued climate change, migration from rural to urban communities will continue to rise owing to increasing sea levels, drought and decline of resources. The resultant effect of which will be tensions over ownership and competing for the limited resources such as land (Warner, 2010; Tacoli, 2009). Africa is already experiencing the distressing impacts of climate change such as frequent floods, increased temperatures and droughts. A further increase in temperature of 4.5 degrees centigrade predicted to occur by the year 2030 will be devastating (World Meteorological Organization, 2002). It is expected that agricultural land will be decreased as potential areas will become arid and coastal areas will be submerged thereby affecting human settlement. It has also been predicted that the Gezira in Sudan is likely to disappear due to the possible drying up of the Nile which flows through the deserts. Also, desertification will continue to be on the rise whereas ice and snow will disappear on mountains such as the Kilmanjaro while famine and starvation will continue to rise (Ngaira, 2007). Onu and Ikehi (2016) in their study on mitigation and adaptation strategies for environmental impacts of climate change and agriculture, explained that, climate change consequences like drought, erosion, excessive rainfall, flooding, excessive temperature, rising sea levels and water scarcity affect agricultural production.

Impacts of Agriculture on Climate Change

The Intergovernmental Panel on Climate Change (IPCC) (2007b), explains that there are basically three key reasons for the rise in greenhouse gas emissions (GHGs) that has been observed for over 250 years. These are fossil fuels, land use, and agriculture. At the same time, agriculture which is the mainstay of more than half the worlds' population is an important land user and consumer of fossil fuel (IPCC, 2007b). The lands used for agricultural purposes make up about 40- 50 percent of the Earth's land surface (Smith *et al.*, 2007).

The key GHGs produced as a result of agriculture are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), which contribute significantly to climate change in a variety of ways. CO_2, which is the largest GHG produced as a result of agricultural activities, is primarily released from microbial decay or from the burning of plant litter and soil organic matter (Smith, 2004; Janzen, 2004) and the process of deforestation through which CO_2 is released. CH_4 is also produced when organic materials are decomposed in oxygen-deprived conditions, in particular by fermentation of ruminant livestock, manures stored and rice grown in flooded conditions while N_2O is formed by microbial amendment of nitrogen in soils and manures (Mosier, Duxbury, Freney, Heinemeyer, Minami & Johnson, 1998). This is frequently improved where available nitrogen (N) surpasses plant requirements, particularly under wet conditions (Oenema *et al.*, 2005; Smith & Conen, 2004). Agriculture alone accounts for 10-12 percent of the overall global anthropogenic GHG emissions (US-EPA, 2006). Agricultural activities consist of about 54 percent of methane discharge, nearly 80 percent emissions of nitrous oxide and almost all carbon dioxide discharges which has to do with the use of land (Koffi-Tessio, 2009).

Climate Change and Rice Production

Climate change is a global problem impacting all sectors of the economy, including the agricultural sector. Crop production in agriculture is vulnerable to changes in climate and requires knowledge and information for adaptation and mitigation. Climate change can easily be detected from the variations in rainfall, wind speed and direction, and temperature (Lansigan, De los Santos & Coladilla, 2000). Climate change in crop production has significance relation with rice production. Rice continues to be the world's main staple food crop with other staples like wheat and maize. Rice production is classified into four types of production systems: lowland rain-fed, irrigated, deep-water and upland (Hunink, Droogers, & Tran-Mai, 2014). Quarshie (2000) classified the rice culture in Northern Ghana into three types. This included the upland rice culture, rain-fed lowland rice culture and irrigated rice culture (Sheehy, Ferrer, & Mitchell, 2006). Lowland rain-fed production system depends mainly on rainfall, where the land is submerged for 2-3 months during the growing season. This also involves hydromorphic lands on the lower slopes with water tables in their root areas for a large part of the growing season. Irrigated rice systems deal with the provision of irrigation for production and the farmers have total authority over water permitted on the plot under cultivation. The yield from irrigated rice systems is higher during the wet season as is the second production cycle during the dry season. The deep-water production system in practice is subject to a long annual flood season. Yield in this system is low. Lastly, upland rice production system is subjected to drier conditions, and produces the lowest yield. Rice is usually grown in rain fed, naturally well drained soils without surface water accumulation. It includes upland portions of hydromorphic soils where there is no water table in the root zone (Hunink *et al.*, 2014; Quarshie, 2000). Approximately 80 percent of rice produced in Ghana is by small scale farmers under lowland ecosystems (Boansi, 2013)

Effect and Impact of Climate Change on the Production of Rice

Generally, climate change impacts on rice cultivation and food security is usually quantified by the increase in CO_2 and detrimental effects of severe weather events on rice production, which include storm (flood), precipitation, variations in average temperatures, drought, and sea level increasing (Nguyen, 2002). Hunink *et al.* (2014) stated that the impact of climate change on food production can be both direct, through the changes in temperature, rainfall and CO_2, as well as indirect, through water shortage or availability, pests, diseases and so on. The direct effects of changes in climate affects crop growth and yield. The effects of changes in climate is seen at four different phases in the production of rice. These include germination, vegetative, reproductive and ripening phases. Increasing CO_2 level from 340 parts per million (ppm) to 680 ppm is predicted to increase productivity and yields on average by 30 percent under optimum conditions, mainly through the simulation of photosynthetic processes in the plant and improvement in the water use efficiency. Floods cause indirect harm to rice production by damaging farmers' assets and means of production, and infrastructure supporting rice production, such as dams, dikes and roads. Nguyen (2002) reported that humidity stress severely affects, or even kills, rice plants in an area that has as much as 200 mm of precipitation per day and no rainfall for the next 20 days. Total crop failure typically occurs when extreme drought stress occurs during reproductive stages.

The supply of water in rice growing areas which is largely dependent on rainfall is critical to the growth and yield of the rice plant as the amount and timing is essential (Bhattacharya & Panda, 2013). The production of rice is largely dependent on rainfall with timing and amount of rainfall playing a crucial role. Early arrival of the monsoon and heavy rainfall can cause flooding, which is harmful to young rice seedlings. On the other hand, late arrivals typically lead to extreme water stress. Ample rainfall during the growing season is also important in order to achieve optimum yield. The variability of rainfall during the monsoon season also results in extreme flooding and crop losses. In order to resolve crop losses during floods, farmers periodically re-plant rice seedlings to prevent food shortages. Temperature relates to the phonological development of plants (Bhattacharya & Panda, 2013). A higher temperature influences the faster growth of plants but potential production will be generally low as it prevents pollination. Changes in mean temperature have a major effect not only on the period of growth, but also on the growth pattern and productivity of rice crops. Nguyen (2002) stated that extreme temperature, either low or high, causes injury to the rice crops which leads to rice production constraints. He added that the most damaging effect is on grain sterility. Just 1 or 2 hours of high temperature at flowering period of a plant result in large percentage of grain sterility. Johnston *et al.* (2009), laid emphasizes to the fact that for every 1^{o}C increase in minimum temperature, rice yields will decrease by 10 percent during the growing season. This suggests that under global warming, the production of rice and other tropical crops will decrease as global temperature rises. Lansigan *et al*. (2000) stressed that the yield of rice is expected to decrease especially at the flowering stage due to high temperatures. This is because high temperature-induced sterility in rice causes pollen shedding problems and reduces the viability of pollen grains, which reduces the stigma of the amount of pollen grains germinated. As high temperature is causing sterility during flowering, it is different at the vegetative and ripening stage. At these two stages, high temperature alters the grain filling thus, the grain quality of the rice is high (Karn, 2014). Higher temperatures also influence the physical and chemical properties of the soil (Khanal, 2009).

Climate change will also increase the incidence of pests and diseases. Increases in temperature has the tendency of favouring harmful species of pests (Johnston *et al.* 2009). Khanal (2009), noted that increases in temperature typically presents a suitable climate for the bulk of insect pests. He further argued that long growing seasons, higher night temperatures and warmer winters allow insect pests to undergo multiple life cycles, increasing their likelihood of affecting crop production. The predicted rise in sea levels as a result of climate change would certainly raise salinity levels in the soils of key rice-growing areas in low-lying deltas and flood plains in key river systems. Hunink *et al.* (2014) stated that the danger of rising sea levels is salt intrusion.

Intrusion of salt water and rising sea levels would affect both irrigated and rain-fed rice thus there will be water quality constraints, shorter growth period and high flood level and duration. Standard varieties of rice are badly affected when the salinity in the soil solution triggers the electrical conductivity of the soil solution, thus suppressing the growth of rice (Shrivastava & Kumar, 2015). The results of Nguyen (2002), suggested that rising temperatures, rising seas and changes in patterns and distribution of rainfall as a result of global climate change might lead to major changes in land and water supplies for rice production as well as the productivity of rice crops grown in various regions of the globe.

With respect to the distribution of rice, the tropical regions have higher dependency on rice for food and a shift in rice production areas due to changes in climate would cause difficulties in the distribution and access of rice. Emodi and Bonjoru (2013) in the study of the effect of changes in climate on rice farming in Nigeria indicated that farmers perceived drying and withering of seedlings, difficulty in predicting planting seedlings, delayed rainfall, drying up of streams, too much heat which evaporates water from rice plants, widespread of pests and diseases, chemicals no longer effective on rice farms, stunted growth of rice plants and low yield as serious consequence of change in climate on rice cultivation. Ibrahim (2017) also in Nigeria reported low yield as one of the effects of climate change for farmers while Dadzie, Okorley, Bosompem and Okwei (2012) in Ghana stated the outbreak of pest and diseases as an outcome of the change in climate. The most severe effects of climate change were crop failure and poor yields, wilting and decaying of farm produce, poor fish harvest as well as the increase in pests/diseases of crop and animal (Idoma & Mamman (2016).

Contribution of Rice Production to Climate Change

Rice production is both a significant sequestration of atmospheric carbon dioxide and a key source of greenhouse gas emissions. Flooded rice fields emit methane, the second largest greenhouse gas (Leip & Bocchi, 2007.). Under anaerobic environments of submerged soils of flooded rice fields, methane is released but much of it escapes from the soil into the atmosphere as gas in rice roots and stems, and the remaining methane bubbles up from the soil and/or gradually spreads through the soil and flooding waters. Nguyen (2002) also stated the production of methane and nitrous oxide gasses from lowland rice cultivation and indeed the deforestation of upland rice production by slash-and-burn and shifting cultivation are considered to contribute to anthropogenic climate change.

Climate Change Adaptation Technologies Recommended by AEAs /Researchers and Used by Farmers

Research on the antecedents of the participation of extension agents in the dissemination of smart agricultural environment initiatives in Nigeria revealed that extension agents disseminated the use of organic manure (86 percent), herbicides (85 percent) and zero/minimum tillage (76 percent). However only 8.7 percent of AEAs disseminated information about changes in dates of planting and harvesting to adapt to climate change (Olorunfemi, Olorunfemi & Oladele, 2019). Afful (2016) in his results on the need for competencies of public extension agents in South Africa suggested that the extension agents had been enthusiastically involved in the promotion of minimum/zero tillage among farmers. The Alliance for a Green Revolution in Africa (AGRA) in a report on climate change and smallholder agriculture in Africa discovered that zero tillage was successful in enhancing soil structure, organic soil content and improved soil moisture content.

Clements *et al.* (2011) have indicated that technologies such as improved weather prediction, water conservation, sustainable soil management and enhanced varieties of crops by researchers to facilitate adaptation. According to Etwire *et al.* (2013), research institutions have also introduced high yielding varieties, early maturing varieties, drought resistant varieties, harrowing, planting in rows, conservation agriculture, irrigation, tree planting, and the use of inorganic fertilizers, herbicides and insecticides to adapt to climate change. Hussain *et al.* (2020) have also indicated that the adaptation technologies recommended under rice production were alternate wetting and drying, stress resistant cultivars, climate forecasting and change in planting dates.

Alhassan, Osei-Asare, Kurwornu and Shaibu (2018), in their study on local and research-based adaptation measures of subsistence women rice farmers to climate variations in the Northern Region of Ghana established that 75 percent of farmers constructed earth bunds in their farms to adapt to climatic change. Also 80 percent, 62.3 percent and 36.2 percent respectively planted during recommended times, harrowed after ploughing and planted trees on their farms to adapt to climate change. Furthermore, 68.1 percent of the farmers reported planting early maturing varieties while 74 percent used inorganic fertilizer to improve soil nutrients for the rice crop. A research by Mensah

(2018) on the understanding and adaptation strategies of rice farmers to climate change in Adaklu district suggested that approximately 98 percent, 74 percent, 69 percent, 38 percent and 10 percent modified planting dates, used early maturing varieties, chemical fertilizers, bunding and fallowed their rice farms respectively to adjust to climate change.

Arimi (2014) in his study on determinants of climate change adaptation strategies used by rice farmers in Southwestern, Nigeria found that 99.1 percent of farmers often changed their planting dates, 85.6 percent of farmers farms have never been covered against risk while 27 percent of farmers sometimes used additional reservoirs for water storage. Also in Nigeria, Onyegbula and Oladeji (2017), indicated that, rice farmers used early planting pest and disease resistant varieties, drought and flood resistant varieties, appropriate use of fertilizer and frequent weeding to adapt to climate change.

Effectiveness of Climate Change Adaptation Technologies

Determining whether adaptation is effective solely depends on the long standing objectives of adaptation technologies and thereafter measuring the degree to which objectives have been achieved (Craft & Fisher, 2016). Three main objectives of adaptation activities have been identified in the determination of adaptation effectiveness. First of all, the adaptation activity/activities must be able to reduce the deficit in development. Activities should ensure that people satisfy the essential needs and get out of poverty. When they get out of poverty, they are in a better place to resist shocks and stresses. Also, adaptation activity/activities should be capable of assisting families and societies address existing climate variability and risks associated with the variability. Finally, adaptation activity/activities ought to be able to address impending climate threats, thus reducing impending climate change risk (McGray, Hammill & Bradley, 2007). Approaches for assessing the effectiveness of adaptation activities can either be the process of adaptation or outcomes of the adaptation activities on communities, individuals and households (Craft & Fisher, 2016). The process assesses an institution's capacity to manage adaptation efforts. Brooks *et al*., (2013) identifies eight dimensions in measuring institutional capacity. These are the integration in planning, institutional coordination for integration, budgeting and finance for climate change integration, institutional knowledge and capacity, and use of climate information. The rest are planning under uncertainty using appropriate methodologies, participation of relevant stakeholders in the national planning and awareness among stakeholders. The outcome of adaption technologies in agriculture is resilience which translates into reduced pest attacks, increased soil fertility, reduced weed growth, and reduced soil erosion among others ultimately leading to increased yields. Stadelmann, Michaelowa, Butzengeiger-Geyer and Köhler (2015) also mentions three methods relevant for measuring effectiveness of adaptation projects and they include vulnerability assessment, cost-benefit and cost-effectiveness assessments. The outcomes of adaptation activities were therefore used to measure the effectiveness of adaptation technologies.

A study by Muthelo, Owusu-Sekyere and Ogundej (2019) on smallholder farmers' adaptation to drought in South Africa revealed that improving insurance schemes and awareness campaign to climate change were effective in adapting to climate change. Another study by Zanmassou (2017) on adaptive potential of smallholder farmers and the option of climate risk adaptation strategies in Northern Benin indicated that early maturing seeds, soil and water management were effective in adjusting to climate change. Assan, Suvedi, Olabisi and Allen (2018), in a study on coping with and adapting to climate change in Ghana revealed that both male and female household heads indicated that varying planting and harvesting dates, crop diversification and perceived adaptation measures to be efficacious in minimizing the undesirable impact of climate change such as rainfall and temperature. In a study on the evaluation of adaptation practices, Arfanuzzaman, Mamnun, Islam, Dilshad and Syed (2016) found that rain water harvesting, fertilizer use, pesticide use, change in plating dates, short duration varieties and drought resistant varieties were effective in adapting to climate change in rice production.

Rice Species and Varieties in Ghana

There are basically two species of rice that are grown in Ghana. These are the Asian rice (*Oryza sativa*), and the African (*Oryza glaberrima*) species. The *Oryza sativa* (O.S) is grown worldwide while the *Oryza glaberrima* (O.G.) is primarily grown in African nations. However, *Oryza glaberrima* is grown on a limited scale in West Africa (Subudhi, Sasaki, & Khush, 2006) and in Ghana, it is rapidly being phased out and replaced by the O.S due to its lower yields, inability to tolerate weed, resist pest and mature at shorter durations (Calpe, 2006). Although commercially cultivated O.S varieties exist, they belong to two major subspecies: the Indica and Japonica. Whereas the Indica is characterized by its long grain and wide adaptability to different conditions, the Japonica is a round grain, characterized by its strong response to fertilizer applications and grown primarily in India, AustraliaTaiwan, Korea, the European Union (EU), Japan, Russia, Turkey and the United States (FAO, 2006b).

There are several indigenous and Asian varieties of rice that are grown in the country. A study by Ansah, Dogbe, Cudjoe, Iddrisu and Eseoghene (2017), on the agronomic performance of rice varieties in the Northern region mentioned some five varieties that farmers cultivate in the northern region. They included: S72180002 (Hybrid), Exbaika, Gbewaa (Jasmine 85), AGRA rice (IR841) and Long grain ordinary 2. A research the production of rice Northern Region showed that 71 percent of farmers cultivated improved rice varieties like Mandi (4 percent), GR 18 (Afife, 22 percent), Farro 15 (22 percent), TOX (7 percent) and others (7 percent) whiles 29 percent cultivated indigenous varieties (Asare, 2000). The local varieties consisted of Kpukpula (13 percent) and Anyofula (7 percent) among others. In another study on rice production in the Volta region, Donya (2000) observed that indigenous people planted rice varieties of Glaberrima origin while inland valley farmers made up of settlers used both local varieties and improved rice varieties obtained from MOFA.

Yakubu (2003) in a study in the Upper West region stated that most farmers prefer lindigenous/local rice (O. glaberiima) than the improved varieties. This he mentioned was because majority (65 percent) of farmers mentioned that local varieties do well even without chemical inputs with 13 percent claiming they are drought resistant while 10 percent stated the absence of improved varieties.

Farmers' Awareness to Climate Change

Once farmers are aware of the situation, and possible advantages of taking action, it helps in the adoption of agricultural technologies (Olutegbe & Fadairo, 2016). Maddison (2007) established that farmers' awareness of changes in climatic variables (temperature and precipitation) is essential for adaptation decision making. Debala, Mohammed, Bridle, Corkrey and McNeil (2015) and Adger *et al.* (2009), from their researches put forward a solid association between farmers' awareness and perception of climate change and adaptation to its impact.

Studies by Gould, Saupe and Klemme (1989), and Araya and Adjaye (2001), have found that farmers' awareness and perceptions of soil erosion problems had positive and significant effects on decisions to embrace soil management measures. This denotes that when farmers are conscious of climate change, it is easier to make decisions on adaptation. This is affirmed by Dang, Li, Bruwer and Nuberg (2013) who are of the view that adaptation technologies used by farmers are influenced by their awareness and understanding of climate change. A study by Arbuckle Jr, Morton and Hobbs (2015) in Iowa, in the United States of America [USA], indicated that great proportion of farmers (68 percent) had no doubt that climate change is occurring. According to Save Cambodia's Wildlife [SCW] (2012), the bulk of farmers in Choam Khsant district and Preah Vihear province in Cambodia explained that they experienced variations in higher temperature, changes in time of rain, frequent or intense droughts and frequent lightning. In the Northern Philippines, farmers were highly aware of climate change concepts, causes and impact (Ngilangil, Olivar & Ballesil, 2013). A study by Raghuvanshi, Ansari and Amardeep (2017), of farmers' awareness of climate change and adaptation practices in India suggested that some 27 percent of farmers were conscious the extinction of plant species. They further revealed that about 23 percent and 27.3 percent of farmers had high and low awareness level about climate change. Their results also showed that 50 percent of respondents demonstrated 'medium' awareness level about climate change. A report by Raghuvanshi and Ansari (2016) in India were of the view that the capacity of farmers to manage climate change is reliant on their level of awareness about climate change.

Pelham (2009), reported that awareness of climate change in developing countries is poor as compared to developed countries, with African countries considered to be the least aware of it. In a study by Oduniyi (2013) in South Africa, majority (82.9 percent) of respondent were unaware of any change in climate. This, they explained was as a result of extension agents' inability to create awareness. Almost 60 percent of farmers interviewed in the Niger Delta in Nigeria knew next to nothing about the change in climate and its aftermaths. Exactly 41.5 percent of respondents said they knew something about the phenomenon, whereas 17.5 percent simply didn't know anything about climate change (Nzeadibe, Egbule, Chukwuone & Agu, 2011). A related study done by Oloke *et al.* (2013), also in Nigeria observed that most only see changes in climate to be the result of the mysteries of nature and industrial development. This confirms the study by Pelham (2009) who asserted that there is diminutive awareness of climate change in developing countries. However, Nkwusi, Adeaga, Ayejuyo, and Annuk (2015) in a study in urban Lagos showed that farmers have been aware of the changing trend in the climate in the last decade. Also, Idrisa, Ogunbameru, Ibrahim and Bawa (2012) revealed that about 82 percent of farmers in their study area were conscious of the changing nature of the climate in Nigeria. Tambo and Abdoulaye (2013) in a research of the perspective of farmers and their adaptations to climate change revealed that more than 60 percent of respondents were aware of a decrease in rainfall. There has also been an increase in temperature according to the majority of farmers in

Kaduna (Ishaye & Abaye, 2008). Mugula and Mkuna (2016) in a study on farmers' perceptions of the impacts of climate change on various rice production systems in Tanzania have also shown that farmers are aware of the detrimental effects of climate change on rice production.

Mandleni and Anim (2011) in South Africa revealed that the marriage status, structured education and the manner land is utilized for cultivation has been obtained have a significant and positive influence on climate change knowledge. They however found that level of education and temperature influenced awareness of climate change negatively. This insertion is interesting because one would assume people with higher education will have more access to information on climate change. Also in South Africa, it was revealed by Gbetibouo (2009) that farmers were aware of a reduction in the duration of the rainy season and reduction in the amount of rainfall. Ajuang, Abuom, Bosire, Dida and Anyona (2016) in Kenya suggested that the sex of the household, education level and age had a major effect on farmers' knowledge of climate change indicators. In their analysis, the Chi square test also found that the degree of perception was substantially different across the 11 sub-locations, despite their almost identical characteristics and proximity to each other.

In a study by Codjoe, Ocansey, Boateng and Ofori (2013) on climate change awareness and coping strategies of cocoa farmers in Ghana, respondents in all the cocoa-growing areas in the country were very well aware of climate change. It was also observed by Adusei (2016) in a study on the analyses of perceptions and adaptations to climate change by rice farmers in the Ashanti and Northern Regions of Ghana that 94 percent of rice farmers had noticed and were aware of changes in climatic conditions. Similarly, Ohene-Asante (2015) in a research on climate change cognizance and risk perception in Ghana realized that all person in the study area observed shifts in the pattern of rainfall, temperature and windstorms and hence were aware of climate change. In the same way, Saah (2015) in her study on indigenous knowledge and adaptations to climate change gathered that about 77 percent of the total respondents confirmed they were aware of climate change.

This conversely contradicts the findings of Nyadzi (2016) who found out that only 2 percent of respondents in Northern Ghana knew what climate change was. Correspondingly, the results of Etwire, Al-Hassan, Kuwornu and Owusu (2013a) revealed low understanding of climate crisis and public education amidst farmers in Ghana. According to a study on farmers' perception of climate change in sub-Saharan Africa, including Ghana, it was revealed that respondents perceived late onset of rainfall, with consistent decreases in its amount accompanied by an increase in dry spells (drought) over the previous two to three decades (Akponikpè, Johnston & Agbossou, 2010). The reduction in rainfall was also confirmed by Yaro (2013) in a similar research on the perception and adaptation to climate variability in Ghana. Also in Ghana, studies by Fosu Mensah, Vlek and MacCarthy (2012), and, Acquah and Onumah (2011), have both shown farmers awareness of the rise in temperature. Acquah and Annor-Frempong (2011) found that 91 percent of farmers perceived a rise in temperature while 51 percent perceived a decrease in precipitation and 46 percent perceived an abnormal trend in rain fall in the Ketu district of the Volta region of Ghana.

Agricultural Extensions' Awareness of Climate Change

Abegaz and Wims (2015), in Ethiopia revealed that majority of extension agents were mindful of the changes in climate and that women extension agents were more aware than their male counterparts. They also observed that no statistically significant association existed between extension agents' awareness of climate change and the job experience, educational level and previous exposure to training opportunities. Zikhali (2016) in South Africa similarly made bare that male and female extension agents are conscious of the climate crisis. It was also revealed in California, USA, that 54 percent of extension agents were aware of climate change (Haden, Niles, Lubell, Perlman & Jackson, 2012). Iwuchukwu and Onyeme (2013), in a study on cognizance and acuities of climate crisis among extension agents in Anambra State revealed that extension agents were conscious of the impacts of climate change on yield. Ogunlade, Aderinoye-Abdulwahab and Mensah (2014) from their study on knowledge levels of extension agents and their perceived impact of climate change on extension service provision in Ghana revealed that extension agents had high awareness of the concept -climate change.

Relationship between Farmers' Awareness of Climate Change and Demographic Characteristics

Age of farmers

In a study on analysis of climate change and rural farmers' perception in North Central Nigeria, it was revealed that the age of household head impacted significantly on the perception that there was decreased water flow in streams (Falaki, Akangbe & Ayinde, 2013). However, Ado, Leshan, Savadogo, Bo and Shah (2019) found no significant influence of age on the awareness of climate change. Chaudhary, Mumtaz, Yaseen and Afzal (2018), indicated that there was insignificant relationship between age of farmers and awareness of climate change in Faisalabad, Pakistan. A study in Western Nigeria by Apata and Adekunmi (2013) indicated that, aged farmers were not aware of climate change while the youth were more aware of the vagaries of climate change. It was revealed by Kabir *et al.* (2016) in a study on knowledge and perception about climate change in Bangladesh that age had a significant association with knowledge of climate change.

Sex of Farmers

Male farmers are usually more engaged in rice farming than their female counterparts owing to the fact that the activities in rice farming or production are very intense and time-consuming (Osanyinlusi & Adenegan, 2016). Rice production in Ghana is traditionally known to be a male dominated activity (Addison, Ohene-Yankyera, & Fredua-Antoh, 2016). Addison, Edusah and Sarfo-Mensah (2014), in a study on lowland rice ecosystems in Ghana, revealed that only 17 percent of farmers interviewed were women while the rest (83 percent) were men. This implies that there were only a handful of female rice farmers involved in rain-fed lowland rice production compared to their male farmers. This is similar to the results of Kranjac-Berisavljevic, Blench and Chapman (2003) who indicated that rice is mainly cultivated by men whereas women are more involved other activities such as weeding, selection of seeds, broadcasting and winnowing. In contrast, a study by the World Bank (2009) revealed that more females are now engaged in rice production as the males sought alternate income generation activities in non-farm activities in Ghana.

Results of a study by Adekunle (2013) revealed that a considerable lower proportion of women rice farmers were involved in upland rice cultivation in Sub-Saharan Africa. This is similar to the outcome by Osanyinlusi and Adenegan (2016) who further revealed that a bulk (73.1 percent) of the rice farmers in Ekiti State, Nigeria were men while 26.9 percent were women.

A report on determinants of climate change awareness level in Kenya showed significant differences between the sex of respondents and cognizance of the changes relating to temperature were observed. Majority of males indicated awareness of declining temperature while the females were more aware of rising temperature than their males counterparts (Ajuang, Abuom, Bosire, Dida & Anyona, 2016). Opiyo *et al.* (2016), on the determinants of climate change perception and adjustment among Turkana nomads in Northwest of Kenya, revealed that climate change awareness and knowledge is greater in male-headed households compared to female-headed households. A study by Adebayo, Mubi, Zemba and Umar (2013) who revealed that there was no substantial association between sex and knowledge of climate change.

Educational Level of Farmers

It has been asserted that education plays a significant role in creating awareness among farmers on climate change because it is believed that people with formal education have more sources of information (Idrisa, Ogunbameru, Ibrahim & Bawa, 2012). Furthermore, basic education is important for farmers so they can read and understand relevant news and notices which are key and can affect production (Alam, Siwar, Talib & Toriman, 2011). Also, the education level of household heads has been known to increase the likelihood of adapting to climate change (Deressa, Hassan & Ringler, 2010). According to

Mandleni and Anim (2011), a significant but negative relationship was found between education and awareness of changes in climate. They attributed this to the adverse impact climate change had on production which made people aware rather than his/her education. A study by Raghuvanshi, Ansari and Amardeep (2017) showed a positive association between farmers' level of awareness and size of land holdings and education but showed no relationship between awareness and age.

Findings of Olumba (2014), in a study conducted in the State of Anambra, Nigeria, revealed that a majority of plantain farmers had basic education. In another study in Nigeria on record keeping among small farmers, found that about 37.8 percent of interviewees had no formal education (Dudafa, 2013). This is similar to the findings of Omoregbee, Ighoro and Ejembi (2013) who discovered that almost 35.7 percent of farmers had no formal education relative to 64.3 percent of respondents who had various types of formal education.

The results of a study of the effect of varietal shift in demand for pineapple in Ghana by Kpare (2016) indicate that a large number (35.4 percent) of farmers have primary education. This was followed closely (34.2 percent) by respondents who have had no formal education while 19 people representing 24.1 percent had junior secondary education. Results from an analysis by Boateng, Amoah and Anaglo (2015) on the influence of demographic factors on repayment performance among farmers in the eastern region of Ghana showed that respondents who never had any education formed 39 percent while those who with formal education consisted of 61 percent of the total population. Okutu (2012) also revealed that approximately 44.9 percent of the sample had attained JHS/Middle school with 21 percent attaining primary education and only 6.4 percent with no formal education. The general trend in this literature shows that a high proportion of farmers have had some sort of formal education. There existed a significant relationship between farmers with higher education and awareness of climate change (Chaudhary, Mumtaz, Yaseen & Afzal, 2018).

Number of years in Enterprise

The experience of a farmer is important in the process of making choices, especially agricultural based decisions (Etwire, Al-Hassan, Kuwornu & Osei-Owusu, 2013b). This implies that the greater the number of years a farmer takes part in farming, the more sophisticated the choices made. Agwu and Adeniran (2009) also revealed a significant correlation between farming experience and use of different sources of knowledge, which means that the longer a farmer has been farming, the more the farmer accesses information from different sources. On the relationship between farmers' experience and their awareness to climate change, Mustafa *et al*. (2019) and Maddison (2007) reported a significant positive relationship whiles Okonya, Syndikus, and Krosche (2013) found a negative relationship.

Nyadzi (2016) reported on a study on Climate Variability and Farmers' Observations in the Northern regions of Ghana that a great proportion (93 percent) of respondents started farming between the ages of 5 and 10 while 6 percent had been farming between the ages of 10 and 15. Ndamani and Watanabe (2017), on the predictors of farmers' climate perceived risks in agriculture in Ghana reported that majority (44.1 percent) of farmers in the Lawra district had been farming for more than 25 years. 32.4 percent had been farming between 11 and 25 years while 23.5 percent were farmers for less than

10 years. A research by Acquah and Annor-Frempong (2011), on farmers' perception of the consequences of climate change on food production in the Volta region of Ghana revealed that the majority (52 percent) had 10-20 years of farming experience, with an average of 19 years of farming experience. This was followed by 18 percent who had experience between 21-30 years while 16 percent had been farming for less than 10years. Mumuni, Yaa and Oladele (2013) on rice production as a livelihood option among migrant farmers in the Ashanti region of Ghana found that 48.8 percent of farmers had farming experience between 0-10 years, 39.3 percent had between 11-20 years of experience, 9.4 percent had 21-30 years of experience, while 2.4 percent had over 31 years of experience.

Research on the economic performance of small-scale cassava farmers in Nigeria showed that a greater percentage (93 percent) of respondents interviewed had more than 10 years farming experience (Adeyemo, Oke & Akinola, 2010). Similarly, Onoh *et al.* (2014) also in Nigeria found that 53.3 percent of farmers had farming experience between 16-20 years.

Marital Status of Farmers

Adams and Ohene-Yankyera (2014) in a study on socio-economic characteristics of subsistent small ruminant farmers in three regions of Northern Ghana indicated that more than half (73.5 percent) of respondents were in the marriage category. Other respondents were divorced, single, widowed or separated. A different study in the Upper West region showed 99 percent of farmers were married with just 1 percent being single. Abubakari and Okorley (2015) in their study on strategies for managing vulnerabilities of women vegetable farmers, indicated that about 66 percent of farmers were married, while about 34 percent were either single, separated, divorced or widowed.

The study by Odoemelam and Okoro (2014) in Abia State, Nigeria on perceived usefulness of information sources by rice farmers in disseminating best practices revealed that 73.9 percent of farmers were married whereas 26.1 percent were single. Addisu, Fissha, Gediff and Asmelash (2016), in a study on perception and adaptation models of climate change in Ethiopia indicated that marital status significantly influenced farmers' perception of climate change. Asekun-Olarinmoye *et al*. (2016) on public perception of climate change in rural south-western Nigeria found that marital status statistically influenced the perception of climate change.

Household Size of Farmers

The findings of Mustapha, Undiandeye, Sanusi and Bakari (2012) on the analysis of adoption of improved rice production technologies in Borno state in Nigeria showed that the majority of household sizes were between 6 and 10 members. A great number of respondents (47 percent) had family sizes in the range of 11-20 while 39 percent had household sizes between 1 and 10 people (Maji *et al.*, 2012). Nwobodo and Agwu (2015) on knowledge level of young farmers on climate change in the state of Benue, Nigeria also revealed that 58.6 percent of respondents had family sizes in the range of 6 and 10 persons while 33.7 percent of respondents had between 1 and 5 persons. The rest of the farmers had family sizes of 11 and above persons. Oduniyi, Antwi and Nkonki-Mandleni (2018), on the determinants of climate change awareness among rural farming households in South Africa indicated that there household size did not predict awareness of climate change. A study in Pakistan by Mustafa, Abd Latif, Bashir, Shamsudin and Daud (2019) reported of positive relations farmers' awareness of climate change and education, experience, landholding, family size and member of farmer organizations while no relationship was found between access to finance and awareness of climate change.

A study by Baidoo, Yusif and Anwar (2016) on the effect of smallholder livestock production on income of farm households in Northern Ghana, revealed a mean household size of 9 persons. According to the Statistical Service of Ghana (2014), the average household size of the country is 4 people, which is lower than the average household size of 5 people in the Northern Region. A study by Ghulam, Ismail, Muhammed, Mad and Wan (2019) on determinants of farmers' awareness of climate change in Pakistan revealed that family size significantly influenced farmers' awareness to climate change. Acquah (2011) in Ghana also indicated there existed a positive significant relationship between household size and farmers' awareness of climate change.

Farm Size of Farmers

The size of a farm can affect the adoption rate of a technology. It may also be affected by some other factors that can influence adoption (Lavison 2013). Male farmers with large farm lands will probably be the first to adopt new technologies as they can spare portions of their land and income to try new technologies unlike majority of their female counterparts who have smaller farm sizes (Uaiene, Arndt & Masters, 2009).

In a research on factors influencing pesticide use among rice farmers in the Northern part of Ghana, it was observed that the average farm size for rice was 2.4 acres (Anang & Amikuzuno, 2015). Also, in Northern Ghana, it was found out that farmers who were non-irrigators had a mean farm size of 2ha with a least farm size of 0.2ha and a maximum of 7.4ha (Al-hassan, 2008). A study by Nketiah (2017) on agricultural land deals, farm land access and livelihood choice decisions in the Northern Ghana shows that majority (34 percent) of farmers cultivated between 0.5 – 5.5 acres of land, but 10 percent of those who cultivated 15.6 – 20.5 acres of land were the least reported.

In Nigeria, Kolawole (2006) revealed that the average farm size of small-scale rice farmers was 0.9 ha with a minimum farm size of 0.4 ha and a maximum of 3.8ha. Also in Nigeria, Fakayode (2009), revealed that about 61 percent of the farmers in Kwara State owned 1-3 hectares of rice fields, while 9.3 percent and 33 percent cultivated less than 1.0 hectares and 4-6 hectares respectively. In a study of determinants of productivity levels among rice farmers in Ogun State, about 31 percent of farmers had farm sizes ranging from 0.5 to 1 ha, this was followed closely by 30 percent of farmers who had between 1.5 ha and 2 ha (Akinbile, 2007). Farm size did not increase the possibility of farmers' awareness of climate change in Delta State, Nigeria (Ofuoku, 2011).

Mustafa *et al*. (2019) indicated that, farmers with bigger landholdings had a positive relationship with their awareness to climate change. They further indicated that as landholdings increased, awareness of climate change also increased. The results is consistent with the findings of Oduniyi (2014) who also indicated a significant positive relationship between farm size and farmers' awareness of changes in climate. In the Punjab province in Pakistan, a positive association was observed between land area and the understanding of climate change by farmers (Abid, Scheffran, Schneider & Ashfaq, 2015).

Relationship between Awareness of Climate Change and Demographic Characteristics of AEAs

Sex of AEAs

Ntifo-Siaw and Agunga (1994) in their results on the comparative analysis of organizational performance under the training and visit and general extension systems in Ghana, highlighted that 75 percent training and visit (T&V) extension officers were male while 25 percent were female. This trend also showed in the general extension where 77.8 percent were males and only 22.2 percent were female. An appraisal of information needs of agricultural extension agents in all the regions of Ghana indicated that about 85 percent of the extension personnel were males with only 14.6 percent being females (Sam, Osei, Dzandu & Atengble, 2016).

Adeola and Ayoade (2011) on the perception by extension agents of the knowledge needs of women farmers in Oyo State, Nigeria, showed that the bulk (64.3percent) of respondents were male, whereas just 35.7 percent were female. Ogunremi and Olatunji (2013) explained in their study that 66.7 percent of extension agents were males while females were 33.3 percent. Ogunremi, Faturoti and Oladele (2012) in their study also reported higher percentage of males. This validates the findings of Jiggins, Samanta and Olawoye (1998) who in a study on enhancing women farmers' accessibility to extension services, revealed that extension services have been staffed mostly by men. This is also in line with Fadiji, Atala, Omokore and Abdulsalam (2014) who asserted in their results that 80.2 percent of extension agents were males and 9.7 percent were females. Similar findings were obtained by Agumagu and Nwaogwugwu (2006), who observed that male extension officers constituted the bulk of the agricultural extension service workforce in the Niger Delta states, like Abia and Rivers. However, Okwuokenye and Okoedo-Okojie (2014) on the analysis of the dedication of extension agents to the Agricultural Loans and Inputs Supply Program for special rice production in the State of Delta, Nigeria, found out that all respondents were males. This clearly indicates that the extension service in Nigeria is mainly male dominated. Male extension agents were less likely to agree that the climate is changing (de Koff & Broyles, 2019).

Age of AEAs

Akpotosu, Annor-Frempong and Bosompem (2017) pointed out that majority (53.9 percent) of AEAs in the Eastern region of Ghana had ages between 31 and 50 while 19.8 percent were in their youthful years (up to 30 years) with a mean age of 41.7. The results of a study on the evaluation of skills and training needs of agricultural extension staff in Lagos State, Nigeria, indicated that 43.8 percent of extension staff were between the age brackets of 20 to 30 years, 41.7 percent were in the range of 31-50 and only 14.6 percent of AEAs were above 50 years (Okeowo, 2015). Ogunremi and Olatunji (2013) in their research on the perspective of agricultural extension agents on the privatization of services to rural fish farmers in Ondo State , Nigeria, reported that a bulk (50 percent) of respondents were between the ages of 41 and 50, with 27.1 percent older than 50. It was also realized that 19.8 percent and 3.1 percent had ages within 31-40 and 20-30 respectively. Also, in Nigeria, Ajayi, Alabi and Akinsola (2013) in their results, showed that a little over 50 percent of responders were within the ages of 41 and 50years, 37 percent were between the ages of 31-to 40 whiles eight percent and four percent were less than or equal to 30 years and greater than or equal to 51years respectively. According de Koff and Broyles (2019) indicated in their study on extension agents' perception of climate change and training need that elderly farmers were much less expected to be conscious of changes in climate.

Educational level of AEAs

Literacy is an important factor in the delivery of extension services as agents themselves must understand a concept before teaching or transferring knowledge to farmers (Arisa & Osondu, 2016). Badii, Billah, Afreh-Nuamah, Obeng-Ofori and Nyarko (2015), on in-service training needs of agricultural extension agents for the control of fruit-infesting flies in Northern Ghana, highlighted that 2.7 percent of respondents had senior secondary certificate, 54.7 percent possessed training college certificate in agriculture and 42.5 percent were university degrees holders.

Ajayi (2001) in a study in Nigeria revealed that more than half (57 percent) of extension agents had B.Sc./B. Agricultural Certificates, with 18.3 percent having Ordinary National Diploma Certificates and 15 percent and 10 percent possessing West African School Certificates and while those who had M.Sc. certificates respectively. Also in Nigeria, Folorunsho (2010) indicated that 51 percent of respondents had Higher National Diploma (HND/ Bachelor's Degree certificates, Ordinary National Diploma (OND) / NCE accounted for 33 percent, 10 percent of the respondents had MSc while six percent. of the extension personnel had WASC certificate. Abegaz and Wims (2014) in their study on extension agent's awareness of climate change in Ethiopia indicated that no significant relationship was observed between extension agent's levels of education and awareness of changes in climate.

Working Experience of AEAs

A positive relationship exists between work experience and performance (Judge, Jackson, Shaw, Scott, & Rich, 2007). This implies that the longer you stay on the job the better your performance. In the USA, extension agents with more working experience were less likely to agree that the climate was changing and hence not aware of any change in the climate (de Koff & Broyles, 2019). The results of Abegaz and Wims (2014) in Ethiopia showed no significant relationship between working experience of agricultural extension agents and awareness of changes in climate. Sam, Osei, Dzandu and Atengble (2016), in their study on AEAs in Ghana, revealed that about 46.6 percent of respondents had been on the job were between 1 and 10 years of age, 25.8 percent between 21 and 30 years of age, 21 percent between 11 and 20 years of age and 6.4 percent between 21 and 30 years of age and 0.2 percent between 31-40 years and 40 years and above respectively.

The results of Okeowo (2015) revealed that 42 percent had working experience of 6-10 years while 38 percent had working experience of between 1-5 years. Fadiji, Atala, Omokore and Abdulsalam (2014), on the socio-economic characteristics of village extension agents as factors in the use of information and communication technologies, disclosed that 56.8 percent of extension agents had been working for 19 years and above followed by 12.7 percent who had been working for 15-18 years and 11.3 percent who had been working for less than 3 years. A study on communication for strengthening agricultural extension and rural development in Malawi indicated that 38.2 percent of AEAs had been working for 6-10 years followed by 23.6 percent who had been extension agents for 3-5 years, 19.1 percent had worked for 2 years or less and 14.7 percent had working experience of 11 years or more (Agunga & Manda, 2014).

Training Attended by AEAs

Abegaz and Wims (2014) in a study on extension agents' awareness of climate change in Ethiopia indicated that there was no significant relationship between awareness of climate change and previous exposure to training opportunities.

Relationship between Awareness of Climate Change and Demographic Characteristics of Researchers

Literature on the relationship between researchers' awareness of climate change and demographic characteristics such as sex, age, educational level and working experiences was not found. This could probably be due to the fact that research is rarely carried out on researchers. The concentration is mostly on farmers and agricultural extension agents.

Sources of Information on Improved Climate Change Technologies

Chukwuji, Tsafe, Sayudi, Yusuf and Zakariya (2019), emphasized the fact that information is meaningless unless it is gathered, processed, distributed and used. The wrong source of information can be suicidal as the wrong information might be given.

Statrasts (2004) states that information sources can be individuals or institutions that create or bring messages to the fore. Small farmers usually access less information than medium or large scale farmers, especially in developing countries (Adhiguru, Birthal & Kumar, 2009). The lack of information in agriculture is very critical and access to it more central than some other areas of human endeavor (International Service for Agricultural Research [ISNAR], 1991).

A study on the analysis of cocoa-based agricultural knowledge and information systems in the Eastern Region of Ghana by Codjoe, Asuming-Brempong and Mabe (2012) revealed that information sources by farmers were grouped into four by their similarities, namely personal, public private and mass media. Majority (54.3 percent) of farmers got their information from personal sources made up of family, friends and colleague farmers. This was followed by the mass media (26.0 percent) which constituted radio and television and public sources (18.3 percent) which comprised of extension agents, research institutes and university staff. The least was the private source (1.3 percent) which involved Licensed Buying Companies (LBCs). Acquah (2011) on public awareness regarding climate change in Ghana revealed that 65 percent got their information from radio and television, 30 percent from school while five percent got information from books, journals and magazines. A study in Nigeria argued that the most important sources of knowledge for farmers came from expert sources and interpersonal sources consisting of extension agents, radio, fellow farmers and television. Other relevant sources were farm demonstrations and agricultural shows and contact farmers (Opara, 2008).

In a related development, Chukwuji *et al.* (2019) reported on the types of climate change information accessible to farmers in Zamfara which included rainfall prediction, warning rainfall, rainfall establishment, drought prediction, drought resistant variety, flooding menace, flood prediction, temperature, humidity, bush burning and deforestation. The rest were desertification, soil erosion, time of fertilization application, short time variety crops, long time variety crops, mitigation, irrigation, mixed farming, pesticide/herbicide application, right storage facilities and bush fallow.

Yaseen, Xu, Yu and Hassan (2016), in their results on access to agricultural information by farmers in Pakistan revealed that, majority of these farmers got their information from neighbours/friends/relatives followed by the media (electronic and print), the various companies or input dealers and lastly by agricultural extension staff. Also in Pakistan, Rehman *et al.* (2013), found out that sources of information outlets such as print media, fellow farmers and television were the most widely used while sources such as extension field workers, the private sector, radio and NGOs were the least consistent sources of information for farmers. In a study in India by Mittal and Mehar (2013), the most important sources of information to farmers were other farmers (41 percent), input dealers or private companies (21 percent), mobile phones (10 percent), television (4 percent) while 2 percent of farmers sourced information from radio and research stations respectively.

The results of agricultural information access among smallholder farmers in Kenya showed that the top four sources of information by respondents were government extension agents, private companies, farmers' own experience and neighbours (Odongo). Lwoga, Stilwell and Ngulube (2011), in a study on access and usage of agricultural information and knowledge in Tanzania, showed that neighbours/friends were the primary sources of agricultural information and knowledge which was closely shadowed agricultural extension officers and family members. Also in Tanzania, it was revealed that interpersonal means of communication and traditional sources of information such as social gatherings, farmer association and village leaders remained the important sources through which farmers got information. Input suppliers, extension officers and the radio were also mentioned as sources of information they however ranked 6th, 7th and 8th respectively (Elly & Silayo, 2013).

Interactions between Farmers and Agricultural Extension Agents

Good relations between agricultural extension agents and farmers is essential for farmer efficiency (Battese, Malik & Broca, 1993). This is because extension acts as vital linkage in the transfer of technology from the laboratory to the farm and contacts between farmers and extension agents have been known to increase productivity (Samarpitha, Vasudev & Suhasini, 2016). The provision of extension programmes for farmers has had a positive but substantial impact on understanding of the changes in climate and adaptation. Therefore, if more extension resources and climate change expertise are available, farmers are more likely to adapt to changes in climate. (Luseno, Mcpeak, Barrett, Little & Gebru, 2003). This is in line with Bryan, Deressa, Gbetibouo and Ringler (2009), who point out that access to extension programmes had a strong positive relationship with adaption to climate change. The Food and Agriculture Organization (FAO) recommends extension agents visit farmers at least once a week during farming seasons (Idrisa, Ogunbameru, Ibrahim & Bawa, 2012).

In several parts of the developing world, especially in SSA, it has been noted that low access to extension services continues to reduce agricultural productivity (Kabungo, 2008; Okoedo-Okojie & Onemolease, 2009). Extension has also been known to influence farmers' ability to adopt technologies and provide farmers with requisite agronomic knowledge which informs them to either reject or accept technologies (Namwata, Lwelamira & Mzirai, 2010). The results of Mandleni and Anim (2011) in their study indicated a strong association between farmers' awareness of climate change and their access to extension services. Studies by Gbetibouo (2009) and Deressa *et al.* (2011), have also indicated a significant relationship between access to extension services and awareness of climate change. They also found that membership of farmer organizations was positively associated with awareness of changes in climate. Mudombi, Nhamo and Muchie (2014) has established a connection between access to extension services and awareness of changes in climate.

Role of Agricultural Extension

Several studies have suggested that the core motivation of extension is to disseminate the benefits of enhanced farming techniques, increase food production and subsequently reduce poverty levels (Picciotto & Anderson, 1997; Anderson, 2007; Ngomane, 2006; Zwane, 2012). It also play a significant role improving the human capital as it communicates valuable and practical findings by researchers to farmers in a way that is easy to understand (Ojha & Sinha, 2001). Agricultural extension is the primary tool used by developing countries to help farmers extend their ability to embrace and adopt new methods and to share information on new technologies (Betz, 2009).

Agricultural extension is characterized as a chain of conversational approaches used to solve problems (Leeuwis, 2004). It is also often denoted as a structure that equips growers with knowledge needed to proliferate not only farm output but also income and improve the livelihood of farmers (Bello & Salau, 2009). For this reason, it remains the most essential means of reaching households in rural areas especially sub-Saharan Africa (Adejo, Okwu & Ibrahim, 2012).

Extension acts as a link between research and farmers as well as transfer innovations developed by research to farmers (Evenson, 2001; Anderson & Feder, 2003). Agricultural extension also empowers farmers to adapt technologies that suit their climate and needs, eventually increasing level of technological innovations and thus increasing productivity (Ojha & Sinha, 2001; Evenson, 2001; Anderson & Feder, 2003). Farrington (1994) also explains that extension has the duty of diagnosing socio-economic, agro-ecological conditions of farmers as well as their constraints and opportunities. They also transfer message to farmers, provide feedback to researchers on reactions of farmers to new technologies so that future research may be refined, develop linkages with stakeholders such as researchers, government planners, farmer organizations and NGOs as well as monitor extension systems and evaluate its performance.

AEAs Interactions with Farmers and Researchers

Extension agents have the role of ensuring that farmers have access to all kinds of information including climatic information and adaptation technologies which will subsequently increase the yields of farmers (Anyadike, 2009).The Neuchatel Group (1999) is of the view that the effectiveness of extension is more enhanced when farmers are directly involved in defining, managing and implementing agricultural programmes. This is to say that when there is effective communication between extension agents and farmers, productivity increases. There is usually little or no contact between poor/marginalized farmers and extension however, model or contact farmers are generally consulted by extension (Feder, Anderson, Birner & Deininger, 2010). This is contrary to the findings of Adesoji and Aratunde (2012) who discovered that there was a 100 percent contact between extension agents and farmers. Also, Okoedo-okojie and Okon (2013), in Nigeria revealed that, there was contact between AEAs and researchers and AEAs and farmers even though it was more effective between AEAs and researchers than AEAs and farmers. A study on extension officers' perceptions of farmers' groups in Trinidad and West Indies indicates that all of the respondents surveyed had direct contacts with at least one farmers' group while a considerable percentage (33 percent) interacted with more than three farmers' groups (Ramdwar, Stoute & Ganpa, 2015).

Sources of Information of AEAs Regarding Improved Technology

The sources of information for extension agents comprise people and places where they can be served with relevant technologies, practices, knowledge and skills to improve their competency and improve farmers' productivity. A study in Pakistan showed that majority (85 percent) of the extension agents' main source of information was extension publications while a minor proportion received updated information from other sources such as Agricultural Research Institutes (8 percent), TV/Radio (3 percent), through training and Agricultural Officers (2 percent) respectively (Farooq, Ishaq, Shah & Karim, 2010). Another study in Pakistan also disclosed that Agricultural Research Institutes and Agricultural Officers were main sources of information for extension agents (Farooq, *et al.*, 2010).

In Nigeria, Alfred and Odefadehan (2007) revealed that extension workers get their information from organizations, individual associates, local, national and international seminars, workshops, trainings, print and electronic media, telecommunication, and internet services. Koyenikan (2011) also in Nigeria classified information sources into formal and informal. He stated that the formal sources included state radio stations, the print media comprising newspapers, newsletters, and journals and finally seminars or workshops whereas the informal sources were farmers, family, friends, personal assessments and judgment of extension agents. Mbaya (2015) also declared that majority of extension agents got their information from colleagues and workshops or seminars. This was followed closely by sourcing information radio and research institutes. However, it was realized that printed sources such as books or journals and getting information from superior officers were ranked least.

Dulle (2000) in Tanzania also reiterated that agricultural extension workers get their information from personal sources, attendance at professional meetings, seminars, short courses and conferences and the reading of newspapers while the contact with researchers and the use of agricultural libraries were very unpopular among extension workers. Mugwisi, Ocholla and Mostert (2012) on the other hand argued that extension workers in Zimbabwe favored information from print sources while Radhakrishna, and Thomson (1996) acknowledged information sources such as agricultural agents stationed in offices, agent in other countries, extension specialists, immediate supervisor, news agencies, state/federal agencies, school teachers and administrators as noticeable information sources to agricultural extension workers.

Agricultural information in Ghana is supplied through two key channels, known as formal and informal channels. The formal networks are composed of libraries, television, radio, information centers and posters while the informal source of information is oral contact that can be performed by friends, family members, other farmers and neighbours.

Researchers' Contact with Farmers and Extension Agents

Research and agricultural extension are dependent on each other for their successful operation. Whereas extension requires research findings to deliver solutions to the technical problems of the farmer, research needs technical information from extension for generating useful technologies to farmers (Agbamu, 2000; FAO, 2005).

Adesoji and Aratunde (2012) on the evaluation of the linkage system of Research-Extension-Farmers in Oyo State, Nigeria revealed that researchers contact with farmers was 97.5 percent indicating that more contacts between researchers and farmers. This shows that there was a high level of farmer's exposure to modern methods of farming. Researchers' contact with extension agents' in Nigeria showed high levels of interactions. However, agricultural extension agents had the least relationship with research institutes (Adesoji & Aratunde, 2012**).** The research-extension linkage in Ethiopia has been very poor and this is partly due to extension agents' involvement in other activities that are usually outside extension work (Fasil & Habtemariam, 2006).

Effectiveness of Extension Teaching Methods

Extension teaching approaches are techniques used to establish circumstances in which effective contact and interaction can take place between the teacher and the learner. They are ways of spreading new knowledge and skills to rural people by attracting their attention to them, increasing their awareness and encouraging them to have a positive experience of the new practice (Okoedo-Okojie, 2015). Doamekpor (2005) highlighted in his study on the Research-Extension-Farmer interface in the cassava industry in the Volta region that all three categories of respondents ranked farm visits, method and results demonstrations in descending order as the most efficient methods to transfer technology. This is in line with the findings of Androulidakis, Siardos and Crunkilton (1995) who, in the study on perceptions of agricultural extension agents' effectiveness to reach farmers in Greece, revealed that that farm visits, methods and result demonstrations were very appropriate in the transfer of technologies to farmers. It is also consistent with the findings of Chizari, Karbsioun and Lindner (1998) in Iran.

Folorunsho (2010) in Nigeria indicated that 45 percent of respondents preferred presentation/lecture, 40 percent favored demonstrations, 10 percent liked group discussions and 1 percent preferred role play, exercise, case study and assigned reading respectively. Oladele (2002) Nigeria also confirmed that the three most important methods frequently used by extension agents to reach farmers were personal contacts, model farmers and method and result demonstrations. He highlighted that extension agents rarely used office calls and booklets in the delivery of extension services. It was also revealed by Oladele that researchers on their part used demonstrations, radio and television to reach farmers. In a study on agricultural extension agents and challenges for sustainable development in the Peshawar Valley of Pakistan, 33 percent of the extension agents reported that method demonstration was the most important learning techniques for farmer education. This was closely followed by formal group meetings (30 percent) with result demonstration (20 percent), demonstration plot (10 percent), informal discussion (5 percent) and direct contact method (2 percent) being the least training method. (Farooq, Ishaq, Shah & Karim, 2010).

FAO (2001) asserted that participatory approach of extension training methodology should be encouraged as it helps farmers and extension personnel to interact and offer solutions to their problem. A study by Okunade (2007) on how effective teaching methods were in knowledge acquisition, skills and attitudes development in Nigeria revealed that Farm and Home visit, result demonstration, field day, agricultural show, radio and method demonstration used by the extension agents were effective in acquiring knowledge, skill and attitude. Another study in Nigeria on processors preference and effectiveness of extension teaching methods used by Raw Material Research Development Council for dissemination of shea butter processing technologies in Moro Local Government Area of Kwara State Nigeria showed that demonstration, lectures and group discussion were the most used extension teaching methods. The respondents however perceived group discussion to be the most effective which was followed by demonstration, lectures and workshops at 2nd, 3rd and 4th positions respectively (Igene, Sedibe, Van der Westhuizen & Solomon, 2018). In India, Ojha (2017) found that farm and home visits, calls from farmers, method demonstrations, the internet and agricultural shows were successful in knowledge acquisition, skills growth and attitude formatting in a study on effectiveness of different teaching methods under the KVK system.

Conceptual Framework of Knowledge Systems for Adaptation to Climate Change

The diagrammatic representation of the analysis of rice knowledge systems towards adaptation to climate change in the Northern Region of Ghana based on the theoretical, conceptual and empirical review is presented in Figure 2.

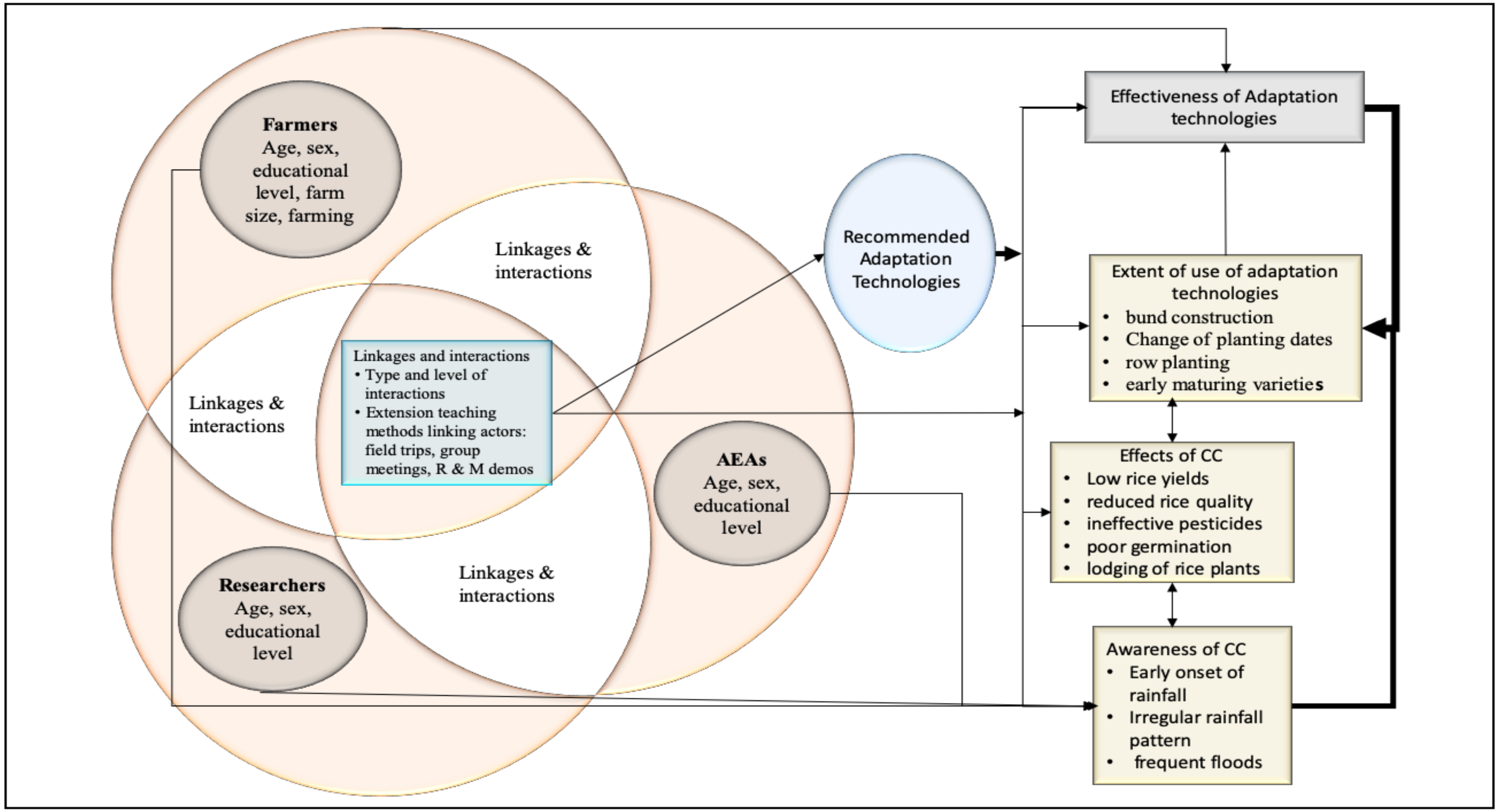

Figure 2: Conceptual Framework for Rice Knowledge Systems Analysis for Climate Change Adaptation in the Northern Region
Source: Abubakari Von (2018)

The rice knowledge system consists of farmers, AEAs and researchers who interact through activities such as meetings, training sessions, workshops/ seminars, model farmers, group discussions, field days and results and method demonstrations. These activities bring together farmers, AEAs and researchers to generate technologies, influence knowledge on climate crisis awareness, effects, use of adaptation technologies, recommended adaptation technologies and the effectiveness of climate change adaptation technologies.

The knowledge system also comprises farmers with diverse demographic characteristics such as age, sex, level of education, marital status, household size, years of experience in the growing of rice, ownership of land, area of land under rice cultivation and work experience. The knowledge system is also made up of AEAs of different demographic and work related characteristics such as sex, age, work experience number of villages served, number of farms served, number of farmers served, educational level and trainings received on climate change. Researchers' demographic and work related characteristics such as sex, age, work experience, educational level, trainings attended and job position. The varied characteristics of farmers, AEAs and researchers can increase their awareness of climate change and effectiveness of adaptation technologies.

Effects of climate change on rice production include soil nutrient depletion, soil erosion, poor seed germination, withering of seedlings, widespread of new crop pests, pesticide ineffectiveness, lodging of rice plants, low yield, reduced rice quality, change in planting time, change in the duration of the rainy season and reduction in the length of the growing season. When the effects of climate change become apparent to farmers, AEAs and researchers, their awareness of the phenomenon becomes more pronounced and farmers, striving to increase productivity, avoid negative outcomes by increasing the use of adaptation technologies.

Farmers, AEAs and researchers' awareness of climate change in the rice knowledge system were extremely hot days in the dry season, irregular rainfall patterns, early end of rainfall, long periods of intense heat, decrease in amount of rainfall, reduction in flow of streams, new weeds which previously not found in the north now growing, extremely cold days in the rainy season, severe dry spells in the rainy season, crops previously grown in the north difficult to survive, flooding annually, early onset of rainfall and increase in off-season rains. Once these key actors are aware of climate change, its consequences become apparent, hence the perception of risk. Once farmers are aware of climate change, the extent of use of adaptation technologies is likely to increase.

The adaptation technologies recommended by AEAs and researchers, and used by farmers include early maturing varieties, treatment of seeds with fungicides, pest resistant varieties, bund construction, rain water harvesting, row planting, afforestation and crop insurance. The rest are rice-legume intercrop, zero/minimum tillage on rice farm and fallowing rice farms. Farmers' ability to use these technologies is dependent on recommendations of AEAs and researchers. In addition, the extent to which these technologies are used will either increase or reduce the effectiveness of the technologies.

Similarly, recommended adaptation technologies by AEAs and researchers include early maturing varieties, treatment of seeds with fungicides, pest resistant varieties, bund construction, rain water harvesting, row planting, afforestation, crop insurance, rice-legume intercrop, zero/minimum tillage on rice farm and fallowing rice farms. Recommendations made by AEAs and researchers will increase the extent to which farmers use adaptation technologies.

The effectiveness of these adaptation technologies is seen in the form of outcomes of the adaptation activities. These include improved drought tolerance, reduced weed populations, rice maturing early, retention of water on rice fields, improved water holding capacity and soil fertility, good grain quality and increase in yields. These results depend on six (6) main factors (independent variables) namely;

a) Background and farm/work related characteristics;
b) Awareness to climate change;
c) Linkages and interactions among farmers, AEAs and researchers;
d) Effect of changes in climate on production of rice
e) Extent of recommendation of adaptation technologies; and
f) Extent of use of climate change adaptation technologies

Chapter Summary

The chapter comprised a review of the literature relevant to the analysis of rice knowledge systems for climate change adaptation. It presented information on the theory underpinning the study and its relevance to other fields. Literature was reviewed on the concepts of climate change, awareness, adaptation, knowledge systems and impacts of climate change. Also reviewed were empirical literature on demographic characteristics, awareness of climate change, the relationship between demographic characteristics and climate change awareness, effects and impacts on the production of rice and also the effectiveness of adaptation technologies to climate change. Furthermore, a review of findings relating to adaptation technologies recommended and used by AEAs, researcher and farmers respectively was also done. This was followed by a review of literature relating to interactions between farmers, AEAs and researchers and the effectiveness of these interactions. The extension teaching methods used for these interactions and the effectiveness were also reviewed. Finally, the conceptual framework of the study was provided indicating the relationship between variables.

CHAPTER THREE

RESEARCH METHODS

Introduction

The chapter explains the procedures and techniques used to collect and analyze data. It captures and discusses the research design, study area, population, sampling procedure, sampling and sample size, instrumentation, pre-testing of research instrument, data collection and analysis as well as the analytical framework.

Research Design

According to Abutabenjeh and Jaradat (2018), a research design is an outline to guide the research procedure by positioning how a study will move from the research purpose to the outcomes. It also refers to the general approach employed to integrate various components of a study in a logical and coherent manner (De Vaus, 2001). The research design establishes the plan for the collection, measurement and analysis of data. Cresswell (2014), emphasizes the potential of the research design to offer explicit guidance for the research study procedures.

The study adapted the explanatory sequential mixed method design. According to Ivankova, Creswell and Stick (2006), the explanatory sequential mixed method design incorporates quantitative and qualitative approaches within one study in two consecutive phases of the research process. This consists of collection and analysis of quantitative data after which qualitative data is gathered and analyzed to elaborate the quantitative findings.

Usually, the explanatory sequential mixed method design is based on the quantitative results that qualitative data is collected. However, due to the difficulty of getting farmers, the explanatory sequential mixed method design was modified so that a portion of the farmers used for the quantitative study could be used for the FGD session. Later on after analysis of quantitative data, key informant interviews and FGDs (for those chosen farmers who were willing to participate) was done. In the first instance, after quantitative data was collected, some qualitative data was also collected from participants of the quantitative study based on modification of an already formulated interview guide. In the second instance, quantitative data was analyzed and follow-up key informant interviews were conducted based on the results of the data to provide insight into the quantitative results.

The choice of the design stems from the fact that quantitative data and its subsequent analysis provided a general understanding of the research problem. Qualitative data and analysis improved and explained the statistical results by exploring the views of participants of the research in greater depth. Also, qualitative results was used to assist in explaining and interpreting the findings of quantitative study. (Tashakkori & Teddlie 1998; Creswell 2003; Creswell & Plano, 2011). The quantitative approach of the sequential explanatory mixed method design first used a survey to gather data from a portion of the target population for the purpose of examining the characteristics, opinions, behaviour and experiences of that population (Polit & Beck, 2004; Creswell, 2005). Surveys assess many variables, infer temporal order about past behavior and examine multiple hypotheses (Best & Khan, 1998). Survey also methodically asks several people the same questions about the state of a programme or project (Neuman, 2003).

Phenomenological inquiry was used to describe the experiences of farmers, AEAs and researchers on climate change, adaptation, awareness and knowledge systems as part of the qualitative approach of the explanatory sequential mixed method design (Creswell, 2007). The approach tried to understand the perception and perspectives of people on a specific phenomenon (Pathak, 2017). It provides a coherent summary of experiences by drawing insights into the meaning of experiences from individual stories (Creswell, 2007; Creswell, 2013). Lester (1999) describes the approach as the gathering of in-depth information and perceptions through interviews, discussions, experiences and observations about a phenomenon. According to Donalek (2004), phenomenological approach examines experiences through the description provided by the people involved. Respondents are often asked to describe their experiences as they perceive them and this is mostly done through interviews. The essential objective of the approach is to identify and describe in detail the actual phenomenon.

Study Area

The Northern Region is one of the sixteen regions in Ghana. It is located within latitude 9°29'59.99"N and longitude -1°00'0."W of Ghana and made up of fourteen districts, one municipal and one metropolitan assembly. The region shares boundaries to the north with North East Region, to the east with Togo, to the south with the Oti Region and to the west with the Savannah Region. The main language spoken is Dagbanli but there are other dialects. Islam is the major religion and out of every five inhabitants, three are associated with Islam (Otuo-Akyampong, 2020).

The Northern Region experiences a unimodal rainfall pattern which often begins in April/May and end in October. The mean annual rainfall fluctuates between 750mm and 1,050mm. Relative humidity of between 75-76 percent in the region aggravates the effect of the heat during the day (Mabe, Sarpong & Osei-Asare, 2014). The dry season in the region begins in November and ends at peak temperatures in March. Also, the Harmattan winds from the Sahara blow frequently between December and the beginning of February. This has considerable effects on the temperature which varies between 20ºC to 26ºC at night and 33ºC to 40ºC during the day (Ghana Statistical Service, 2013). The vegetation in the region consists predominantly of grassland interspersed with woodland characterized by drought-resistant trees such as baobab, dawadawa, shea, neem and acacias (Shu-aib Jakpa, Owusu & Gandaa, 2019).

The soils in the region are fundamentally voltarian sandstones which easily give worked light soils with a guinea savannah vegetation (Obeng, 2000). The major crops cultivated in the region are maize, millet, rice, yam, sorghum, groundnut, cowpea, and Bambara groundnuts. The most common farm implement is the hoe. However, some are able to afford tractor services for ploughing while a few use bullocks (Houssou, Kolavalli, Bobobee & Owusu, 2013). The main economic activity in the Northern Region is farming which accounts for 71.2 percent of the economically active population. About 70 percent of these farmers are found in the rural areas of the region (MOFA, 2016), a figure higher than the national average of about 41 percent (GSS, 2012). The percentage of males in Agriculture and related activities in the region is higher than that of females in all districts of the Northern region.

The Department of agricultural extension services in the Northern Region ensures that agricultural extension agents contribute in an effective and efficient way towards the social and economic development of the Region by utilizing scientific research and new information on agricultural practices via education of farmers (MoFA, 2019). The Savannah Agricultural Research Institute (SARI) is one of the very few research institutes located in the Northern Region. It is one of the thirteen (13) research institutes of the Council for Scientific and Industrial Research Institute (CSIR) in Ghana. The mandate of SARI is to provide farmers within Northern Ghana with suitable technologies to increase food and fibre production through sustainable production system while maintaining and increasing soil fertility.

The map of the Northern region shows the Tamale Metropolis, Tolon, Savelugu and Nanumba North districts in Figure 3.

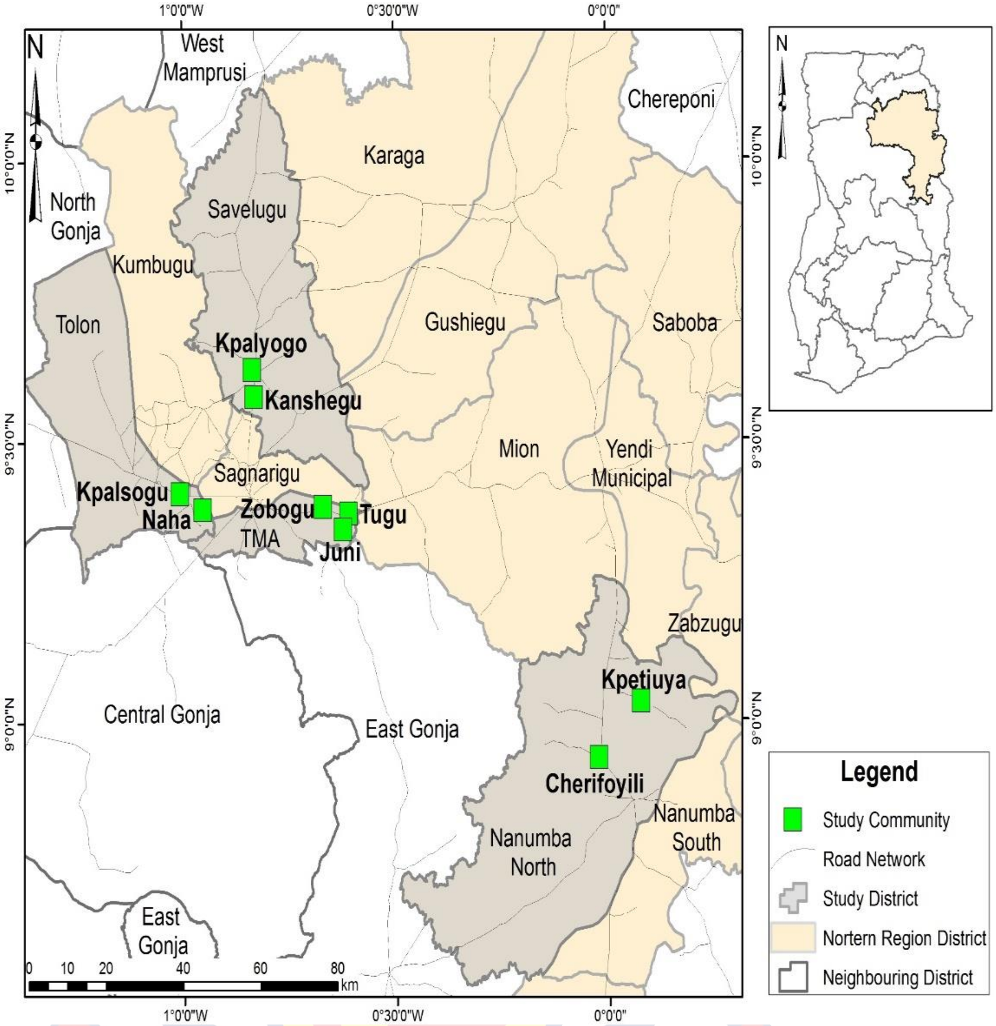

Figure 3: Map of the Study Area
Source: cartography and Remote Sensing Unit of the Department of Geography and Regional Planning, University of Cape Coast (2019)

Population of the Study

The study population comprised all rice farmers in the Northern Region of Ghana. It also consisted of all Agricultural Extension Agents (AEAs) in the four selected districts of the study in the Northern Region of Ghana. Moreover, it included all researchers at the Savannah Agricultural Research Institute (CSIR-SARI) in the Northern Region of Ghana investigating and or finding solutions to challenges of rice and how to respond to climate change in rice production. SARI was chosen because unlike other institutions like the

University for Development Studies whose mandate includes teaching students, the mandate of SARI was mainly to provide farmers in the North (Northern, North-East, Savannah, Upper East and Upper West Regions) with appropriate technologies, innovations and options to increase food production based on sustainable production system. According to the Northern Regional Directorate of Agriculture, the population of rice farmers in the Northern Region is estimated to be about 50,000.

Sample Size Determination

The study focused on three key categories of respondents: rice farmers, AEAs and researchers. As a result, different mechanisms for determining the sample size were adopted to estimate the representative sample size for each category of respondents. Theoretically, deriving an appropriate and representative sample size depends on the nature of the study population, the type of data and the analysis to be done (Best and Khan, 1998). In determining the representative size of sample for the farmers, the table for sample size determination (Krejcie & Morgan, 1970). Data from the Regional Directorate of Agriculture suggests that the estimated population size of rice farmers in the Northern region is about 50,000. For a population of 50,000, the table of sample size suggests 381 rice farmers as representative sample (see Appendix G for sample size calculation). In determining the appropriate sample size of AEAs in the study area, data of all AEAs that work directly with rice farmers in the four selected districts was generated. The data gave a population size of 30 AEAs. Consequently, to get a statistically representative sample size for AEAs, a census approach was used to include all the 30 AEAs as the size of the sample of the study. Again, in determining the size of the sample for researchers that have worked in the area of climate change and rice production, SARI was contacted to generate the sampling frame of 36 researchers. Six of the researchers had been used to pre-test the instrument therefore the remaining 30 were used for the main study given the small number.

Sampling Procedure

Selection of farmers

The study adopted a multistage sampling approach to randomly select the 381-rice farmers from whom data was collected for the study. The process was operationalized as follows. The first stage involved the selection of the major rice growing districts in the Northern region of Ghana. Available data from the regional department of Agriculture indicate ten (10) major rice growing districts in the region. Taking this as the first sample frame, the simple random lottery technique was then used to randomly select four (4) districts (Tolon District, Savelugu District, Nanumba North District, and Tamale Metropolis) out of the ten (10) districts, which according to Check Market (2019) is a good representation. At the second stage, a list of the major rice growing communities was generated from each of the four selected districts. The simple random lottery technique was then used to randomly select three communities from the Tamale Metropolis, two communities from the Tolon district, two communities from Savelugu districts and two communities from the Nanumba North district to give a sample of nine communities. In the third stage, a list of farmers engaged in rice production from each of the nine selected communities was generated (see *Appendix G*). Based on the predetermined sample size of 381 rice farmers in the Northern region, a proportionate sample size was estimated for each community following the Kejcie and Morgan (1970)

Table. Having determined the proportionate and representative size of sample for each community, the simple random lottery technique was then used to randomly select the individual rice farmers to constitute the sample size of 381. A response rate of 84.3 percent comprising of 321 farmers was obtained. Purposive sampling was used to select fourteen (14) farmers for two (2) focus group discussions to gain in-depth qualitative information. These 14 farmers were chosen based on the number of years of farming (farming experience) and interactions or non-interactions with AEAs and researchers in the generation, modification and transfer of adaptation technologies to climate change.

Selection of AEAs and Researchers

A census sampling approach was used to select all agricultural extension agents in the three selected districts and the metropolis for the study. This was due to their small population size. In all, 30 AEAs were selected for the study. Again, because of the small population size of the researchers, a census sampling approach was used to select all researchers who have directly worked in the field of knowledge system, climate change and rice production in the SARI. This resulted in a total of 30 researchers being selected for the study.

Eight AEAs were purposively chosen for FGDs, while three researchers were approached and used as key informants to collect in-depth qualitative data. They were chosen on the basis of the number of years spent working with rice farmers and their interactions with farmers in the generation, modification and transfer of adaptation technologies to climate change.

Data Collection Instruments

Content validated questionnaires, structured interview schedules and interview guides as well as FGD guides were created and thereafter used to amass primary data for the study. The questionnaires were used for the collection of data from AEAs and researchers while the structured interview schedule were used to collect data from the rice farmers. The researcher ensured face validity by checking how suitable the items on the instruments seem to be on the surface. Content and construct validity were ensured by the student researcher's supervisors. They assessed the extent to which the instruments measured the constructs.

The researcher's ability and skills as well as trustworthiness are important to ensure validity and reliability of data during the qualitative research process (Seale, 1999; Patton, 2001). As a result, the student researcher accurately recorded the opinions of farmers, researchers and AEAs, and reported the views and opinions of respondents verbatim. Also, the student researcher asked the same questions differently to ensure that responses to the questions were consistent. Permission was sought from participants during the focus group discussions (FGDs) and key informant interviews and, the transcription of recorded data was meticulously done to ensure accuracy of the data. The interview and FGD guides were used to direct the inter FGDs. The supervisors reviewed the guides and coached the student researcher to know what questions to ask, the sequencing of questions, how to pose questions, and how to pose follow-ups in FGDs and interviews.

The structured interview schedules and questionnaires used to collect quantitative data were made up of five key sections. The first section was on awareness level of respondents to climate change. Section two centered on perceived effect of climate change on rice production. The section three measured the extent of use/recommended adaptation technologies to climate change. Section four was made up of items that measured level of interaction between farmers, AEAs and researchers in the generation, modification, transfer and use of adaptation technologies and the effectiveness of extension teaching methods used to link farmers, AEAs and researchers in the generation, modification, transfer and use of adaptation technologies. The last section focused on items measuring the demographic and farm/work related characteristics of respondents. (See appendices A, B and C interview schedule and questions for farmers, AEAs and researchers). Table 1 presents how the major constructs were measured.

Table 1: Interpretation of Scales Used to Measure the Main Constructs of the Study

Level of effect of climate change on the production of rice	Level of effectiveness of adaptation technologies	Level of awareness to climate change e	Extent of recommended and used adaptation technologies	Level of interactions between farmers, AEAs and researchers	Numerical value of responses	Range of numerical value
Very high	Highly effective	Very much aware	Always	Very strong	5	4.45-5.00
High	Effective	Very aware	Often	Strong	4	3.45-4.44
Moderately high	Moderately effective	Moderately aware	Sometimes	Moderately strong	3	2.45-3.44
Less high	Lowly effective	Less aware	Rarely	Weak	2	1.45-2.44
Least high	Negligibly effective	Least aware	Very rarely	Very weak	1	1.00-1.44

Source: Author's construct, (2017)

The interview and FGD guides were in six parts. Part one looked at the awareness of respondents to climate change where respondents described climate change, its duration and its effect on rice production. Part two considered the rice varieties cultivated by farmers and recommended by AEAs and researchers as well as reasons for the cultivation and recommendation of the rice varieties. Part three focused on the rice adaptation technologies used by farmers and recommended by AEAs. Part four looked at the effectiveness of rice production technologies in addressing climate change in terms of yield, pest management, weed management, quality of paddy and soil improvement. Part five presented questions on knowledge systems among farmers, AEAs and researchers in climate change adaptation. This included the type of interactions between farmers, AEAs and researchers; and the effectiveness of extension teaching methods used to link farmers, AEAs and researchers in the generation, modification, transfer and use of adaptation technologies. The interview guides for farmers, AEAs and researchers are found in *Appendices D, E* and *F* respectively.

Pre-testing of Research Instruments and Estimation of Reliability of Scale Items

The research instruments for AEAs and farmers were pretested in Sagnerigu district in the Northern Region while that of researchers was per-tested at SARI to establish the reliability of variables. Interview schedules and questionnaires for farmers, AEAs and researchers were pre-tested. The weaknesses and ambiguity in the framing of questions which made the questions difficult to comprehend were identified and corrected. The Sagnerigu district in the Northern Region was selected due to its accessibility and proximity to Tamale, the regional capital.

Statistical Package for the Social Sciences (SPSS) software version 21 was used to analyze the scale of items and generate Cronbach's Alpha coefficient to find the reliability of all scale items. A sample of 30 farmers deemed appropriate for the Cronbach's Alpha coefficient test for reliability was used (Yurdugül, 2008). 10 AEAs and six researchers were chosen for the pre-test. These numbers were less than 30, contrary to what Yurdugül (2008) suggested to be ideal to establish Cronbach's Alpha coefficient test for reliability. However, the face to face approval used enabled the respondents to determine if the item was not clear and this allowed the researcher to explain for a more concrete response from the respondents. Not only did the process give us the opportunity to address reliability issues but also issues of validity.

A reliable instrument is expected to give consistent results when used by different researchers. Loewenthal (2004) concluded that an Alpha coefficient of 0.60 or more on an instrument is reliable. Vaske (2008) also indicated that an Alpha coefficient of 0.65 or more scale is reliable and acceptable for human related research. Table 2 presents the results of Cronbach's Alpha reliability of subscale of the research instrument of farmers, AEAs and researchers.

The Cronbach's Alpha of five constructs namely, awareness level to climate change, perceived effect changes in climate, extent of use and recommendation of adaptation technologies, effectiveness of adaptation technologies and level of interactions for farmers, AEAs and researchers ranged from 0.63 to 0.97. The instruments on the scale items were deemed reliable (Loewenthal, 2004).

Table 2: Reliability Analysis of Subscale of the Research Instrument of Farmers, AEAs and Researchers Using Cronbach's Alpha

Construct	No. of items	Farmers Alpha (N=30)	AEAs Alpha (N=10)	Researchers Alpha (N=6)
Awareness level to climate change	15	0.80	0.73	0.87
Perceived effect of climate change	12	0.73	0.87	0.87
Extent of use/recommendation	22	0.97	0.84	0.66
Effectiveness of adaptation technologies	13	0.71	0.85	0.63
Level of interactions	3	0.82	0.74	0.79

Source: Field survey, Abubakari Von (2018)

Ethical Clearance and Data Collection Procedures

The University of Cape Coast Institutional Review Board ethically cleared the instruments for data collection. Copies of the research proposal and instruments were submitted to the Review Board. The attached letter (see *Appendix S*) indicated the research would be conducted in a responsible and ethically accountable manner leading to beneficial outcomes and was thus approved for data collection. Introductory letters which stated the objectives, its expected benefits and introducing the student researcher were sent to the Regional directorate of Agriculture and the Savannah Agriculture Research Institute for consent. A letter of consent that stated the rational of the research and its benefits was explained to respondents/interviewees. Consent forms were signed by respondents/interviewees indicating their consent to be interviewed. The letter also contained assurance of anonymity by the student researcher.

Six enumerators were recruited and trained by the researcher on how to administer the instruments. Data collection from farmers, AEAs and researchers was conducted from 22nd June 2019 to 8th August 2019.

Data Processing and Analysis

Data collected were coded, entered and cleaned using the Statistical Package for the Social Sciences (SPSS) version 21 software for the data analysis.

The recordings were listened to and transcribed from the local language (Dagbanli) to English for the qualitative data. Thematic analysis which methodically identifies, organizes and provides insight into meaningful patterns (themes) across a dataset was used for the analysis (Braun and Clarke, 2012). Microsoft Word Document Review Tab was used to code the transcribed document after which the themes were created. Specifically, the transcribed document was read severally and critical segments identified and given meaningful names (codes) using the new comment tab. Afterwards, all codes were then brought together by clicking on the reviewing pane to copy all comments into a different document. Similar codes were put together to form themes which were named to convey its contents. The contents of each theme were then extracted from the transcribed document.

Data Analysis, Model Estimation and Diagnostic Tests

Data analysis

The analytical framework presented in Table 3 provides the variables of the study according to the objectives based on thorough literature review and inputs from supervisors and experience of the student researcher. It also offers a snapshot of various analysis conducted to achieve each of the objectives of the study. The statistics deemed appropriate for analyzing each objective and level of measurement are included. The interpretation of the strength of correlation coefficients in the analysis of objective one is shown in *Appendix R.*

Table 3: Framework for Data Analysis

SPECIFIC OBJECTIVES	VARIABLES	LEVELS OF MEASUREMENTS	TYPE OF STATISTICS/TEST	STATISTICS USED
1. Relate the socio-demographic and farmer-related characteristics of rice farmers, agricultural extension agents and researchers to level of awareness of climate change on rice production.	**Socio-demographic and work/farm characteristics:** Sex, marital status, area of specialization, self-finance, type of farming system, type of rice ecosystem, rice varieties recommended, no. of villages served, training attended on climate change, no. of farms served, no. of farmers served, education level, household size, farm size, farming/work experience, age, yield, class, rank	Nominal Ordinal Ratio	Descriptive statistics:	Frequencies, percentages, means, standard deviations
	Awareness level to climate change Very hot days in the dry season, very cold days in the rainy season, long period of intense heat, severe dry spells in the rainy season irregular rainfall pattern, decrease in amount of rainfall, early onset of rainfall in the rainy season, frequent floods, early end of rainfall in the rainy season, Crops previously grown in the north now able to survive, new weeds which previously not found in the north now growing, increase in off-season rains.	Interval	Inferential statistics	Point biserial, Spearman rank and Pearson correlations, Kruskal Wallis test.

Table 3 Continued

2. Describe farmers, agricultural extension agents and researchers perceived effect of climate change on rice production in the Northern region.	Effect of climate change in rice production Soil nutrients loss, erosion of soil, poor seed germination, withering of seedlings, widespread new crop pests, pesticide no longer effective, Drying up of water bodies which previously never dried up, lodging of rice plant, low rice yields, reduced rice quality, reduction in length of growing season, changes duration of rainy season, changes in times of planting.	Interval	Descriptive statistics Describe and explain Inferential statistics	Frequencies, means, standard deviations. Thematic analysis Kruskal-Wallis H test Mann-Whitney U test
3. Determine the extent of recommendation/use of rice production climate change adaptation technologies by AEAs, researchers and farmers in the Northern region	**Recommended/used adaptation technologies** Early maturing rice varieties, pest resistant varieties, change of planting dates, bund construction, row planting, water harvesting, crop insurance, construction of spillways, fallowing, rice-legumes intercrop, afforestation, right amount of fertilizer application, treatment of rice seeds with fungicides, split application of inorganic fertilizer,	Interval	Descriptive statistics Describe and explain	Frequencies, means, standard deviations. Thematic analysis
4. Examine the linkages and interactions in the generation, modification, transfer and utilization of climate change adaptation rice production technologies.	**Linkages and interactions** Level of interactions: Linkages between farmers and researchers, farmers and AEAs, AEAs and researchers, and farmers, AEAs and researchers Effectiveness of methods used to link farmers, AEAs and researchers generate, modify, transfer and use	Interval	Descriptive statistics Describe and explain	Means, standard deviations. ANOVA Thematic analysis

Table 3 Continued

	adaptation technologies: field trips, group meetings, result and method demonstrations, workshops, farmer field schools, radio.			
5. Assess the effectiveness of rice production adaptation technologies in addressing climate change in the Northern Region.	Effectiveness of adaptation technologies Early maturing rice varieties, pest resistant varieties, change of planting dates, bund construction, row planting, water harvesting, crop insurance, construction of spillways, fallowing, rice-legumes intercrop, afforestation, right amount of fertilizer application, treatment of rice seeds with fungicides, split application of inorganic fertilizer	Interval	Descriptive statistics Describe and explain	Frequencies, means, standard deviations. Thematic analysis
6. Determine the best predictors of effectiveness of adaptation to climate chine in rice production	**Best predictors of effectiveness of climate change adaptation technologies in rice production** Sex, educational level, age, household size, farming experience, yield/ha, farm size, land ownership, level of awareness to change in climate, CC effects on production of rice, extent of use of adaptation technologies, linkage and interactions among farmers and researchers, interactions among the three actors, linkage and interactions among farmers and AEAs	Interval	Inferential statistics	OLS regression

Source: Author's construct, (2017)

Model Estimation to Predict Effectiveness of Adaptation Technologies

The study adopted the Ordinary Least Squares (OLS) multiple linear regression procedure to assess how the independent variables in the study influenced effectiveness of climate change adaptation rice production technologies. The OLS regression analytical tool was used due to the dependent variable, which is the effectiveness of climate change adaptation technologies, being a continuous variable or measure on an interval and ratio scale (Cohen, Cohen, West, & Aiken, 2003). The Ordinary Least Squares (OLS) multiple regression uses two or more independent variables to predict the dependent variable and determine the intensity between these variables (Hutcheson, 1999). Williams, Gómez and Kurkiewicz (2013) indicate that OLS multiple linear regression requires that the dependent variable be continuous, independent variables be more than one, data is normally distributed, without autocorrelation and multicollinearity, homoscedastic and most importantly parametric. The OLS multiple regression for this study is implicitly specified as

$$Y = f(\beta, X, \varepsilon) \quad (1)$$

This is further expanded in equation (2) as

$$Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_{14} X_{14} + \varepsilon_i \quad (2)$$

Where

Y = defines effectiveness of farmers' climate change adaptation rice production technologies.
β_0 = value of Y when all of the independent variables (X_1 through X_{14}) are equal to zero (constant)
β_1- β_{14} = estimated regression coefficients
ε_i = error term
X_1 = Level of awareness to climate change
X_2 = Effects of CC to rice production
X_3 = Extent of use of climate change adaptation technologies
X_4= Farmers interactions with AEAs
X_5 = Farmers interactions with researchers
X_6= Interactions between farmers, AEAs and researchers

X_7 = Sex
X_8 = Age
X_9 = Educational level
X_{10}= Farming experience
X_{11} = Land ownership
X_{12} = Land size of rice
X_{13} = Yield
X_{14} = Household size

The Stepwise selection method of the OLS multiple linear regression was considered appropriate because, the contribution of each explanatory variable entered previously was determined at each step of the analysis. The contribution of previous variables are understood now that other variables are added and variables are maintained or removed based on their statistical contribution. Out of the 14 explanatory variables that were used in the Stepwise Regression model, only three statistically contributed in explaining the dependent variable. Hence the 11 other explanatory variables were removed from the equation since they had no significant contribution to the dependent variable.

Table 4: The Codes, Sign and Explanatory Variables Used in the Regression Analysis

Explanatory variables	Codes	Expected sign	Explanation (Assumption)
Extent of use of climate change adaptation technologies	Extent of use	+	Higher use of adaptation technologies increases the probability of attaining high effectiveness
Linkage and interactions among farmers and researchers	Level of interactions	+	Higher level of interactions with researchers increases the probability of attaining high Effectiveness
Sex	1=Male 0 =Female	+	Probability that males have higher effectiveness than females
Level of awareness of Climate Change	Level of awareness	+	Higher awareness of adaptation technologies increases the probability of attaining high effectiveness

Table 4 continued

Perceives effects level of Climate Change	Effect level	+	Higher perception of effects increases the probability of attaining high effectiveness
Educational level	Educational level	+	Higher education increases the probability of high effectiveness
Household size	Number of people	+	More people in the household is expected to improve access to information on climate change adaptation technologies, which is likely to increase the likelihood of effectiveness
Farming experience	Number of years of farming	+/-	Long years of farming increases/decreases the Probability of effectiveness of adaptation technologies
Ownership of land	1=Yes, 0= No	+	Ownership of land increases the probability of attaining high Effectiveness
Farm size	Farm size/ ha	+/-	Greater farm size increases/decreases the Probability of effectiveness of adaptation technologies
Linkage and interactions among the three actors	Level of interactions	+	Higher level of interactions with AEAs and researchers increases the probability of attaining high Effectiveness
Linkage and interactions among farmers and AEAs	Level of interactions	+	Higher level of interactions with AEAs increases the probability of attaining high Effectiveness
Yield/ha		+	Higher yield increases the probability of attaining high Effectiveness
Age	Number of years	+/-	Adult age increases/decreases the probability of attaining high Effectiveness

Source: Author's construct, (2020)

Diagnostic tests

According to Ahad, Yin, Othman and Yaacob (2011), a p-value >0.05 in the Shapiro-Wilk test of normality indicates a normal distribution and p-value < 0.05 indicates a deviation from normality. The p-values of 0.000 from the Shapiro-Wilk test for normality in Appendices K and L indicated the data was not normally distributed. Hence, the Kruskal-Wallis H test which is the non-parametric alternative of analysis of variance (ANOVA) was used to test significant differences between farmers, AEAs and researchers. In the case where the Kruskal-Wallis H test is significant, the Post-hoc Mann-Whitney U test between groups is used to determine where the significant differences exist among two samples at a time since more than two samples cannot be compared at a time. However, to control for type 1 error where the null hypothesis is rejected although true, the Bonferroni adjustment to the alpha values was applied since the three actors were compared with one another (farmers with AEAs, farmers with researchers, researchers with AEAs). This is done by dividing the alpha level of .05 by the number of test to be conducted and then use the new value as the required alpha level (Pallant, 2007). This means a new alpha level of .05/3 = .017. The magnitude of the differences (effect size) is also computed.

Where effect size (r) = z/√n, n = total number of cases.

According to Cohen (1988) a criterion of 0.1= small effect, 0.3 = medium effect and 0.5 = large effect.

Appendices M and N show p-values of 0.083 and 0.069 from the Shapiro-Wilk test for normality indicating that the data sets for extent of use of climate change adaption technologies, and the level of interactions between farmers, AEAs and researchers to generate, modify, transfer and use of adaptation technologies are normally distributed. A one-way ANOVA was conducted to determine statistically significant differences between farmers, AEAs and researchers' level of interactions with each other. Where significant differences were found, a Tamhene's T2 post-hoc test was conducted since the analysis violated Levene's equality test for variance and had unequal sample sizes.

Also, the p-value of 0.071 from the Shapiro-Wilk test for normality in Appendix O indicated the data was normally distributed. Further tests such as the Durbin-Watson, multicollinearity diagnostic and homoscedascity tests were performed to satisfy the Ordinary Least Squares (OLS) regression assumptions. The study sample was randomly taken from the population (parametric). Furthermore, the Durbin-Watson test in Table 26 showed that the observations (farmers) of each variable were not related. A value of 1.905 indicated no autocorrelation as the thumb rule suggests values between 1.5 and 2.5 as normal. (Field, 2009). The values of the predictor variables have the same variance around the regression line suggesting homoscedasticity (Salkind, 2010) as shown in *Appendix Q*.

The Multicollinearity Diagnostic Test was performed to determine whether there was a strong correlation between two or more predictor variables. Tolerance values less than 0.10 indicate high probability of collinearity and VIFs greater than 5 shows high correlation while VIFs exceeding 10 are signs of serious multicollinearity requiring correction (Field, 2013; Daoud, 2017).

Table 5: Collinearity Diagnostic Test

Collinearity tests	Minimum	Maximum
Tolerance	0.53	0.99
VIF	1.01	1.89

n = 320. $p > 0.05$.

Source: Field Survey, Abubakari Von (2019)

The results of the collinearity diagnostic test showed no significant multicollinearity likely to prejudice the output of the regression analysis.

Results presented in Table 5 revealed the minimum and maximum tolerance values were 0.53 and 0.99 respectively indicating no statistically significant multicollinearity. The minimum (1.01) and maximum (1.89) VIF values were less than 10 also indicating no statistically significant multicollinearity according to Field (2013) and Daoud (2017) (see *Appendix P* for the tolerance and VIF values of all 14 predictors).

Myths about the use of Likert-types scales

Carifio and Perla (2009) address the misconceptions about the use of the Likert scale as interval and ratio scales. They indicate that it is perfectly appropriate to generate means and standard deviations from Likert scales. They also specify that parametric techniques such as ANOVA can be used to analyze Likert scale and Pearson correlations can be calculated using summative ratings from Likert scales while being used as a basis for multivariate analytical techniques such as multiple regression and factor analysis.

CHAPTER FOUR

CLIMATE CHANGE AWARENESS AND BACKGROUND CHARACTERISTICS, AND EFFECT OF CLIMATE CHANGE ON RICE PRODUCTION

Introduction

Specific Objective one of the study sought to correlate demographic and farm/work related characteristics to level of awareness to climate change. The level of awareness of farmers, agricultural extension agents and researchers was first presented and discussed before they were correlated with the demographic and farm/work related characteristics.

Level of Awareness of Farmers' AEAs and Researchers to Climate Change

Weighted means and standard deviation of level of awareness indicate that interviewees were very aware of changes in climate the opinions of farmers and researchers greatly varying from the mean (rice farmers ($\bar{X}w = 3.59, SD = 1.05$), AEAs ($\bar{X}w = 3.86, SD = 0.99$) and researchers ($\bar{X}w = 3.62, SD = 1.16$)). This point to the seriousness of climate change in the Northern region. The rice crop is most susceptible to climate change (Mohanty *et al.*, 2013) and it's not unusual that respondents showed high levels of awareness. AEAs awareness of climate change was higher than that of researchers since AEAs received varied information on the changes in climate from NGOs, formal trainings and even from researchers, and this came out during the FGDs. An AEA indicated that: *"We have received a lot of trainings on climate change from NGOs and researchers. Those of us that pursued higher degrees also learnt about it from school".* (AEA1, a 46-year-old male extension agent).

This result is consistent with the findings of Arbuckle *et al.* (2015), Nkwusi, Adeaga, Ayejuyo, and Annuk, (2015), Saah (2015) and Adusei (2016) that most farmers are aware of climate change. On the other hand, findings of Oduniyi (2013) and Nzeadibe, Egbule, Chukwuone and Agu (2011) in Nigeria were contrary to the opinions of farmers. The study by Etwire, Al-Hassan, Kuwornu and Osei-Owusu (2013a) also had showed a low climate change awareness among farmers in Ghana. The high opinion of AEAs is similar to the findings of Ogunlade *et al*. (2014) in Ghana. Zikhali (2016) in South Africa and Abegaz and Wims (2015) in Ethiopia had all reported of AEAs' high awareness of the concept of climate change.

Results presented in Table 6 specifically indicated that AEAs (mean= 4.25, SD=1.04) and researchers' (mean= 4.37, SD=0.88) were very much aware of extremely hot days in the dry season while farmers (mean= 3.97, SD=0.88) indicated to be very aware, although the opinions of AEAs were varied from the mean (SD=1.04). Farmers being on the field always were expected to indicate such results on extremely hot days in the dry season. During one FGD session, AEAs confirmed their awareness of hot days in the dry season. The AEA indicated that: *"in the last 25 or so number of year, there's been considerable rise in temperature"*. (AEA2, a 53-year-old male extension agent). Available actual data from Mabe *et al.* (2014) indicate the mean temperature as high as 28.66°C in the dry season. The result of the study is consistent with the findings of Acquah and Annor-Frempong (2011), that most farmers in Ghana perceived an increase in temperature.

Table 6: Rice Farmers' AEAs and Researchers' Level of Awareness to Climate Change

Climate change variables	Farmers		AEAs		Researchers	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Extremely hot days in the dry season	3.97	0.88	4.25	1.04	4.37	0.88
Irregular rainfall pattern	3.95	1.00	4.48	0.63	4.54	0.71
Early end of rainfall	3.85	1.07	4.25	1.24	4.17	0.76
Long period of intense heat	3.81	0.92	4.03	0.85	4.08	1.08
Decrease in amount of rainfall	3.81	1.09	4.28	0.84	3.14	1.35
Reduction in flow of streams	3.65	1.07	4.23	0.73	4.11	0.91
New weeds which previously not found in the north now growing	3.60	0.97	3.42	1.30	3.11	1.49
Extremely cold days in the rainy season	3.56	0.95	3.52	1.09	3.37	1.12
Severe dry spells in the rainy season	3.48	1.02	3.58	1.29	3.58	1.30
Crops previously grown in the north difficult to survive	3.40	1.01	3.45	.99	2.53	1.12
Flooding annually	3.40	1.05	4.09	.81	3.61	1.44
Early onset of rainfall	3.29	1.18	3.80	.83	3.60	1.55
Increase in off-season rains	2.86	1.39	2.86	1.29	2.91	1.34
Weighted Mean ($\bar{X}$w)	3.59	1.05	3.86	.99	3.62	1.16

Scale: 1= Least aware, 2 = Less Aware, 3 = Fairly Aware, 4 = Very Aware, 5= Very Much Aware

Source: Field Survey, Abubakari Von (2019)

The study results also revealed AEAs (mean = 4. 48, SD = 0.63) and researchers' (mean = 4.54, SD = 0.71) were very much aware of the irregular pattern of rainfall; whereas farmers (mean =3.95, SD =1.00) were very aware of the phenomenon although opinions varied widely from the mean according to the SD. Furthermore, AEAs disclosed very much awareness of early end of rainfall (mean = 4.25, SD =1.24) and reduction in the flow of water bodies (streams) (mean= 4.23, SD=0.73) while farmers and researchers were very aware of early end of rainfall and reduction in flow of water bodies. The results of the study also showed AEAs (mean= 4.28, SD=0.85) were very much aware of a decrease in the amount of rainfall whereas farmers (mean= 3.81, SD=1.09) and researchers (mean= 3.14, SD=1.35) were very and moderately aware respectively. Farmers (mean=3.40, SD=1.01) and researchers (mean= 2.53, SD=1.12) expressed moderate awareness of crops that were growing well previously in the north but now finding it difficult to survive while AEAs ($\bar{X}$ =3.45, SD=0.99) were very aware of such occurrence. This statement was confirmed during a FGD. "*We've been known to produce so much millet, sorghum and yam, but these crops that used to thrive very well don't do that well when they're grown now*." (F1, 61 year-old rice farmer). Moreover, AEAs ($\bar{X}$ =4.09, SD=0.81) and researchers ($\bar{X}$ =3.61, SD=1.44) were very aware of the annual flooding of rice fields whiles farmers ($\bar{X}$ =3.40, SD=1.05) expressed moderate awareness of flooding of rice fields annually though researchers (1.44) and farmers (1.05) varied in their opinions.

Figure 3: A Flooded Rice Field at Tugu in the Tamale Metropolis

Table 7 shows the Kruskal Wallis test among respondents on the level of awareness of climate change. The results show that level of awareness of climate change did not differ between the three categories of respondents: X^2 (2) =4.36, Asymp. Sig =0.113, (p > 0.05) with a mean rank level of awareness score of 187.28 for farmers, 206.20 for researchers and 228.57 for AEAs.

The alternative hypothesis that there are significant differences between farmers, extension agents and researchers' on level of awareness of climate change in rice production therefore rejected.

Table 7: Kruskal Wallis Test among Respondents Level of Climate change Awareness

Stakeholders	n	Mean rank	Chi-Square	df	Asymp. Sig
Farmers	324	187.28	4.36	2	.113
Researchers	30	206.20			
AEAs	30	228.57			

Source: Field Survey, Abubakari Von (2019)

Demographic and Farm-Related Characteristics Associated with Farmers' Level of Climate Change Awareness

The relationship between demographic characteristics and farmers' level of consciousness of changes in climate change is presented in Table 8. The findings showed a low but positive association between the sex of farmers (r=0.121*; p< .05) and the awareness level of changes in climate. The results further indicated that males were more aware of climate change compared to females. These statements were confirmed during the FGDs. *"The male farmers are frequently in touch with extension agents who explain the climate change phenomena to them"* (F3, 49-year-old female rice farmer). *"Male farmers tend* *to attend training sessions where the concept of climate change is discussed in comparison to females"* (F6, 42-year-old male rice farmer). *"The time of training and meetings with AEAs are not conducive for the participation of female farmers and has contributed their low awareness compared to the males"* (F4, a 51-year-old male rice farmer). The results are similar to those of Opiyo, Wasonga Nyangito, Mureithi, Obando and Munang (2016), who reported that climate change awareness is higher in male-headed households than in female-headed households. However, Mubi, Zemba and Umar (2013) found no significant correlation between sex and awareness of climate change. Age, marital status, farming experience, land ownership and farm size did not relate significantly with awareness level of changes in climate. The result is similar to the study by Ajuang, Abuom, Bosire, Dida and Anyona (2016) in Kenya where there was a significant relationship between male farmers and awareness of a changing climate.

Table 8: Rice Farmers' Level of Awareness of Climate Change and Demographic and Farm-related Characteristics

Independent variables	Type of correlation	Correlation coefficient	Significance
Sex (1=Male, 0=Otherwise)	Point biserial	0.121*	0.032
Age	Pearson	-0.080	0.079
Marital status (1=Married, 0=Otherwise)	Point biserial	-0.033	0.558
Household size	Pearson	0.134*	0.016
Educational level	Spearman rank	0.179**	0.001
Farming experience	Pearson	0.007	0.451
Land ownership (1=Yes, 0=No)	Point biserial	0.055	0.329
Farm size	Pearson	0.090	0.053
Yield (bags)	Pearson	0.204**	0.001

Table 8 continued

Type of farming system (1=Continuous, 0=Fallowing	Point biserial	0.160**	0.004
Type of rice ecosystem (1= lowland, 0= Irrigation)	Point biserial	0.319**	0.000
Self-financing (1=Yes, 0 – Otherwise)	Point biserial	-.0192**	0.001

n = 324, p < 0.05*, p < 0.01**

Source: Field Survey, Abubakari Von (2019)

There was a low, positive and significant association between the size of the farmer's household (r=0.134 *; p <0.05) and the level of awareness of climate change. During an FGD session, a farmer indicated that "*a large household size provides more family members with opportunities for contact with other farmers, extension agents, and training sessions where issues relating to climate change was likely to be discussed*" (F7, a 61-year-old male rice farmer). This result agrees with the studies of Acquah (2011) and Mustafa *et al*. (2019) where positive relationships have been established between household size and awareness to climate change. A moderate, positive and significant relationship between the rice ecosystem type (r=0.319**; p <0.01) and level of awareness of climate change was observed. A farmer observed that: "*farmers cultivating in lowland areas require sufficient rainfall, therefore irregular rainfall, early onset and early end of rainfall have not gone undetected thereby increasing awareness of climate change*" (F5, 35-year-old male rice farmer).

Educational level (r=0.179**; p<0.01) was low, positive and significantly related to level of awareness of climate change. The result implies that highly educated farmers had a higher likelihood of awareness to changes in climate. It was indicated by a farmer that "t*hose of us with high educational* *level are able to access, read and learn about the climate change phenomena from the internet and books*" (F2, 45-year-old male rice farmer). Latif (2018) also noted a positive relationship between farmers' education and awareness of climate change. The finding, however, runs counter to the study by Mandleni and Anim (2011), which reported a significant but negative relationship between education and awareness to climate change in South Africa.

A low, positive and significant relationship was found between yield (r=0.204**; p<0.01) and farmers' awareness to climate change. During one of the FGD sessions, one farmer pointed out: *"Our awareness of climate change has increased the reality of the phenomenon and has also raised our awareness of imminent vulnerability. We then make efforts to reduce our vulnerability by using adaptation technologies which increases our yield"* (F8, a 64-year-old male rice). In addition, low, positive and significant relationship existed between type of farming system (r=0.160**; p<0.01) and climate change awareness. This statement made during the FGDs by a farmer attests to the quantitative result. "*We the farmers who have continuously cultivated rice on the same parcel of land have felt the greater than before effect of climate change, such as soil nutrient loss and soil erosion, which has been enhanced by high temperatures and floods"* (F11, a 58-year-old male rice farmer). Moreover, the results in Table 8 show a low, significant but negative relationship between farmers self-financing their production (r= -0.192**; p<0.01) and level of climate change awareness. A farmer indicated that those that are not self-financing are more aware of climate change. He indicated that "*with farmers who have had some sort of financial help from NGOs, the financial help usually* *came with training of which climate change was a component of the training. Hence they became more aware of changes in climate"* (F1).

AEAs Awareness of Climate Change Associated with Demographic and Work-Related Characteristics

Table 9 shows that sex, marital status, trainings attended, age, work experience, number of communities served, number of farms served and number of farmers served are not significantly related to the awareness level of changes in climate. Furthermore, no substantial relationships ($p>0.05$) existed between the class, rank, highest academic degree, type of rice variety recommended and level of awareness of climate change. This was due to the obvious devastating effects the change in climate had on agriculture and information obtained from the Ghana meteorological services rather than demographic and work-related characteristics. An AEA indicated that *"I have only been on the field for five years and have observed floods as well as early end of rainfall causing decreases in rice yields. Therefore, I don't need workshops to tell me climate change is happening"* (AEA4, a 43-year-old male extension agent). Another AEA stated that "*data is often collected from Ghana's meteorological services on climatic conditions, such as rainfall, to notify farmers about the best time to plant. This data gives us a good understanding of how the climate is slowly changing*" (AEA5, a 52-year-old male extension agent). This results is similar to that of Abegaz and Wims (2015) in Ethiopia who observed that no significant relationship existed between climate change awareness of extension agent and their work experience, levels of education and prior exposure to training opportunities.

Table 9: AEAs Awareness of Climate Change and Demographic and Work-related Characteristics

Variable	r	p-value	Type of Correlation
Sex (1=Male, 0=Otherwise)	0.089	0.640	Point biserial
Marital status(1=Married,0=Otherwise)	0-.012	0.948	Point biserial
Attended trainings (0=No, 1=Yes)	0.122	0.556	Point biserial
Age	0.062	0.745	Pearson
Work experience	0.165	0.383	Pearson
No. of communities served	0.166	0.380	Pearson
No. of farms served	-0.110	0.564	Pearson
No. of farmers served	0.087	0.648	Pearson
Class	-0.134	.0479	Spearman rank
Rank	0.103	0.588	Spearman rank
Highest academic degree	0.039	0.839	Spearman rank
Type of rice variety recommended	-0.203	0.281	Point biserial

n=30 $p<0.05$*
Source: Field Survey, Abubakari Von (2019)

Researchers Awareness Climate Change Associated Demographic and Work-Related Characteristics

There was a significant, moderate and positive relationship between the attendance of researchers in training ($r = 0.487$**, $p < 0.05$) and the level of awareness of climate change. Researchers reported that the training they attended usually had topics relating to climate change. A researcher reported that "*I have attended workshops about the effect changes in climate has on agriculture and also strategies for increased yield which has considerably improved my awareness of climate change in this region*" (R2, 40 year-old male researcher).

However, sex, age, work experience, marital status, highest academic degree and job position of researchers had no significant relationships with level of awareness of climate change.

Table 10: Researchers Awareness of Climate Change and Demographic and Work-related Characteristics

Variable	r	p-value	Type of Correlation
Sex (1=Male, 0=Otherwise)	-0.275	0.141	Point biserial
Age	0.055	0.787	Pearson
Work experience	0.266	0.164	Pearson
Marital status (1=Married, 0=Single)	-0.095	0.616	Point biserial
Highest academic degree	0.286	0.126	Spearman rank
Training attended	0.487**	0.006	Point biserial
Job position	-0.325	0.080	Spearman rank

n = 324 $p < 0.01$**
Source: Field Survey, Abubakari Von (2019)

Farmers, AEAs and Researchers Perceived Effects of Climate Change on Rice Production

Results presented in Table 11 indicated that farmers, agricultural extension agents (AEAs) and researchers agreed that climate change has a high effect on rice production as shown by weighted means of 3.82, 4.04 and 3.90 respectively for farmers, AEAs and researchers. However, the opinion of farmers (SD = 1.33) and that of researchers (SD = 1.03) greatly varied from the mean compared to AEAs (SD = 0.93).

Specifically, AEAs and researchers had very high perception that climate change is responsible for low yields in rice (AEAs ($\bar{X} = 4.27$), researchers ($\bar{X} = 4.43$), changes in planting time (AEAs ($\bar{X} = 4.50$), researchers ($\bar{X} = 4.72$), soil erosion (AEAs ($\bar{X} = 4.31$), researchers ($\bar{X} = 4.27$). The results also showed that AEAs and researchers had very high perception on climate change as being responsible for changed duration of rainy season (AEAs ($\bar{X}$ = 4.48), researchers ($\bar{X}$ = 4.46) and reduced length of growing season (AEAs ($\bar{X}$ = 4.40), researchers ($\bar{X}$ = 4.43)). However, farmers have high perception that climate change is accountable for low yields in rice ($\bar{X}$ =4.14), changed time of planting ($\bar{X}$ =3.99), soil erosion ($\bar{X}$ =3.93), changed duration of rainy season ($\bar{X}$ =3.89) and reduced length of growing season ($\bar{X}$ =3.79).

Farmers, AEAs and researchers also have high perception that climate change influenced soil nutrient loss (farmers ($\bar{X}$ = 4.03), AEAs ($\bar{X}$ = 4.18), researchers ($\bar{X}$ = 4.24)), widespread of new crop pests (farmers ($\bar{X}$ = 3.98), AEAs ($\bar{X}$ = 3.81), researchers ($\bar{X}$ = 4.12)) and poor seed germination (farmers ($\bar{X}$ = 3.95), AEAs ($\bar{X}$ = 3.45), researchers ($\bar{X}$ = 4.00)). In addition, farmers, AEAs and researchers have a high perception that changes in climate resulted in withering of seedling (farmers ($\bar{X}$ = 3.55), AEAs ($\bar{X}$ = 3.78), researchers ($\bar{X}$ = 3.64)) and reduced rice quality (farmers ($\bar{X}$ = 3.55), AEAs ($\bar{X}$ = 3.87), researchers ($\bar{X}$ = 3.52)). The opinions of AEAs (SD =1.11, 1.22) and researchers (SD =1.23, 1.14) varied from the mean on the perceptions of widespread of new crop pests and poor seed germination, respectively.

Table 11: Farmers, AEAs and Researchers Level of Perceived Effects of Climate Change on Rice Production

Effect of climate change	Farmers		AEAs		Researchers	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Low rice yields	4.14	0.89	4.27	0.83	4.43	0.79
Loss of soil nutrients	4.03	0.88	4.18	0.73	4.24	0.92
Changes in times of planting	3.99	0.87	4.50	0.69	4.72	0.54

Table 11 continued

Widespread new crop pests	3.98	0.88	3.81	1.11	4.12	1.23
Drying up of water bodies which previously never dried up	3.96	0.91	4.31	0.85	3.52	1.45
Poor seed germination	3.95	3.09	3.45	1.22	4.00	1.14
Soil erosion	3.93	0.89	4.31	0.76	4.27	0.87
Changes duration of rainy season	3.89	0.93	4.48	0.73	4.46	0.76
Reduction in length of growing season	3.79	0.87	4.40	0.64	4.43	0.73
Withering of seedlings	3.55	3.35	3.78	0.95	3.64	1.15
Reduced rice quality	3.55	1.04	3.87	1.08	3.52	1.19
Pesticide no longer effective	3.51	1.11	3.76	1.30	2.90	1.33
Lodging of rice plant	3.34	1.13	3.45	1.14	2.47	1.33
Weighted mean ($\bar{\boldsymbol{X}}$**w**)	3.82	1.33	4.04	.93	3.90	1.03

Scale: 1= Least effect, 2=Less effect, 3= Moderate effect, 4= High effect, and 5=Very high effect

Source: Field Survey, Abubakari Von (2019)

It was also revealed from the study that farmers ($\bar{X} = 3.51,\ SD = 1.11$)and AEAs ($\bar{X} = 3.76, SD = 1.30$) perceived highly that climate change was responsible for pesticides no longer being effective against pests, while the perceptions of researchers ($\bar{X} = 2.90,\ SD = 1.13$) were moderate even though the opinions of farmers, AEAs and researchers differed from the mean. AEAs ($\bar{X} = 3.45, SD = 1.14$) highly perceived climate change had an effect on rice lodging, while farmers ($\bar{X} = 3.34, SD = 1.13$) and researchers ($\bar{X} = 2.47, SD = 1.33$) had moderate perceptions, although the opinions of farmers, AEAs and researchers varied widely from the mean.

The results are in consonant with the study conducted by Acquah *et al.* (2011) on farmers' perceptions of the impact of climate change on food crop production in the Ketu North district in the Volta Region of Ghana. That study concluded that climate change resulted in increase in weeds and pests, decrease in crop quality, decline in the crop yield, a decrease in soil resource quality and seedling drying after germination. Furthermore, the results are akin to the report by Idoma and Mamman (2016) which stated that the most severe effects of climate change were crop failure and poor yields. Additionally, Emodi and Bonjoru (2013) in Nigeria indicated that low yields and pesticide ineffectiveness were perceived by farmers as a serious effect of climate change on rice production. The findings of Hunink *et al.* (2014), Dadzie, *et al.* (2012) and Johnston *et al.* (2009) that, yield losses as well as pests and disease incidence were direct and indirect effects of climate change are also comparable to results of the study. The outcome of the study is similar with that of Sabatier *et al.* (2014), who found that post-emergency herbicides had an effect on soil erosion.

Statements from respondents during the FGD sessions and interviews attest to the effect of climate change on rice production. A researcher noted that *"the increased incidence and severity of diseases such as rice blast and yellow moth virus along with the famous weed known as wild rice are due to temperature rises that favor the growth of these pests and diseases*" (R1, a 58-year-old male researcher). Another researcher indicated that "*increased temperatures affect yield as rice plant spikelets become sterile and reduce grain filling thereby, reducing yield and quality of rice*" (R2). It was further indicated that "*we used to have these diseases but the increase in temperature has just worsened the situation*". R1 recounted that *"drought results in delayed flowering time, reduced leaf growth and reduced photosynthesis resulting in* *low rice yields"*. One farmer also revealed that "*climate change reduced soil nutrients due to leaching, which invariably resulted in low yields"* (F1). "*The use of agrochemicals as a result of widespread pest infestation affects the soil structure and causes erosion"* (F9, 64-year-old male rice farmer).

Since the data on climate change effect on the production of rice violated the normality assumption, Kruskal-Wallis H test was conducted to establish statistically significant differences in the perceived effect of climate change on rice production of the farmers AEAs and researchers.

Table 12: Stakeholders Perception on Climate Change Effect on Production of Rice

Stakeholders	n	Mean rank	Chi-Square	df	Asymp. sig.
Farmers	324	185.64	8.333	2	0.016
Researchers	30	220.65			
AEAs	30	238.48			

Source: Field Survey, Abubakari Von (2019)

Results in Table 12 indicated that there was a statistically significant difference in the effect of climate change on rice production between the different actors, X^2 (2)=8.333, p=0.016, with a mean rank 185.64 for farmers, 220.65 for researchers and 238.48 for AEAs.

A post-hoc Mann-Whitney U test was performed to determine where differences in the effects of climate change on rice production existed between farmers, AEAs and researchers. The results in Table 13 showed that climate change effect on production of rice among AEAs (median = 4.05) was statistically significantly higher than that of farmers (median = 3.85), U = 2682.5, z = -3.834, r = .204 and p < .000. However, the magnitude of the differences between farmers and AEAs on the effect of climate change on rice production was small on the basis of the Cohen (1988) criteria.

During the FGD sessions with AEAs, it was revealed that “AEAs reading materials on climate change effect on the production of rice linking the information with what is happening on farmers’ fields contributed to their higher perceived effect”. Another AEA indicated that “*observing climatic patterns and the cumulative losses of farmers as a result of climate change has increased our perception on the effect of climate change on rice production*” (AEA3, 46-year-old male extension agent). This suggests that AEAs observed higher effects of climate change on rice production than farmers, since AEAs, besides witnessing and even living their experiences through farmers' eyes, also had knowledge of what caused the effects.

Table 13: Farmers and AEAs Perceived Climate Change Effect on the Production of Rice

Stakeholders	N	Median	Mean rank	U	Z	r	p
Farmers	324	3.85	170.78	2682.5	-3.834	.204	0.000
AEAs	30	4.05	249.50				

U = Mann-Whitney U test statistic, Z= absolute standardized test statistic, r = effect size, $p < 0.05$

Source: Field Survey, Abubakari Von (2019)

Table 14 showed that the effect of climate change on rice production in researchers (3.92) was not significantly different from that of farmers (median = 3.83), U = 3937.5, z = -2.521, r = .013 and p > .817. No significant differences were observed for farmers and researchers because, while farmers had experience-based working knowledge of the effects of climate change, researchers had deeper knowledge focused on what triggered or exacerbated these effects (F2).

Table 14: Farmers and Researchers Perceive Climate Change Effect on the Production of Rice

Stakeholders	N	Median	Mean rank	U	Z	p
Farmers	324	3.83	174.65	3937.5	-2.521	0.817
Researchers	30	3.92	179.50			

U = Mann-Whitney U test statistic, Z= absolute standardized test statistic, r = effect size, $p < 0.05$

Source: Field Survey, Abubakari Von (2019)

Results in Table 15 indicated that the effect of climate change on rice production in AEAs (median = 4.05) was not statistically significantly higher than in researchers (median = 3.90), U = 253.50, z = -2.005, r = .026 and p < .045, and the magnitude of differences between AEAs and researchers in the effect of climate change on rice production was small based on the Cohen (1988) criteria. An AEA, during the FGD stated "*I am not surprised by this result because both AEAs and researchers have seen the reality of the effect of climate change on the field even though we AEAs see these effects more. Also, researchers and us AEAs also have the opportunity to read wide on the effect of climate change and relate it to what is happening on farmers' fields.* This suggest that climate change effect on the production of rice were perceived similarly by researchers and AEAs.

Table 15: Researchers and AEAs Perceived Climate Change Effect on the Production of Rice

Stakeholders	N	Median	Mean rank	U	Z	r	p
Researchers	30	3.90	23.14	253.50	-2.005	.026	0.045
AEAs	30	4.05	31.26				

U = Mann-Whitney U test statistic, Z= absolute standardized test statistic, r = effect size, $p < 0.05$

Source: Field Survey, Abubakari Von (2019)

According to the study, AEAs demographic and work-related characteristics had no influence on their awareness of climate change which contradicts what is stated in the conceptual framework. Only the trainings that researchers attended had a relationship with their awareness of climate change. Farmers' sex, household size, yield, type of farming system, type of rice ecosystem and self-financing rice production on the other hand, had a relationship with climate change awareness which falls in line with the conceptual framework.

CHAPTER FIVE

RECOMMENDATION, UTILIZATION AND EFFECTIVENESS OF RICE PRODUCTION TECHNOLOGIES IN ADDRESSING CLIMATE CHANGE

Introduction

The Chapter presented and discussed results on the extent of recommended and used climate change adaptation rice production technologies. The effectiveness of adaptation technologies in addressing climate change in rice production in the Northern Region is also discussed.

Hard Rice Adaptation Technologies Recommended to Address Changes in Climate

Table 16 indicate that hard climate change adaptation technologies were sometimes recommended by AEAs and researchers as shown by weighted means (AEAs($\bar{X}$w $= 3.13$) and researchers ($\bar{X}$w $= 3.39$)). The AEAs ($\bar{X} = 3.45, SD = 0.69$) and researchers ($\bar{X} = 3.75, SD = 0.44$) indicated early maturing varieties of rice were often recommended to farmers to adapt to climate change. Also, the treatment of seeds with fungicides was sometimes recommended by AEAs ($\bar{X} = 2.72$) and researchers ($\bar{X} = 2.61$) though the opinions of AEAs ($SD = 1.13$) and researchers ($SD = 1.17$) on the treatment of seeds with fungicides widely varied from the mean. Researchers ($\bar{X} = 3.81, SD = 0.40$) often recommended pest/disease resistant varieties while AEAs ($\bar{X} = 3.18, SD = 0.86$) sometimes recommended these pest resistant varieties.

Table 16: Hard Rice Adaptation Technologies Recommended by AEAs and Researchers to Farmers

Hard Technologies	AEAs (n = 30)			Researchers (n = 30)		
	f	$\bar{X}$	SD	f	$\bar{X}$	SD
Early maturing rice varieties	29	3.45	0.69	28	3.75	0.44
Pest/disease resistant varieties	28	3.18	0.86	26	3.81	0.40
Treatment of seeds with fungicides	18	2.72	1.13	26	2.61	1.17
Composite Mean		3.13	0.89		3.39	0.67

Scale: 1 = Very rarely, 2 = Rarely, 3 = Sometimes, 4 = Often, 5 = Always
Source: Field Survey, Abubakari Von (2019)

During the FGDs and interviews, AEAs and researchers explained why the hard technologies were recommended. A researcher indicated that two varieties of rice, "*AGRA and Gbewaa (Jasmine) are often recommended to farmers because they have superior grain quality, early maturation and are high yielding which was necessary in the face of climate change*" (R3, 54-year-old male researcher). He also pointed out "*they have tolerance to diseases such as blast, iron toxicity and rice yellow mottle virus*" (R3). Another researcher also recounted that "*AGRA and Gbewaa have early to intermediate maturity days (120/115 days hence its recommendation*". It was however lamented that "*older varieties such as 'Mandii', which is resistant to wild rice and 'Degan' which grows tall and thus able to survive in deep valleys during prolonged flooding are no longer recommended due to its long maturation, low yield, and inferior grain quality*" (R1). An AEA stated that "*seed treatment with fungicides is only sometimes recommended for farmers who use their own rice seeds which are prone to fungal infection because we (AEAs) want to promote the purchase and use of certified seeds from MoFA and SARI* *which are more viable as well as disease and pest resistant"* (AEA7, 36-year-old male extension agent).

Soft Rice Adaptation Technologies Recommended by AEAs and Researchers to Address Changes in Climate

Weighted means of extent of recommended soft adaptation technologies in Table 17 showed AEAs ($\bar{X}$w = 2.89) and researchers ($\bar{X}$w = 2.91) sometimes recommended soft technologies, with the views of AEAs (SD = 1.00) varying considerably from the mean. Soft adaptation technologies often recommended by researchers were row planting ($\bar{X}$ = 3.70), right amount of fertilizer application ($\bar{X}$ = 3.71), inorganic-organic fertilizer integration ($\bar{X}$ = 3.70), split application of inorganic fertilizer ($\bar{X}$ = 3.57) and application of inorganic fertilizer to crops root zone ($\bar{X}$ = 3.60). The results also revealed that researchers ($\bar{X}$ =2.68) sometimes recommended the creation of drainage channels while AEAs ($\bar{X}$ =3.41) often recommended the same technology. AEAs indicated row planting ($\bar{X}$ = 3.33), right application of fertilizer ($\bar{X}$ = 3.19), split application of inorganic fertilizer ($\bar{X}$ = 3.35) and applying inorganic fertilizer as close to the crops root zone ($\bar{X}$ = 2.96) were sometimes recommended to farmers. However, AEAs rarely recommended inorganic-organic fertilizer integration ($\bar{X}$ = 2.44) to their clientele.

The results also highlighted that AEAs and researchers sometimes recommended change in planting dates (AEA; $\bar{X}$ =3.32, researchers; $\bar{X}$ =3.24) water harvesting (AEA; $\bar{X}$ =2.96, researchers; $\bar{X}$ =3.24), bund construction (AEA;

$\bar{X}$ =3.17, researchers; $\bar{X}$ =3.20), fallowing (AEA; $\bar{X}$ =2.56, researchers; $\bar{X}$ =2.57) and zero/minimum tillage (AEA; $\bar{X}$ =2.60, researchers; $\bar{X}$ =2.48).

Table 17: Soft Rice Adaptation Technologies Recommended by AEAs and Researchers to Farmers

Soft technologies	AEAs (n = 30)			Researchers (n = 30)		
	f	$\bar{X}$	SD	f	$\bar{X}$	SD
Change of planting dates	25	3.32	0.90	25	3.24	0.78
Row planting	30	3.33	0.76	23	3.70	0.56
Water harvesting	27	2.96	0.98	25	3.24	0.88
Bund construction	30	3.17	1.02	25	3.20	0.91
Creation of drainage channels	22	3.41	0.91	22	2.68	0.99
Fallowing rice farms	18	2.56	1.04	12	2.57	0.98
Crop insurance subscription	13	2.38	1.19	21	2.33	1.15
Rice-legume intercrop	9	2.56	1.13	18	1.83	0.86
Afforestation of rice farm	6	2.33	1.37	9	1.56	0.88
Right amount of fertilizer application	26	3.19	0.85	24	3.71	0.55
Zero/minimum tillage on rice farm	15	2.60	1.05	23	2.48	1.20
Inorganic-organic fertilizer integration	18	2.44	0.92	27	3.70	0.54
Split-application of inorganic fertilizer	26	3.35	0.85	28	3.57	0.63
Application of inorganic fertilizer to crop's root zone	23	2.96	0.93	15	3.60	0.63
Weighted mean ($\bar{X}$**w**)		2.89	1.00		2.91	0.84

Scale: 1 = Very rarely, 2 = Rarely, 3 = Sometimes, 4 = Often, 5 = Always

Source: Field Survey, Abubakari Von (2019)

On zero/minimum tillage, the opinions of AEAs (SD=1.05) and researchers (SD=1.20) deviated from the mean, while AEAs opinions deviated from the mean on bund construction (SD=1.02) and fallowing (SD=1.04) respectively.

Furthermore, AEAs ($\bar{X}$ =2.56) sometimes recommended rice-legume intercrop and researchers ($\bar{X}$ =1.83) rarely recommended this technology, despite AEAs divergent opinions (SD=1.13) from the mean.

Statements during the FGD and interviews attest to the extent of soft adaptation technologies recommended by AEAs and researchers. An AEA stated that "*change in planting dates was always recommended due to the change in time of rainfall"* (AEA4). It was indicated by another AEA that *"the washing away of the top soil caused by floods decreases soil fertility and thus row planting is often recommended to avoid overcrowding of rice plants by reducing nutrient competition from the already nutrient-deficient soil"* (AEA8, 39-year-old male extension agent). R3 opined that "*bund construction is always recommended particularly in lowland areas, to retain water and ensure that the soil remains saturated for rice growth when rainfall is low*". AEA1 also specified that "what *we usually recommend for farmers is the reduction in their farm sizes so that they can employ good agronomic practices to the latter and increase yield by way of adaptation"*. AEA5 indicated that "we recommend *harrowing and ploughing across slopes which has several advantages in adaptation to climate change such as controlling run-off water, erosion and maintaining soil structure during floods*". Furthermore, it was noted by AEA3 that *"farm afforestation and fallowing are rarely recommended because farmlands are gradually being converted for residential and commercial purposes leading to the decline of agricultural land, particularly in urban areas"*. R2 also highlighted that "*zero/minimum tillage is sometimes recommended because even though it prevents soil erosion, enhances* *soil quality, preserves soil moisture and increases soil organic matter that is lost floods caused by climate change, we don't think it is our duty to recommend it. Our focus is on recommending the technologies that are developed by us*". AEAs and researchers clarified that the rare recommendation of subscription to crop insurance was due to the fact that most of them had no knowledge and training of what crop insurance was all about.

The findings are consistent with the research by Olorunfemi, Olorunfemi and Oladele (2019) in Nigeria that extension agents recommended zero / minimum tillage, fallowing, organic manure use, contour-cropping across slopes and afforestation. The findings are also similar to the study by Afful (2016) which showed that extension agents in South Africa promoted zero tillage and manure usage to farmers. In addition, the results are also akin to the findings of AGRA (2014), which stated that zero tillage was important to the efficiency of farm water usage as it led to increased soil moisture, organic soil quality and soil structure.

Nonetheless, the results on change in planting dates contradict the findings of Olorunfemi *et al*. (2019) in Nigeria, where extension agents have rarely encouraged changes in planting dates, but similar to the results that crop insurance is sparingly promoted by extension agents.

Use of Hard Rice Technologies to Adapt to Changes in Climate

It was revealed that hard adaptation rice production technologies were often ($\bar{X}\text{w} = 4.12, \text{SD} = 0.86$) used by farmers. The results further revealed that early maturing varieties were always ($\bar{X}\text{w} = 4.29, SD = 0.82$) used by farmers. In addition, seeds treated with fungicides ($\bar{X}\text{w} = 4.10$) and pest/disease resistant varieties ($\bar{X}$w = 3.96) have also often been used by farmers to adapt to climate change

Table 18: Use of Hard Rice Technologies to Adapt to Climate Change

Hard technologies	f	$\bar{X}$	SD
Early maturing varieties	306	4.29	0.82
Treated seeds with fungicides	39	4.10	0.85
Pest/disease resistant varieties	55	3.96	0.90
weighted mean ($\bar{X}$**w**)		4.12	0.86

Scale: 1=Very rarely, 2 = Rarely, 3 = Sometimes, 4 = Often, and 5 = Always

Source: Field Survey, Abubakari Von (2019)

Statements from respondents during the FGDs sessions attest to the use of hard technologies in adapting to climate change. A farmer said that "*early maturing varieties have become essential with the change in the rainy season and you won't get anything if you don't plant these varieties because the rains will stop early before the rice plant fully matures*" (F10, 50-year-old female rice farmer). F5 pointed out that "*AGRA and Gbewaa mature early and have high grain quality that we use to respond to climate change*". A farmer also indicated that *"when rice seeds is treated with fungicides, it prevents yellow spots (diseases) that are favored by high temperatures from appearing on the rice plant*" (F14, 44-year-old male rice farmer). The result on early maturing varieties is consistent with the study by Mbah and Ezeano (2016) which reported that farmers in the State of Benue, Nigeria, use early maturing rice varieties to adapt to climate change.

Use of Soft Rice Technologies to Adapt to Climate Change

Weighted mean of the extent of use of soft climate change adaptation rice production technologies indicates that farmers often ($\bar{X}$w = 4.00, SD = 0.94) use soft technologies to adapt to climate change. Specifically, change in planting dates ($\bar{X}$=4.42) and bund construction ($\bar{X}$ = 4.39) were always used by farmers.

Figure 4: A Bunded Rice Field at Cherifoyili in the Nanumba North District

The study also revealed that rain water harvesting ($\bar{X}$=4.13), creation of drainage channels ($\bar{X}$=4.11), afforestation ($\bar{X}$=4.07), row planting ($\bar{X}$=4.07), right amount of fertilizer application ($\bar{X}$=4.05) and inorganic-organic fertilizer integration ($\bar{X}$=4.03) were often used for adaptation by farmers.

Figure 5: Rice Planted in Rows

It was revealed in Table 19 that crop insurance ($\bar{X} = 3.93$), rice-legume intercrop ($\bar{X} = 3.86$), split fertilizer application ($\bar{X}$=3.81), application of inorganic fertilizer to crop's root zone ($\bar{X}$=3.75), zero/minimum tillage ($\bar{X}$=3.61) and fallowing of farms ($\bar{X} = 3.55, SD = 1.03$) were often used for adaptation by farmers. However, farmers' opinions on crop insurance($SD = 1.18$), rice-legume intercrop($SD = 1.03$) and fallowing of rice farms($SD = 1.03$) varied widely from their respective means.

Table 19: Extent of Use of Soft Adaptation Rice Production Technologies by Farmers

Soft Technologies	f	$\bar{X}$	S.D
Change of planting dates	78	4.42	0.73
Bund construction	178	4.39	0.84
Rain water harvesting	276	4.13	0.80
Creation of drainage channels	79	4.11	0.96
Rice farm afforestation	41	4.07	0.96
Row planting	139	4.07	0.97
Right amount of fertilizer	201	4.05	0.89
Inorganic-organic fertilizer integration	68	4.03	0.90
Crop insurance subscription	31	3.93	1.18
Rice-legume intercrop	37	3.86	1.03
Split application of inorganic fertilizer	103	3.81	0.99
Application of inorganic fertilizer to crop's root zone	132	3.75	0.89
Zero/minimum tillage on rice farm	36	3.61	0.84
Fallowing rice farms	67	3.55	1.03
Weighted mean ($\bar{X}$w)		4.00	.94

Scale: 1=Very rarely, 2 = Rarely, 3 = Sometimes, 4 = Often, and 5 = Always

Source: Field Survey, Abubakari Von (2019)

Statements during the FGDs sessions reflect the extent to which soft technologies are used for adaptation to climate change. Most of the farmers indicated that they have had to adjust the dates of planting of rice to align to the continuous shift in the time of rainfall. F2 noted that "*with the way the time of rainfall is changing, if I don't alter my planting time, I will harvest nothing in the end*". F8 said, "*most of us farmers have never heard of crop insurance*", while another farmer said, "*I've heard of crop insurance, but I don't really know what it is or what it does so how can I use such a technology*" (F12, 55-year-old male rice farmer). In addition, F9 also reported that "*typically the intercropping of rice is done with maize, but when it is cultivated on lowlands and floods occur, the water often becomes too much for the maize plant and it dies off* ". F6 also clarified that "*I fallow my rice farms to improve soil fertility, which is lost due to flooding and erosion, but most of the time I'm forced to fallow my rice farms not because of the benefits I will reap from doing so, but because there's no money for production in that particular crop season*". Furthermore, F14 disclosed that "*split application of fertilizer is done to minimize the amount of fertilizer that is washed away by heavy rains and floods*". F7 stated that "*our soils already have low fertility and, combined with erosion caused by heavy rainfall, the situation has worsened, so I practice rowing planting on my farm because I want every rice plant to get the maximum nutrient requirement from the soil*". F3 reported that "*I harrow my farm after ploughing to help loosen the soil to allow more drainage and aeration because the soil is typically compacted as a result of flooding*". He also pointed out that "*because of climate change, it is important for my farm size to rely on the money available for production. It is to ensure that I buy sufficient inputs and apply suitable technologies that will help to cope with climate change and increase the yield on my farm*". The farmers also stated that inorganic fertilizers were used because of low soil fertility in the area but also organic manure was also mixed especially in acidic soils.

The results of the change in planting dates and use of inorganic fertilizers confirm the findings of Mensah (2018), which showed that most farmers changed planting dates and used chemical fertilizers to respond to climate change. Again, the result on the fallowing of land is consistent with the finding of Mensah (2018) that only a few rice farmers performed fallowing to respond to the changes in climate. The finding on bund construction is also parallel to the study of Alhassan, Osei-Asare, Kurwornu and Shaibu (2018), who found that over 70 percent of smallholder women rice farmers in the northern region of Ghana have created bunds in their farms to adapt to climate change. This is also similar to the Arimi study (2014) which found that over 85 per cent of Nigeria's rice farmers have never been covered by crop insurance. Moreover, the rare use of crop insurance and inter-cropping in the results of the study is consistent with the UNFCCC (2006b) which reported that soft technologies, such as insurance schemes and inter-cropping by farmers in sub-Saharan Africa, are low and relatively new to farmers.

Effectiveness of Adaptation Technologies in Addressing Climate Change

The outcomes of adaptation activities on rice farmers was used as a measure of effectiveness of rice adaptation technologies.

Effectiveness of Hard Adaptation Technologies in Addressing Climate Change

The results indicated that hard technologies used in were moderately effective (Weighted mean=$3.19, SD = 0.82$). The early maturing varieties were shown to be effective ($\bar{X} = 3.45, SD = 0.71$) in adapting to climate change for farmers. Treatment of rice seeds with fungicides ($\bar{X} = 3.15, SD = 0.84$) and use of pest resistant varieties ($\bar{X} = 2.96, SD = 0.90$) were found to be moderately effective. The result on early maturing varieties is consistent with the findings of Zanmassou (2017) whose study found early maturing seeds effective in adapting to climate change in Northern Benin.

Table 20: Farmers Perceived Effectiveness of Hard Technologies to Adapt to Climate Change

Hard technologies	f	$\bar{X}$	SD
Early maturing rice varieties	306	3.45	0.71
Treatment of rice seeds with fungicides	39	3.15	0.84
Pest resistant varieties	55	2.96	0.90
Weighted Mean ($\bar{X}$w)		3.19	0.82

Scale: 1= Negligibly effective, 2 = Lowly effective, 3 = Moderately effective, 4 = Effective, and 5 = Highly effective
Source: Field Survey, Abubakari Von (2019)

Farmers, AEAs and researchers confirmed these results signifying the effectiveness of hard adaptation technologies in adapting to climate change. F5 explained that *"the improved varieties such as AGRA and 'Gbewaa' from SARI is high yielding but you need to make time for weeding and applying fertilizer at the right time"*. F6 also indicated that *"even though the improved varieties are high yielding and effective, we still cultivate a bit of the older varieties such as 'mandi' and 'degang' for home consumption because when the improved varieties are prepared by our wives, they are usually soggy"*. Researchers asserted that improved varieties released were high yielding especially AGRA and Gbewaa (Jasmine). R2 gave details that *"these two varieties can yield averagely between 7.2-7.6 t/ha compared to the average yield of 2.5 t/ha of farmers' varieties. Moreover, they have good grain quality, tolerant to drought and resistant to some common diseases and pest of rice"*. Researchers were however of the view that no one variety could resolve all climate change issues. Nonetheless, they declared that no variety tolerant to floods had been developed. However, all farmers established that no weedicide was effective in eradicating 'wild rice' a notorious weed on the farms. Although farmers had no data to show the extent of damage caused by 'wild rice,' their experiences with yield losses associated with 'wild rice' was enough evidence. F8 detailed that *"when 'wild rice' invades your rice farm just forget about it because no matter the type and amount of weedicide you use the rice farm cannot be reclaimed"*. Researchers also indicated further that no weedicide had been effective in controlling the notorious wild rice. R1 highlighted that "*if the seed unit of SARI finds one seed of wild rice in a farmer's seeds, they will reject it because it spreads quickly and dominates rice fields. All the selective chemicals for rice have not been successful in eliminating it'*.

Effectiveness of Soft Adaptation Technologies in Addressing Climate Change

Weighted mean of effectiveness revealed that soft technologies were moderately effective ($\bar{X}$w $= 3.04, \mathrm{SD} = 0.90$) in adapting to climate change. Results in Table 21 indicated that bund construction ($\bar{X} = 3.39$), change of planting dates ($\bar{X} = 3.34$), organic-inorganic fertilizer integration ($\bar{X} = 3.22$), row planting ($\bar{X} = 3.21$), waterway creation ($\bar{X} = 3.20$) and rainwater harvesting ($\bar{X} = 3.18$) were moderately effective in adapting to climate change. Also, right amount of fertilizer Application ($\bar{X} = 3.14$), application of inorganic fertilizer to crop's root zone ($\bar{X} = 3.02$) and split application of inorganic fertilizer ($\bar{X} = 2.99$) were moderately effective in climate change adaptation. The findings further showed that rice-legume intercrop ($\bar{X} = 2.97$), crop insurance subscription ($\bar{X} = 2.90$), rice farm afforestation ($\bar{X} = 2.80$) and fallowing rice farms ($\bar{X} = 2.66$) were moderately effective in adapting to climate change even though farmers opinions varied widely from the means of rice-legume intercrop, crop insurance and fallowing of rice farms. However, zero/minimum tillage on rice farm ($\bar{X} = 2.56$) was lowly effective in climate change adaption. The findings of the study are similar to that of Zanmassou (2017) who had found soil and water management strategies to be effective in assisting farmers to adapt to climate change. However, the results contradict the finding of Muthelo, Owusu-Sekyere and Ogundej (2019) that insurance schemes were very effective in enabling farmers adapt to climate change in South Africa.

Table 21: Farmers Perceived Effectiveness of Soft Technologies to Adapt to Climate Change

Soft adaptation technologies	f	$\bar{X}$	SD
Bund construction	178	3.39	0.84
Change of planting dates	276	3.34	0.77
Organic-inorganic fertilizer Integration	68	3.22	0.79
Row planting	139	3.21	0.89
Waterway creation	79	3.20	0.87
Rain water harvesting	78	3.18	0.78
Right amount of fertilizer Application	201	3.14	0.88
Application of inorganic fertilizer to crop’s root zone	132	3.02	0.96
Split application of inorganic fertilizer	103	2.99	0.95
Rice-legume intercrop	37	2.97	1.09
Crop insurance subscription	30	2.90	1.14
Rice farm afforestation	41	2.80	0.86
Fallowing rice farms	62	2.66	1.05
Zero/minimum tillage on rice farm	36	2.56	0.77
Weighted mean ($\bar{X}$w)		3.04	0.90

Scale: 1= Negligibly effective, 2 = Lowly effective, 3 = Moderately effective, 4 = Effective, and 5 = Highly effective
Source: Field Survey, Abubakari Von (2019)

During FGDs and interviews with farmers, AEAs and researchers, it was revealed that:

"*Before I started receiving information on bund construction and the need to change date of planting, my yield was usually 2bags or 0.41/ha but after adopting these technologies, my minimum is 5bags/0.41ha"* (F2). AEA4 observed that *"when information on fertilizer use is adopted, it helps rice crops to adapt to climate change. This is because, fertilizers are effective in root and leaf development, which helps to increase yield. Furthermore, farms without irrigation when bunded allow crops to adapt to climate change by retaining rainwater for plant growth and subsequently increasing yield"*. In addition, F12 indicated that "*the construction of bunds and waterways are successful in adapting to climate change, as water is kept in the rice fields and permitted to flow out of the farms when the water is no longer required*". AEA1 indicated that "*farmers have complained about the ineffectiveness of 20:20:20 in adjusting to climate change due to its failure to increase soil fertility and yield*". Researchers rebutted that inorganic fertilizers such as NPK, sulphate of ammonia and urea were effective in replenishing the nutrients which were mined the previous season as a result of flooding but should be applied appropriately. R3 explained that "*urea, which has now been pelleted and applied through the deep placement method combined with bund technology, has been shown to increase yields by 40 percent and to adapt effectively to climate change by delivering nutrients to the root zone in a more reliable and timely manner as a result of poor fertility caused by flood-induced leaching"*. R1 noted that "*changing rice planting dates to take advantage of rainfall* *is very successful in adjusting to climate change*". He also revealed that "*harvesting and using rainwater during dry spells is effective in responding to climate change*". Researchers agreed that rice legume intercrop was effective in adapting to climate change by fixing soil nitrogen as a result of nutrient losses caused by floods and soil erosion. Also during the FGDs, F5 indicated that "*fallowing is successful in adjusting to climate change as the farm field is uncultivated for some time to reclaim the nutrients lost during the floods*". In addition, F11 noted that "*while fallowing is useful for adaptation to climate change, majority of farmers who practice it do so only when there is no money for farming during that cropping year*".

The conceptual framework worked in the sense that the extent of technology recommendation was also found to influence the extent of technology use in the results. The small number of AEAs recommending zero/minimum tillage and crop insurance for example, had an influence on the number of farmers who used these technologies.

CHAPTER SIX

LINKAGES AND INTERACTIONS BETWEEN FARMERS, AEAs AND RESEARCHERS AND BEST PREDICTORS OF EFFECTIVENESS OF RICE ADAPTATION TECHNOLOGIES

Introduction

The chapter presents and discusses findings on the level of interactions between farmers, AEAs and researchers. Effectiveness of extension teaching methods used to link farmers, AEAs and researchers in the generation, modification, transfer and utilization of climate change adaptation technologies are also discussed. Furthermore, the best predictors of effectiveness of adaptation technologies for climate change are highlighted in this chapter.

Level of Interactions by Farmers, AEAs and Researchers in the Generation, Modification, Transfer and Use of Adaptation Technologies

The weighted means of the level of interactions by farmers ($\bar{X}$w $= 2.81$), AEAs ($\bar{X}$ $= 3.16$) and researchers ($\bar{X}$w $= 3.52$) as shown in Table 22 revealed that level of interactions were moderately strong for farmers and AEAs, but strong for researchers with farmers varying in opinion. Specifically, farmers indicated that the level of interaction between researchers was weak ($\bar{X}$=2.25,SD $= 1.52$), despite the fact that there were variations of opinions from the mean. Farmers also revealed that the level of interactions between AEAs were strong ($\bar{X}$=3.64,SD $= 2.69$) with wide variations in opinions of farmers. On the interactions with AEAs and researchers, farmers indicated that interactions were moderate ($\bar{X}$=2.54,SD $=$

0.76). The results for AEAs showed that interactions with farmers ($\bar{X}$=3.48,SD = 0.64) were moderate while interactions between researchers ($\bar{X}$=3.51,SD = 0.94) were strong. The interactions between AEAs, farmers and researchers were found to be moderate ($\bar{X}$=2.50,SD = 0.51). The results of the study also showed that researchers' interactions with farmers ($\bar{X}$=3.50,SD = 0.51), with AEAs ($\bar{X}$=3.43,SD = 0.57) and interactions with AEA and researchers ($\bar{X}$=3.63,SD = 0.25) were all strong.

Table 22: Level of Interactions by Farmers, AEAs and Researchers

Type of interactions/joint linkages	Farmers		AEAs		Researchers	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Linkage between farmers and researchers	2.25	1.52	-	-	3.50	0.51
Linkage between farmers and AEAs	3.64	2.69	3.48	0.64	-	-
Linkage between AEAs and researchers	-	-	3.51	0.94	3.43	0.57
Linkage between farmers, AEAs and researchers	2.54	0.76	2.50	0.51	3.63	0.25
Weighted mean ($\bar{\boldsymbol{X}}$**w**)	2.81	1.66	3.16	0.70	3.52	0.44

Scale: 1 = Very weak, 2 = Weak, 3 = Moderate, 4 = Strong, and 5 = Very strong
Source: Field Survey, Abubakari Von (2019)

The FGDs session and interviews with farmers, AEAs and researchers give insight into the level of interactions and the effectiveness of these interactions in climate change adaptation. Farmers specified that poor interactions with researchers were due to the low involvement of farmers in research activities such as technology generation, modification and utilization. F10 indicated that *"researchers don't usually solicit our views when generating technologies for us aimed at adaptation to climate change*". F4 said, "*I was contacted by SARI to* *observe how a new variety they had developed was faring on their site and see how well it was able to adapt to climate change*". F3 revealed that *"when research do involve farmers, they invite individual farmers instead of FBO representatives which does not help to increase the scope of participation since a smaller group of farmers will be beneficiaries of the activities*". F5 added that "*when individual farmers are selected for engagement with researchers on technology development, these technologies are usually not what farmers really need so farmers end up not using them. This makes the technologies generated not effective in adapting to climate change*". "*If more interactions between researchers and farmers occurred, maybe some rice varieties such as 'degan' would have been modified to adapt to flood, thus climate change*" (F6). F11 also noted that "*our low interactions with researchers has also led to the inappropriate use of technologies which makes the technology ineffective in the adaptation of climate change*".

Researchers, however, indicated that, farmers claim of poor interactions between farmers and researchers was due to inadequate funding of research, which made it difficult for researchers to involve more farmers during the generation of technologies such as early maturing rice varieties. However, R3 said that "*we always try as much as possible to involve more farmers during the generation of technology because they are end-users, so their views on technology are very important to us, particularly those around SARI, because they are closer and less costly to transport*". "*Those farmers we interact with have reported improvement in yield resulting from the adequate and proper use of adaptation technologies*" (R1). F12 during the FGDs reported that *"our interactions with AEAs are on* *adaptation technologies like change in planting dates, use of improved rice varieties, bunding, row planting and the time to use inorganic fertilizer which are very effective in adapting to climate change when used appropriately".* F1 said that "*when technologies such as improved varieties are released to us through AEAs and do not meet our expectations and needs, we get in contact with AEAs, complain about these varieties, and our concerns are passed on to researchers who may modify or substitute these technologies to our taste, even if it takes time, so indirectly we are involved in modifying technologies". I am tempted to think that when our problems are passed through AEAs, the researchers take these problems for granted* (F4). F8 clarified that "my *interactions with AEAs generally depend on the challenges I encounter with climate change impacts on soil, crops and the use of adaptation technologies. I seldom communicate with AEAs if I don't have a problem"*. AEA7 confirmed the farmer's assertion by indicating that "*an AEA can visit the same farmer twice within a week depending on the severity of the problem at hand*".

Farmers were also of the opinion that AEAs have constant interactions with them but indicated that the time of interactions sometimes made it difficult for them to attend all interaction sessions. F2 further clarified that "*interactions typically take place during the rainy season when we have begun farming activities in earnest, which makes it difficult for us to engage in activities such as a demonstration on how to use a technology, hence our absence from such interactions affect the effectiveness of technologies transferred to us".* AEA2 revealed that "*we usually transfer and teach farmers how to use technologies such* *as improved varieties developed by researchers but sometimes it is difficult to reach most farmers, particularly during the farming season when they are engaged in farming activities. Farmers' inability to engage in such interactions with us have negative implications for the appropriate use of technologies that lead to the ineffectiveness of technology to adapt to climate change*". AEA4 also explained that "*our interactions with farmers also depend on our relationship with them and their attitudes towards the adoption of technologies*".

Some AEAs noted that, apart from the regional RELC planning session that took place once a year, their interactions with researchers relied on donor-funded projects and climate change workshops. Farmers also reported that it was uncommon for them to communicate with AEAs and researchers at the same time regarding adaptation technologies. Occasionally, farmers, AEAs and researchers interacted on issues relating to transfer and use of technologies during workshops and development and modification of technologies during farmer's field school. Nevertheless, F7 said that "*I barely interacted with AEAs and researchers at the annual RELC planning session in Tamale because it was difficult to understand and make substantive contributions to what was being discussed because English was the medium of communication at the RELC planning sessions. This made discussions geared at developing and modifying adaptation technologies ineffective*". AEAs however indicated that they sometimes translated these discussions to farmers but agreed it was not very effective. On the issue of farmers making meaningful contributions during RELC planning sessions that will inform the generation of the right technologies, AEA3 observed that "*sometimes the wrong* *farmers are invited to the RELC planning session, as some of these farmers were unaware of the real problems faced by the farmers because they were handpicked by the bosses*". This also leads to the defeat of the RELC goal of moving away from a top-down approach, because the right farmers are not allowed to prioritize their own problems for the future generation of suitable technologies. Researchers also stated that their interactions with AEAs and farmers at the RELC planning sessions were not specifically geared towards adaptation in the production of rice, but were generally related to increasing growth in agriculture, including livestock, and offered an example that during the 2015 RELC planning session, rice, which is besieged by a lot of problems, was not even discussed. R3 also noted that "*the late compilation and submission of problems faced by farmers, as well as the inadequacy of funds, restrict the timely development, modification, transfer and use of appropriate interventions, making it challenging for adaptation by farmers".* AEAs also deplored the fact that the two-day period allotted to the RELC discussions was inadequate to sufficiently address both animal and crop issues, such as rice, and to provide an in-depth debate on technologies that could be used to respond to climate change.

FGDs sessions and interviews with AEAs and researchers showed that they frequently interacted with each other when technologies for adaptation to climate change were generated or new information on adaptation to climate change became available. R1 noted that "*when new evidence or information on climate change adaptation is discovered, we would typically arrange workshops and training sessions for AEAs to update their knowledge of current trends*". R2 indicated that '*at times we develop technologies which are shot down by AEAs during our interaction with them based on their knowledge and experience on the field with farmers. In such cases, we have to improve the technology before we re-engage them".* AEA1 on the other hand indicated that "*once a new technology on adaptation is developed, researchers by means of method and result demonstrations teach us the process of using the new technology and the results that will be produced when the process is correctly followed, after which protocols are provided which help in training farmers at a later date*".

A one-way analysis of variance (ANOVA) presented in Table 23 revealed interaction levels between farmers, AEAs and researchers were statistically significant F (2, 376) = 5.95, p= .003.

Table 23: ANOVA to Determine Significant Differences in Level of Interactions between Farmers, AEAs and Researchers

Interaction Levels s	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	13.539	2	6.769	5.950	.003
Within Groups	427.811	376	1.138		
Total	441.350	378			

Source: Field survey, Abubakari Von (2019) $p < 0.05$

The Levene's test of homogeneity of variance revealed that the variances for all three groups were highly significant at 0.05 alpha level. Implying that equal variances for the three groups were not assumed, F (2,376) =5.950, p=0.000.

Table 24: Levene's Test of Homogeneity of the Groups

Levene's statistic	p
42.608	0.000

$p < 0.05$ Equal variances not assumed

A post hoc analyses using the Tamhene's T2 criterion for significance indicated that farmers' perception on the level of interaction was significantly lower (Mean = 2.87, SD = 1.14) than the perception of AEAs (Mean = 3.19, SD = 0.48) and researchers (Mean = 3.52, SD = 0.32). According to the findings, researchers had a significantly higher perception of the level of interactions than AEAs, who had a significantly higher perception of level of interactions than farmers. Farmers, who are the ultimate beneficiaries of interactions, thought that interactions with researchers and AEAs was lower.

Table 25: Mean Comparison of the Level of Interactions among Farmers, AEAs and Researchers

Actors of interactions	f	Mean	SD
Researchers	30	3.52^{a}	0.32
AEAs	30	3.16^{b}	0.48
Farmers	318	2.81^{c}	1.14
Total	378	3.19	0.65

$p < 0.05$ Source: Field survey, Abubakari Von (2019)

Note: Means with different superscript are significantly different from each other.

Farmers indicated that their low level of interactions in the knowledge system was due to individual farmers instead of FBO representatives invited to participate in research activities. Also, the time of visits for researchers and extension agents usually during the cropping season when farmers are busy, made it difficult for farmers to engage in discussion and activities leading to the generation, modification, transfer and use of adaptation technologies. Farmers also pointed out that some extension agents have only been attending to farmers who are known to adopt technologies and English as a medium of communication, particularly during the RELC planning sessions. This situation made it difficult for farmers to communicate their problems, which would ultimately lead to accurate generation and modification of climate change adaptation technologies.

Agricultural extension agents indicated that the reason why their level of interactions in the joint generation, modification, transfer and use of adaptation technologies was higher than that of farmers, was due to inadequate extension staff, and this made it next to impossible for AEAs with large operational areas to have contact with all farmers. AEAs also noted that their low level of interactions relative to researchers in the joint generation, modification, transfer and use of adaptation technologies was because not all AEAs were involved in interactions with researchers.

Researchers specified that the level of interactions in the joint generation, modification, transfer and use of adaptation technologies was lower for farmers and AEAs due to inadequate funding that made it difficult for a large number of farmers and AEAs to participate in the generation, modification and use of climate change adaptation technologies. However, they indicated that they tried to involve as much as possible more farmers and AEAs, especially those around SARI.

Effectiveness of Extension Teaching Methods Used to Link Farmers, AEAs and Researchers

Weighted means of methods used to link farmers ($\bar{X}w$ =3.54), AEAs ($\bar{X}w$ =4.01) and researchers ($\bar{X}w$ =4.16) in the generation, modification, transfer and use of adaptation technologies in Table 26 showed that the methods were effective. The farmers indicated that field trips ($\bar{X}$ =3.10), group meetings ($\bar{X}$ =3.38), and workshops ($\bar{X}$ =3.24) were moderately effective in interacting with AEAs and researchers while method ($\bar{X}$ =3.72) and result demonstrations, ($\bar{X}$ =3.80), farmer field schools ($\bar{X}$ =3.95) and radio discussions ($\bar{X}$ =3.60) were effective in the generation, modification, transfer and use of climate change adaptation technologies. However, farmer opinions on field trips(SD = 1.10), farmer field schools(SD = 1.30) and radio(SD = 1.24) widely varied from the mean. AEAs and researchers also indicated that field trips (AEA; $\bar{X}$ =4.04, researchers; $\bar{X}$ =3.82), group meetings (AEA; $\bar{X}$ =3.70, researchers; $\bar{X}$ =3.81) and workshops (AEA; $\bar{X}$ =3.85, researchers; $\bar{X}$ =4.08) were effective in interacting with farmers while method (AEA; $\bar{X}$ =4.34, researchers; $\bar{X}$ =4,76) and result demonstrations (AEA; $\bar{X}$ =4.30, researchers; $\bar{X}$ =4.72), farmer field schools (AEA; $\bar{X}$ =4.41, researchers; $\bar{X}$ =4.51) and radio discussions (AEA; $\bar{X}$ =3.42, researchers; $\bar{X}$ =3.43) were highly effective during interactions with farmers in the generation, modification, transfer and use of adaptation technologies for climate change even though AEAs (SD = 1.10) and researchers (SD = 1.04) opinions on radio discussions varied widely from the mean.

Table 26: Effectiveness of Extension Teaching Methods Used to Link Farmers, AEAs and Researchers

Extension teaching methods	Farmers			AEAs			Researchers		
	f	$\bar{X}$	SD	f	$\bar{X}$	SD	f	$\bar{X}$	SD
Field trips	101	3.10	1.10	21	4.04	0.32	28	3.82	0.50
Group meetings	134	3.38	0.84	29	3.70	0.51	24	3.81	0.73
Workshops	61	3.24	0.70	26	3.85	0.73	20	4.08	0.82
Method demonstration	127	3.72	0.54	30	4.34	0.42	24	4.76	0.34
Result demonstration	142	3.80	0.44	30	4.30	0.50	24	4.72	0.32
Farmer field schools	42	3.95	1.30	10	4.41	0.60	22	4.51	0.41
Radio	228	3.60	1.24	21	3.42	1.10	27	3.43	1.04
Weighted mean ($\bar{X}$**w**)		3.54	0.88		4.01	0.60		4.16	0.59

Scale: 1= Negligibly effective, 2 = Lowly effective, 3 = Moderately effective, 4 = Effective, and 5 = Highly effective
Source: Field Survey, Abubakari Von (2019)

Statements from respondents during the FGD and interviews provide insight into the effectiveness of methods used to link farmers, AEAs and researchers in the generation, modification, transfer and use of adaptation technologies. Farmers indicated that while group meetings and workshops were moderately effective in generating, modifying, transferring and utilizing climate change adaptation technologies, it did not provide the practical knowledge they required. F4 indicated that "*we prefer farmer field schools, result and method demonstrations because, AEAs and researchers take us through the practical process of how to use a technology and the outcome of the process. We are now in a position to see for ourselves how a specific technology should be used and the outcome from the application of that technology*". F9 on the other hand indicated that "*even though AEAs and researchers often use demonstration plots to* *demonstrate methods and results during trainings on the use of adaptation technologies, we prefer on-farm trials/technology testing because we are able to ascertain how technologies fare on our farms rather than demonstration plots*".

It was reiterated that "*farming practices or rice varieties can produce good results on demonstration plots, but will not do well on our farms or will have problems that are not noted by AEAs or researchers. It is therefore better to test this technology on our own farms so that we can provide feedback on the problem(s) identified for possible changes to be made to the said technology*". F11 indicated that "*group meetings, workshops and radio programmes are very effective in knowledge and information acquisition. When AEAs and researchers want to pass information on adaptation technologies to us, these extension methods are very effective*". R1 recounted that farmer field school were highly effective because *farmers after identifying their problems were able to test possible solutions which were provided by research after which the farmers adopt the most suitable technologies that solves their problems*. AEA3 indicated that "*radio discussions were effective in linking farmers and AEAs because the coverage of radio extended to places which were difficult for us to reach in times of flooding. However, radio discussions are usually time bound and it becomes difficult for most farmers to ask questions for clarification*". AEA2 also added that "*it is difficult for us to know if farmers understand and follow the discussions on radio as we are not able to ask farmers questions*".

Best Predictors of the Effectiveness of Adaptation Technologies for Farmers in Rice Production

The results in Table 27 show that only three of the 14 predictor variables best predict the effectiveness of climate change adaptation technologies in the multiple regression model using the step-wise approach. Extent of use of adaptation technologies, farmers' interactions with researchers, and sex were statistically significant F (3, 232) = 17,684, $p < 0.000$, and accounted for approximately 51.2 percent of variance in the effectiveness of adaptation technologies as indexed by the Adjusted $R^2 = .512$. Individually, extent of use of adaptation technologies contributed 45 percent to the variation while farmers' interaction with researchers and sex contributed 5 percent and 1.2 percent respectively.

Table 27: Stepwise Regression for Variables Predicting Farmers' Effectiveness Adaptation Technologies

Variables	B	SE β	T	R^2	Adjusted R^2	F	Durbin-Watson	p-value
Constant	1.214	.357	3.401			17.684	1.905	.001
X_3	.794	.120	6.617	.472	.450			.000
X_5	.091	.034	2.676	.530	.500			.009
X_7	-.334	.138	2.420	.543	.512			.020

n= 321 *$p < 0.05$

X_3 = Extent of use of climate change adaptation technologies
X_5 = Farmers interactions with researchers
X_7 = Sex
$Y = 1.214$ if $X_3 = X_5 = X_7 = 0$
Source: Field Survey, Abubakari Von (2019)

The regression equation for predicting the effectiveness of farmers' adaptation technologies was found to be $Y = 1.214 + .794X_3 + .091X_5 - 334X_7$.

The variable of extent of use of adaptation technologies as indexed by its β value of 0.794 indicates that effectiveness of farmers' adaptation technologies increased by a margin of 0.794 each time there was a marginal increase in farmers' use of adaptation technologies. The effectiveness of adaptation technologies for farmers also increased by a margin of 0.091 each time there was a marginal increase in farmers' interactions with researchers. Again, there is a higher likelihood of female farmers perceiving the effectiveness of adaptation technologies to be higher than their male counterparts.

R1 indicated that "*when adaptation technologies are always used by farmers, it drastically diminishes climate change effect on the production of rice, also increases yield and thus effectively adapts to climate change*". As regards interactions between farmers and researchers being a best predictor of effectiveness, F6 explained that, "*when we interact directly with the researchers, they are able to see first-hand the challenges we face in the use of the technologies they have developed. They are also able to give us detailed explanations about the technologies they have developed. Sometimes when we transfer information through AEAs to researchers, the information changes along the way"* (F6). AEA5 also noted that farmers' interactions with researchers were more effective in adapting to climate change because "*we AEAs sometimes are not timely in giving feedback and extending adaptation technologies to farmers*".

On female farmers perceiving the effectiveness of adaptation technologies to be higher than male farmers, F2 indicated that "*there are a range of adaptation technologies that farmers need to use to respond well to climate change. Most of* *us male farmers have more than one farm where we work equally in those farms and buy inputs. Because of these other farms and a lack of money to hire workers, the majority of us male rice farmers are unable to use these technologies. This has resulted in a higher perception of the effectiveness of adaptation technologies among women. Bunding, for example adapts well to climate change but, because of the size of my rice farm and other obligations on my other farms, I can't construct all the bunds in my farm without help. However, my money is not enough to hire people, so I end up not using this technology*". AEA 4 also explained that "*some men feel they know everything and sometimes don't listen to how technologies are to be used. However, the women even though don't attend meetings regularly listen attentively when present at meetings*".

The findings have shown and explained that the extent to which climate change adaptation technologies are used, farmers' interactions with researchers and sex are the best predictors of effectiveness of adaptation technologies. Contrary to this finding, Assan, Suvedi, Olabisi and Allen (2018), reported that both males and females perceived measures of adaptation to be effective in reducing the adverse effects of changes in climate.

According to the findings, there were linkages and interactions between and among farmers, AEAs and researchers, which was consistent with the conceptual framework. Hierarchy played a role in who could select farmers for regional RELC planning sessions. Extension teaching methods were also effective in the generation, modification, transfer and use of climate change adaptation technologies.

CHAPTER SEVEN

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Introduction

The chapter draws the study to a close by presenting the summary of key findings, conclusions and recommendations based on the objectives of the study. It also demonstrates the contribution to knowledge and literature as well as the conceptual framework and areas for further research.

Summary of Study

Effective knowledge systems between farmers, AEAs and researchers are essential for accurate assessment of farmers' resources, constraints and priorities as they ensure that rice technologies generated and modified are relevant, and are transferred and used appropriately to successfully adapt to climate change. The study therefore analyzed the rice knowledge systems towards adaptation to climate change in the Northern region of Ghana.

The study adopted an explanatory sequential mixed method design in the form of descriptive survey and phenomenological designs that helped to collect quantitative and qualitative data respectively. The target population of actors in the rice knowledge system namely farmers, AEAs and researchers engaged in the generation, modification, transfer and utilization of climate change adaptation technologies in the Northern region of Ghana were used. The mixed methods sampling procedures were used to select appropriate samples from the population. Simple random and census approach were used to select 321 farmers and 30 AEAs and researchers each for the quantitative data while, 14 farmers, eight AEAs and three researchers were purposively sampled for qualitative data. Data collection was carried out using content-validated and pre-tested interview schedules for farmers, while validated and pre-tested questionnaires were used for AEAs and researchers. Interview guides were used to steer focus group discussions and key informant interviews with the target farmers, researchers and AEAs. Frequencies, percentage, means, standard deviations, correlations, Kruskal-Wallis H tests, Mann-Whitney U test, ANOVA and OLS multiple regression were the statistical tools used to analyze the data. Thematic analysis was also carried out for qualitative data, where transcribed documents were read several times, essential parts of the documents were identified and meaningful names (codes) were provided, after which similar codes were placed together to form themes named to express their contents. Major findings based on the objectives of the study are presented in the ensuing paragraphs.

Key Findings of the Study

Results of the study revealed a positive but significant association between farmers' level of awareness to changes in climate and sex, household size, educational level, yield, type of farming system and type of rice ecosystem. However, there was negative significant relationship between farmers self-financing rice production and awareness to climate change. There was no significant relationship between AEAs awareness to climate change and demographic characteristics. Researchers' attendance to training and awareness to climate change had positive significant relationship. The results imply that male farmers were much more aware of changes in climate compared to the opposite sex due to their contact with extension agents and attendance to meetings. Farmers with larger household sizes, formally and highly educated, practiced continuous cropping on lowlands and had higher rice yield were more conscious of changes in climate. However, self-financing farmers were less conscious of changes in climate. The demographic and work-related characteristics had no bearing on AEAs awareness of climate change. Researchers who attended trainings were more aware of climate change because essential facts on changes in climate were shared.

Overall effect of climate change as perceived by farmers, AEAs and researchers was high. There were significant differences between farmers, AEAs and researchers' observed consequences of changes in climate on the production of rice. Significant differences were found between farmers and AEAs perceived effects of climate change because AEAs, besides witnessing and even suffering the negative effects of changes in climate through farmers' eyes , also had knowledge of what caused the effects. There were no significant differences between farmers and researchers, and AEAs and researchers perceptions of climate change's effect on rice production.

The overall recommendation of AEAs and researchers on hard technologies was 'sometimes'. Recommendations for the treatment of seeds with fungicides by AEAs and researchers were 'sometimes' because AEAs and researchers wanted to promote the purchase and use of certified seeds from MoFA and SARI. Recommendations on early maturation varieties by AEAs and researchers were however 'often'. Overall, AEAs and researchers 'sometimes' recommended soft adaptation technologies. Specifically, crop insurance and zero/minimum tillage were rarely recommended by AEAs and researchers. Farmers' overall use of hard technologies was often. The overall use of soft technologies by farmers was also often. Even though farmers often used technologies such as crop insurance and zero/minimum tillage, the number of farmers using these technologies was small.

The overall effectiveness of hard technologies was moderate in adapting to climate change. Specifically, fungi-treated seeds and pest resistant varieties were moderately effective while early maturing varieties such as AGRA and Gbewaa were effective in adapting to climate change. However, no rice variety was resistant to floods and no rice variety or weedicides was resistant or effective in the elimination of wild rice. Overall, the effectiveness of soft technologies in climate change adaptation was moderate. Specifically, all soft adaptation technologies in the study were moderately effective in changes in climate change adaptation.

Overall interaction levels by farmers and AEAs in the joint generation, modification, transfer and use of adaptation technologies was moderate, while that of researchers was strong. The moderate interactions of farmers with AEAs and researchers resulted in ineffective development, modification, transfer and use of adaptation technologies. There were significant differences between farmers, AEAs and researchers' interactions in the joint generation, modification, transfer and use of adaptation technologies. Farmers' interactions with AEAs and researchers in the knowledge system were the lowest, followed by AEAs whose interactions in the knowledge system were lower than that of researchers. Specifically, farmers' low level of interactions in the knowledge systems was due to individual farmers instead of FBO representatives invited for research activities and the time of AEAs and researchers visits. Furthermore, some extension agents only attending to farmers who are known to adopt technologies and English as a medium of communication especially during Regional RELC planning sessions also contributed to farmers' low level of interactions in the knowledge systems. AEAs level of interactions being higher than that of farmers and lower than that of researchers in the joint generation, modification, transfer and use of adaptation technologies was on account of inadequate extension staff and the non-involvement of a section of AEAs in interactions with researchers.

Researchers' high level of interactions compared to that of farmers and AEAs in the joint generation, modification, transfer and use of adaptation technologies was due to inadequate funding that made it impossible for a large number of farmers and AEAs to participate in researchers' activities. Extension teaching methods used by farmers, AEAs and researchers to link together in the generation, modification, transfer and use of adaptation technologies were generally effective. Specifically, workshops, group meetings and radio programmes were effective in terms of knowledge and information acquisition while farmer field schools, result and method demonstrations were effective in skill acquisition. However, farmers preferred on-farm trials to demonstration plots used to demonstrate the methods and results of technologies.

Extent of use of adaptation technologies, farmer's interactions with researchers and sex explained more than half (51.2 percent) of the variance in effectiveness of adaptation technologies.

Conclusions

Based on the key findings of the study, the following conclusions were drawn:

1. Male farmers, larger household sizes, farmers with formal education, farmers continuously farming, farmers farming on low land, farmers with financing, and researchers who attended trainings were more aware of climate change.
2. AEAs perceive a higher climate change effect on the production of rice than Researchers and farmers.
3. Crop insurance and zero/minimum tillage technologies were generally not recommended or used by AEAs and farmers because they were unfamiliar with them.
4. Rice varieties (AGRA and Gbewaa) and selective chemicals were not effective in resisting floods and eradicating wild rice
5. Farmers' perception of interactions with AEAs and researchers were significantly lower than AEAs and researchers' perceptions.
6. The extent of use of adaptation technologies, farmer's interactions with researchers and sex mainly influenced the level of effectiveness of adaptation technologies.

Recommendations

Based on the study's findings, the following recommendations were made:

1. Training workshops and group discussions by MoFA and SARI to raise awareness among farmers about climate change should concentrate more on women rice farmers, farmers with low or no formal education, smaller household sizes, low-yield farmers, and farmers self-financing rice production.
2. AEAs should consider organizing workshops, community meetings and radio programmes aimed at educating farmers on the causes of climate change and its effects on rice production.
3. The Ghana Agricultural Insurance Programme and Mennonite Economic Development Associates should consider organizing training workshops to improve AEAs knowledge of crop insurance and zero/minimum tillage respectively.
4. Plant breeders at SARI and for that matter CSIR should consider the development of rice varieties resistant to floods and wild rice.
5. MoFA and SARI should consider organizing informal grassroots planning sessions with farmers to improve interactions.
6. Training workshops organized by MoFA and SARI to improve the effectiveness of adaptation technologies ought to concentrate more on male rice farmers and level of use of adaptation technologies.

Contributions to Knowledge

The study is one of its kind to take a broad approach to analysing rice knowledge systems for climate change adaptation in the Northern Region of Ghana. It employed an explanatory sequential mixed method approach, which offered a multi-level strategy for delving deeper into the experiences of farmers, AEAs and researchers in their efforts to adapt to climate change. The conceptual framework provided a broad view of knowledge systems' position in the adaptation to climate change. This conceptual framework uncovered that effective adaptation is dependent on interrelated factors.

Furthermore, this study employs systems theory to shed more light on knowledge systems for climate change adaptation in rice production. Most studies on climate change have not examined the interactions and linkages between farmers, AEAs and researchers. This study, on the other hand, has provided empirical evidence to that effect, thus filling that knowledge gap.

Finally, the study adds to knowledge by highlighting the best predictors of effectiveness of adaptation technologies for rice farmers in the Northern Region of Ghana. The extent to which farmers use adaptation technologies, their interactions with researchers and their sex were identified as major factors influencing effectiveness of adaptation technologies.

Recommendations for Further Studies

For further research, the following are suggested:

1. A nationwide study of knowledge systems of farmers, AEAs and researchers in Ghana. Comparisons could be made among the regions so that policy on knowledge systems will be region specific.
2. A research on the analyses of knowledge system for adaptation to changes in climate concentrate on farmers' indigenous knowledge

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APPENDICES

Appendix A: Structured Interview Schedule for Rice Farmers

My name is Fatimah Abubakari Von, a student from the University of Cape Coast, respectfully ask for your involvement for this PhD research that aimed at finding the"Rice knowledge systems towards adaptation to climate change in the Northern Region of Ghana". The study is strictly for academic purposes only and your anonymity is greatly assured. The interaction is scheduled to last 45 minutes. Thanks in advance for agreeing to participate in this research. Your answering of this interview schedule presuppose that you have given your consent to participate in this research project. Please you are entitled to voice your concerns or ask questions before commencement, during or after the interview.

Confidentiality

This interview schedule is purely for academic purposes and all information given by you would be treated as confidential. You will not be named in any reports. Therefore, be sincere in answering questions, expressing your opinion and suggestions as much as possible as your participation in this study is completely solicited. Once again, your anonymity is greatly assured.

Thank you.

Please, do you have anything to say concerning the study? ☐ Yes ☐ No

If yes, kindly state the question

………………………………………………………………………………………………

SECTION A

Awareness level of rice farmers to climate change

1. Please indicate your awareness and the level of awareness on the following as variables of climate change.

Awareness

0- Not aware

1- Aware

Level of Awareness

1- Least Aware
2- Less Aware
3- Fairly Aware
4- Very Aware
5- Very Much Aware

Climate change variables	Awareness		Level of Awareness				
	0	1	1	2	3	4	5
Very hot days in the dry season							
Very cold days in the rainy season							
Long period of intense heat							
Severe dry spells in the rainy season							
Irregular rainfall pattern							
Decrease in amount of rainfall							
Early onset of rainfall in the rainy season							
Early end of rainfall in the rainy season							
Frequent floods							
Crops previously not grown in the north now able to survive							
New weeds which previously not found in the north now growing							
Increase in off-season rains							
Drying up of water bodies which previously never dried up							
Reduction in flow of streams							
Increase in soil erosion							
Others							

SECTION B

Effect of climate change on rice production

2. Please indicate whether the following are effects of climate change in rice production and to what extent do you agree the effects are as a result of a change?

Effect of climate change

0 – No
1 – Yes

Level of Agreement

1- Least Agree
2 – Less Agree
3 – Fairly Agree
4 – Agree
5- Strongly Agree

Effect of climate change in rice production	Effect		Level of Agreement				
	0	1	1	2	3	4	5
Climate change leads to loss of soil nutrients							
Climate change leads to soil erosion							
Climate change leads to poor seed germination							
Climate change leads to withering of seedlings							
Climate change leads to widespread new crop pests							
Climate change leads to pesticide no longer effective							
Climate change leads to lodging of rice plant							
Climate change leads to low rice yields							
Climate change leads to reduced rice quality							
Climate change leads to reduction in length of growing season							
Climate changes duration of rainy season							
Climate change leads to changes in times of planting							
Others							

SECTION C

Extent of use of adaptation technologies for climate change

3. Please indicate whether you use the following adaptation technologies and to what extent do you agree in using them in rice production?

Use by farmers

0 – No

Extent of use

1-Very rarely

1 – Yes

2 - Rarely
3- Sometimes
4- Often
5- Always

Rice Adaptation technologies	Use by farmers		Extent of use				
	0	1	1	2	3	4	5
Use of early maturing rice varieties							
Use of pest resistant varieties							
Change of planting dates							
Diversifying from rice farming to short time maturing crops							
Diversifying from rice farming to animal production							
Implementation of row planting							
Implementation of water harvesting							
Implementation of bund construction							
Construction of spillways							
Fallowing rice farms							
Altering amount of irrigation							
Altering timing of irrigation							
Subscribe to insurance for rice farm							
Intercropping rice with legumes							
Afforestation of rice farm							
Efficient fertilizer application							

Zero tillage on rice farm							
Treatment of rice seeds with fungicides							
Use of certified seeds							
Integrating inorganic fertilizer with organic fertilizer on rice farms							
Split application of inorganic fertilizer							
Apply the inorganic fertilizer close to the crop's root zone as possible							

SECTION D

Effectiveness of use of climate change adaptation technologies by farmer

3. Please indicate the effectiveness of the following adaptation technologies and to what extent do you agree they are effective in rice production?

Effectiveness

0 – Not effective
1 – Effective

Extent of effectiveness

1- Less effective
2- Fairly effective
3 - Moderately Effective
4 – Very effective
5 – Very much effective

Rice Adaptation technologies	Effectiveness		Extent of effectiveness				
	0	1	1	2	3	4	5
Use of early maturing rice varieties							
Use of pest resistant varieties							
Change in planting dates							
Diversifying from rice farming to short time maturing crops							

Diversifying from rice farming to animal production							
Implementation of row planting							
Implementation of water harvesting							
Implementation of bund construction							
Construction of spillways							
Fallowing rice farms							
Altering amount of irrigation							
Altering timing of irrigation							
Subscribe to insurance for rice farm							
Intercropping rice with legumes							
Afforestation of rice farm							
Efficient fertilizer application							
Zero tillage on rice farm							
Treatment of rice seeds with fungicides							
Use of certified seeds							
Integrating inorganic fertilizer with organic fertilizer on rice farms							
Split application of inorganic fertilizer							
Apply the inorganic fertilizer close to the crop's root zone as possible							

SECTION E

Level of linkages and interactions

4. Please indicate whether you have had linkages and interactions with farmers and researchers. Also specify your level of linkages and interactions with farmers and researchers on climate change.

Linkages or interactions | **Level of linkages and**

0 = No
1 = Yes

1= Very weak
2= Weak
3 = Moderate
4 = Strong
5 = Very strong

Linkages and interactions	0	1	Level of linkages and interactions				
			1	2	3	4	5
Linkage between farmers and researchers							
Linkage between farmers and AEAs							
Linkage between farmers, AEAs and researchers							

Extension teaching methods for climate change adaptation

7. Please indicate whether these teaching methods are used to link farmers, AEAs and researchers in the generation, modification, transfer and use of adaptation technologies. Rate the effectiveness of the extension teaching methods.

Extension teaching methods | **Effectiveness of extension teaching methods**

0 = No
1 = Yes

1= Negligibly effective
2= Lowly effective
3 = Moderately effective
4 = Effective
5 = Highly effective

Extension teaching methods	By AEAS		Effectiveness of teaching methods1				
	Yes	No	1	2	3	4	5
Method demonstration							
Result demonstration							
Presentation/Lectures							
Group discussions							
Model farmers							
Field days							
radio							

SECTION F

Socio-demographic and farm-related characteristics of farmers

11. Name of district farm is located
    a) Tolon Kumbungu [ ]
    b) Tamale Metropolitan [ ]
    c) Savelugu Nanton [ ]
    d) West Mamprusi [ ]

12. Name of community ……………………………………………

13. What is the sex of respondent 1. Male [ ] 2. Female [ ]

14. What was your age at last birthday …………………… (in years)

15. What is your highest level of education Please tick (√)
    a) No formal education [ ]
    b) Primary [ ]
    c) Middle school/JSS [ ]
    d) Senior secondary school [ ]
    e) GCE O'level [ ]
    f) GCE A'level [ ]
    g) Tertiary [ ]

16. What is your marital status
    a. Single [ ]
    b. Married [ ]
    c. Divorced [ ]

d. Widowed [ ]
e. Cohabitation [ ]

17. How many people in your household depend on you for sustenance? …………………..
18. How many people in your household are involved in your rice farming? ………………….
19. Do you belong to a FBO? Yes [ ] No [ ]
20. If yes, what is your status in the group?
    a) Ordinary member [ ]
    b) Executive member [ ]
21. How long have you been a rice farmer? ………………………… (in years)
22. Do you own the land on which you farm rice? Yes [ ] No [ ]
23. If yes, what is the ownership of the land?
    a) Inherited [ ]
    b) Purchased [ ]
    c) Rented [ ]
    d) Shared cropping [ ]
24. How many acres of land have you put under cultivation for various crops?
    a) Rice ………………………………
    b) Other ………………………………
25. How many bags of rice do you get per acre?
    ……………………………………..
26. Is rice farming your main source of income? Yes [ ] No [ ]
27. Do you engage in non-farm income activities? Yes [ ] No [ ]
28. If yes please specify? ……………………………..
29. What type of farming system do you use?
    a) Bush fallowing [ ] b) Continuous cropping [ ]
30. What type of cropping system do you practice?
    a) Mixed cropping [ ] b) Intercropping [ ] c) Monoculture [ ]
31. What type of rice ecosystem do you farm on? (Tick all that apply)
    a) Upland [ ]
    b) Lowland [ ]
    c) Irrigation [ ]
32. What variety of rice do you cultivate? ……………………………………
33. How do you finance your rice farming? (Tick all that apply)
    a) Self- finance [ ]
    b) Bank [ ]
    c) Credit union [ ]
    d) Susu [ ]
    e) Family [ ]

f) Friends [ ]

34. What training have you received from AEAs?

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

APPENDIX B

Questionnaire for Agricultural Extension Agents

My name is Fatimah Abubakari Von, a student from the University of Cape Coast, respectfully ask for your involvement for this PhD research that aimed at finding the "Rice knowledge system towards adaptation to climate change in the Northern Region of Ghana". The study is strictly for academic purposes only and your anonymity is greatly assured. The interaction is scheduled to last 45 minutes. Thanks in advance for agreeing to participate in this research. Your answering of this interview schedule presuppose that you have given your consent to participate in this research project Please you are entitled to voice your concerns or ask questions before commencement, during or after the interview.

Confidentiality

This interview schedule is purely for academic purposes and all information given by you would be treated as confidential. You will not be named in any reports. Therefore, be sincere in answering questions, expressing your opinion and suggestions as much as possible as your participation in this study is completely solicited. Once again, your anonymity is greatly assured.

Thank you.

Please, do you have anything to say concerning this study? Yes ☐ No ☐

If yes, kindly state the question
……………………………………………………………………………………………..

SECTION A

Awareness level of AEAs to climate change

1. Please indicate your awareness and the level of awareness on the following as variables of climate change.

Awareness

0- Not aware

1- Aware

Level of Awareness

1- Least Aware

2- Less Aware

3- Fairly Aware

4- Very Aware

5- Very Much Aware

Climate change variables	Awareness		Level of Awareness				
	0	1	1	2	3	4	5
Very hot days in the dry season							
Very cold days in the rainy season							
Long period of intense heat							
Severe dry spells in the rainy season							
Irregular rainfall pattern							
Decrease in amount of rainfall							
Early onset of rainfall in the rainy season							
Early end of rainfall in the rainy season							
Frequent floods							
Change in time of rainy season							
Crops previously not grown in the north now able to survive							
New weeds which were not previously found in the north now growing							
Influx of off-season rains							
Drying up of water bodies which previously never dried up							
Reduction in flow of streams							
Increase in soil erosion							
Others							

SECTION B

Effect of climate change on rice production

2. Please indicate whether the following are effects of climate change in rice production and to what extent do you agree the effects are as a result of a change?

Effect of climate change **Level of Agreement**

0 – No
1 – Yes

1- Least Agree
2 – Less Agree
3 – Fairly Agree
4 – Agree
5 – Strongly Agree

Effect of climate change in rice production	Effect		Level of Agreement				
	0	1	1	2	3	4	5
Climate change leads to loss of soil nutrients							
Climate change leads to soil erosion							
Climate change leads to poor seed germination							
Climate change leads to withering of seedlings							
Climate change leads to widespread new crop pests							
Climate change leads to pesticide no longer effective							
Climate change leads to lodging of rice plant							
Climate change leads to low rice yields							
Climate change leads to reduced rice quality							
Climate change leads to reduction in length of growing season							
Climate changes duration of rainy season							
Climate change leads to changes in times of planting							
Others							

SECTION C

Extent of recommendation of adaptation technologies to climate change

3. Please indicate whether you recommend the following adaptation technologies to farmers and the extent of recommendation given in rice production?

Recommended by farmers	**Extent of recommendation**
0 – No	1-Very rarely
	2 - Rarely
1 – Yes	3- Sometimes
	4- Often
	5- Always

Rice Adaptation technologies	Recommended to farmers		Extent of recommendation				
	0	1	1	2	3	4	5
Use of early maturing rice varieties							
Use of pest resistant varieties							
Change of planting dates							
Diversifying from rice farming to short time maturing crops							
Diversifying from rice farming to animal production							
Implementation of row planting							
Implementation of water harvesting							
Implementation of bund construction							
Construction of spillways							
Fallowing rice farms							
Altering amount of irrigation							
Altering timing of irrigation							
Subscribe to insurance for rice farm							
Intercropping rice with legumes							
Afforestation of rice farm							
Efficient fertilizer application							
Zero tillage on rice farm							
Treatment of rice seeds with fungicides							
Use of certified seeds							
Integrating inorganic fertilizer with organic fertilizer on rice farms							
Split application of inorganic fertilizer							

Apply the inorganic fertilizer close to the crop's root zone as possible							

SECTION D

Effectiveness of use of climate change adaptation technologies by farmer

3. Please indicate the effectiveness of the following adaptation technologies and to what extent do you agree they are effective in rice production?

Effectiveness

0 – Not effective
1 – Effective

Extent of effectiveness

1- Less effective
2 – Fairly effective
3 – Moderately effective
4 – Very effective
5 – Very much effective

Rice Adaptation technologies	Effectiveness		Extent of effectiveness				
	0	1	1	2	3	4	5
Use of early maturing rice varieties							
Use of pest resistant varieties							
Change of planting dates							
Diversifying from rice farming to short time maturing crops							
Diversifying from rice farming to animal production							
Implementation of row planting							
Implementation of water harvesting							
Implementation of bund construction							
Construction of spillways							
Fallowing rice farms							
Altering amount of irrigation							
Altering timing of irrigation							
Subscribe to insurance for rice farm							
Intercropping rice with legumes							
Afforestation of rice farm							
Efficient fertilizer application							
Zero tillage on rice farm							
Treatment of rice seeds with fungicides							
Use of certified seeds							

Integrating inorganic fertilizer with organic fertilizer on rice farms							
Split application of inorganic fertilizer							
Apply the inorganic fertilizer close to the crop's root zone as possible							

SECTION E

Level of linkages and interactions

4. Please indicate whether you have had linkages and interactions with farmers and researchers. Also specify your level of linkages and interactions with farmers and researchers on climate change.

Linkages or interactions
0 = No
1 = Yes

Level of linkages and
1= Very weak
2= Weak
3 = Moderate
4 = Strong
5 = Very strong

Linkages and interactions	0	1	Level of linkages and interactions				
			1	2	3	4	5
Linkage between AEAs and researchers							
Linkage between farmers and AEAs							
Linkage between farmers, AEAs and researchers							

Extension teaching methods for climate change adaptation

7. Please indicate whether these teaching methods are used to link farmers, AEAs and researchers in the generation, modification, transfer and use of adaptation technologies. Rate the effectiveness of the extension teaching methods.

Extension teaching methods **Effectiveness of extension teaching methods**

0 = No
1 = Yes

1= Negligibly effective
2= Lowly effective
3 = Moderately effective
4 = Effective
5 = Highly effective

Extension teaching methods	By AEAS		Effectiveness of teaching methods1				
	Yes	No	1	2	3	4	5
Method demonstration							
Result demonstration							
Presentation/Lectures							
Group discussions							
Model farmers							
Field days							

SECTION F

Socio-demographic characteristics of AEAs

7. Name of district where you work. ………………………………………..
8. What is the sex of respondent? 1. Male [ ] 2. Female [ ]
9. What is the age of respondent? …………………… (in years)
10. What is your marital status?
    f. Single [ ]
    g. Married [ ]
    h. Divorced [ ]
    i. Widowed [ ]
    j. Cohabitation [ ]
11. What is your current position/job title?
    ………………………………………………..

12. Please tick your class and indicate your rank.

Class	Rank
[ ] Technical class	-------------------------------------

[ ] Sub professional -------------------------------------

[ ] Professional -------------------------------------

13. What is your major area of specialization? ……………………………
14. How long have you been working with farmers? ……………………… (years)
15. What is your highest academic degree? ………………………………
16. Have you attended training courses? Yes [ ] No [ ]
17. If yes, what type of training courses have you attended? ………………………………………………………………………………… ………………………………………………………………………………… ………………………………………………………………………………… ……………………………………………
18. What are your main responsibilities? ……………………………………
19. How many villages do you serve? ………………………………………
20. How many farms do you serve? ……………………………….
21. How many farmers do you oversee? ……………………………………
22. Average farm size of rice farmers ……………………………………………………..
23. What variety(ies) of rice do you recommend to farmers? …………………………………………………………………………………
24. What are the reasons for recommending that variety of rice? …………………………………..……………………………………… ………………………………………………………………………………… ………………………………………………………………………………… ……………………………………………

Appendix C: Questionnaire for Researchers

My name is Fatimah Abubakari Von, a student from the University of Cape Coast, respectfully ask for your involvement for this PhD research aimed at finding the "Rice knowledge system towards adaptation to climate change in the Northern Region of Ghana". The study is strictly for academic purposes only and your anonymity is greatly assured. The interaction is scheduled to last 45 minutes. Thanks in advance for agreeing to participate in this research. Your answering of this interview schedule will presuppose that you have given your consent to participate in this research project. Please you are entitled to voice your concerns or ask questions before commencement, during or after the interview.

Confidentiality

This interview schedule is purely for academic purposes and all information given by you would be treated as confidential. You will not be named in any reports. Therefore, be sincere in answering questions, expressing your opinion and suggestions as much as possible as your participation in this study is completely solicited. Once again, your anonymity is greatly assured.

Thank you.

Please, do you have anything to say concerning the study? Yes ☐ No ☐
If yes, kindly state the question
……………………………………………………………………………………

SECTION A

Awareness level of researchers to climate change

1. Please indicate your awareness and the level of awareness on the following as variables of climate change.

Awareness

0- Not aware

1- Aware

Level of Awareness

1- Least Aware

2- Less Aware

3- Fairly Aware

4- Very Aware

5- Very Much Aware

Climate change variables	Awareness		Level of Awareness				
	0	1	1	2	3	4	5
Very hot days in the dry season							
Very cold days in the rainy season							
Long period of intense heat							
Severe dry spells in the rainy season							
Irregular rainfall pattern							
Decrease in amount of rainfall							
Early onset of rainfall in the rainy season							
Early end of rainfall in the rainy season							
Frequent floods							
Change in time of rainy season							
Crops previously not grown in the north now able to survive							
New weeds which were not previously found in the north now growing							
Influx of off-season rains							
Drying up of water bodies which previously never dried up							
Reduction in flow of streams							
Increase in soil erosion							

SECTION B

Perceived effect of climate change on rice production in the Northern region

2. Please indicate whether the following are effects of climate change in rice production and to what extent do you agree the effects are as a result of a change?

Effect of climate change **Level of Agreement**

0 - No
1 – Yes

1- Least Agree
2 - Less Agree
3 – Fairly Agree
4 – Agree
5 – Strongly Agree

Effect of climate change in rice production	Effec		Level of Agreement				
	0	1	1	2	3	4	5
Climate change leads to loss of soil nutrients							
Climate change leads to soil erosion							
Climate change leads to poor seed germination							
Climate change leads to withering of seedlings							
Climate change leads to widespread new crop pests							
Climate change leads to pesticide no longer effective							
Climate change leads to lodging of rice plant							
Climate change leads to low rice yields							
Climate change leads to reduced rice quality							
Climate change leads to reduction in length of growing season							
Climate changes duration of rainy season							
Climate change leads to changes in times of planting							
Others							

SECTION C

Extent of recommendation of adaptation technologies to climate change

3. Please indicate whether you recommend the following adaptation technologies to AEAs/farmers and the extent of recommendation given in rice production?

Recommended by farmers	**Extent of recommendation**
0 – No	1-Very rarely
	2 - Rarely
1 – Yes	3- Sometimes
	4- Often
	5- Always

Rice Adaptation technologies	Recommended to farmers		Extent of recommendation				
	0	1	1	2	3	4	5
Use of early maturing rice varieties							
Use of pest resistant varieties							
Change in planting dates							
Diversifying from rice farming to short time maturing crops							
Diversifying from rice farming to animal production							
Implementation of row planting							
Implementation of water harvesting							
Implementation of bund construction							
Construction of spillways							
Fallowing rice farms							
Altering amount of irrigation							
Altering timing of irrigation							
Subscribe to insurance for rice farm							
Intercropping rice with legumes							
Afforestation of rice farm							
Efficient fertilizer application							
Zero tillage on rice farm							
Treatment of rice seeds with fungicides							
Use of certified seeds							
Integrating inorganic fertilizer with organic fertilizer on rice farms							
Split application of inorganic fertilizer							

Apply the inorganic fertilizer close to the crop's root zone as possible							

SECTION D

Effectiveness of use of climate change adaptation technologies by farmer

3. Please indicate the effectiveness of the following adaptation technologies and to what extent do you agree they are effective in rice production?

Effectiveness

0 – Not effective

1 - Effective

Extent of effectiveness

1 – Less effective

2 – Fairly effective

3 – Moderately Effective

4 – Very effective

5 – Very much effective

Rice Adaptation technologies	Effectiveness		Extent of effectiveness				
	0	1	1	2	3	4	5
Use of early maturing rice varieties							
Use of pest resistant varieties							
Change of planting dates							
Diversifying from rice farming to short time maturing crops							
Diversifying from rice farming to animal production							
Implementation of row planting							
Implementation of water harvesting							
Implementation of bund construction							
Construction of spillways							
Fallowing rice farms							
Altering amount of irrigation							
Altering timing of irrigation							
Subscribe to insurance for rice farm							
Intercropping rice with legumes							
Afforestation of rice farm							
Efficient fertilizer application							
Zero tillage on rice farm							
Treatment of rice seeds with fungicides							
Use of certified seeds							

Integrating inorganic fertilizer with organic fertilizer on rice farms							
Split application of inorganic fertilizer							
Apply the inorganic fertilizer close to the crop's root zone as possible							

SECTION E

Level of linkages and interactions

4. Please indicate whether you have had linkages and interactions with farmers and researchers. Also specify your level of linkages and interactions with farmers and researchers on climate change.

Linkages or interactions
0 = No
1 = Yes

Level of linkages and
1= Very weak
2= Weak
3 = Moderate
4 = Strong
5 = Very strong

Linkages and interactions			Level of linkages and interactions				
	0	1	1	2	3	4	5
Linkage between AEAs and researchers							
Linkage between farmers and researchers							
Linkage between farmers, AEAs and researchers							

Extension teaching methods for climate change adaptation

7. Please indicate whether these teaching methods are used to link farmers, AEAs and researchers in the generation, modification, transfer and use of adaptation technologies. Rate the effectiveness of the extension teaching methods.

Extension teaching methods **Effectiveness of extension teaching methods**

0 = No
1 = Yes

1= Negligibly effective
2= Lowly effective
3 = Moderately effective
4 = Effective
5 = Highly effective

Extension teaching methods	By AEAS		Effectiveness of teaching methods1				
	Yes	No	1	2	3	4	5
Method demonstration							
Result demonstration							
Presentation/Lectures							
Group discussions							
Model farmers							
Field days							

SECTION F

Socio-demographic characteristics of researchers

7. What is the sex of respondent? 1. Male [ ] 2. Female [ ]
8. What is the age of respondent? …………………… (in years)
9. What is your marital status?
   a. Single [ ]
   b. Married [ ]
   c. Divorced [ ]
   d. Widowed [ ]
   e. Cohabitation [ ]
10. What is your current position/job title?
    ………………………………………………..
11. Please tick your class and indicate your rank.

Class Rank

[ ] Technical class -------------------------------------

[ ] Sub professional -------------------------------------

[ ] Professional -------------------------------------

12. What is your major area of specialization?
    ………………………………………………
13. How long have you been working as a researcher?
    ………………………(years)
14. What is your highest academic degree?
    …………………………………………………
15. Have you attended training courses? Yes [ ] No [ ]
16. If yes, what type of training courses have you attended?
    ……………………………………………………………………………
    ……………………………………………………………………………
    ……………………………………………………………………………
    ………………………………………………
17. What are your main responsibilities? …………………………………..
18. What variety(ies) of rice do you recommend to farmers?
    ……………………………………………………………………
19. What are the reasons for recommending that variety of rice?

Appendix D

Guide of Focus Group Discussion for Rice Farmers

1. AWARENESS OF CLIMATE CHANGE

a) Have you observed any change in climate over the past twenty years?

b) If yes, describe it and for how long have you observed this change?

c) What are the effects of the change in climate on rice farming in this area

2. EFFECTS OF CLIMATE CHANGE ON RICE PRODUCTION

What climate change variables affect rice production?

How do these variables affect rice production?

3. RICE ADAPTATION TECHNOLOGIES

a) What technologies are available to you to adapt to climate change?

b) Which person(s) transfers these rice adaptation technologies to you?

c) What indigenous technologies do you use as rice farmers to adapt to climate change?

d) What unique characteristics of the indigenous technology makes you continue to use them?

e) What kinds of information do researchers/AEAs take from you on climate change adaptation?

4. VARIETIES OF RICE CULTIVATED BY FARMERS

a. Which variety(ies) of rice do you grow in this area?

b. What are your reasons for growing these varieties?

c. Do you know the sources of varieties you grown?

d. What are the characteristic differences between the types you grow?

e. What rice varieties do you think are suitable for upland, lowland and irrigation ecologies respectively from your experience?

4. EFFECTIVENESS OF RICE PRODUCTION TECHNOLOGIES IN ADDRESSING CLIMATE CHANGE IN TERMS OF;

a. Yield
b. Pest management
c. Weed management
d. Quality of paddy rice
e. Soil improvement

i. Soil structure
ii. Soil nutrients
iii. Soil acidity
iv. Water holding capacity of soil
v. Soil organic matter

5. KNOWLEDGE SYSTEMS AMONG FARMERS, AEAs AND RESEARCHERS TOWARDS CLIMATE CHANGE ADAPTATION

a) Are there any linkages and interactions among farmers, AEAs and researchers regarding climate change adaptation?

b) Are climate change issues in rice production discussed as part of these interactions?

c) What adaptation technologies are discussed during interactions

d) Are the interactions effective in climate change adaptation?

e) How are extension teaching methods effective in interactions in climate change adaptation

f) What is the frequency of interactions

g) Do you think it is important for farmers, AEAs and researchers to form linkages towards reducing the effect of climate change?

Appendix E

Guide of Focus Group Discussion for Agricultural Extension Agents

1. AWARENESS OF CLIMATE CHANGE

a) Have you observed any change in climate over the past twenty years?

b) If yes, describe it and for how long have you observed this change?

c) What are the effects of the change in climate on rice farming in this area

2. EFFECTS OF CLIMATE CHANGE ON RICE PRODUCTION

a. What climate change variables affect rice production?

b. How do these variables affect rice production?

3. RICE ADAPTATION TECHNOLOGIES

a) What technologies are available to farmers to adapt to climate change?

b) Which person(s) transfers these rice adaptation technologies to you?

c) What indigenous technologies do you use as rice farmers to adapt to climate change?

d) What unique characteristics of the indigenous technology makes you continue to use them?

e) What kinds of information do researchers/AEAs take from you on climate change adaptation?

4. VARIETIES OF RICE CULTIVATED BY FARMERS

a. Which variety(ies) of rice do you grow in this area?

b. What are your reasons for growing these varieties?

c. What are the sources of varieties you grow?

d. Have you been introduced to any new varieties by AEAs? Researchers?

e. What are the characteristic differences between the types you recommend and those grown by farmers?

f. What rice varieties do you think are suitable for upland, lowland and irrigation ecologies respectively from your experience?

5. EFFECTIVENESS OF RICE PRODUCTION TECHNOLOGIES IN ADDRESSING CLIMATE CHANGE IN TERMS OF;

a. Yield
b. Pest management
c. Weed management
d. Quality of paddy rice
e. Soil improvement
i. Soil structure
ii. Soil nutrients
iii. Soil acidity
iv. Water holding capacity of soil
v. Soil organic matter

6. KNOWLEDGE SYSTEMS AMONG FARMERS, AEAs AND RESEARCHERS TOWARDS CLIMATE CHANGE ADAPTATION

a) Are there any linkages and interactions among farmers, AEAs and researchers regarding climate change adaptation?

b) Are climate change issues in rice production discussed as part of these interactions?

c) What adaptation technologies are discussed during interactions

d) Are the interactions effective in climate change adaptation?

e) How are extension teaching methods effective in interactions in climate change adaptation

f) What is the frequency of interactions

g) Do you think it is important for farmers, AEAs and researchers to form linkages towards reducing the effect of climate change?

Appendix F

Guide of Interviews for Researchers

1. AWARENESS AND EFFECT OF CLIMATE CHANGE

a) Have you observed any change in climate over the past twenty years?

b) If yes, describe it and for how long have you observed this change?

c) What are the effects of the change in climate on rice farming in this area

2. EFFECTS OF CLIMATE CHANGE ON RICE PRODUCTION

c. What climate change variables affect rice production?

d. How do these variables affect rice production?

3. RICE ADAPTATION TECHNOLOGIES

a) What technologies are available to farmers to adapt to climate change?

b) Which person(s) transfers these rice adaptation technologies to you?

c) What technologies do you recommend to rice farmers to adapt to climate change?

d) What unique characteristics of the technology makes you continue to recommend them?

e) What kinds of information do researchers/AEAs take from you on climate change adaptation?

4. VARIETIES OF RICE CULTIVATED BY FARMERS

a. Which variety(ies) of rice do you grow in this area?

b. What are your reasons for growing these varieties?

c. What are the sources of varieties you grow?

d. Have you been introduced to any new varieties by AEAs? Researchers?

e. What are the characteristic differences between the types you recommend and those grown by farmers?

f. What rice varieties do you think are suitable for upland, lowland and irrigation ecologies respectively from your experience?

5. EFFECTIVENESS OF RICE PRODUCTION TECHNOLOGIES IN ADDRESSING CLIMATE CHANGE IN TERMS OF;

a. Yield
b. Pest management
c. Weed management
d. Quality of paddy rice
e. Soil improvement
   i. Soil structure
   ii. Soil nutrients
   iii. Soil acidity
   iv. Water holding capacity of soil
   v. Soil organic matter

6. KNOWLEDGE SYSTEMS AMONG FARMERS, AEAs AND RESEARCHERS TOWARDS CLIMATE CHANGE ADAPTATION

a) Are there any linkages and interactions among farmers, AEAs and researchers regarding climate change adaptation?

b) Are climate change issues in rice production discussed as part of these interactions?

c) What adaptation technologies are discussed during interactions

d) Are the interactions effective in climate change adaptation?

e) Are the extension teaching methods effective in climate change adaptation

f) How are extension teaching methods effective in interactions in climate change adaptation?

g) What is the frequency of interactions

h) Do you think it is important for farmers, AEAs and researchers to form linkages towards reducing the effect of climate change?

Appendix G

Sample Size

Study area	Sampling frame	Sample size
Tamale Metropolitan		
Tugu	55	48
Zoborgu	45	40
Juni	42	38
Sub-total	142	126
Tolon District		
Voggu Kpalsogu	36	33
Naha	48	42
Sub-total	89	75
Savelugu District		
Kanshegu	31	29
Kpalyogo	35	32
Sub-total	78	61
Nanumba North District		
Cherifoyili	37	34
Kpetiuya	30	28
Sub-total	72	62
Total	381	324

Source: Regional Directorate of Agriculture (2018)

Appendix H

Demographic and Farm-Related Characteristics of Rice farmers

Variables	Categories	f	percent	$\bar{X}$	SD
Sex (n= 315)	Male	269	85.7		
	Female	45	24.3		
Age (n= 318)	Youth (18-35)	109	34.3	41	10.6
Min. = 20 Max. =80	Adults (36-60)	196	61.6		
	Elderly (+60)	13	4.1		
Marital status (n=324)	Married	294	90.7		
	Single	22	6.8		
	Widowed	4	1.2		
	Divorced	4	1.2		
Household size (n=321)	1-10	172	53.6	12	7.1
Min. = 1 Max. = 40	11-20	119	37.0		
	21-30	24	7.5		
	31-40	6	1.9		
Educational level (n=323)	No formal education	233	72.1		
	Primary	29	9.0		
	Middle school / JHS	31	9.6		
	SHS	21	6.5		
	GCE O'level	2	0.6		
	Tertiary	7	2.2		
Belong to FBO	No	141	43.9		
(n=321)	Yes	180	56.1		
Status in FBO	Ordinary member	136	74.7		
(n=182)	Executive member	46	25.3		
Rice farming as main	No	108	33.8		
income (n=320)	Yes	212	66.2		
Type of farming system	Bush fallowing	35	10.8		
(n=323)	Continuous cropping	288	89.2		
Type of cropping system	Mixed cropping	19	6.0		
practiced (n=316)	Monoculture	265	83.9		
	Intercropping	32	10.1		
Type of rice ecosystem	Upland	6	1.9		
	Lowland	284	88.5		
(n=321)	Irrigation	31	9.6		
Experience (years)	<10	134	43.5	12.7	9.3
(n=308)	10-20	126	41.0		

Min. = 1 Max. = 42	21-30	33	10.7		
	31-40	14	4.5		
	>40	1	0.3		
Land Ownership (n=320)	No	79	24.7		
	Yes	241	75.3		
Status of ownership (n=241)	Inherited	221	91.7		
	Purchased	17	7.1		
	Inherited/Purchased	3	1.2		
Farm size (ha)	<1	112	34.6	2.9	5.4
(n=323)	1-10	204	62.9		
Min.= 0.4, Max = 80	10.1-20	5	1.6		
	20.1-30	2	0.6		
	>30	1	0.3		
Bags/ha (100kg)	<1	6	2.1	3.6	5.5
(n=280)	1-4.2	208	74.3		
Min.= 0.4, Max = 16	4.3-7.5	53	19.0		
	7.6-10.8	7	2.5		
	10.9-14.1	4	1.4		
	14.2-17.4	2	0.7		
Self-financing	No	19	5.9		
	Yes	305	94.1		
Friends financing	No	316	97.5		
	Yes	8	2.5		
Family financing	No	296	91.4		
	Yes	28	8.6		
Susu financing	No	300	92.6		
	Yes	24	7.4		

Source: Field Survey, Abubakari Von (2019)

Appendix I

Demographic and Work-Related Characteristics of AEAs

Variables (n=30)	Categories	f	percent	$\bar{X}$	SD
Sex	Male	26	86.7		
	Female	4	13.3		
Marital status	Married	27	90		
	Single	3	10		
Experience (years)	<10	10	33.3	15.5	10.7
Min. = 2 Max. = 37	10-20	13	43.4		
	21-30	4	13.3		
	>30	3	10.0		
Age (n= 30)	Youth (18-35)	7	23.3	42.9	8.5
Min. = 28 Max. = 58	Adults (36-60)	23	76.7		
Rice varieties recommended	Jasmine and AGRA	19	63.3		
	AGRA	6	20.0		
	Jasmine	3	10.0		
	Nerica and AGRA	1	3.3		
	AGRA, Jasmine & Togo Marshal	1	3.3		
No. of villages served	<10	9	30.0	13.0	6.7
Min. = 3 Max. = 29	10-20	18	60.0		
	21-30	3	10.0		
No. of farms served	<500	2	6.7	2139	4383
Min. = 240 Max. = 2500	500-1000	13	43.3		
	1100-1500	5	16.7		
	1501-2000	3	10.0		
	2100-2500	4	13.3		
	>2501	3	10.0		
No. of farmers overseen	<500	1	3.3	1886.7	1173.2
Min. = 200 Max. = 5000	500-1000	7	23.3		
	1100-1500	9	30.0		
	1501-2000	2	6.7		
	2100-2500	3	10.0		
	>2501	8	26.7		
Average farm size of rice farmers	<1	10		1.9	1.7
	1-3	14			
Min. = 0.4 Max. = 6	3.1-6	6			
Class	Technical class	18	60.0		
	Sub-professional	1	3.3		
	Professional	11	36.7		
Area of specialization	Agronomy (crops)	11	36.7		
	Post-harvest	4	13.3		

	General agriculture	14	46.7
	Extension	1	3.3
Educational level	Certificate	12	40
	Diploma	8	26.7
	HND	3	10
	University degree	7	23.3
Training attended on CC	No	9	30
	Yes	21	70

Source: Field Survey, Abubakari Von (2019)

Appendix J

Demographic and Work-Related Characteristics of researchers

Variables (n=30)	Categories	f	percent	$\bar{X}$	SD
Sex	Male	25	83.3		
	Female	5	16.7		
Marital status	Married	26	86.7		
	Single	4	13.3		
Experience (years)	<10	14	48.3	9.58	5.62
Min. = 2 Max. = 26	10-20	13	44.8		
	21-30	2	6.9		
Age	Youth (18-35)	11	40.7	39.96	9.26
Min. = 29 Max. = 58	Adults (36-60)	16	59.3		
Current position	Principal technologist	4	13.3		
	Research scientist	17	56.7		
	Deputy head of Division	2	6.7		
	Senior technical officer	2	6.7		
	Research principal technologist	2	6.7		
	Field technician	2	6.7		
	Plant breeder	1	3.3		
Area of specialization	Irrigation	3	10.0		
	Rice breeding	4	13.3		
	Soil fert.& mgt	7	23.3		
	Agronomy & weed sci.	8	26.7		
	Plant breeding & genetic	6	20.0		
	Seed sci. dev't & tech.	2	6.7		
Rice varieties recommended	AGRA	6	20.0		
	AGRA and Gbewaa	19	63.3		
	AGRA, Digan and C93	3	10.0		
	Gbewaa and Basmati	2	6.7		
Educational level	HND	2	6.7		
	First degree	2	6.7		
	MSc	4	13.3		
	MPhil	6	20.0		
	PhD	16	53.3		
Attended workshops on climate change	No	4	13.3		
No = 0 Yes = 1	Yes	26	86.7		

Source: Field Survey, Abubakari Von (2019)

Appendix K

Shapiro-Wilk Test of Normality for Climate Change Awareness Level

	Statistic	df	Sig.
Level of awareness of climate change	.978	383	.000

Source: Field Survey, Abubakari Von (2019)

Appendix L

Shapiro-Wilk Test of Normality Effects of Climate Change on Rice Production

Level of effects of climate change on rice production	Statistic	df	Sig.
	.982	384	.000

Source: Field Survey, Abubakari Von (2019)

Appendix M

Shapiro-Wilk Test of Normality for Extent of Use of Climate Change Adaption Technologies

Extent of use of Adaption Technologies	Statistic	df	Sig.
	.992	320	.083

Source: Field Survey, Abubakari Von (2019)

Appendix N

Shapiro-Wilk Test of Normality for Level of Interactions between Farmers, AEAs and Researchers to Generate, Modify, Transfer and Use of Adaptation Technologies

	Statistic	df	Sig.
Level of interactions	.993	370	.069

Source: Field Survey, Abubakari Von (2019)

Appendix O

Shapiro-Wilk Test of Normality for Effectiveness of Climate Change Adaption Technologies

	Statistic	df	Sig.
Effectiveness of climate change adaptation technologies	.992	320	.071

Source: Field Survey, Abubakari Von (2019)

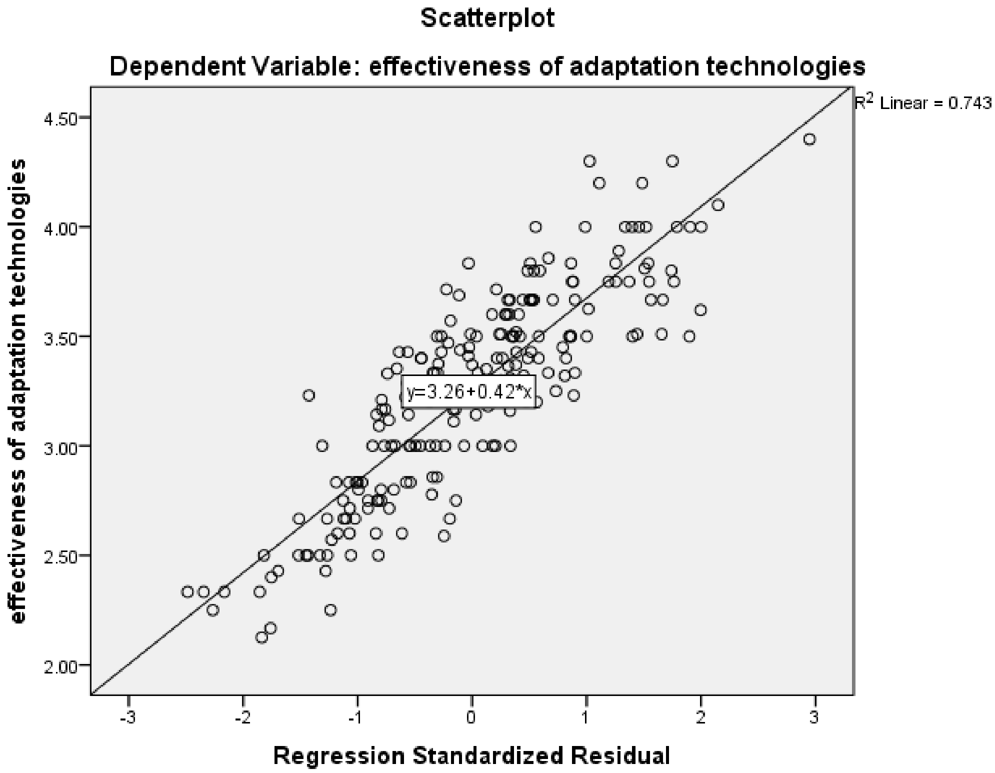
Appendix P

Collinearity Statistics

Variables	Collinearity Statistics	
	Tolerance	Variance Inflation Factor (VIF)
Constant		
Extent of use of climate change adaptation technologies	.985	1.015
Linkage and interactions among farmers and researchers	.981	1.019
Sex	.990	1.010
Level of awareness of Climate Change	.776	1.288
Perceives effects level of Climate Change	.717	1.394
Educational level	.887	1.127
Household size	.945	1.058
Farming experience	.892	1.121
Ownership of land	.530	1.888
Farm size	.901	1.110
Linkage and interactions among the three actors	.713	1.403
Linkage and interactions among farmers and AEAs	.927	1.079
Yield/ha	.734	1.362
Age	.967	1.035

Appendix Q

Homoscedasticity



Appendix R

Davis Convention on the Description of the Magnitude of Correlations

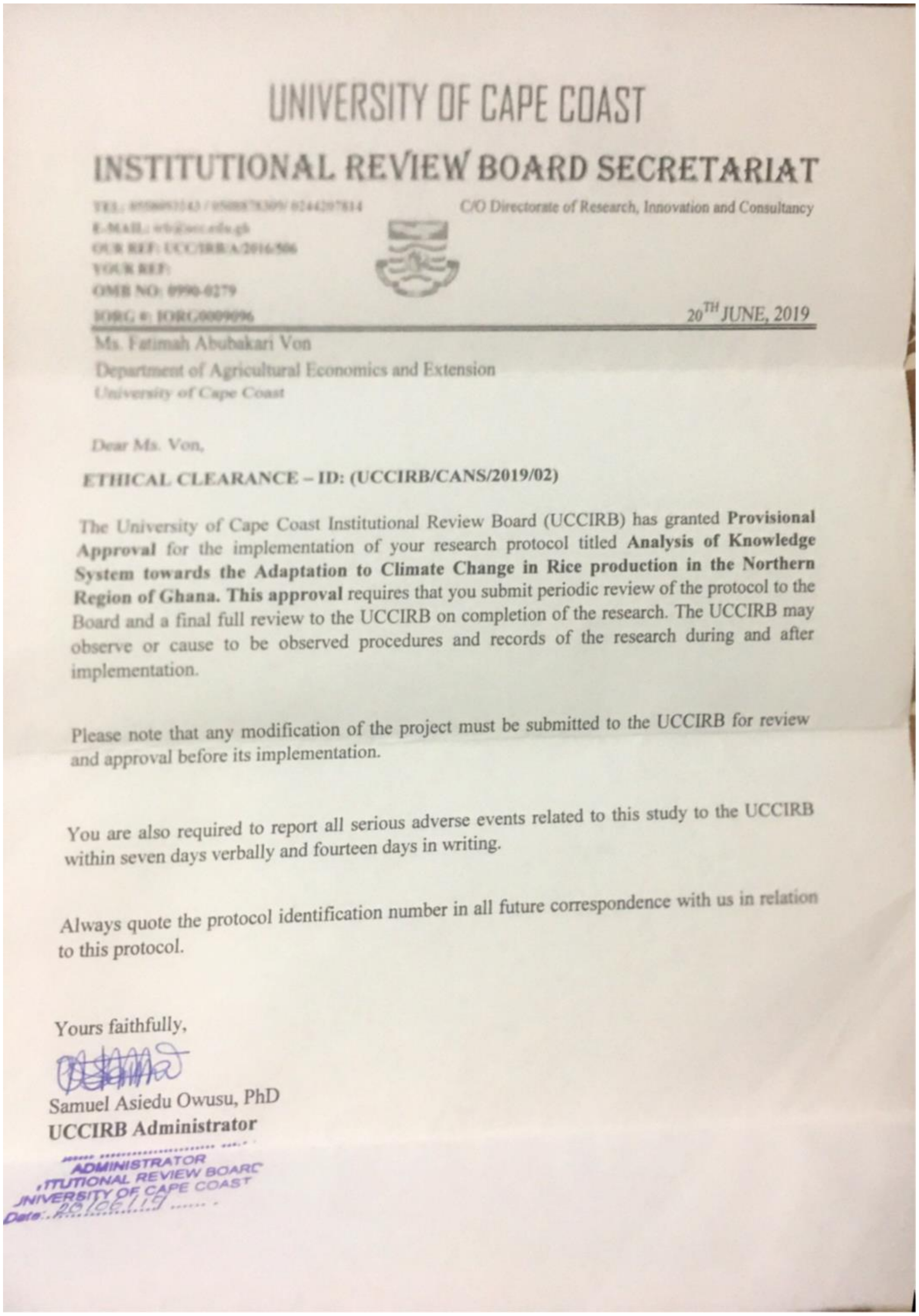
Coefficients

Magnitude of Correlation coefficient (+/-)	Description
1.0	Perfect
0.70 - 0.99	Very High
0.50 - 0.69	Substantial
0.30 - 0.49	Moderate
0.10-0.29	Low
0.01 - 0.09	Negligible

Source: Davis (1971)

Appendix S

Approval for the Implementation of Research-Ethical Clearance



UNIVERSITY OF CAPE COAST

INSTITUTIONAL REVIEW BOARD SECRETARIAT

TEL: 0558093143 / 0508878309/ 0244207814
E-MAIL: irb@ucc.edu.gh
OUR REF: UCC/IRB/A/2016/506
YOUR REF:
OMB NO: 0990-0279
IORG #: IORG0009096

C/O Directorate of Research, Innovation and Consultancy

20TH JUNE, 2019

Ms. Fatimah Abubakari Von
Department of Agricultural Economics and Extension
University of Cape Coast

Dear Ms. Von,

ETHICAL CLEARANCE – ID: (UCCIRB/CANS/2019/02)

The University of Cape Coast Institutional Review Board (UCCIRB) has granted **Provisional Approval** for the implementation of your research protocol titled **Analysis of Knowledge System towards the Adaptation to Climate Change in Rice production in the Northern Region of Ghana. This approval** requires that you submit periodic review of the protocol to the Board and a final full review to the UCCIRB on completion of the research. The UCCIRB may observe or cause to be observed procedures and records of the research during and after implementation.

Please note that any modification of the project must be submitted to the UCCIRB for review and approval before its implementation.

You are also required to report all serious adverse events related to this study to the UCCIRB within seven days verbally and fourteen days in writing.

Always quote the protocol identification number in all future correspondence with us in relation to this protocol.

Yours faithfully,

Samuel Asiedu Owusu, PhD
UCCIRB Administrator

ADMINISTRATOR
...ITUTIONAL REVIEW BOARD
...NIVERSITY OF CAPE COAST
Date: 20/06/19