UNIVERSITY FOR DEVELOPMENT STUDIES

ADOPTION OF CLIMATE SMART AGRICULTURAL INNOVATIONS AMONG FOOD CROP FARMERS IN THE SISSALA EAST DISTRICT

BY

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DECLARATION

I hereby declare that this thesis is the result of my own original work towards the award of a Master of Philosophy (Mphil) Degree in Environment and Resource Management, and that no part of it has been presented for another degree in this University or elsewhere except where due acknowledgement has been made in the manuscript:

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ABSTRACT

NGOs and MoFA have been initiating and implementing Climate Smart Agricultural projects in the Sissala East District of the Upper West Region of Ghana particularly from 2010 to 2016. The study examines the adoption levels of CSA innovations by smallholder farmers and how adoption of CSA impact on food crop production. The sample size for the study was 399 farmers. Primary data was collected through household survey, focus group discussions and key informant interviews. The adoption quotient was used to categorize farmer's adoption of various CSA practices into high, medium and low. The Ordinary Least Square estimation was then used to determine the effect of farmer's adoption of CSA practices on the yields of four major crops namely, maize, soya, beans and groundnuts. Farmers identified various permutations between indigenous and introduced CSA practices. Their various pairings were further analyzed using percentages. The most adopted introduced CSA was the use of improved seeds whiles sulphate weedicide mixture for weeds control was highest for indigenous CSA practices. The ordinary Least Square results show that farmer's adoption of both Indigenous and introduced CSA practices were significant in determining the yield of maize and soya at 1 percent. Farmers who adopted CSA increased their yields per acre by 0.72kg and 0.19kg for maize and soya respectively. Twelve (12) areas for synergies were identified between indigenous and introduced CSA practices however; current CSA model does not give room for effective synergies. It is concluded that adoption of CSA has a positive contribution to sustainable agricultural intensification and improved livelihoods. It is recommended that current indigenous practices being used by farmers be further examined for their effectiveness and best ways of blending with introduced CSA to promote high adoption.

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DEDICATION

This thesis is dedicated to my lovely wife Alfredina Buunaaim and son Francis Awonnala Adajagsa.

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LIST OF ABBREVIATIONS

AGRA	Alliance for A Green Revolution
ASUDEV	Action For Sustainable Development
AU	African Union
CSA	Climate Smart Agriculture
CSLA	Community Savings and Loans Association
CO_2	Carbon Dioxide
FAO	Food Agricultural Organization
FBO	Farmer Base Organization
GSS	Ghana Statistical Service
IFAD	International Food and Agricultural Development
IFDC	International Fertilizer Development Center
IPCC	Intergovernmental Panel on Climate Change
MEDA	Mennonite Economic Development Associates
MoFA	Ministry of Food Agriculture
NCRC	National Conservation Research Center
NEPAD	New Partnership for Africa's Development
NGO	Non-Governmental Organization
OECD	Organisation for Economic Co-operation and Development
PFBO	Primary Farmer Base Organization
REG	Regional Economic Committee
SARI	Savannah Agricultural Research Institute
SFBO	Secondary Farmer Base Organization

THC	Thermohalin Circulation
TUDRIDEP	Tumu Deanery Rural Integrated Development Programme
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organization
VSLA	Village Savings and Loans Association
WHO	World Health Organization
WOCAN	Women Organizing for Change in Agriculture and Natural Resource Management

CHAPTER ONE

BACKGROUND

1.1 Introduction

According to Liper et al. (2014), the population in developing countries is expected to increase by 2.4 billion additional people in the year 2050. With this projected increases in population, the Food and Agricultural Organization [FAO] (2013) indicates that agricultural productivity will need to increase by 60% by the year 2050 for attaining food security in developing countries. However, increasing food productivity sustainably according to Jeeva (2015) will require all countries to advance their uptake of climate smart agriculture by 65%.

Though earlier approaches to addressing world food security concerns most especially the green revolution made gains in terms of farm level increase in food productions of maize and wheet by 9.5% and 11.5% per acre respectively in developing countries, its overly concentration on yield has being described as unsustainable as it gives little premium to the environmental implications of some of the practices it promoted (Pingali, 2012). This situation has put developing countries in a cycle of perpetual poverty and hunger (Etwure, 2012). Already, 23% of people in Sub Saharan Africa especially the rural poor are food insecure (FAO, 2015). It is precisely to cater for this issue of achieving sustainable world food security that the Food and Agriculture Organization (FAO) coined the concept of Climate Smart Agriculture (CSA) in 2010. CSA aims to improve food security, help communities adapt to climate change and contribute to climate change mitigation by adopting appropriate practices and developing enabling policies and institutions (FAO, 2010)

CSA as defined and presented by the Food and Agriculture Organization (FAO) at The Hague Conference in 2010 integrates the three dimensions of sustainable development (economic, social, and environmental). It is an approach to develop the technical, policy and investment conditions to achieve sustainable agricultural development for food security under climate change (FAO, 2013). For an intervention to be truly climate-smart, it must be one that provides farmers a pathway to be food secure and such a practice must empower them to live a sustainable livelihood amidst climate change (Daisy, 2013).

Climate Smart Agriculture has been gaining momentum in the last five (5) years among policy cycles with development organizations such as the United Nations, Inter Governmental Panel on Climate Change and the World Health Organization prioritizing CSA interventions for achieving food security in developing countries around the world (Jeeva, 2015). Efforts to promote CSA in Africa are advancing at the policy level. At the 23rd ordinary session of the African Union (AU) held in June 2014 in Malabo, Equitorial Guinea, African leaders endorsed the inclusion of CSA in the New Partnership for Africa's Development [NEPAD] programme on agriculture and climate change. The session also led to the development of the African Climate Smart Agriculture Alliance which is expected to enable the NEPAD Planning and Coordinating Agency to collaborate with Regional Economic Committees (RECs) and Non-Governmental Organizations (NGOs) in targeting 25 million farm households by 2025 (FAO 2016). This is following some successes being recorded in some countries on the adoption of CSA. Studies by Neate (2015) for example have revealed an increase in crop food production by farmers in Kenya by 15% and a contribution to the vegetation of the Sahel. In Ghana, major steps taken to mainstream CSA into the policy cycle includes the initiation of the National Climate-Smart Agriculture and Food Security Action Plan (2016-2020) under the Ministry of Food and Agriculture which seeks to provide the implementation framework for an effective development of climate-smart agriculture on the ground (Essegbey, 2015). Despite these efforts at the policy level, adoption of CSA innovations is still low among smallholder farmers in Ghana most especially the northern parts of the country (Ferdenal et al., 2015). Farmer's adoption of less climate resilient practices is still on the high in spite of the series of project interventions working to introduce CSA innovations to farmers (Deribile, 2016).

One of the challenging factors to CSA enhancement is limited context specific evidence based on which farmer sensitization of the need for CSA could be articulated (Basche et al., 2015). Also, for CSA to be better mainstreamed into the agricultural policy cycle, to the benefit of the smallholder farmer there is the need for local context evidence of the importance of adopting CSA innovations to be available to inform policy actions (Ferdenal et al., 2015).

1.2 Problem statement

In the Upper West Region of Ghana, agriculture contributes to about 72% of the livelihood support of the population especially smallholder farmers in the rural areas (Buduan, 2016). The Sissala East District is the food basket for the Upper West Region in Ghana despite the one cropping season it experiences yearly (MoFA, 2013). A major decline in food production in this District as a result of any factor would negatively affect food security and development of the region (Naab & Koranteng, 2012). Already, studies by the Savannah Agricultural Research Institute (2014) evidenced a reduction of food productivity by 10% in the Sissala East District between the years 2010 to 2014 which have some food security concerns for the Upper West Region. The impact of climate change on food security could even be worst considering the fact that over 80% of the population of the Sissala East District are classified as poor (Deribile, 2016).

Agriculture in the Sissala East District is mainly rain fed and largely vulnerable to changes in rainfall patterns and low technological capacity for adaptation (GSS, 2010). In addition, Climate change is affecting the basic elements for food production in the Sissala East District which includes soil and water resulting in increasing levels of poverty (MEDA, 2012). Even though farmers are adjusting their farming practices to help adapt to the unpredictable patterns of rain and soil degradation, their traditional mechanisms are not sufficient in dealing with the impacts of Climate change (Diasob, 2012).

Over the last five years (2013 to 2017), works of Non Governmental organizations and Ministry of Food and Agriculture (MoFA) have focused on initiating Climate Smart Agriculture (CSA) in the District to mitigate the negative impact of climate change on food production and to achieve sustainable increase in food production

(Buduane, 2016). Despite these efforts made by NGOs and MoFA, Derebile et al. (2016) documented that adoption of climate resilient agriculture is still low in the Sissala East District as some farmers are not certain if investing in new farm innovations could propel improved farm performance. The limitations on the adoption of Climate Smart Agriculture according to the FAO (2013) is further pronounced when dealing with the smallholder farmers who form the majority of farmers in most African countries. Unfortunately earlier studies on CSA and food security such as, Ferdenal et al., (2015) and Moore et al., (2014) failed to focus much attention on the smallholder farmer dynamics and how best CSA could be promoted among this group of farmers. However, for studies on CSA to better inform policy in Ghana, emphasis must be placed on the smallholder farmers since they form the majority of Ghana's agricultural force (Peterson, 2014). Also, while CSA policy recognizes the need for synergies between introduced and indigenous CSA for the purposes of achieving sustainability, implementing this aspect of CSA on farm is limited due to limited knowledge on how farmers are merging introduced CSA with their indigenous practices (Elbehri, 2015).

This study examines CSA practices in the context of the smallholder food crop farmer and how their indigenous practices could be brought up for potential policy and project advancement.

1.3 Research questions

1.3.1 Main question

- How can the adoption of climate smart agriculture innovations be enhanced among food crop farmers in the Sissala East District?

1.3.2 Sub questions

(i) What are the adoption levels of various CSA practices among smallholder farmers?

(ii) What are the factors influencing smallholder farmers adoption of CSA innovations

(iii) What is the effect of CSA adoption on food crop production?

(iv) How can synergies be achieved between indigenous and introduced CSA practices?

1.4 Research Objectives

1.4.1 Main objective

- To examine how the adoption of climate smart agriculture innovations can be enhanced among food crop farmers in the Sissala East District.

1.4.2 Sub objectives

(i) To examine the levels of farmers adoption of various CSA innovation

(ii) Assess the factors affecting smallholder farmers adoption of CSA innovations

(iii) To determine the effect of CSA adoption on food crop production

(iv) To assess areas for synergies in indigenous and introduced CSA practices

1.5 Scope of Study

This study focused on the smallholder farmers and their farming practices in the context of CSA in the Sissala East District towards meeting their main farming objective of increased farm production. It looked at how farmers have been innovative based on their personal experiences to adopt practices that seek to address the limitations posed on them by the changing climate. It also centered on CSA practices being championed by MoFA and other Non-Governmental Organizations in the Sissala East district and how farmers are responding to these efforts by way of adoption and the impact of the adoption on food production.

1.7 Significance of study

Studies on farmer's adoption of CSA have centered on introduced practices that farmers are adopting with little on indigenous innovations. This study seeks to help fill this gap by broadening the scope of CSA to include the current innovations that farmers have initiated themselves jointly with the introduced CSA practices and how their adoption is influencing farm production. A great limitation in the discourse of Climate Smart Agriculture is the difficulty to establish the impact of CSA innovations adoption on food production of which this study seeks to address. Lessons from this study would be very useful for lead agencies implementing climate Smart Agriculture projects on the climate smart agricultural innovations that fit into the local context of food crop farmers.

1.8 Organization of the Study

The study is presented in five chapters. The chapter one gives a background and justification for the study. Wide review of the existing body of knowledge on the concepts of Climate change, Climate Smart Agriculture, CSA innovation, CSA adoption, impact of CSA adoption on food production; the systems theory and its relation among others is presented in chapter two. Chapter three focuses on the methodology used in the study, which comprises of data sources employed and methods of sampling and data analysis. The results and discussions of the study are presented in the chapter four with chapter five containing the summary, conclusions and policy recommendations for enhancing CSA practices in the study area.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This chapter reviews relevant literature that helps to address the three objectives of the study. It includes literature on climate, climate-change and Agriculture Nexus and the systems theory propounded by L.Von Bertalanffy (1930) which is used to explain how the major concepts of the study interrelate in a complex farming system. Additionally, literature has been reviewed on the three objectives of the study that seek to assess, the impact of climate Smart Agriculture (CSA) innovation adoption on food production, farmer's choice of CSA practices and how synergies could be built in promoting CSA practices.

2.1 Climate change and agriculture nexus

Finding a common meaning to the term climate is perhaps one of the greatest difficult and contentious phenomenon in the whole science of meteorology (Swim et al., 2008). Lenton and Andrew‘s study (2000, as cited in Lucht, 2010) described the shaping of the earth life as a combination of evolutionary biology and geo chemistry which makes it quiet complex for the earth system to be easily understood. The IPCC (2007) has defined Climate as the mean of temperature, precipitation and wind over a period of time, ranging from months to millions of years (the classical period is 30 years) resulting from both earth's internal dynamics and external forces such as volcanic eruptions, solar radiation and human induced changes in the atmosphere. Even though there have been varied definitions on the concept, the element of time in the definition of climate is often emphasized usually using the classical period of thirty (30) years (Gray, 2009).While acknowledging the importance of time factor is defining the concept, Hsiang (2011) has pointed that using actual evolution of the climate variables (rain, temperature and humidity) observed over thirty (30) years to make conclusions about changes in the climate could be misleading. This is exemplified in Alatalo,Jagerbrand & Malau (2013) in their study of impact of different climate regimes on alpine community. They observed that different warming regimes varied among functional groups, and the short-term perturbations had negative effect on species richness and diversity.

Frigg, Thompson, and Werndl (2015) have further argued that, during a period of thirty (30) years, a meteor hitting the earth in the 15th year for example could change the actual distribution of the variables for the next 15 years hence the cumulative change recorded for the thirty (30) year period would not be reflective of the change. In otherwise put by Kaijseer&Kronsell (2014) the external conditions could contribute significantly to the extreme change of climate over time period even though often silent in the definition of climate and therefore, a better understanding of the concept of climate and its related concepts would require a profound analysis of relations among human and between humans and nature and how they influence one another to create the phenomenon called climate.

To avoid this problem, Alatalo,Jagerbrand & Malau (2013) considered a definition of climate as the mean and variability of temperature, precipitation and wind over a period of time, ranging from months to millions of years under a particular external regime. While agreeing with Alatalo,Jagerbrand & Malau (2013) Leiserowitz et al., (2014) believes that certain opinions must essentially be assumed on what amounts as an external regime emphasizing that the mean of the external conditions should at least be approximately constant. This definition is however new and yet to be explored by many studies (Kaijseer&Kronsell, 2014). Despite the on gong debate on the appropriate description on what climate should be, Etwure (2012) recommends the use of definition as presented by the IPCC (2007) because much of the climate analysis in the world have deployed the averages for periods of 30 years in explaining the changes occurring in the climate.

Understanding the theory of "anthropogenic global warming" is a very good point of entrance to understanding the concept of climate change (Leiserowitz et al., 2014). According to Kaijseer and Kronsell (2014), the Earth's atmosphere is mostly transparent to the incoming sunlight, allowing it to reach the planet's surface where some of it is absorbed while some get reflected back as heat into the atmosphere. Certain gases in the atmosphere, called "greenhouse gases," absorb the outgoing reflected or internal thermal radiation, resulting in Earth's atmosphere becoming warmer than it otherwise might be (IPCC 2010). Romero and Molina (2015) in their definition of climate change broadened it to include any change in climate in time regardless of the cause of the change while Leiserowitz et al., (2014), refers climate change as change of the Earth's climate including changes in temperature, precipitation and wind patterns over a period of several decades or longer.

Even though the above definitions are silent on the causes of climate change, scientists have proven that human activities including agriculture have become a dominant force, and are responsible for most of the warming observed over the past 50 years (Hsiang, 2016). It is based on this conviction that, world bodies have drawn consensus by emphasizing on the human induced climate change in their description of this concept (Frigg et al. 2016). According to the FAO (2015) for example, climate change can be said to have occurred when the mean of one climate regime observed over a long period of time changes from its previous because of direct or indirect human activity in addition to natural climate variability. The IPCC (2013) have also placed much attention on anthropological bases of the changing climate in recent times with the rapidity of change being the greatest global concern.

Even though climate change is now been likened to human induced climate change, this is not yet a generally accepted phenomenon (Lucht, 2011). Socolow et al. (2011) explain with the Bio-thermostat theory to justify the importance of CO_2 in the atmosphere using carbon sequestration in plants. The theory explains that, earthly plants perform much better when they absorb much CO_2 from the atmosphere hence increasing CO_2 turns to contribute to the earth cooling due to increased plants performance. Hsiang (2016) however disagrees because increasing human needs have resulted to increased loss of vegetation hence there are no many trees to absorb the excess CO_2as Socolow et al. (2011) claim. Gray (2009) has also suggested that global increasing temperature was rather the result of the slow-down of the ocean's Thermohaline Circulation (THC) but not due to human action. Bast (2013) agrees with this accession and explained that ocean water is constantly transferred from the surface mixed layer to the interior ocean through a process called ventilation that increases the ocean temperatures and contributes seriously in the world-heating pattern after every 200 years. Earlier, Knorr (2009) sort to disagree with any attempts to define climate change to mean human induced change because sunspots set in the atmosphere had the potential to cause serious changes in the radiant energy emitted by the sun in cycles in every 210 years. Despite the various debates Cicerome and Nurse (2011) maintained that the place of humanity in defining climate change cannot still be down played especially when placing climate change in the context of agriculture.

In relating climate change to agriculture, Jeeva (2015) described humans as part of an entire system where many interrelations take place that subsequently leads to climate change. In this case, it is appropriate to depart from complete attribution where much emphasis is placed on one element (Chinwei et al., 2015). A much practical definition to the concept climate change that links agriculture and climate change is perhaps the one given by Scarno (2016). According to Scarno (2016) climate change is "the change in the mean of climate distribution which is observed over comparable time periods (30 years) caused by the interactions of the various elements in the earth system including the interactions in the agricultural systems".

2.2 Climate smart agriculture (CSA) innovation and adoption

The intensifying atmospheric CO_2 concentration is set to decrease food and forage quality, increase price and yield volatility most likely to put world food security at risk (FAO, 2013). Even though this problem has been with science for long, CSA seems to promise a more sustainable solution to addressing this problem (Timorthy et al., 2015). While acknowledging the contribution of earlier approaches like the Green revolution to increasing food production and a reduction in world poverty and hunger, these approaches were not very friendly to the environment (Jeeva, 2015). This situation has put developing countries in a cycle of perpetual poverty and hunger as noted by Essegbey et al. (2015). Adopting a more sustainable approach to food production according to Bernard et al. (2012) is therefore very crucial to feeding the world's expected increase in population of 2 million people by the year 2050.

The FAO in 2009 coined the concept CSA as the newest buzz-worthy solution to this trinity of problems confronting the world today namely food security, climate change and environmental sustainability. CSA as defined by FAO (2013) is an integrated approach encompassing three dimensions of sustainable development (economic, social and environmental) and seeks to jointly address food security and climate challenges by sustainably increasing agricultural productivity, building resilience of farmers to climate change and reducing greenhouse gases emissions. Simply put, CSA addresses food productivity, adaption and mitigation (Neate, 2013).

Essegbey et al. (2013) described food productivity in the context of CSA as seeking to achieve a sustainable growth in agricultural production and incomes from either crops, livestock and fish with very minimal impact on the environment where as Lipper et al., (2014) described adaptation as a means of strengthening farmers physical and economic resilience to deal with the immediate stresses of climate change through the altering of their production systems. The final element, which is mitigation, is also explained by Chambell et al. (2012) to mean the reduction in the emissions or volume of CO_2 in the atmosphere through the avoidance of deforestation from agriculture.

Since the inception of the concept CSA, a number of attempts has been made to broaden the understanding for application at the ground level persistent (Sugden, 2015). At the second Global Conference on Agriculture, Food Security and Climate Change in Hanoi (2012), much emphasis was placed on the context specific dimension in describing and understanding CSA (FAO 2013). This context specificity of CSA according to Timothy et al. (2015) is very central when describing CSA because the foundation of CSA is sustainability that only emanates from the ground level. Alternatively, sustainability means context specificity. This is consistent with FAO's (2015) assertion that, there could not be a common approach or definition to CSA at all places even though the broad objectives are common. This meant that what is smart in one context would certainly not be smart in another point (Diane 2015).

Depending on your setting and the needs therefore, Andrieu et al. (2017) posit that the description of a climate smart agriculture should focus on at least one of the three pillars (Productivity, Adaptation and mitigation) in the short term but should have an overall long term objective for contributing to addressing all the three pillars. In the case of Africa, it is recommended that CSA should focus much on improving food production that can be achieved by building farmers resilience (Neate et al, .2013). CSA in Ghana and for that matter the Upper West Region would include interventions or practices that seek to promote sustainable increase in food production due to the food security limitations in the region (Peterson, 2014). It is important to point out however that these practices or interventions are not limited to farm level practices because CSA is an integrated approach that addresses problems in a systemic manner (FAO 2013). The production system consist of farmers who work at the farm level, input dealers, financial institutions and market actors who integrate to create results in the farm (Sugden, 2015). CSA in this context therefore covers interventions from all these parts that contribute to pushing the farmer to increase production sustainably (Chambell et al 2014).

FAO (2015) notes that, no single organization or sector can alone address the intertwined problems of climate change, environmental sustainability and food security. For this reason Peterson (2014) believe that there is need for strategic partnerships that bring together farmers, policy-makers and researchers (across disciplines), the private sector and civil society to identify and address the most important interactions, synergies and trade-offs between climate change and agriculture. Therefore, CSA should include initiatives and interventions that seek to build synergies among actors of the production system or among organizations that seek to promote CSA interventions (Frankhauser & Stern, 2016).

Neaste (2013) also describe CSA as a new way of thinking hence in classifying or identifying CSA practices, there is the need to look out for what is new from the usual practices. However, Essegbey et al. (2015) disagrees with this viewpoint explaining that in smallholder farming systems for example, their traditional practices have elements of sustainability in them that qualifies them as CSA practices. To address this challenge, Bayala (2017) has suggested the introduction of the word innovation to help distinguish between CSA practices that are traditionally known and other new thinking's that have emerged based on farmers experience and the advance in science. CSA in a broader picture therefore include all practices and interventions be they indigenous or introduced that support farm level food production in a sustainable manner as summarized by Frankhouser and Stern (2016) while CSA from the innovation context looks more at entirely new ways of farming practices be they introduced or based on farmers own experience resulting due to the changes in the entire farming system (Beever et al., 2013).

Many experts have given varied definitions to the concept innovation in disciplines such as economic, business and sociology (Popa, Preder & Boldea, 2013). The simplest description of this term is one given by OECD (1997) who defined innovation, as anything new made known into an economic or social process. The basic definitions of innovation resonates agricultural innovation. For example, Wright and Shir, (2010) considered agriculture innovation as the economically successful use of invention for increased agricultural performance;

where invention is referred as a solution to new challenges posed by climate change. In addition, Rajalahti (2011) gave more elaboration and described agricultural innovation as new concepts, products or processes gotten from either farmers, value chain actors, scientific research or a novel combination of existing knowledge that are used to promote agricultural production. Accordingly, Sulaiman (2015) agreed with the commercial component of innovation but argued that innovations are more likely to emerge in response to scarcity and economic opportunities in the entire farming system that includes the end users of agricultural products. In the broader context, agricultural innovation is the process of making large or small changes to product, process and services that result in the beginning of something new that improve farm performance (Rajalahti, 2011).

The difference between Agricultural innovation and CSA innovations is that; CSA innovations are context specific in nature with the assumption that new things only emerge from the experiences people gather from the local context environment (Wright & Shih., 2010). CSA innovation according to Steenwert et al. (2014) puts into context, the geographic, economic, cultural and social circumstance of the rural sector for better understanding of farmers innovation process. Defining innovation in the local context according to Sulaiman (2015) further allows researchers to appreciate rural people's knowledge, motivations and values that play an important role in advancing their ways of life. Jeeva (2015) was thus of the view that, the nature of interaction between and among the rural actors is an important aspect for consideration when defining innovation from a CSA viewpoint.

Traditionally, agricultural innovation has been seen more as a linear process, which happens because of the flow of new knowledge originating in a formalized way in the production process through a single action that can easily be traced (Neate, 2011). However CSA innovation posit that farmer's practices and actions are very complex just as their ways of approaching new challenges (Rajalahti, 2011). This new view is consistent with Popa et al. (2013) who had earlier noted that agricultural innovation should include all processes associated with production, distribution, adaptation viewed as a joint unit not separate units. Time is yet another element that some writers suggest should be considered for a better description of innovation in the agricultural context (Sunding & Zilberman, 2010). According to Essegbey et al. (2015), determining a new agricultural practice required a clear time benchmark that distinguishes the period of old practices from the new era. However, European Union [EU], (2012) cautioned that generalization of innovation change especially when dealing with smallholder farmers would certainly be challenging because smallholder innovation adoption processes are often haphazard by nature. Bill & Melinder Gates Foundation (2013) has also explained that a practice that is old to one farmer might be new to another within the same period creating potential confusions during categorization of what an innovation entails from a broader perspective. This notwithstanding, Iheke and Nwaru (2013) was certain that the role of time in defining CSA innovation should not be overlooked. To avoid potential confusions in categorization of agricultural innovations, Rajalahti (2011) suggested that references be made to literature to help categorize practices into old and new where emphasis is put on the new practices when identifying the CSA innovations.

Based on the above, Timothy et al., (2015) gave a practical description of CSA innovation as "practices at the farm level, service level or market chain be they introduced or indigenous which fall outside the traditional practices documented". For any innovation to make an impact, it has to be adopted by people. This also applies in the case of agricultural innovations (Sunding & Zielberman, 2000). Adoption has been defined in diverse ways by different authors using different approaches but the appropriateness of each approach depends on the particular context (Baltimore, 2008). Kaine (2003) had advised that in defining farmer's adoption of technologies, the first thing to consider is whether adoption is a in discrete state with binary response variables while Sulaiman (2015), emphasized the need for a clear distinction between an adopter and a non-adopter using values 0 and 1 which makes it easier for categorization.

Based on the above, a number of definitions have come up in the area of agriculture innovation adoption. According to Bever et al. (2013), agriculture innovation adoption can be defined as the combination of a novel technology into present farm and value chain practices that is usually preceded by a period of trying. Sulaiman (2015) has also described innovation adoption as a mental progression that farmers go through from first hearing about an innovation to final utilization of it on the farm level. This means that for innovation adoption to take place there must necessarily be a procedure to be followed which decision to be made, an action to be taken and knowledge created (European Union [EU], 2012).

Wisdom et al., (2014) identified five major stages leading to adoption as; Knowledge (Awareness), Persuasion (Interest), Decision (Evaluation), Implementation (Trial) and Confirmation (Adoption) but Lai (2017) believes that the speed with which each individual passes through these five (5) stages will vary depending on the particular innovation, its overall complexity, its costs, and just how disruptive the innovation is to the old system. This was consistent with Ficher (1993) two categories of adoption namely "rate of adoption" and "intensity of adoption" when looking at agricultural innovations. The first is the relative speed with which farmers adopt an innovation with the element of time being emphasized while intensity refers to the level of use of a given technology in any period. Straub (2009) however believed that a distinction between adoption and adoption intensity would result in methodological problems, as there is no reason to suppose that the factors that influence the farmer's first use of a technology or practice are unavoidably the same as those that influence any subsequent expansion in the use. Swinton (2003) was however consistent with Smale et al., (2001) explaining that, there is no justification to suppose that the farmer pursues similar advantage in their first use of a technology just as in their subsequent increase in use of a new practice.

Ndah et al. (2010) avoids these confusions by defining adoption as the first use of a technology with the intent to use the agricultural innovation for as long as the use provides the best benefit to farm performance.

According to Peterson (2014), Agricultural innovations may vary in their divisibility just as adopters characteristics. For example depending on the financial strength of a farmer he may decide to cultivate half an acre of farm and adopt a particular practices on it while another may have the strength to adopt on his ten (10) acres of farm. Drawing on farming systems theory, Wright & Shih (2010) concluded that the expected benefits of adopting an agricultural innovation are influenced by farm context elements in a farming system that are specific to each adopter. To this, Beever et al. (2013) was of the view that emphasis on the scale of adoption may mean that the farmer adopting on a larger scale is necessarily a higher adopter than those adopting on the small scale but Sulaiman (2015) was sure that defining farmers innovation adoption relative to the scale on which the practice is adopted is appropriate for studying climate smart practices.

Parven (2010) made three divisions in categories of adoption that must necessarily reflect when defining adoption from agricultural innovation context. They included, individual vs. aggregate adoption, singular vs. packets of technologies available for adoption, and divisible vs. non-divisible technologies (Feder, 2016). Individual adoption according to FAO (2016) includes an inner purposeful procedure but is eventually displayed as a dichotomous decision while Sonal and Blaskar (2015) gave a clear distinction from the individual adoption as the collective level of use of a specific innovation among one specific group of farmers or within one particular area. Grainger-Jones (2011) further noted that farmers can be presented with a single choice of an innovation but in most instances especially with introduced innovations, Kaine (2008) was of the view that they mostly come in bundles and these bundles are often complementary hence adoption should be described in this respect. Depending on whether the technology is considered as a singular one or comes in pockets, Writght and Shir (2010) emphasized the need to consider the divisibility component of the innovation especially when placing the innovation in the field of agriculture. Steenwerth et al., (2014) builds on the above and describes adoption in line with climate smart agriculture innovation as, the first or subsequent use of a single or a combination of practices be they self-induced or externally introduced at the farm level due to the general changes in the climate variables with the aim of improving short term or long term farm performance.

Building on the various views, it can be concluded that the understanding of CSA practices differ from place to place and among different categories of people. However, lessons from adoption of these practices in different locations influence the definition and understanding of others on the same concept with the availability of information. Therefore, CSA innovation adoption can be explained is a process resulting from the combination of experience and information that reveals workable practices for achieving increase food production while mindful of environmental implications of the practices adopted. Farmers by their own experience in farming know which indigenous practices would help achieve results. Through policy interventions and works by development organizations, information of modern practices for achieving sustainable food security are being promoted with lessons being shared among areas. The combination of these farmers' experiences and information defines a process known as CSA. Results of these combinations are the farm level adoption of practices that are known as CSA practices.

2.3 Examples of CSA practices adoption among smallholder farmers

According to Naing et al. (2010), Farmyard manuring is one of the indigenous forms of farming practices that remain climate smart for farmers in developing countries. Scientifically, animal manure contains soil nutrients such as nitrogen and potassium that have a great potential of contributing to increased farm productivity (Yousof et al., 2016). Even though adoption of animal manure fertilization practice does not support large scale farming, adoption levels are still high among smallholder farmers especially women farmers in most developing countries where farming is still at the subsistence level (Asuming, 2010).

Another type of indigenous CSA practice adopted by farmers is crop rotation. This involves the planting of different crops interchangeably in different production seasons with the aim of improving upon the nutritional content of the soil (Cassi et al., 2015). Crop rotation is yet another indigenous CSA practice that is used among many crop farmers across many parts of the world (Etwuri, 2012). Even though the scientific explanation for crop rotation is not understood by farmers, they continue to use this practice due to the experience on the positive impact of this practice evident on their farms (Farid et al., 2015). However much of the adoption of crop rotation is practiced among female farmers (Daisy, 2013).

Use of pesticidal plants for weeds control is also an indigenous CSA practice adopted among smallholder farmers aimed at improving farm performance (Asuming, 2010). Even though modern forms of weeds control exist, access to some of these inputs is low among farmers especially women necessitating other farmers to rely on this traditional mode of weeds control in their farming (Peterson, 2014). Unfortunately, there have been few scientific attempts to integrate much of pesticidal plants into modern pesticides formulations to reduce the chemicals used in agriculture (Naing et al., 2010).

Development organizations are also promoting introduced CSA to make farmers resilient to climate change. It is important to note that, introduced CSA are not very new ideas but mostly a buildup on farmer's traditional ideas (Iheke & Nwaru, 2013). Use of improved varieties and breeds of seeds such as high yielding varieties, early maturing varieties, drought tolerant varieties and improved breeds are introduced CSA practices that are common among the agricultural development cycle (Etwuri, 2012). According to Asuming (2010), use of improved seeds make possible for the farmer to increase yields of cereals and legumes regardless of the unfavorable climatic conditions. For instance, Smallholder farmers who use early maturing varieties are not affected badly by the unpredicted nature of rains ensuring better yields in drought years (Etwire, 2012).

Introduced CSA interventions have also consciously promoted the adoption of soil health related strategies that help to improve soil fertility which include use of inorganic fertilizers and compost (Farid et al., 2015). Composting helps to improve both soil structure and fertility after periods of floods and droughts when adopted on maize farms despite the low levels of adoption (Yousof et al., 2016).

Some introduced CSA practices also target crop management that include; planting during recommended period, planting in rows and conservation agriculture (Cassim et al., 2017). Conservation agriculture practices include minimum tillage or direct seeding, planting of cover crops and legumes for nitrogen fixation but adoption is still low among African countries (Kamanula et al., 2010). Another conservation agricultural practice mostly adopted by farmers is the Cultivation of leguminous crops such as soya beans and mocuna cover crops (Naing et al., 2010). Leguminous crops help fix nitrogen from the air into soil. Soya for have root nodules with some microorganism that can fix atmospheric nitrogen and convert it in to a form that can be absorbed by plants (Etwire, 2012).

2.4 Impact of CSA on food production

It is important to note that some empirical studies have already demonstrated the importance of adopting some of these practices for improving farm productivity that subsequently contribute to enhancing food security (Lipper et al., 2011).

Use of cover crops is reported to have a great potential of resulting in improved food production (Perterson, 2014). Youssof et al. (2016) explained that, the use of cover crops have the potential to decrease soil erosion and nutrient leaching, and reduce grain losses from pest attacks. For example, Suleiman (2015) further established that beans cover crops reduced soil erosion by 42-95. In addition, the use of cover crops are found to add organic carbon to cropping systems through root and shoot decomposition that enhance many physical characteristics of soil, such as improving aggregate stability which subsequently leads to increase in yield (Farid et al., 2015). Moore et al.,(2014) further showed that maize yield increased from 1.2 to 1.8-2.0 t/ha with the use of mucuna cover crop while Marray et al. (2016) evidenced that farmers who adopted mucuna cover cropping profited from higher yields of maize with fewer labour input for weeding without application of nitrogen. Cassim et al. (2017) were therefore convinced that increasing the use of cover crops should be one in a list of options that have potential as climate-smart practices for the crop farming communities. It is therefore not surprising that the Ghana Climate Smart policy have mentioned the use of cover crops in the list of CSA practices recommended for the Savannah ecological zone of which the upper west is part (Etwire, 2012).

Other important farming practices that are considered as climate smart are crop rotation and intercropping designed to ensure differential nutrient uptake and use (FAO, 2015). These practices have also been proven of their ability to enhance soil fertility, reduce reliance on chemical fertilizers, and enrich nutrient supply to subsequent crops leading to increased crop yields (Taylor, 2017). A study by the International center for research in organic food systems [ICROFS], (2010) proved that maize yields increased to 3,414 kg/ha (71% increase in yields) while soya bean yields increased 68% through crop rotation. Yousof et al., (2013) were conclusive therefore that studies that aim to assess the impact of farmers adoption of CSA practice needed to consider as matter of necessity crop rotation as part of the thematic areas of measurement.

Studies have also proven use of new crop varieties as climate smart especially in food security prone areas due to the potential of increasing yield performance (McCarty 2011). Improved maize and soya yields increased by 60% and 44% respectively above local seeds in most parts of Africa when introduced and have contributed to reduced hunger (CIAT, 2008).

The use of new fertilizer that is mainly organic in nature is yet another practice being promoted by CSA initiatives (FAO 2010). Adopting organic fertilization (compost and animal manure) is widely found to have positive effects on yield. Taylor (2017) showed that maize yields increased by 100% while millet yields increased by 75-195% after the application of the organic fertilizer in most African countries.

Minimal tillage is yet another crop-based practice that falls under the description of CSA (FAO 2015). Tillage systems which adopt no-tillage, minimum tillage and crop residue management provide opportunities for increasing soil water retention therefore, crop yields are often higher than conventional tillage, especially in and dry agro ecosystems (Yousof et al., 2016).

2.5 Farmer's choice of CSA practices

Technological change has been the major driving force for increasing agricultural productivity and overall agricultural development in all developing countries (Barnard, 2015). These changes in technology have come in handy considering the growing complexity in the challenges faced in the agricultural sector because of climate change (Khatri-Chetri et al., 2017). Over the years, the approaches to agricultural technology innovations have not only changed at the international policy levels (FAO 2013) but also at the farmer level where farmers have based on their experiences to make advances in their farm level practices (Nyasii et al., 2017).The general objective for adopting new farm innovations is to improve farm production but beyond this objective are multiple factors that influence the farmer's choice of a particular farm innovation (Cassim et al., 2017).

The common premise for many studies that sort to give an understanding to farmer choice of farm innovation is summarized by Romero & Mmolina (2015) as the "innovation path dependent concept" which explains that, an innovation adoption is a result of a process involving different integrated factors from an environmental system where the farmer originates. Farmers adopt a mix of technologies to deal with a multitude of agricultural production constraints based on certain social, economic and political factors (Deribile, 2016). These factors according to Barnard (2016) could further be classified into Internal and external factors. For instance, Social internal factors could be factors that are more personal to the adopter such as age, sex and education while the external could be market dynamics (Marran et al., 2016).

Farid et al. (2015) revealed that educational levels of adopters were the clearest point of influence on farmer's choice of different types of agricultural innovations especially with smallholder farmers. They further added that a woman's education level for example has the most positive impact on the adoption of commercial fertilizers and conservation tillage. While agreeing that education influence farmer's preference of CSA practices, Etwire (2012) pointed out that sex of the farmer was the basic `driver of farmer's choices and actual adoption of innovations. This was consistent with Deribile & Drammani and Dangzagla (2016) who further noted that men generally adopted higher cost innovations such as improved seed varieties as compared to women. From a cultural viewpoint, Sugden (2015) explained that men who are mostly heads of their families in Northern Ghana had greater economic responsibilities than women and adopted more innovations to increase their food production to meet the food requirements of their families.

Access to farm input has a definite influence on the type of CSA practices that farmers adopt because 80% of farmer's activities have to do with inputs (Romero & Molina, 2015). Even though Marran et al. (2016) explained access to inputs from the cost point of view, Jeeva, (2015) was of the view that distance of inputs from market translated into high or low input cost hence the distance of communities from input markets was a major factor influencing the type of CSA practices that farmers adopt. Chambell (2014) was consistent with Marran et al. (2016) indicating that distance to the input market has a negative and significant effect on the adoption of improved crop varieties, new fertilizers, and new organic weedicides because there is always an inverse relationship between input demand and transaction costs. While distance generally had a negative influence on introduced innovations, Nuntui (2014) pointed a rather positive influence on the adoption of indigenous innovations. He explained that farmers who had difficulties accessing chemical weedicides would for the purposes of convenience adopt pesticidal plants for weeds control.

Another factor that has influence in a farmer's choice of CSA practices is their level of associations and belongingness to farmer networks (Peterson, 2014). Daisy (2013) had earlier hypothesized that, farmers who benefited from social capitals such as loans and labor support from associations had a positive adoption of Sustainable Agricultural Practices. Ajayi (2007) was consistent with Daisy (2013) noting that farmers who had groups or people they could turn to in times of crop failure were much risk lovers who stood the chance of adopting new farming systems such as crop rotation with new legumes and improved crop varieties. Romero & Molina (2015) had explained that, farmers in organizations could easily access loan facilities from banks using the concept known as "group solidarity". With this concept, every group member is responsible for group loan repayment to prevent default. Farmers who belong to formal farmer networks also turn to adopt new farm practices (Essegbey et al., 2015). This is so because members of such networks get better understanding on how new innovations work at their meetings that builds their confidence to adopt innovations better than farmers without networks (Timothy et al., 2015).

In order to improve the adoption of maize CSA technology, Deribile et al. (2016) proposed that local institutions and service providers need to be supported to effectively assist farmers in providing credit, inputs, information, and stable market outlets. Communities who have for example NGO support schemes for service providers such as aggregators and input dealers will have more opportunities to adopt new innovation than those without such schemes (FAO, 2015). Bernard et al. (2015) have further noted that innovation adoption in a farming system happened in a chain of which service providers play very important roles for ensuring that farmers get access to innovations.

Adoption of climate smart practices further have a positive correlation with the access of agro based information (Tadesse, 2008). Obdike (2011) have shown that the presence of extension agents contributed positively to adoption of new farm innovations while Uzonia & Qijie (2013) observed a low adoption of CSA practices among farmers with limited access to Weather information. According to Tadesse (2008), availing climate information to the farmer enhanced the adoption of appropriate crop varieties by 17.6% in the Nile basin of Ethiopia. To ensure effective dissemination of agro climate and weather information to enhance adoption of climate smart practices, Nyasimi et al. (2017) suggests the need to strengthen and enhance capacity for collection, downscaling and disseminating agro weather and climate information by meteorological services and extension service providers in a timely manner.

The discussions show that the probability and extent of adoption of CSA would be influenced by several factors including farmer demographic characteristics, social capital, asset ownership, distance to markets, the farmer networks and confidence in the skill of extension agents as noted earlier by Agwu, Ekwueme & Anyanwu (2008).

2.6 Building synergies for enhancing CSA innovations

In achieving the triple win objectives of CSA in an African smallholder farming system which is so complex in nature (FAO 2013), there is an urgent need for research and development to support adaptation decision making, including identifying priority thematic areas taking into consideration the social, economic and political synergies that are important for to supporting agriculture transformation (Beever et al., 2013). Adopting CSA at field or farm scale may be influenced by institutional mechanisms, landscape governance, resource tenure, economic, social, ecological and climate conditions (Steenwerth et al., 2014). The context-specific nature of CSA requires that a diversity of options are developed for the various context across scales (Cassim, Chakufwa & Timika, 2017) including identifying linkages between socially differentiated groups (gender, age, educational status),the assessment of interactions and priorities across different social groups and trade-offs among the CSA pillars across the landscape (different agro-ecological zones, climate regimes, social groups and land-uses) (Campbell et al., 2014).

Terdoo & Adekola (2014) in their work acknowledged the importance of farmer's indigenous knowledge and wisdom in up scaling and out scaling CSA. Even though scientific knowledge and approaches are inevitable for up scaling CSA (FAO, 2015), Morras and Mmungai (2015) opines that farmer's valuable knowledge on seed varieties, crop management and ecosystem services needed to be assessed to get which new practices fit with their traditional practices. Singh & Singh (2017) therefore concluded that, the value of local innovations should not be underestimated, especially because they can easily be scaled jointly with new innovations than tackling upscale in isolation. Terdoo & Adekola (2014) in their outline of points of entry between indigenous wisdom and scientific innovations recommended the identification of pure indigenous practices through research and thereafter making the possible linkages with science.

Earlier studies have proven the successes of some CSA initiatives that succeeded due to their involvement of the indigenous wisdom (World Bank 2012). The International Food and Agricultural Development initiative to upscale soil and water conservation practices through its portfolio of investments in Burkina Faso resulted in a spectacular increase in the number of trees – a phenomenon known as the "re-greening of the Sahel" due to its indigenous knowledge led approach (Nyasimi, 2017). Upholding, invigorating and scaling up existing technologies and consolidating new ones is therefore a straightforward pathway for scaling up CSA because when technologies are successful, they are spontaneously taken up by the farmer (Beever et al., 2013).

The accessibility of farmers to a well-aligned and comprehensive system of financial incentives that supports innovation and demand for services from the grass roots is also an important catalyst for scaling up CSA (Feder, 2016). The FAO (2013) in their CSA source acknowledged the importance of financial systems for CSA while Iheke & Nwaru (2013) have added that any innovations in the financial sector that promotes farmers adoption of CSA were also indeed CSA innovations beyond the farm level. The Gate and Melinder Foundation (2013) further emphasized that any innovation that did not consider the financial stand of potential adopters was not smart and encouraged the need for financial systems be considered in selecting appropriate innovations. This is important especially for smallholder farmers who are unable to wait long for earnings on investments or yield increases (Rajalahti, 2011). Eture (2012) therefore proposed that financial service providers needed to continuously streamline their packages to fit with smallholder farmer characteristics through stakeholder engagement between farmers, financial institutions and organizations promoting CSA innovations (Sugden, 2015).

The scaling up of climate-resilient approaches can be facilitated by identifying and understanding different local institutional efforts in CSA (Schwilch et al., 2012). Tadesse (2008) agreed with this but further added that this is especially necessary since it helped to prevent duplications of efforts among organizations. Not being able to identify all CSA efforts at any locality according to Obidike (2011) also causes conflicting actions which does not promote comprehensive adoption of CSA practices. To address this challenge, Agwu, Ekwueme & Anyanwu (2008) proposed the need for the establishment of learning networks among various institutions where platforms are created for information sharing on all ongoing CSA interventions and potential areas for complementing.

It is important to note that not all institutions playing roles in the farming value chain have environmental background and able to understand and appreciate issues of climate change and agriculture very well (Farid, Tanny & Sarma, 2015). For this reason, Nyasimi et al. (2017) proposed the need to build local institutions capacity and ability to obtain access to climate information for guiding decision-making towards a holistic upscale of CSA. Meanwhile Uzonna (2013) had stressed on the need for local institutions to identify and pilot risk management associated with farmer level decisions that relate to their services so that they could become more innovative and move towards smart decisions and services that are farmer friendly. In their conclusion on the various roles institutions need to play in CSA, Morras & Mungai (2015) emphasized that building institutional synergies in CSA would eventually enable proper coordination and harmonization of actions at multiple levels, within and outside at a particular targeted location. In this regard, Feder (2016) identified agents that may facilitate the scaling-up process of CSA to include financial institutions; insurance companies, research and development partners, knowledge providers and value chain actors (aggregators, input dealers, tractor service providers).

Promoting of CSA aims at ensuring a proper management of natural resources and environment (FAO 2010) which has a strong cultural dimension (Taylor, 2017). For this reason, Terdo & Adekola (2014) propose that the cultural dynamism of any locality needs to be examined to identify best points of entry for CSA interventions. This is especially important because CSA interventions often involve access and tenure rights and other issues affecting women and indigenous peoples (Sigh & Sigh, 2017) hence possible cultural obstacles need to be identified and considered towards scaling up of CSA practices (Obidike, 2011).

Communication is keen for merging traditional views into CSA and for enhancing effectiveness in CSA adoption; Agwu et al. (2008) opine that much importance should be placed on the identification of the traditional ways of receiving feedbacks of CSA interventions. Unfortunately, most CSA initiatives and promoters have placed little emphasis on this indigenous feedback channels and resorted to scientific ways of getting feedbacks (Feder, 2016). Identifying Local cultural platforms would serve as entry points for sensitization of communities on CSA initiatives (FAO 2015) .Alternatively appreciating indigenous wisdom would not only promote understanding of CSA initiatives but also encourage community ownership of CSA interventions for enhanced adoption (Uzonna & Qijie, 2013).

2.7 Systems theory for establishing the need for synergies

The study was grounded on the assumption that the adoption of an agricultural innovation by farmers contributes to satisfying three main objectives namely social, hedonic and utilitarian goals (Wisdom et al., 2013). Therefore, the adoption of agricultural innovations are characterized by a complex decision making process. Considering the fact that the benefits an innovation offers to a producer depend on the producer's perception of their specific needs, a theory that fully supports the identification of those aspects of the specific needs was hence very necessary (Terdoo & Adekola, 2014). To this end, the researcher proposed the open systems theory. Closely related to the open systems theory were the farm systems theory and the consumer behavior theories but these were not considered because of their failure to recognize casual relationship in farming system and the context specificity of the farmers decision respectively.

The open system theory forms the foundation for the study well known as 'general system theory (Drack &Schwarz, 2010). The theory states that groups are open systems, which are influenced by such independent variables as; openness to environment, interdependence, input variables, process variables, and output variable (Leighninger, 1978).

According to Riis (2013) the systems theory is ontologically deterministic, because it recognizes the environment as a provider of the resources and processes that are used to gain the correct outputs. This perspective of the theory according to Mele, Pelis, & Polese (2011) is scientific and alternatively has one truth in epistemology since groups will use processes and their resources within their environment to cultivate the desired outputs.

Riis (2013) was also of the view that, to understand the systems theory, it was prudent to first look at the meaning of what a system means. Earlier, Drack & Schwarz (2010) described a system as a set of interconnected things or parts forming a complex whole in a particular domain. The four parts that come together to make a system according to Almaney (1978) included; objects – (the parts, elements, or variables within the system), attributes (the qualities or properties of the system and its objects), internal relationships among its objects and existence in an environment. Even though different authors have tried defining a system in their own literature, Riis (2013) was certain that the fundamentals of what a systems means have not changed in literature and further described the concept as a set of things that affect one another inside an environment and form a larger pattern that is different from any of the parts.

An open systems theory is therefore a theoretical viewpoint that examines a phenomenon understood as a whole and not just the sum of elementary parts, which helps to understand an entity's organization, functioning and outcomes (Bertalanffy, 1972). In agricultural problem solving, Forder (1976) was of the view that, open systems theory is appropriate because it takes into account all likely causes of the problem and examines each independently and what role they play in the system. This was consistent with Jackson (1985) who recommended that in finding solutions to agriculture related problems the start point should be an analysis of the elementary components (farmers) in order to fully comprehend the issues.

Rajalahti (2011) described agricultural innovation and adoption as a greatly complex process characterized by an extraordinary degree of nonlinearity. This is because farmers partake in social change not as passive subjects, but rather as social actors resulting in much complex meaning of agricultural advancement (EU, 2012). Even though farmers and services providers easily come to light at the mention of agricultural innovations and adoption as put by Sunding & Zilberman (2010), other forces and actors play roles in creating solutions to the production challenges facing the sector in this era of climate change (Iheke & Nwaru, 2013). To this end, any agricultural development and advancement agenda needed to adopt a holistic approach because tackling any agricultural related problem from a narrow viewpoint would yield limited outcomes (Beever et al., 2013).

The farm systems theory which terms of usage and application is close to the open systems theory is notably used by Lai (2017) and Lipper et al (2014). The farm systems theory treats agricultural enterprises as managed systems that consist of hierarchical networks of complicated, interdependent sub-systems that are open to biophysical, economic and social influences (Marreay et al., 2016). Even though this theory practically fit into the concept CSA innovation, it suggests that relationships within the process of innovation are a well structured and hierarchically in nature. It failed to recognize that the presence of causal relationships between the components of farms, farmers and their environment which restricts its appropriateness to achieve the objectives of the farmer under the CSA concept (Khati et al., 2017). These ideas are supported by Nyasimi (2017) who was of the view that the benefits to be had from introducing an innovation into a farm system will depend on precisely how the innovation changes the practical constraints to achieve the objectives of the farmer.

Open systems theory however assumes that, the farmer's decision for adopting agricultural innovations is defined by the way in which they change the practical constraints to achieve the objectives which are not restricted to a logical sequence of events (Peterson, 2014). Also in the open systems theory, the benefits to be had from introducing an innovation into a farming system will depend on the manner in which the interrelationships between the components in the system are modified and how these modifications contribute to making it appropriate for CSA innovation adoption process (Hsiang, 2016).

The consumption behavior theory is yet another theory some proponents have suggested for the study of farmer behavior and farmers decisions to adopt innovations on their farms. Diasy (2013) indicated how the consumption situation for an agricultural innovation is defined by the way in which the innovation allows the farm system to be modified and how these modifications contribute to attaining the objectives of the primary producer. These considerations suggest that a correct description of the consumption situation for agricultural innovation requires the identification of those components and relationships within a farm system that are functionally related to the innovation (Feder, 2016). Andrieu et al.,(2017) also suggest that the components and relationships in the farm that are functionally related to an innovation are the fundamental sources of the purchase criteria used by the farmer to evaluate the innovation. However, the assumptions of the consumption behavior does not relate very well to agricultural innovations that are farm context which denotes the components in a farm and the relationships between them, that are causally related to the innovation and so shape the benefits to be had from it.

The open systems theory addresses this limitation by defining the farm context for an agricultural innovation by elements in the farm that are functionally related to the innovation such as resources, constraints, agricultural technology and management practices, and strategies for managing risks (Grainer, 2011). This definition of farm context provides the basis for identifying the population of potential adopters of a CSA innovation.

Given that the farm context for an agricultural innovation is defined by elements in the farm that are functionally related to the innovation, and thereby influence the achievement of the objectives of producers, then the experiences, knowledge and skills of producers may influence the adoption of agricultural innovations which make the open systems theory appropriate in this regard for explaining the inter dependence (Essegbey et al, 2015).

In summary, the differences in the components of farm such as resources, constraints, technologies and practices together with differences in the strategies and objectives of producers create different types of on farm and off farm linkages that can be best explained by the open systems theory. The study therefore tried to meet the challenge of understanding farmer innovations by conducting research that draws on the unique knowledge of the farmer and the multiple perspectives of researchers from different disciplines. Consequently, key features of the open systems theory that are brought to the study of farmers adoption of CSA innovations were a whole systems approach to the analysis of agricultural enterprises, collaborative research involving scientists from a range of biophysical and social disciplines and partnerships between farmers and development workers.

The study explicitly recognizes that the adoption of agricultural innovations is driven by the self-interest of farmers as expressed by their objectives. In addition, this study also recognizes that farmers have a thorough knowledge of their local environment including spatial and temporal variability; have an intimate understanding of their farms, problems and priorities; have criteria for evaluation of options; and actively engage in experimentation as part of their farming routine. The emphasis in open systems theory on the creation of technical solutions to constraints on agricultural productivity informed the study to have a practical focus on the design of innovations that fit with a particular type of farm.

Following Wejnert (2002), a diagrammatical representation of open systems theory is presented in figure 1.

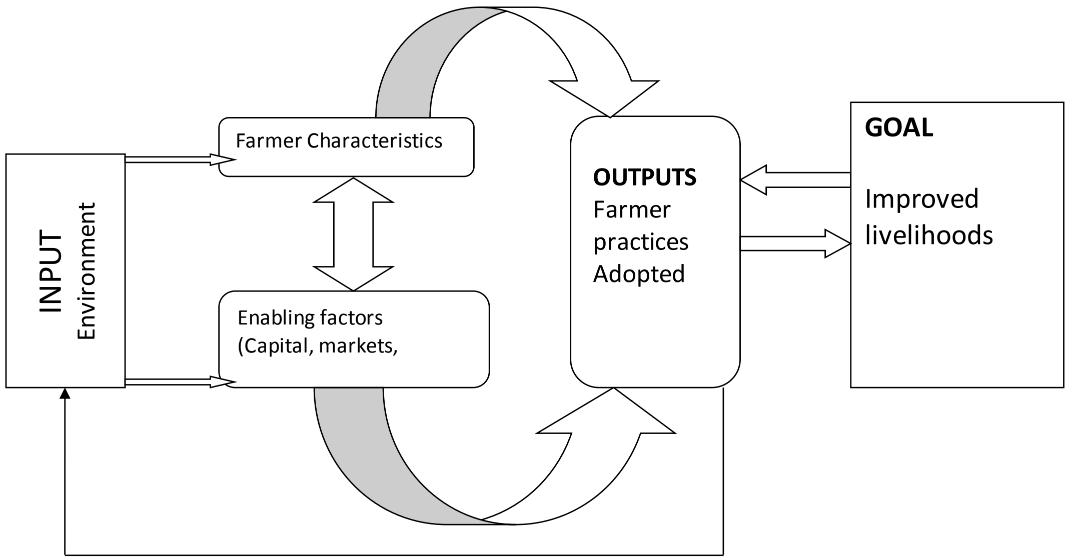

Figure 1Diagramatical representation of the systems theory.

Source: Wejnert (2002)

According to Wejnert (2002) as presented in figure 1, humans relate in an open system with the environment, which is the basic source of energy for their survival. Farming requires input energy such as rain, sunlight and soil nutrients to function. The level of influence of the environment on farmers is defined by the farmer's basic characteristics of the farmer including, sex, economic status, culture as well as the knowledge. In addition, the level of environmental impact on the farmer is defined by the level of access to socially constructed enablement that includes access to technology, markets, education, inputs and information. There is interdependent existance between farmer characteristics and his enabling environment that are sub systems. Solow (1956) in the production theory assumes that essential inputs that contribute to production of goods and services are labor and capital further supporting the interconnections established in the systems theory.

The result of farmers interaction with the environment and further influenced by their characteristic as well as their enabling social setting leads the farmer to take actions and decisions geared towards improving his living situation and relation with the environment. There is a feedback from the actions of the decisions of the farmer on the environment, which the environment processes and return back to the farmer.

CHAPTER THREE

RESEARCH METHODOLOGY

3.0 Introduction

This chapter deals with the methodological underpinnings of this study. It first looks at the characteristics of the population of study. It also explores the design of his study and the various techniques that were used to sample respondents and get information from them as well as methods and procedure to process the information in order to find answers to the research questions.

3.1.0 Characteristics of the study area

This section presents some characteristics of the study District that are relevant to the study. They include; the location, climate, vegetation, economy and market networks. The location of the district describes the physical land mass of the District particularly the land size. This characteristic helped the researcher to assess the suitability of the district for agricultural activities. The climate of the district helped to inform the researcher how farmers are influenced by the rain and temperature patterns and how that informs the need for CSA interventions. The vegetation of the district helped the researcher to assess how farmer's activities could influence their vegetation and the third objective of CSA which seeks to reduce emissions from agriculture could be realized. The local economy helped to assess the importance for agriculture for livelihood advancement in the district and how CSA can help advance agriculture. The availability of markets influences farmer's decisions on production (Etwure, 2012). It was very important therefore to understand the market dynamics of the district and how that influenced farmer's adoption of CSA practices.

3.1.1 Location and Size

The Sissala East District is one of the eleven districts in the Upper West Region. The Sissala East District Assembly was created in the year 2004 by Legislative Instrument (LI.) 1766 with Tumu as its district capital, as part of the decentralization policy. The Sissala East District is located in the North- Eastern part of the Upper West Region of Ghana. It falls between Longitudes 1.20^0 W and Latitude 10.10^0 N and 2.20^0 W and 11.00^0 N. It shares boundary on the north with Burkina Faso, on the east with Kassena Nankana West and Builsa District, to the south-east with West Mamprusi District, south-west with Wa East and Daffiama-Bussie-Issah districts and to the west by Sissala West District. The Sissala East District has a total land size of 5,092.8 square kilometers representing 26.7 percent of the total landmass of the region (GSS, 2014).

3.1.2 Climate

The climate of the Sissala East District follows a general pattern identified with the three northern regions. It has a single rainy season from April to September, and an average annual rainfall of about 121 mm. This is followed by Harmattan - a prolonged dry season characterized by cold and hazy weather from early November to March. The Harmatan season followed by an intensely hot weather that ends with the onset of early rainfall in April. The mean monthly temperature ranges between 21^{c} C and 32^{c} C. Temperatures rise to their maximum (42^{c}) C in March. This abundant sunlight in the district can be harnessed as energy to improve on the district's energy mix. The District experiences a single maxima rainfall regime. As a result of the single maxima rainfall prevailing in the district crop production is only done during the rainy season (May to September/October), apparently resulting in the migration of the youth to the south in search of none existing jobs (Sissala East District Assembly, 2004 and 2010)

3.1.3 Vegetation

The Sissala East District is located in the Guinea Savannah vegetation belt. The District is one of the most forested areas in the region and the vegetation consists of grasses and scattered fire resistant trees such as the Sheanut, the Baobab, *Dawadawa* and Acacia. Timber harvesting trees of commercial quantities such as Mahogany, Rosewoods also thrive very well in the district and can be grown and harvested. The District also host forest reserves such as Gbele Resource Reserve, Pudo Hills among others. The grassy nature of the vegetation is excellent for grazing, a potential for livestock production (Kansaki, 2015)

3.1.4 Economy

The economy of the district is largely agrarian (69%), service and commerce (15%), and the industrial sector (16%). The Sissala East District is basically rural with more than 80 percent of the people living in rural settlements are engaged in farming. The people engaged in the cultivation of food crops (grains such as millet, sorghum and maize; roots and tubers, particularly yams and legumes, including groundnuts and beans). Households in the district are also actively engaged in rearing livestock, including cattle and ruminants (GSS, 2010 PHC).

3.1.5 Market size and Opportunities

The District is very active when it comes to commerce especially trade within the Upper west Region, country and even beyond the borders of Burkina Faso. The District has two major markets at Tumu and Bugubelle aside several minor markets that cut across its length and breath. These markets especially the Tumu and Bugubelle have a regional and international patronage. The District is the trade hub for the value chain of maize, soya and shea nuts very close to a major market in Burkina Faso (Leo) which is about 10Km from Tumu. Aside the opportunities of market from Upper East, Brong Ahafo, other districts of Upper West and Burkina Faso, Sissala East's current population of 67,679 can sustain any investment in terms of the demand for goods and services (GSS, 2014).

3.1.6 Map of the study Area

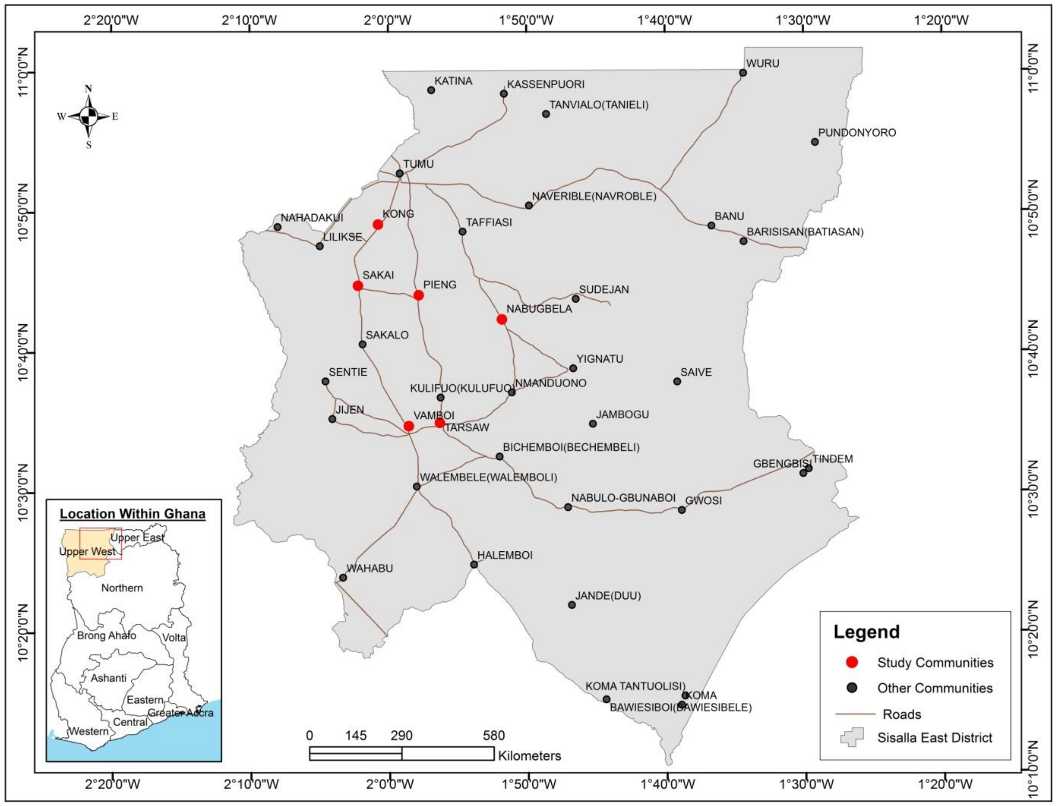

Plate 1 Map of the study area

3.2 Research Design

The researcher bases the inquiry on the supposition that gathering diverse types of data best offers an understanding of a research problem. The research was a cross sectional study where both quantitative and qualitative data was collected at one point in time. The use of triangulation helped to balance the weaknesses of both qualitative and quantitative approaches (Yeasmin & Rahman, 2012). The study employed gender-disaggregated methods, including gender differences in perceptions in appropriate climate smart agricultural options that gave much understanding on the cultural perspective of the results of the study.

3.3.0 Target population selection

3.3.1 Population

Six (6) communities namely Vamboi, Kong, Tarsaw, Chinchang, Naabugubelle and Sakai were purposively selected for their long involvement in the activities of the Secondary Farmer Base Organization (SFBO) and benefit of major CSA projects in the study District from 2010 to 2015. Most project interventions on climate change agricultural adaptation are implemented through primary base farmer organizations (PBFO) who are under the umbrella of the SFBO. Even though the SFBO works in 25 communities in the district the above communities were selected because of their long experience with SFBO activities as well as with most project interventions in the District.

3.3.2 Sample size

The sample frame was 932 farmers registered under the SFBO in the selected six (6) communities. With studies like this where the study population is finite or known, Louangrath (2013) recommends the use of the Yamane 1965 formula for sample size where, $n = \frac{N}{1+N(e^2)}$ (n is sample size, N represent Sample frame and e representing margin of error). $n = \frac{932}{1+932(0.05^2)}$ =399. However, 394 farmers were reached for interview due to the absence of some of the respondents in the communities at the time of the survey. The margin of error of 0.05 was used because it is the recommended margin of error for using the Yamane formula which allows for getting a representative sample (Singh & Masuku, 2014)

3.3.3 Multi stage sampling

Quota sampling was first used to distribute the total sample proportionately among the various six (6) communities based on the total number of farmers registered under the SFBO. This was followed by simple random sampling for selecting the various units for the interview. Simple random sampling gives each unit in the sample a chance of inclusion in the study and provides better estimate of parameters (Singh & Masuku, 2014). The method made it easier for the researcher to make estimates of adoption rates, production yields and productivity in arriving at its objectives

Table 1 Summary of sample distribution per community

Community	total number of farmers under SFBO	Sample size	proportion of sample size	sample per community
Vamboi	213		0.2	91
Kong	123		0.1	53
Tarsaw	120		0.1	51
Chinchang	190	399	0.2	81
Nabugubelle	138		0.1	59
Sakai	148		0.2	63
Total	932		1.0	399

Source: Field survey, 2017

3.3.4 Purposive sampling

In this technique, sampling units are selected according to the purpose. Purposive sampling was used to select six (6) primary farmer base organizations for focus group discussion. Simple random sampling was used to sample one (1) FBO each from the study communities for the discussion. The selected FBOs included; the lachodonga, Wesekendei, Laa-na, Nimogdanga, Laffaisi, Jimbilia from

Naabugubelle, Tarsaw, Pieng, Sakai, Kong and Vamboi communities respectively. These organizations were appropriate due to their experience with many NGOs in the implementation of projects that promote CSA in the district. Two (2) governmental institutions (MoFA) and Savannah Agricultural Research Institute and three (3) non-governmental organizations (TUDRIDEP, ASUDEV and SAVE Ghana) who contribute to the promotion of CSA practices in the study District were purposively selected for key in-depth interviews on the various topical issues of the study.

3.4.0 Methods for Data collection

3.4.1 Data

Both primary and secondary data was used in the survey. Primary data included household composition and structure, crop and livestock production and management, farm history, household economy (assets, incomes and expenses) as well as the adoption levels of both indigenous CSA and Introduced CSA practices. Secondary data was collected on climate CSA projects undertaken for farmers by MoFA, TUDRIDEP, SAVE Ghana and ASUDEV in the District.

3.4.2 Interviews

Semi structured interviews was used to capture both qualitative and quantitative data from 394 farmers through interviews using questionnaire from the six (6) communities of study. Data collected included information on the climate change adaptation agricultural practices being adopted and the practices farmers consider best for their local context. In addition, six focus group interviews were constituted to confirm the responses gathered from the individual farmers and seek explanations to some for the results after analysis.

Key informant interviews were also held with 5 institutional heads (TUDRIDEP, ASUDEV, SAVE Ghana, SARI and MoFA) to understand their various efforts and contributions they were making in the area of CSA. Through these interviews, the researcher accessed some project documents for a desk review that enabled the researcher to understand the CSA model being adopted in the District.

3.4.3 Desk review

Desk review of CSA project documents from MoFA, TUDRIDEP, SAVE Ghana and ASUDEV enabled the researcher to understand the efforts that these organizations were putting in place to promote CSA practices in the District and to be informed about the very current practices being introduced to farmers. This information was very useful to the researcher as it gave the researcher information on the introduced practices that enabled farmers ranking of these practices.

3.4.4 Field Observations

In addition, the researcher obtained on farm information from farmers on their farms. This afforded the researcher the opportunity to have a practical appreciation of some of the practices been described by the institutions and farmers. In all, 30 farms were visited throughout the study.

Table 2 Summary of data collection methods used

Sampling Technique	Target	number	Location	Method for data collection
Multi stage sampling	Farmers	399	Tarsaw, Naabugubelle, Kong, Sakai, Vamboi, Pieng	Interviews using questionnaire
Purposive	Farmer groups	12	2 in each community	Focus group
	Heads of institutions	5	Tumu (Save Ghana, MoFA, TUDRIDEP, ASUDEV	Key informant Interviews
	Aggregators	8	Kong, Sakai, Naabugubelle, Vamboi	Interviews
	Financial institutions	2	Tumu Cooperative Credit Union, Sissala Rural Bank	Key informant Interviews

Source: field survey, 2017

3.4.5 Names of CSA projects reviewed

Table 3 Names of CSA projects reviewed

Project Title	Project name	Document	Implementer	Donor	Period
Market Development Programme for Northern Ghana	MADE	Annual reports for 2016	SAVE Ghana	Innovation without Borders	2015-2017
Agricultural Technology Transfer	ATT	Annual reports for 2015 and 2016	SAVE Ghana	International Fertilizer Development Center	2015-2017
Groundnuts project		Annual reports for 2015 and 2016	SAVE Ghana	Innovation without borders	2015-2017
Climate Resilient Agriculture	CRA	Annual Project Activities Document	ASUDEV	Action Aid	2017
Climate Change in Northern Ghana Enhanced	CHANGE Project	End of project evaluation report	TUDRIDEP	Canadian Feed the Children (CFTC)	2013-2015
Enhancing Integrated Soil Fertility Management	EISFERM project	End of second year evaluation report	TUDRIDEP	Alliance for a Green Revolution in Africa (AGRA)	2015-2018
Greater Rural Opportunities for Women	GROW project	End of fifth year evaluation report	TUDRIDEP	Mennonite Economic Development Associates	2013-2017
Farmers' Cooperative and Market Access Development	FACOMAD	End of project Evaluation report	TUDRIDEP	Misereor	2013-2016

Source: Field survey, 2017

Reference was also made to the FAO CSA handbook to help the researcher identify those practices promoted by these projects that qualify as CSA.

3.5 .0 Data Analysis

The major statistical software tools used are found in SPPSS and Eviews. They include, frequency distribution tables and charts, regression analysis, chi-square (×2) statistical test and cross tabulation. These software tools were very useful in analyzing relevant data in this study which include the following; the level of adoption of different climate change adaptation agricultural practices by small holder farmers, relationship between adopters crop production and their adoption of climate change adaptation agricultural practices, farmers ranking of climate change adaptation agricultural practices based on their fitness for their local context and stakeholders experiences and inputs on building synergies for enhancing climate smart agricultural practices in the district.

3.5.1 Measure Farmer levels of adoption of various CSA practices

Adoption is a decision making mental process to continue use of an innovation. In this study, it means acceptance and use of a practice for at least one cropping season. Base on this definition, an attempt has been made to measure the extent of adoption of various practices by farmers using frequencies. Firstly the descriptive statistics tool using frequencies in SPPSS was used to determine the rates of farmer's adoption of various CSA practices. In addition, the cross tabs tool was also used to estimate the various adoption rates based on gender of the farmer. The study then followed Farid et al. (2015) using the adoption quotient developed by Sengupta (1967). The dependent variable was the quotient of adoption for an individual farmer based on the adoption scores gained. Fourteen Climate Smart Agricultural practices were considered. The adoption quotient was calculated as follows;

$$\text{Adoption quotient} = \frac{\text{Number of farmers adopting a technique for at least a season}}{\text{Total number of farmers questioned}}$$

Source: (Farid et al., 2015)

Based on the adoption quotient farmers adoption of various CSA practices were classified into three levels namely low, medium and high following FAO (2014).

Table 4 Adoption quotient score scale

N.o	Description	Score
1	Low adoption	Below 26.74 percent
2	Medium	26.75 to 50.38 percent
3	High	Above 50.38 percent

Source: FAO (2015)

3.5.2 Explaining difference in farmer's adoption of CSA practices.

This section specifies the empirical model that was employed to achieve objective three of the study. The study uses demographic characteristics of the farmers as well as access to certain services as the determinant factors in the regression model. The model is presented as follows;

$$CSA = f(Gender, Education, Age, Experience, Exsev, Finsev, Famsize)$$
……………... (3.1)

Where CSA represents the adoption of climate smart agricultural practices by farmers, Exsev refers to access to extension services, Finsev represents access to financial services and Famsize referstofarmsize.

The dependent variable of the model (adoption of climate smart agriculture practice) is a categorical variable. Thus, the probit regression model is employed. The probit regression model is specified as follows: In the probit regression model, it is assumed that there is an existence of an underlying continuous ("latent") index y_i^* related to x through the function:

$$y_i^* = \beta X_i + \varepsilon_i \quad ; \varepsilon_i \approx \text{idd} \ldots\ldots(3.2)$$

In equation (3.2) the index variable y_i^* is not observed and this generated by

$$y_i = 1 \quad \text{if } y_i^* > 0 \ldots\ldots(3.3)$$

$$y_i = 0 \quad \text{if } y_i^* < 0 \ldots\ldots(3.4)$$

In this case, if y_i^* exceeds a threshold value (zero), the binary outcome is one, otherwise 0. The major advantage of using index function approach is that *X* can have a linear effect on y_i^*, i.e. can take any value but the outcome variable still takes only two values 0 and 1.

Assuming that the error term follows normal distribution, we estimate the probit model using maximum likelihood method. For this, the log-likelihood of an individual observation can be expressed as:

$$Log(L_i) = y_i \log(1 - \Phi(-\beta X_i) + (1 - y_i)\log(\Phi(-\beta X_i)) \ldots\ldots(3.5)$$

This means that the probability of adoption pi is given by:

$$p_i \equiv \Pr ob(y = 1/X) = F(\beta X) = \Phi(\beta X) = \int_{-\infty}^{\beta x} \Phi(Z)dZ \text{ ....(3.6)}$$

3.5.3 Explanatory variables

The study used eight (8) explanatory various in the ordinary least square model. These included; Adoption of introduced CSA practices, Adoption of indigenous CSA practices, Gender of the farmer, education levels, farm size of the farmer, Age of the farmer, years of experience of the farmer, farmers access to extension services, farmers access to financial services. However, the main explanatory variables of interest were the farmer's adoption levels of introduced and indigenous CSA practices. The summary of the definitions of the various variables are represented in table 5.

3.5.3 Variable Description, Measurement and Expected Signs used in explaining difference in farmer's adoption of CSA practices.

Table 5 Variables for estimating farmer's adoption of CSA practices

Measuring farmers adoption of CSA practices			
Model type	**variables**	**Description**	**Expected sign**
	CSA (Dependent)	probability of farmers adopting climate smart agricultural practice which includes the use of Soora for insects control, neem leaves as inoculant, sulphate plus weedicide mixture, soaking of maize seed overnight, rotation of cereals with yam, neem fruits to control insects and reducing planting space. A dummy variable takes the value 1 if the farmer has adopted any of the CSA spell out and 0, if the farmer has not adopted any of the CSA practice.	
	Gender	The sex refers to the gender of the respondent. It is a dummy, which takes the values 1 for female and 0 for male. The relationship between sex of the farmer and adoption of CSA is expected to be positive or negative.	Positive/negative
	Education	The educational level of the farmer is taken into account where 1 represents no education, 0 for primary education and secondary education. The relationship between education and adoption is expected to be positive. When individuals have some level of education, it is expected that they appreciate new methods of practices and readily to accept and adopt such practices.	Positive
	Farm size	The farm size is a continuous variable and refers to acres of land that is used for cultivation for the four major crops namely, maize, soya, groundnut and beans. It is expected that farm size will have positive effect with adoption of CSA. Large farm size implies more cultivation on large-scale and this will require innovative ways of getting such yield and this innovative ways may include CSA practices.	Positive
probit	**Age**	The age variable represents the age of the respondent (in continuous years) and captures the respondents who are 18years and above. The relationship between age and adoption of CSA is expected to be positive. When individuals are aging, they will need supportive practices to complement their effort in order to sustain the levels of yield from their farm.	Positive
	Experience	Experience is a continuous variable and it refers to the number of years the farmer has engaged his or herself in farming. It is expected that experience will have negative influence on the adoption of CSA. An experienced farmer finds ways and means of improving their yield and therefore less likely to adopt innovative practices such as CSA	Negative
	Extension Services	Extension service is a dummy variable, which takes value of 1 if the farmer has access to extension service and 0 if the farmer does have access to such a service. It is expected that access to extension service influence the adoption of CSA positively.	Positive
	Access to financial services	Financial services is also a dummy a variable which takes value of 1 if the farmer has access to financial services and 0 other wise. Again, the access to financial services is expected to influence adoption of CSA positively.	Positive

Source: Field survey, 2017

3.5.4 Diagnostic Test

To examine the reliability and efficiency of our estimates, diagnostics tests such as Normality test was conducted by adopting the Jarque-Bera Test Approach (JB) statistics for the study. Also for the Heteroscedasticity test, the Breusch-Pagan Godfrey (BPG) test was adopted. These tests were appropriate because the model in use was the ordinary least square which requires a robust test to be carried out. The test helped to know whether the model results for ordinary Least Square estimation were significant for the explanatory variables.

3.5.5 Estimating the relationship between the adoption of climate smart agricultural practices and Farmers' Productivity

This section specifies the empirical model that was employed to achieve objective one of the study. The study uses demographic characteristics of the farmers as well as access to certain services as the determinant factors in the regression model. The crop yield model is based on the standard neoclassical production theory that is due to Solow (1956). Solow assumes that essential inputs that contribute to production of goods and services are labour and capital. Thus, in the framework of neoclassical production theory the crop yield function is specified below:

$$Q_i = AF(K, L) \quad (3.8)$$

Where Q_i is a vector of crop yield that includes maize, soya, groundnut and beans. A denotes the level of technological progress or farmers productivity, K denotes farmland, and L is labour employed on farm. Assuming linear relationship between output and farm inputs, equation (3.2) is specified:

$$Q_i = A + \beta_1 K + \beta_2 L \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.9)$$

A number of factors affect productivity (A) of farmers. It ranges from adoption of new practices to institutional arrangement including access to extension services and financial services. It is also possible for the age of the farmer to affect his or her productivity. Thus, the study endogamies farmers' productivity (A). Hence, the productivity of famer's equation is specified below:

$$A = \lambda_0 + \lambda_1 Age + \lambda_2 Age^2 + \lambda_3 Tradprac + \lambda_4 Exsev + \lambda_5 Finsev + \lambda_6 IP + \lambda_7 CSA + \mu_i \text{ ..(3.10)}$$

Substituting equation (3.10) into equation (3.9), equation (3.11) is derived:

$$Q_i = \phi_0 + \phi_1 Age_i + \phi_2 Age_i^2 + \phi_3 Tradprac_i + \phi_4 Exsev_i + \phi_5 Finsev_i + \phi_6 IP + \phi_7 CSA_i + \phi_8 K_i + \phi_9 L_i + \mu_i$$

..(3.11)

Where Tradprac is traditional practices, Exsev refers to access to extension services, Finsev is the access to financial services, IP is climate smart agricultural practices introduced by N.G.O. and other related institutions.

3.5.6 Method of Estimation

The empirical implementation of this study makes use of Ordinary Least Squares (OLS) technique. The choice of this technique is premised on the Gauss-Markov theorem that portends that the least squares technique is the best linear unbiased estimator (BLUE) with which a straight-line trend equation could be estimated (Gujarati and Porter, 2009).

3.5.7 Variable Description, Measurement and Expected Signs used to estimate impact of CSA on crop yield

Table 6 Variables for estimating the effect of CSA adoption of crop yield

Effects of farmers adoption of CSA on crop yield			
Model	**variables**	**Description**	**Expected sign**
	Crop Yield	It refers to the number of bags cultivated in the farming year. It covers the four major crops in the district namely, maize, soya, groundnut and beans.	Negative /positive
	Indigenous CSA practices	Probability of farmers adopting climate smart agricultural practice, which includes the use of Soora for insect's control, neem leaves as inoculants, sulphate plus weedicide mixture, soaking of maize seed overnight, rotation of cereals with yam, neem fruits to control insects and reducing planting space. A dummy variable takes the value 1 if the farmer has adopted any of the CSA spell out and 0, if the farmer has not adopted any of the CSA practice.	
	Age	The age variable represents the age of the respondent (in continuous years) and captures the respondents who are 18years and above. The relationship between age and crop yield is expected to be nonlinear. Thus, it is expected as farmers' age increases crop yield will increase as well beyond a certain threshold which productivity of the farmer will fall.	Positive
	Extension Services	Extension service a dummy variable that takes value of 1 if the farmer has access to extension service and 0 if the farmer does have access to such a service. It is expected that access to extension service influence the yield of the major crops positively.	Positive
	Financial Services	Financial services is also a dummy a variable which takes value of 1 if the farmer has access to financial services and 0 other wise. Again, the access to financial services is expected to influence adoption of CSA positively.	Positive
Probit	**Farm size**	The farm size is a continuous variable and refers to acres of land that is used for cultivation for the four major crops namely, maize, soya, groundnut and beans. It is expected that farm size will have positive effect on the crop yield of the major crops.	Positive
	Traditional Practices	Traditional practices is the old method of farming which includes early planting, crop rotation with cereal or legumes, intercropping, mixed cropping, use of animal manure and use of fertilizer. It continuous variable whereby the number of practices adopted is used to measure their impact on the crop yield of maize, soya, groundnut and beans. It is expected that as the number of traditional practices adopted increases the yield generated for the major crops will increase as well.	Positive
	Introduced CSA Practices	Introduced practices constitute CSA which are introduced by NGOs and other related institutions. It includes the use of improved seed, use of mocuna cover crops, planting of soya, minimal tillage, farm insurance, use of new fertilizer and use of weedicide. It is a continuous variable where by the number of practices adopted is used to quantify the magnitude and direction on the yield of the major food crops. It is expected that as the number of practices introduced by NGOs increases, the yield of the major crops will increase as well.	Positive
	Labour	This refers to the number of man working hours exerted in farm production. It is the total number of workforce employed on the farmland. Production theory recognizes the role labour plays in production, hence, it is expected that labour employed on the farm field will results in positive yield of the major crops	Positive

3.5.8 Establishing synergies between indigenous and introduced CSA practices.

This section specifies the qualitative approach used to achieve objective three of the study. Through focus group discussion with farmers made permutations of various indigenous and introduced CSA practices that can be combined positively to achieve positive results economically, environmentally and socially in the context of CSA. The various permutations were qualitatively classified into No, weak, strong and High from the farmers perspective. Counts were made of the number of positive permutations based on which percentages were derived. The researcher did a desk review of different documents on six (6) CSA projects implemented in the study area assessed from TUDRIDEP, SAVE Ghana, ASUDEV and MoFA from the period of 2010 to 2015 namely; GROW, CHANGE, MADE, CRA, EISFERM and Groundnuts project. A cross sectional analysis of project information was carried out to help make meaning from the report information describing the various models of CSA practices being used.

CHAPTER FOUR

PRESENTATION AND DISCUSSION OF RESULTS

4.1.1 Introduction

This chapter presents and discusses the empirical results that relate to the objectives of the study. The discussion also covers demographic characteristics of the respondents, the level of adoption of CSA practices by farmers in the Sissala East District and the determinants of the adoption of CSA practices. The chapter also includes the discussion of the effects of the adoption of CSA on the yield and profitability of major crops, namely, maize, soya, groundnut and beans. Additionally, the chapter revealed some areas of synergies between indigenous and introduced CSA practices and how synergies can be achieved between indigenous and introduced CSA in all CSA project interventions.

4.1 .2 Demographic Characteristics of the Respondents

This section gives a summary of the demographic characteristics of the respondents. These included; sex, marital status, educational status and involvement in off farm activities. These characteristics were inculcated in the model for establishing the impact of adoption as explanatory. They also served as importance in explaining the various reasons for differences in adoption levels of farmers. The results are presented in table 7.

Table 7 Demographic characteristics of respondents

Sex		Marital status				Educational status				Off farm economic activities		
		Total	S	M	Divorced	Total response	None	Basic	SHS	Total	Yes	No
Female	N.0	159	20	129	10	159	126	32	1	159	104	55
	percent	40.4	35.7	40.2	58.8	40.4	39.1	45.7	50.0	40.4	64.6	23.6
Male	N.0	235	36	192	7	235	196	38	1	235	57	178
	percent	59.6	64.3	59.8	41.2	59.6	60.9	54.3	50	59.6	35.4	76.4
Total	No	394	56	321	17	394	322	70	2	394	161	233
	percent	100	14.2	81.5	4.3	100	81.7	17.8	0.5	100.0	40.9	59.1

A greater proportion of total respondents (59.6 percent) were males while the remaining 40.4 percent were women. Majority of respondents (81.5 percent) are married while 18.5 percent are either divorced or single. In addition, majority of the respondents are illiterates who could read or write while 17.8 percent of total respondents have some bit of basic and secondary education. More than half of the respondents representing 59.1 percent have not diversified their sources of income besides their farming activities as compared to 41.9 percent of farmers who have diversified.

It is important to observe that a greater percentage of total female respondents (64 percent) are engaged in off farm activities as compared to 35.4 percent of total male respondents.

4.2. 1 Farmers Adoption levels of various CSA practice

This section of the study shows various CSA innovations that farmers are using and their rate of adoption. The various rates of adoption have been classified into low, medium and high following FAO (2015) categorization of various CSA adoption rates of farmers. The summary of the results showing the categorization and adoption rates of various CSA are presented in figure 2 and table 8 to 9 respectively.

Generally, there is a low adoption of CSA practices in the area represented by 6 CSA practices out of the total of 14 CSA practices studied. However, the adoption levels of 4 CSA practices namely sulphate fertilizer mixed with weedicide, use of improved seed, planting of soya and the use of multi action weedicides were within the category of high percentage of adoption. This means that on the score of mostly adopted CSA, introduced CSA practices take a higher place than indigenous CSA practices. The mostly adopted CSA practices among farmers are the use of modern improved seeds for introduced CSA and use of sulphate fertilizer mixture for indigenous CSA represented by 56.4 and 71.4 percent of total respondents. Among all the CSA practices, use of powdered neem leaves for inoculants and use of mocuna cover crops were least adopted indigenous and Introduced CSA practices also represented by 12.0 and 5.1 percent of total respondents respectively.

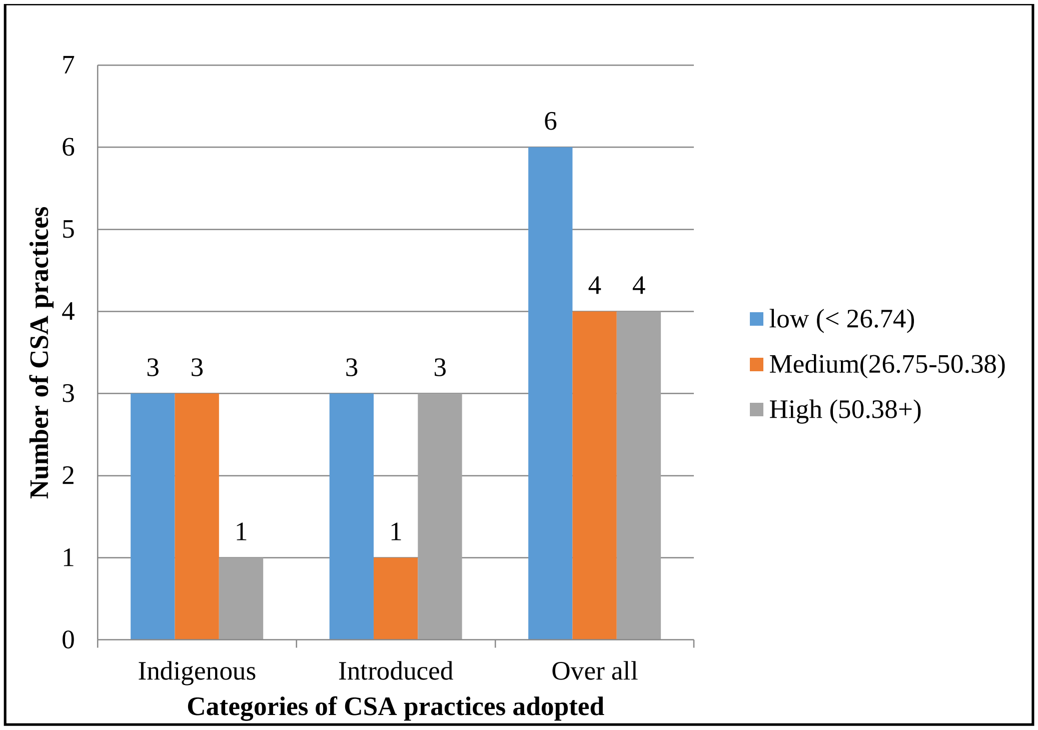

Figure 2 Summary of adoption quotients for various CSA practices

The study revealed that, NGOs have introduced open pollinated seeds to replace earlier hybrid seeds. A male respondent from Tarsaw community explained why these new improved seeds are much preferred. *"We like the new seeds (Sansalsima and wandata) because we can replant the grains for at least three years unlike the pannar".* Even though the indigenous CSA practices are good for farmers, the process of using some of these practices is not friendly. For instance a respondent at Naabugubelle explained; *"The Soora plant is very good to us farmers especially for weeds control. Some farmers don't like it because of the bad smell it has".* At a focus group discussion at Vamboi, farmers explained that, generally adoption of the introduced CSA practice is higher than the indigenous CSA practices because CSA project interventions.

Table 8 Farmers adoption of various CSA practices

	CSA practice	Adoption							Adoption Percentage					
		Male		Female		total			Male		Female		Total adoption quotient score	
		Yes	No	Yes	No	Yes	No	missing	Yes	No	Yes	No	Yes	score
1	Soora for Insect control	38	120	133	96	171	216	6	22	55.6	77.8	44.4	44.2	Medium
2	Soaking of maize before planting	20	104	139	130	159	234	0	13	44.4	87.4	55.6	40.5	Medium
3	sulpahte fertilizer mixed with weedicide for weeds control	180	30	100	82	280	112	1	64	26.8	35.7	73.2	71.4	High
4	Using powdered neem leaves as inoculants	12	196	35	150	47	346	0	26	56.6	74.5	43.4	12.0	low
5	Using ponded neem fruits for weeds control	6	200	80	100	86	300	7	7	66.7	93.0	33.3	22.3	low
6	Rotation of cereals with yam	80	154	22	130	102	284	7	78	54.2	21.6	45.8	26.4	low
8	Reducing plant spacing	55	130	100	102	155	232	6	35	56.0	64.5	44.0	40.1	medium

Source: Field Survey, 2017

Table 9 Farmers adoption rates of introduced CSA practices

CSA practice			**Adoption**							**Adoption Percentage**					
			Male		Female		total			Male		Female		Total adoption quotient score	
			Yes	No	Yes	No	Yes	No	missing	Yes	No	Yes	No	Yes	score
	9	use of improved seed	140	91	80	79	220	170	3	64	53.5	36.4	46.5	56.4	High
	10	use of mocuna cover crops	12	149	8	223	20	372	1	60	40.1	40.0	59.9	5.1	low
	11	Planting of soya	55	176	150	9	205	185	3	27	95.1	73.2	4.9	52.6	High
Introduced	12	minimal tillage	20	215	23	129	43	344	6	47	62.5	53.5	37.5	11.1	low
	13	farm insurance	50	185	0	159	50	344	1	100	53.8	0.0	46.2	12.7	low
	14	new organic fertilizer	153	146	10	82	163	228	2	94	64.0	6.1	36.0	41.7	medium
	15	use multiple action weedicide	209	26	50	105	259	131	3	81	19.8	19.3	80.2	66.4	High

Source: Field Survey, 2017

4.2.2 Farmers adoption experience of indigenous and introduced CSA practices

4.2.2.1 Use of soora plant as weedicide

For the purposes of insect control on beans, soya beans and maize farms. 44.2% of the study respondents have adopted the use of the liquid produced after soaking the bark of the "Soora" plant in water for three (3) hours as insecticide on their beans farms as well as on their maize and soya farms.

Plate 2 Picture showing soara sbrub

The medium adoption of this indigenous practice in the study area confirms other conclusions that reveal a move by farmers from use of pesticidal plants for improving farming among farmers in the world. Kamanula et al., (2010) indicated that most farmers in Zimbawie are adopting the use of synthetic insecticides with just a little (22%) using pesticidal plants. This is perhaps because of the difficult processes farmers have to go through before using this practice. A female farmer from Naabugubelle community recounted her experience with Soora for insect control.

"Soora is a medicinal plant which is very good for controlling insects. I started using it when a friend introduced it to me two years ago. Even though it is good for controlling weeds, it has a very bad scent".

4.2.2.2 Soaking of maize before planting or seed priming

Another practice revealed is the soaking of maize over night before planting. 40.4% (medium) of the total respondents interviewed indicated that they have adopted this practice on their farms as a measure for addressing the challenge of delayed rains. A male respondent from the Tarsaw community explained that the seeds are soaked in water for 8-12 hours and not more than 24 hours. Further discussions from the focus group discussion at Tarsaw revealed that pre-soaked seeds take a relatively shorter period (4 days instead of 7 days) to germinate which make the crops have a competitive advantage over associated weeds. Earlier studies have demonstrated the use of this practice by farmers and the potential of this practice in contributing to increased food productivity. Polthanee (2010) established that, pre-germinating seeds before planting minimizes the lag period between sowing and seedling establishment.

4.2.2.3 Reduce plant spacing

The next common indigenous practice being adopted among farmers is reduced planting space. 40.1 percent (medium) of the farmers. An interview with the Sissala East District MoFA staff confirmed farmer's adoption of this practice.

According to the crops officer; *"The recommended planting space for soya cultivation is 5cm in between plants and 75cm in between rolls for one (1) seed per stand while for maize is 40cm in between plants and 80cm in between rolls for one (1) seed per stand"*. The focus group discussions at Vamboi community however revealed that farmers perceive this spacing as unproductive. Farmers explained that particularly for soya, their consistent experience of low yield (200kg – 300kg) per an acre of farm on an average using the recommended practices have caused many farmers to reduce the distances to roughly 10cm in between plants and 50cem in between rolls and are now able to harvest 450kg-500kg on the same acres of farm.

The discussions further revealed that maize farmers have reduced their planting distance to 40cm between plants and 60cm between rolls. Accordingly, farmers at the focus group were convinced the new planting spaces were much beneficial than what is preached by the NGOs and MoFA. This confirmed the most common reason cited for the adoption of this practice which majority of respondents (90%) indicated to be to increase yield of crops. In addition, majority of respondents (49.5%) who adopted this practice were females as against 29.7% of men who adopted this practice. In Pieng community, farmers in a focus group discussion explained that women farmers are more inclined to this practice because they are unable to afford the needed fertilizer for recommended planting spacing.

4.2.2.4 Sulphate mixed with weedicide to control weeds

The results revealed that majority of farmers have adopted sulphate plus weedicide mixture representing 71.4 percent (high) as against 28.6 percent who have not adopted this practice. This practice is a farmer's innovative means of creating their own forms of chemical mixtures for weeds control. The study revealed a new trend of chemical mixture where farmers mix a tin full of sulphate fertilizer with one (1) litre of post emergence weedicide specifically glyphosate which farmers perceive makes the chemical more effective in weeds control. This practice of mixing different chemicals to weedicides has been revealed quiet common among 56% of farmers in Northern Ghana (NPAS 2012) and described as unsustainable but farmers in the study area have their own reasons why these practices are helping them. Farmers in Kong community during a focus group discussion revealed that when glyphosate is added to salt solution, the weeds die in 6 (six) days and hardly grow again until harvest as compared to using the weedicide only which in most cases does not kill the weeds as expected causing farmers to do manual weeding which further increases their cost of production. This confirms farmers most cited reason for adopting this practice which majority of total adopters (78%) revealed was to increase yield while a minority of them (18%) cited improvement in soil health as their reasons for adopting this practice.

Focus group discussions at Chinchang community explained that, making this weedicide mixture reduces the number of litres of weedicide chemicals that the farmer could possibly use on an acre of farm from two (2) litres to one (1) litre which to them reduces the amount of chemicals been used on the farm. They further explained that it helps to reduce cost of production. Farmers in a focus group discussion at Pieng community also added that, this mixture is a one-time solution to weeds control especially on maize farms. Meaning, if you spray once, you need not to worry about weeds again until harvest which is a motivation for farmers increasingly adoption of this practice.

4.2.2.5 Use of neem tree leaves as inoculants

The least adopted indigenous CSA practice is the use of neem leaves as inoculants. *(Inoculants are preparations containing living cells or latent cells of efficient strains of microorganisms that help crop plants' uptake of nutrients by their interactions in the rhizosphere when applied through seed or soil).* 12 percent (low) of the total sampled farmers have adopted this practice. Powder made from neem leaves is mixed with groundnut and beans seeds ten (10) minutes before planting. Even though the adoption among farmers is low, they perceive that this practice can help to improve the germination of their plants and make them more drought resistant. This was revealed at all the twelve (12) focus group discussions held with farmers. Farmers were however quick to add that the idea was picked from the promotion of inoculants by NGOs promoting CSA practices. Since access to real inoculants for groundnuts and soya beans is very difficult due to high price, farmers who have seen the importance of inoculants have decided to use neem tree leaves as a substitute to chemical inoculants that costs about Ghc 40 per an acre. The discussions further revealed that the idea of inoculants usage was not so much convincing to many farmers but few of them have adopted this idea and are using the neem tree leaves to try on their farms. In all, a greater percent of female respondents (18.9%) adopted this practice as compared to 5.55 percent of total male respondents indicating that this practice is more inclined to women.

4.2.2.6 Use of neem fruits to control insects and weeds

The second less adopted indigenous CSA practice is the use of neem fruits to control insect and weeds. 22 percent (low) of the respondents have adopted this method as against 77.8 percent who have not adopted this Indigenous CSA practices practice. Farmers at Vamboi in a focus group discussion confirmed the adoption of this practice by some farmers but revealed that this was not wide spread. The processes of preparing the neem fruits into weedicide slightly differed among farmers. Farmers in Vamboi explained that the fruits are simply crushed and soaked in water, alcohol, or other solvents. The resulting extracts can be used without further refinement. In Sakai, farmers explained that you have to grind 1kg of nuts from the neem fruit, mix the powder with 15 litres of water and leave to soak for 24 hours. The concoction can then be used with the aid of a knapsack to spray on your beans farm that prevents insect and weeds infestation. This practice according to them was only very common among women. This confirmed the results of the study which show majority of female respondents (44.2%) adopting this practice as compared to 2.91 percent of total male respondents adopting this practice. Even though earlier studies have established farmer's knowledge of this practice in India, the level of adoption among farmers is higher than what is recorded in this study. While Kamanula et al., (2010) established an adoption rate of 70% among farmers in India, the study revealed a lower adoption of 22.7% of total farmers interviewed.

4.2.2.6 Improved seed

Majority of the farmers (56.4 percent) have adopted the use of improved seed. Out of total farmers who have adopted this practice, 63 percent are males as compared with 37 percent females. Thus majority of the males have adopted the use of improve seed relative to the females. The greatest motive for adoption of this practice is to increase yield represented by 64% of total adopters but it is interesting to note that the work of NGOs also had a substantial influence on the adoption of improved seed as indicated by 20% of total respondents as seen in table 4.2. The use of improved seed is one of the major practices being introduced to farmers by MoFA and three (3) NGOs (TUDRIDEP, SAVE GHANA and ASUDEV) as revealed during in-depth interviews held with Directors of these organizations during the study. These improved seeds according to MoFA; are drought resistant and early maturing seeds which makes them more robust to stand the reduced levels of rains and increasing droughts that farmers experience.

Plate 3 Distribution of Certified seed for farmers under ATT project (Picture of Haruna Amina and Batong Kenkeni from Naabugubelle community

It was revealed that some international organizations such as the International Fertilizer Development Company (IFDC), Alliance for a Green Revolution in Africa (AGRA) and the Mennonite Economic Development Associates (MEDA) have committed resources for these local NGOs to promote farmers adoption of new maize and soya varieties. It was revealed that. In the past five (5) years (2010-2015), focus has been on promoting open pollinated varieties (OPVs) of seed as against the hybrid seeds that are much costly to farmers. According to the Directors of NGOs, the OPVs are more climate smart because farmers are able to reuse seeds from their harvest to plant for the next season and still record a relatively good yield as compared to the hybrid that will woefully fail if grains are replanted. This promotion according to the Directors of these NGOs is done through field demonstrations and FBO linkages to input dealers to make these improved varieties of seed much more accessible. For maize, it was revealed that Wandata and Sazalsima varieties are being promoted for their abilities to withstand drought and yield higher while Jenguma and Afaryak varieties are the soya varieties mostly promoted for their non-shuttering and high yielding. Focus group discussion with farmer however suggests that the price of the certified seed was relatively high. Farmers noted that while the price of a kilo of certified seed in the market was Ghc 5. The non-certified seed was going for Ghc 2.

4.2.2 .7 Mocuna cover crops

About 5.1 percent of farmers have adopted the practice of macuna cover cropping. Out of the farmers who have adopted this practice, 35 percent are males while 65 percent of them are males. Mocuna cover cropping is yet another practice listed by MoFA and the three (3) NGOs interviewed. Discussions with the staff of the NGOs revealed that mocuna cover cropping was good for enriching soil fertility. *This crop is planted solely on lands that soil fertility has reduced to enrich the soil within the period of one (1) planting season.* The seeds produced from the mocuna plant can also be used by farmers but this is not very common.

4.2.2.8 Soya cultivation

The results further reveal that majority of the farmers have adopted the planting of soya. 52.6 percent (High) of farmers have adopted this practice. Out of farmers who have adopted the practice, 41.3 percent are males whiles 58.7 percent are females. This means that females prefer the adoption of mocuna and soya beans cultivation that men while men adoption of improve seed is higher. Further interactions with Directors of the three NGOs explained that soya was being promoted as a cash crop for farmers for its ability to improve soil reformation and its ability to contribute to improve household nutrition thereby contributing to enhanced food security. It was also revealed that some international NGOs such as MEDA, AGRA and IFDC were investing immensely to assist over 10,000 smallholder farmers to go into soya cultivation. Focus group discussions with farmers at Pieng community further confirmed that farmers are not only being introduced to soya cultivation but also trained on how to use soya at the household level.

4.2.2.8 Minimal tillage

Minority of the farmers have adopted the practice of minimal tillage as compared to adoption of improved seed (56.4 percent) and soya cultivation (52.6%). 43 percent of farmers have adopted this practice representing 11.1 percent (low) of the sampled farmers. This means that farmers are adopting the practice of minimal tillage above the use of mocuna cover crops. Out of total farmers who have adopted the practice, 18.6 percent are males whiles the remaining 81.4 percent are females.

The increasing use of the conventional method of land preparation where most farmers use tractor continuously for many years was mentioned by Directors of the three NGOs interviewed as not very sustainable for soil conservation hence the championing of the adoption of minimal tillage where farmers who have relatively loosened soils in their farms just use the pre-emergence weedicide such as glyphosate to control weeds and move forward to plant without the use of tractor. Focus group discussions with farmers in Vamboi, Naabugubelle and Sakai however suggest that this practice might not be suitable for farmers in the District.

It was revealed that farmers do not have the conviction that this concept will work because field demonstrations established by NGOs of which farmers participated in farmer field days saw plots where minimal tillage was used performing poorly.

4.2.2.9 Crop insurance

About 12.8 percent (low) of total respondents have adopted the practice of farm insurance. Out of the total farmers who have adopted this practice, 54 percent are male's whiles 46 percent of them are female. Thus, more males have adopted this relative to the females. Farm insurance is yet a new CSA intervention being introduced to farmers by MoFA and all the three NGOs (TUDRIDEP, SAVE GHANA and ASUDEV) as revealed during in-depth interviews held with Directors of these organizations during the study. Promoters (TUDRIDEP, SAVE Ghana and Tumu Cooperative Credit Union) of this intervention stated during the in-depth interviews that the unpredictable nature of rains have often caused farmers loss of crops making investments in farming more risky for farmers. Farm insurance therefore being promoted as a CSA practice to reduce the risk and losses that often arises mainly from rainfall failures. The model for promoting this practice by NGOs according to farmers in Kong was quiet difficult for farmers to comprehend. Crop insurance in promoted mostly among farmers based organizations (FBOs) that secure loan from the banks through the facilitation of NGOs. The bank insures the loan taken for production against serious weather limitations in the form of interest added on for the farmer to pay. However if the farm is hit by serious drought and confirmed by the Bank's technical person, this interest added on as risk is rather deducted from the cost of the loan. In addition, the farmer now only pays 50% of the initial loan as compensation for the losses that would be paid back by the farmer. Discussions with the Tumu Cooperative Credit Union reveled that farmers find it difficult to understand this concept hence low patronage by farmers in the District. The confusion among farmers as revealed in Naabugubelle during a focus group discussion is the method of determining the level of drought effects on a farm. Farmers still do not believe that this system would be fair to them, as they do not understand average rainfall data that is used for the determination of level of drought for the season.

4.2.2.10 Use of organic fertilizer

Minority of the farmers have adopted the use of new organic fertilizer (Omini fert). 41.7 percent of farmers have adopted this practice representing. Out of the total farmers adopting, 65.2 percent are males compared with 34.8 percent who are females. Thus, majority of the males have adopted this practice relative to the females. The use of new organic fertilizer yet another major practice being introduced to farmers by MoFA and all the three NGOs (TUDRIDEP, SAVE GHANA and ASUDEV) as revealed during in-depth interviews held with Directors of these organizations during the study. The increasing use of chemical fertilizer seasonally was mentioned as not very sustainable for soil conservation during the interviews. As a result, these organizations and their donors are championing the adoption of organic fertilizer with 90% of its nutrients made from organic materials. According to the according to MoFA officials in the study area; this fertilizer when adopted by farmers has the propensity of contributing positively to soil formation and conserving existing soil nutrients over years. This fertilizer is highly being championed by TUDRIDEP under its Enhancing Integrated Soil Fertility management project (EISFERM PROJECT) with support from AGRA. Just like other CSA practices, the promotion of organic fertilizer according to TUDRIDEP is done through field demonstrations with their target farmer population of 10,000 smallholder farmers.

4.2.2.11 Multi action weedicide

Finally, the results revealed that majority of the farmers (66.4 percent) have adopted the practice of application of new weedicide on their farm. Out of the total number of adopters, 60 percent are males whiles the reaming 40 percent are females. Focus group discussions revealed that use of weedicides has become very common among farmers as RAPTOR and ODDESEY are being jointly promoted by TUDRIDEP and SAVE Ghana with support from BASE-F chemical company. Discussions with TUDRIDEP and SAVE Ghana revealed that these chemicals are new but have the potential of controlling weeds better with less negative impact on the environment. These new weedicides are accordingly being introduced to farmers through field demonstrations and farmer field days. Discussions from all the focus group discussions explained that generally every farmer uses weedicides every season that makes it easier for them to try new weedicides that have the potential of controlling weeds better. The findings reemphasizes conclusions by Leclers et al., (2013) that farmers have become more innovative and keep changing and adjusting their practices towards achieving their food security objectives in this face of climate change. The study concludes that the level of innovativeness of farmers towards adapting to climate changes on their farms is extremely high in the Sissala East District. This could be attributable to Works by Non-Governmental Organizations promoting CSA adoption in the District that keep educating farmers every season on CSA practices. Focus group discussion with farmers also revealed the increasingly knowledge of farmers about the changing climate environment for which some of them indicated that rains have been very erratic, temperature out of normal zone and other related climate change effects hence making them more innovative. The results are presented in Table 4.2

4.2.3 Factors influencing farmers Adoption of indigenous and Introduced CSA

This section of the chapter discusses the role of other stakeholders such as MoFA extension, financial service, aggregators, NGOs, FBO organizations in the adoption of CSA practices.

Interestingly extension services, there is no significant difference in the probability of adopting indigenous CSA between those who have access to extension officers and those who do not even at the 10 percent level of significance. This is contrary to Ndamani & Watanabe (2016) who established a rather positive correlation between access to extension service and adoption of new efficient practices. The study revealed that even though there are some agricultural extension strategies being promoted by MoFA and local NGOs in the district, the focus has been on providing farmers with training, information, and access to inputs and services and not how farmers can tap into their indigenous wisdom. Women farmers who are the majority of adopters of indigenous CSA practices explained that even though the practices being introduced were good, some of them were costly to access. The reason given by farmers at the focus group discussions is that, extension officers mostly concentrate more on introduced CSA practices which are most of which are not affordable. The focus group discussions further indicate that even though some farmers had access to extension officers, the farmer to extension officer time of contact was very low to influence farmer's adoption decisions.

The results revealed that access to extension services exerts significant effect on the probability of adoption of introduced CSA practices at the 5 percent level of significance. Farmers who have access to extension services are less likely to adopt introduced practices compared with farmers who do not have access to extension services. The probability of adopting introduced CSA practices by farmers who have access to extension service is 10 percent less than those who do not have access.

The results further show that access to financial services exerts significant effect on the probability of adopting indigenous and CSA at 1 percent level of significance. The negative sign implies that those who have access to financial services are less inclined to adopt indigenous CSA relative to non-beneficiaries of financial services. The in-depth interview with Madam Aisha Batong the manageress of Tumu Cooperative Credit Union revealed that 70% of farmers who access loans through the interventions of NGOs are often tied to adopt the introduced CSA practices being promoted by such organizations. This perhaps explains the negative relationship between access to financial services and farmers level of indigenous innovativeness of farmers.

Table 10 Probit Regression Results showing factors influencing farmer's adoption of various CSA practices

Variable	CSA-Indig. coefficient	CSA-Indig. Marginal effect	CSA-IP coefficient	CSA-IP Marginal effect
Gender	-0.56	-0.06	-0.25	-0.02
	(0.36)	(0.04)	(0.37)	(0.04)
Education	-0.72**	-0.07**	-0.58**	-0.06**
	(0.32)	(0.03)	(0.30)	(0.03)
Exoff	0.12	.012	-0.93**	-0.09**
	(0.51)	(0.05)	(0.42)	(0.04)
Finsev	-1.20***	-0.12***	0.25	0.02
	(0.34)	(0.03)	(0.41)	(0.40)
Age	0.05**	0.006**	-0.02	-0.002
	(0.02)	(0.003)	(0.02)	(0.002)
Experience	-0.06**	-0.006**	0.02	0.002
	(0.03)	(0.003)	(0.02)	(0.002)
Farm size	0.06*	0.006*	0.28***	0.03***
	(0.04)	(0.004)	(0.08)	(0.007)
Agg.sev	-0.35	-0.04	-1.04**	-0.10**
	(0.36)	(0.04)	(0.46)	(0.05)
Input dealers	-0.92	-0.09	0.47	0.05
	(0.65)	(0.07)	(0.37)	(0.04)
FBO	-0.63	-0.07	1.41***	0.14***
	(0.53)	(0.05)	(0.48)	(0.05)
Constant	2.37 **		1.03	
	(1.06)	-	(0.87)	-

N = 344, Pseudo R^2 = 0.3538, LRchi2 = 70.38, Log likelihood = -64.281063, Prob > chi2 = 0.000; N = 344, Pseudo R^2 = 0.2999, LRchi2 = 52.20, Log likelihood = -60.94298, prob>chi2 = 0.00. *denotes statistically significant at the10 percent, ** denotes statistically significant at the 5 percent and ***denotes statistically significant at the1 percent

The probability of adopting indigenous CSA for those who have access to financial services is 12 percent less than the non-beneficiaries of financial services. However, access to financial services influence productivity of farmers positively in the area of groundnut and maize production.

The results further indicate that aggregator services have no role to play in the adoption of indigenous practices by the farmers but have a rather significant effect on the probability of adopting CSA introduced by NGOs at the 5 percent level of significance. The negative coefficient for indigenous CSA practices implies that those who have access to aggregator service are less likely to adopt indigenous CSA practices relative to those who do not have. The probability of adopting CSA for those who have access to aggregator services is 13 percent less than those who do not have access. However, access to aggregation services affect productivity of farmers positively and negatively. Access to aggregator services affects productivity of farmers negatively in the productivity levels of farmers in maize production but positively for soya. This implies that access to market is not a much priority for maize farmers as compared to soya farmers.

Again, access to input services affect the productivity of farmers positively in the production of maize and negatively in the production of beans and soya. Focus group discussions with farmers in Chinchang indicated that, farmers needed less input for their soya farms relative to maize farms. It was revealed that the use of fertilizer for example is limited in soya production. Formation of FBO affects the productivity of farmers positively in the production of beans and negatively in the production of maize. Farmers at Vamboi explained that, this was so because most farmers already know how to cultivate maize. Soya was a new crop and farmers who belonged to FBOs had much opportunity to learn about its cultivation, which granted them increased in farm productivity. In addition, FBO formation influences the adoption of introduced practices at the 1 percent level of significance. Those who have formed FBO are more likely to adopt CSA practices relative farmers who do not belong to FBO group. The probability of adoption introduced CSA practice for farmers who have formed FBO is 16 percent higher than those who do not belong to FBO group.

Education of the farmer exerts significant effect on the likelihood of adopting Indigenous CSA practices practice (CSA) at the 1 percent level of significance and 5 percent for introduced CSA practices. The negative coefficient indicates that the non-educated are less likely to adopt CSA relative to the educated farmer. Empirical analyses reveal substantial internal (private) benefits of schooling for farmer productivity, particularly in terms of efficiency gains (Ndamani & Watanabe 2016). This means that educated farmer values significance of these innovations that are more efficient and are ready to adapt to new method of production. Their ability to read afford them the opportunity to interact much with extension officers and make cost benefit analysis before choosing the practices on their farms. The non-educated farmer on the other hand is quite primitive and conservative thus finds it difficult to adapt to new practices. The probability of adopting indigenous CSA for the non-educated farmer is 7 percent less than the educated farmers.

It can be concluded that the use of improved seed is the mostly adopted CSA practice. Even though the activities of stakeholders such as NGOs, MoFA, access to input dealers and financial services have very important role in the adoption of CSA according to the FAO (2013), the study reveals no significance role in the adoption of both indigenous and introduced CSA practices. The study further revealed that, even though farmers received some level of services from value chain actors, the services not generally accessible to many of the farmers and generally not targeted towards the farm level needs of the farmer. Meanwhile Farmer's belongingness to FBOs group plays significant role in the adoption of CSA practices.

4.3.0 Effects of CSA Practices on crop production

This section discusses the empirical results on the effects of adoption of indigenous and introduced CSA practices on the crop yield and profitability of maize, soya, groundnuts and beans production. The results are presented in Table 12 and 13.

4.3.1 Diagnosis Test

This section discusses the diagnosis test results on the ordinary least squares estimation. This includes heteroscedasiticy and normality tests. The results are presented in Table 11.

Table 11 Results of Diagnosis Test

Diagnosis	Chi-square statistic			
	Maize	**Soya**	**Groundnut**	**Beans**

Heteroscedasticity	20.89^{*2015}	-	$38.30933^{***2015}$	$29.56709^{***2015}$
	15.74^{2016}	15.59668	$22.56789^{***2016}$	, 21.20774^{**2016}
Normality	$18.72^{***2015}$	-	$41.68^{***2015}$	1.11^{2015}
	$52.33^{***2016}$	725230.9***	$18.74^{***2016}$	704.40***2016

* denotes statistically significant at 10 percent; **denotes statistically significant at the5 percent; and ***denotes statistically significant at the1 percen**t**

Source : Author's computation based on data obtained from the field

The results revealed that there is heteroscedasiticy in the 2015 regression model for maize and the residuals from the regression model are not normality distributed. The results further revealed that heteroscedasticity is not present in the 2016 regression model for maize but it failed normality test. Again, the results show that there is no heteroscedasticy in the regression model for soya but the regression residuals are non-normality residuals. The regression models for groundnut in 2015 and 2016 were both plagued with heteroscedasticity and non-normality problems. However, the regression residual from beans model in 2015 were normality distributed but it has a problem of heterosceasiticty. In the 2016 regression model for beans, both heteroscedasticty and non-normality were present in the model. Thus, the revelation by the diagnosis test results indicates that there are problems with least squares estimation and conventional hypothesis testing might not be reliable. To resolve this problem, study adopted robust least squares estimation, which correct for non-normality and heterosceasitcy. The robust least square results are presented in Tables 12 and 13.

4.3.2.1 Effects of CSA Practices on crop production the Yield of Maize and Soya

Table 12 Ordinary Least Square estimations of showing effect of CSA adoption on crop yield of maize and soya

Variables	Yield of Maize		Yield of Soya
	2015	2016	2016
	Coefficient	Coefficient	Coefficient
Constant	2.571689 (1.320325)	4.845150*** (1.727821)	4.267402 (1.127412)
Age	0.24*** (0.060718)	0.14* (0.079494)	0.08 (0.053792)
Age sq.	-0.003*** (0.000703)	-0.002* (0.000920)	-0.0009 (0.000621)
Gender	-0.289199 (0.236159)	-0.245851 (0.309965)	0.131843 (0.215410)
Farm size	-0.06** (0.025630)	-0.08*** (0.033744)	-0.02 (0.025491)
Trad.prac.	0.07 (0.081839)	-0.16 (0.107249)	-0.18* (0.099279)
Exoff	0.94*** (0.286163)	1.23*** (0.375386)	0.27 (0.276230)
Finsev	0.31 (0.314313)	0.61 (0.417307)	0.33 (0.270585)
Labour	0.014 (0.030200)	0.05 (0.039666)	-0.02 (0.026679)
CSA-Indig	0.26*** (0.080891)	0.41*** (0.108878)	0.03 (0.113937)
CSA-IP	0.32*** (0.076999)	0.72*** (0.103165)	0.19** (0.089011)
CSA-Joint	0.263152***	0.545319***	0.12* (0.069506)
FBO	-1.16*** (0.270764)	-1.46*** (0.355548)	0.007 (0.261920)
Agg.sev	-0.70*** (0.249106)	-0.60* (0.328206)	-0.17 (0.236120)
Input dealers	0.99*** (0.252644)	1.42*** (0.331724)	-0.30 (0.252355)
Diagnosis Test			
Normality	18.72***	52.33***	725230.9***
Heterosceadasticity	20.89*	15.74	15.59668

R^2 = 0.213182 F = 5.725472 (0.00) N=347 R^2 = 0.268731 F = 9.328489(0.00) N=348 R^2= 0.049173 F = 1.141729 (0.323451) N=301 * denotes statistically significant at 10 percent; **denotes statistically significant at the5 percent; and ***denotes statistically significant at the1

R^2 = 0.213182 F = 5.725472 (0.00) N=347 R^2 = 0.268731 F = 9.328489(0.00) N=348 R^2= 0.049173 F = 1.141729 (0.323451) N=301 * denotes statistically significant at 10 percent; **denotes statistically significant at the5 percent; and ***denotes statistically significant at the1

Source : Author's computation based on data obtained from the field

The results revealed that adoption of indigenous CSA practices exerts significant effect on crop yield of maize in 2016 and 2015 at the 1 percent level of significance. As expected, the adoption of new practice contributes positively to the crop yield of maize. The results showed that the adoption of indigenous CSA propelled an increase in yield of maize by 0.26kg and 0.41kg in 2015 and 2016 cropping seasons respectively. The result is consistent with empirical results obtained by other authors. Study conducted by Branca (2011) proved that maize yields increased to 3,414 kg/ha (71% increase in yields).

Whiles the results relating to maize shows a significant effect of indigenous CSA on maize production, this is not the case with respect to soya production. Again, the results revealed that adoption of Indigenous CSA practices exerts no significant effect on crop yield of groundnut and beans in 2015 and 2016 even at the 10 percent level of significance. The result is similar to the one obtained for soya. This implies that the adoption of Indigenous CSA practices is more inclined to particular crops. Further explanations gathered from the focus group discussions revealed that farmer's objectives of reducing cost mainly had much to do with maize due to the comparatively higher cost of production. According to farmers in Vamboi community who made a rough crop budget for the two crops for an acre, the average total cost of producing an acre of maize was estimated at Ghc 1,100 as compared to Ghc 550 for soya.

4.3.2.2 Effects of CSA Practices on crop production the Yield of Groundnut and Beans

Table 13 Ordinary Least Square estimations showing the effect of CSA adoption of the crop yield of groundnut and beans

Variables	Yield of Groundnut		Yield of Beans	
	2015	2016	2015	2016
Constant	Coefficient	Coefficient	Coefficient	Coefficient
Age	0.05 (0.050222)	0.029 (0.069236)	0.08 (0.086092)	0.04 (0.062479)
Age sq.	-0.0007 (0.000617)	-0.0004 (0.000800)	-0.0009 (0.001036)	-0.0005 (0.000724)
Gender	-0.03 (0.205770)	-0.28 (0.269556)	-0.14 (0.222023)	0.003 (0.239773)
Farm size	0.02 (0.021741)	0.002 (0.028462)	0.03 (0.023312)	0.07*** (0.026134)
Trad.prac.	-0.08 (0.113956)	0.09 (0.148934)	-0.009 (0.104826)	-0.24** (0.092586)
Exoff	0.85*** (0.247586)	1.12*** (0.324075)	0.35 (0.312185)	0.06 (0.294012)
Finsev	0.006 (0.242541)	0.53* (0.317685)	0.31 (0.282751)	-0.12 (0.282588)
Labour	-0.04* (0.026247)	-0.008 (0.034372)	-0.05* (0.027139)	-0.03 (0.031412)
CSA-Indig	-0.58*** (0.159518)	0.001 (0.211564)	-0.06 (0.087023)	-0.09 (0.086602)
CSA-IP	-	-	-	-
CSA-Joint	-	-	-	-
FBO	-0.48** (0.232412)	0.19 (0.304117)	-0.11 (0.284707)	0.80*** (0.278078)
Agg.sev	-0.22 (0.217944)	-0.17 (0.284230)	-0.15 (0.258798)	0.03 (0.264643)
Input dealers	-0.18 (0.223184)	-0.008 (0.291124)	-0.09 (0.314899)	-0.56** (0.258909)
Diagnosis Test				
Normality	41.68***	18.74***	1.11	704.40***
Heteroscedasticity	38.30933***	22.56789***	29.56709***	21.20774**

R^2 = 0.100127 F = 3.486199 (0.00) N=347 R^2 = 0.111300 F = 3.334181 (0.00) N=3489 R^2= 0.040701 F = 1.180918 (0.295316) N= 347 R^2 = 0.119624 F = 4.333813 (0.00) N = 348 * denotes statistically significant at 10 percent; **denotes statistically significant at the5 percent; and ***denotes statistically significant at 1percent.

Source : Author's computation based on data obtained from the field

Adoption of introduced CSA practices also had a significant impact at 1 percent in explaining the differences in crop yield for maize in the 2015 and 2016 cropping seasons and significant at 10 percent for soya in the 2015 cropping season. Thus, the introduced CSA practices by NGO play significant role in generating the needed yield and profitable levels of maize production. The results further show that farmer's adoption of introduced CSA practices propelled an additional increase in the yield of soya by 0.12kg per acre and increased yield of maize per acre by 0.32kg and 0.72kg for the 2015 and 2016 cropping seasons.

The joint effect of adopting both indigenous and introduced CSA practices was significant at 1 percent in explaining the difference in yield of maize and significant at 10 percent in explaining the difference in the yield of soya for the 2015 and 2016 cropping seasons. The results reveal that jointly adopting indigenous and introduced CSA practices propelled an additional increase in yield of maize per acre by 0.26kg and 0.54kg for the 2015 and 2016 cropping seasons respectively. For soya, the joint adoption of indigenous and introduced CSA practices propelled an increase in yield by 0.12kg per acre in the 2015 cropping season. The implication of this result is that combination of indigenous and introduced CSA practices induces an improvement in the yield of soya.

Among the control variables, age of the farmer, traditional practices, and access to extension services have positive impact on the productivity of farmers in maize cultivation. The squared term of age exert significant effect on the crop yield of maize in 2015 and 2016. The sign of the age term is positive whiles the squared term is negative. This implies that as the farmer age increases, the maize yield increases but beyond a certain threshold maize yield will deteriorate. Confounders such as gender, access to financial service, farm size, and labour had negligible role in stimulating productivity levels of farmers in the area of maize cultivation.

The size of a farmer's farm exerted a negative influence on the crop yield of maize. This implies that as farm size increases it has negative effect on crop yield of maize in 2015 and 2016 holding other factors constant such as age, adoption of Indigenous CSA practices, introduced practice, access to financial service, and others. Finally, Access to aggregation service and FBO have negative impact on the productivity of farmers in the area of maize production.

The control variables such as access to extension services, access to financial services, access to aggregator services, access to input dealers, FBO formation, age, farm size, and labour have negligible impact on the production levels of soya. However, traditional practices had significant negative impact on soya production. Confounders like access to extension services and financial access stimulate productivity levels of farmers in groundnut production. FBO formation has negative impact on farmers' productivity in the area of groundnut production. The remaining control variables namely, gender, age, farm size, labour access to input dealers have null impact on the crop yield of groundnut.

The results further show that adoption of Indigenous CSA practices exerts no significant effect on crop yield of beans in 2015 even at the 10 percent significance. The result is similar to the obtained for soya and groundnut. Thus, the adoption of CSA practices is more inclined to some crops such as maize relative to others like groundnut, beans and soya. FBO formation and farm size have positive impact on crop yield of beans whiles access to input dealers and traditional exerted negative impact the productivity of farmers in the cultivation of beans. Age of the farmer, laborers employed on farm, access to extension services and financial services as well as gender of the farmer have negligible role-play in the productivity levels of farmers in the cultivation of beans.

The results indicate that adoption of indigenous practices is more inclined to maize cultivation and do not favor other crops such as soya, groundnut and beans. For the introduced practices, it robust to all crops namely maize and soya. Thus, design of CSA practices by NGOs for other crops such as groundnut and beans may have favorable effect on the productivity of farmers.

4.4.1 Examining areas of synergies in indigenous and introduced CSA

This section discusses areas of potential synergies between ingenuous and introduced CSA practices common among farmers and how the strong synergies can be achieved. Levels of synergies are categorized based on permutations and discussions from farmers, NGOs and MoFA. The results are presented in Tables 13 and 14.

There exist areas of synergies between the indigenous and introduced CSA practices among farmers. In all 31 counts were observed for potential synergies representing 63 percent of total counts. Out of this, 18 counts were made for potential for weak synergies representing 36.7 percent while 12 counts were made for potential for strong synergies representing 24.5 percent of the total counts. There was only 1 count for potential for high synergies representing 2 percent of the total counts. This implies that, there is great potential for achieving multiple results from the conscious blending of indigenous with introduced CSA practices. However, not all practices can be blended to achieve potential positive results as represented by 17 counts.

Table 14 Farmers permutation of indigenous and introduced CSA practices

Scale	Symbol	Interpretation	Number of counts	percentage
0 count	N	No positive synergies	18	36.7
1 to 3 counts	W	Weak areas for synergies exist	18	36.7
4 to 5 counts	S	Strong areas for synergies exist	12	24.5
6 to 7 counts	H	High area for positive synergies exist	1	2.04
Total			49	100.0

Source: Field Survey, 2017

Table 15 Farmers assessment of levels of synergies between indigenous and introduced CSA practices

CSA practices		Indigenous CSA practices						
		soora for insert control	Soaking of maize before planting	Sulphate fertilizer mixed with weedicide for weeds control	use of ponded neem fruits for weeds control	Rotation of cereals with yam	Reducing of planting space	Use of powdered neem leaves for inoculants
Introduced CSA practices	use of mocuna cover crops	3-4 (W)	1-3-4-6 (S)	1-.3-4 (W)	2-3-4 (W)	N	N	N
	planting of soya	4 (W)	N	N	1-2-4 (W)	N	1-2-3-4-6 (S)	1-2-4-5 (S)
	minimal tillage	2-4 (W)	4 (W)	2-4 (W)	2-4 (W)	1-2-3-4-5 (S)	4 (W)	2-4 (W)
	farm insurance	N	N	N	N	N	N	N
	new organic fertilizer	N	1-2-3-4-7 (S)	1-4-5-6 (S)	1-2-4-5-6-7 (H)	1-3-4-5-6 (S)	1-4 (W)	N
	use of multi action weedicide	5 (W)	1-2-3-4-5 (S)	N	2-4 (W)	1-2-3-4 (S)	1-2-3-4-6 (S)	1-4 (W)
	Use of improved seed	1-7 (W)	N	1-6-7 (W)	1-4-6-2 (S)	1-2-4-6-7 (S)	1-7 (W)	N
Benefits of CSA practices		Increase in farm productivity	Cost friendly and affordable	Improve water holding capacity	Improve soil organic build up	Improve vegetation	Easy to understand	Easy to access from value chain
		1	2	3	4	5	6	7
		Economic		Environment			Social	
Potential areas of synergies for achieving objectives of CSA								

Source: Field survey, 2017

4.4.2 Strong areas for synergies and how they can be arrived

4.4.2.1 Mocuna cover crops with soaking of maize before planting

The objective of promoting mocuna cover crops under CSA projects in the study area as revealed by organizations interviewed is to improve the soil performance and retain soil water content. On the other hand, Farmers soak maize before planting to aid quick germination in times of drought. According to farmers in Vamboi community during a focus group discussion, soaked maize produce relatively higher performance when planted on a soil with good fertility. By implication, planting the soaked maize on a land previously used to plant mocuna cover crops has the potential to produce positive. Even though a higher percentage of farmers (40.5 percent) currently practice soaking of maize, it is the opposite for mocuna cover crops (5.1 percent) necessitating a need for synergy building between these two CSA practices. In this regard, it is recommended that trials on mocuna cover cropping showcases plots for soaked maize for farmers understand the potential for achieving positive results or otherwise.

4.4.2.2 Planting soya and reducing plant spacing

NGOs are promoting soya plantation for its ability to improve on soil formation, nutritional value and income generating especially for women. NGOs who are introducing soya cultivation have communicated a recommended spacing of 5cm to 75cm for in between plants and rows respectively. However, farmers during all focus group discussions are of the view that this spacing is not yielding the needed productivity per acre hence have resulted to reducing this planting space to in between 50cm-60cm and 5cm-10cm in between rows and plants respectively. This offers other potential area for synergy between the introduced spacing and the indigenous spacing. It is recommended that demonstrations be set up to try the various line spacing options to get the much productive space and this properly communicated to farmers.

4.4.2.3 Planting soya and use of powdered neem leaves for inoculants

Even though 52.6 percent of farmers have adopted planting of soya under various CSA projects, farmers in a focus group discussion in Naabugubelle explained, access to inoculants for to enhance the performance of their soya crops is still low. Some farmers (12 percent) have devised an indigenous means of creating for themselves easily accessible substance usually used on groundnut farms but have extended its usage on soya production. This provides a potential area for building synergies between science and indigenous experience to help understand the effectiveness of the neem leaves for serving as inoculants.

4.4.2.4 Practicing minimal tillage after rotating yam for cereals

Minimal tillage is promoted under CSA projects in the study area for its ability to contribute to soil restructuring; unfortunately, adoption is low among farmers (911.1 percent). Farmers explained that, the soils before the cropping season are always hard and without loosening through the conventional land preparation, crops find it difficult to thrive. Farmers in Sakai community in a focus group discussion were however convinced that, minimal tillage would best work when a yam field is being rotated for groundnuts and beans. Yams are cultivated on molds that do not get very compacted. In the previous year, the farmer can easily plant on these molds groundnuts or beans but further mentioned that, this practice would not be suitable for maize. An area for synergies is for NGOs promoting minimal tillage to target groundnut, beans and yam farmers to increase adoption of this practice.

4.4.2.5 Applying new organic fertilizer on maize farms and using sulpahte mixed with glyphosate weedicide for weeds control.

The introduction of ominifert fertilizer for farmers under some CSA projects in the study area is aimed at contributing to soil formation and reducing the chemical usage in agriculture. Even though 41.7 percent of farmers have adopted this practice, they reveal in a focus group discussion that, weeds control is often a challenge after applying this fertilizer. Farmers explained that the fertilizer seems to support growth of weeds because it is organic in nature. On the other hand, farmers have made a chemical mixture (glyphosate weedicide plus a tin full of sulphate or salt). This makes the weedicide much effective than it's original. Farmers during a focus group discussion reveal that originally, a farmer will use two (2) litres of glyphsate weedicide for controlling broad weeds on the field before sowing and usually would follow up hand weeding after three weeks however, with this mixture; the farmer uses 1 litre that is enough to suppress all weeds to the harvest. The potential area for synergy would therefore be a promotion of ominifert organic fertilizer alongside this indigenous mode of weeds control to help reduce the chemical usage on farms.

4.4.2.6 New organic fertilizer used on a yam farm rotated for maize

Farmers rotate yam field for maize cultivation because these farms contain much organic matter. In this situation, the use of chemical fertilizer is minimized. What is not clear for farmers is whether the application of organic fertilizer on such fields would produce much positive results. This offers an area for building of synergy between the use of ominifert fertilizer and crop rotation to further understand their compatibility.

4.4.2.7 Applying multi action weedicide on a maize field soaked before planting

NGOs are promoting the use of a multi action weedicide for farmers in the study area. This weedicide promises results that include; suppressing of post emerging weeds, boosting crop performance as the chemical contains a fertilizer component. However, farmers during a focus group discussion at Tarsaw reveal that, when maize is soaked before planting, application of this multi action weedicide rather reduces the crop performance. This necessitates a further examining of this chemical and what reasons could be causing this negative effect of the chemical considering that 66.4 percent of farmers are using this multi action weedicide while 40.5 percent of farmers are also adopting soaking of maize before planting.

4.4.2.8 Using ponded neem fruits as weedicide on a farm where improve seed is used

Use of improved seed is high among farmers the major concern farmers raised about using improved seed is the high cost. Using an indigenous weed control method will not only help reduce the chemical usage on the farm but help to reduce the cost of production this weed control method is less costly. An area of synergy is to help upgrade indigenous weeds control methods to become much effective.

4.4.2.9 Use of improve seed on farms previously used to cultivate yam but rotated for maize.

Even though improve seeds are high yielding; they often require right amounts of chemical fertilizer to be applied. The study revealed that farmers are rotating yam farms for maize because yam crop help to add much nutrients to the soil. However, farmers who do this rotation as revealed in a focus group discussion in Naabugubelle community still apply the recommended amounts specified for use of improved seed since they an able to tell the level and type nutrients added to the land after farming yam. An area for synergy for CSA interventions is to help farmers understand when and where certain quantities of chemical fertilizer can be reduced to benefit improve their crops.

4.4.3.1 Role of CSA models in achieving synergies between indigenous and introduced CSA practices.

This section examines the current CSA model being applied in major CSA projects in the study area for their effectiveness in promoting needed synergies between indigenous and introduced CSA practices. Based on the weaknesses identified in the current model, a different model is proposed help achieve strong synergies between indigenous and introduced CSA practices.

4.4.3.2 Current CSA model in the Sissala East

1. NGOS and MoFA initiate projects and activities that seek to promote particular CSA practices. Current practices being promoted include; the use of improved maize and soya seeds, adoption farm insurance, the use of compost fertilizer, the use of multi purposed weedicide (Odessey) and the cultivation of soya. These activities are supported by multi donor organizations such as MEDA, AGRA and IFDC. The major channel of communication of new practices to farmers is through farm level demonstrations and verbal extension delivery through farm visits.
2. FBOs are mostly the target groups through which many farmers are reached in communities. The average number of farmers in each FBO is between twenty (20) to twenty –five (25) people.
3. Not all farmers in communities where these practices are promoted are part of the FBOs. On an average 60% of farmers in the Sissala East District, belong to FBOs. There are other activities such as farmer field days that other farmers not belonging to the FBOs often take part to learn CSA practices being introduced.
4. Farmer's decision to adopt is determined by the availability of market for the particular crop for which the initiative is adopted. Farmers in the Sissala East District are more likely to adopt practices that contribute to the productivity of crops that they have easy market after harvest. As a result, most CSA project designs involve the facilitation of farmer's access to ready market.

5. Access to finance is also considered very important for promoting CSA adoption in the Sissala East district. Access to farming capital is very essential for farmers in the Sissala East district. As a result, most project designs have included facilitation of farmers to easy access to production credit from various financial institutions. Projects have also introduced the concept of Village Savings and Loans Associations to farmers which a strategy of encouraging community level savings among farmers towards financing farm production.
6. Access to farm inputs such as seeds and agro chemicals are needed for farmer's successful adoption of CSA practices. Most of the CSA projects in the study district have as part of their activities to link farmers to inputs dealers to provide farmers with the needed inputs to facilitate their adoption of CSA practices.

4.4.3.3 CSA innovation model being adopted in projects in the Sissala East District

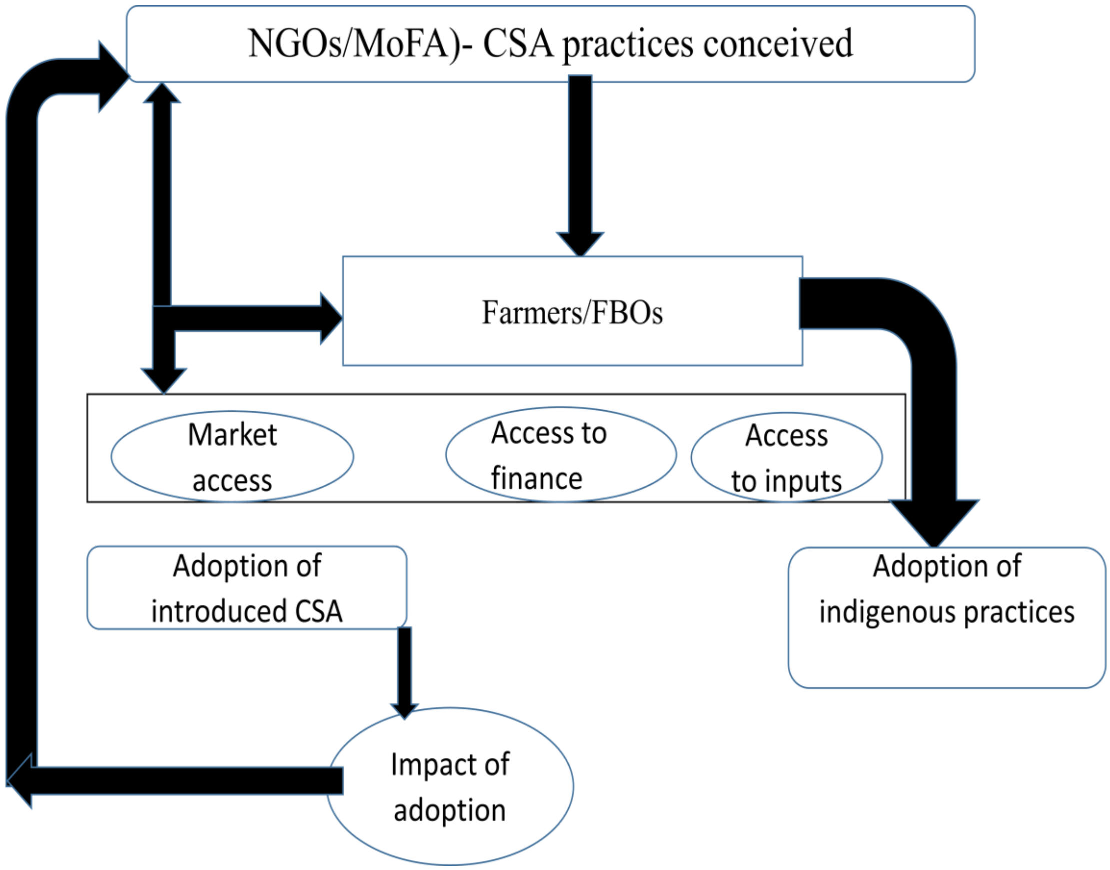

Figure 3 Current CSA model used in CSA projects

7. 60% of farmers in the study district are adopting most of the CSA practices being introduced by NGOs and MoFA.
8. The CSA model does not consider the indigenous knowledge and practices that farmers might be adopting that can best be exploited to improve their adaptive capacities.
9. Much emphasis on the impact of farmer's adoption is placed on introduced CSA practices.

4.4.3.4 Weaknesses of the CSA model and areas for synergies

Based on the study findings, the following areas were identified for the building of synergies among various stakeholders promoting CSA practices;

1. *Inclusion of indigenous practices in project initiative:*

Discussions with stakeholders revealed that the current model does not include farmers own innovations that could contribute positively to CSA practices. There are not links between introduced CSA practices and indigenous practices and the best ways to blend them. The studies however reveal that a combination of introduced and indigenous CSA influence greatly on food productivity. The study further revealed that farmers are adopting different indigenous CSA practices to complement the introduced CSA practices based on their experiences.

2. *Inclusion of challenges of middle stakeholders (Aggregators, Financial institutions, input dealers)*

The model posits that when farmers are linked to these middle actors through facilitation, it will automatically boost farmer's production activities. However the study reveal that these stakeholders are faced with other challenges in their operation ranging from financial, poor commitments from farmers and conflicting roles by other stakeholders that further affect their activities with farmers. For farmers to be more innovative, these challenges have to be addressed systemically. Unfortunately, the model does not address much on this.

3. Passive relationship between farmers and middle stakeholders

The relationship of the middle stakeholders ends at farmer's access of their services. There is no link for feedback between these stakeholders and farmers after adoption. This emphasizes the need for stronger ties between farmers and stakeholders to understand common challenges in the value chain and to find needed solutions.

4. No sustainable FBOs

FBOs are mainly formed based on projects ideas that do not make FBOs much sustainable. Sustainable FBO formation would need sustainable inputs from all the stakeholders based on their challenges and experiences so that FBOs are not formed just to satisfy project needs but the needs of all the stakeholders of concern.

5. Identification of sustainable credit system

The credit system is the major challenge-facing farmer's update of CSA practices as revealed by the study. It is important for more sustainable credit system that will reduce the farmer default of credit. The study further revealed that the work of NGOs negatively affect farmer credit repayment. This calls for synergies especially among NGOs, financial institutions and farmers on how they can improve the system.

4.4.3.5 Proposed model for achieving synergy between indigenous and introduced CSA practices

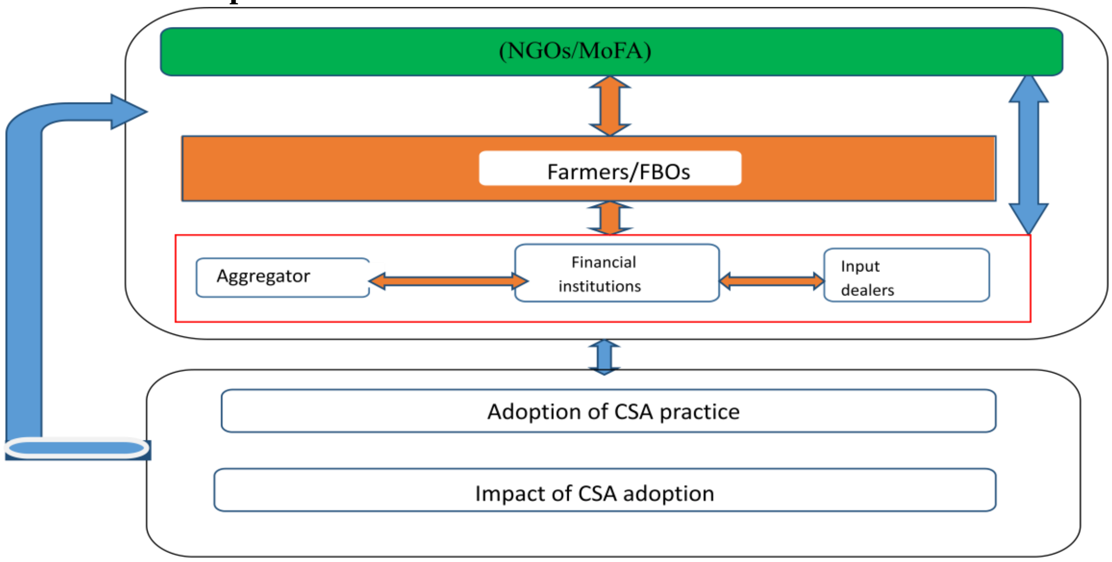

Figure 4 Recommended CSA model

4.4.3.6 Explanation of new CSA Model

1. NGOs will play a much facilitation role rather than initiation if CSA interventions. NGOs and MoFA should undertake much more of capacity building not only for farmers but for other stakeholders or actors in the production value chains to make them be smart and understand how to work closely with farmers to improve the production value chain
2. Farmers should work hard to improve their FBOs systems and make them more sustainable. It is important for farmers to embrace the FBO system as a farmer mobilization strategy for easy farmer sensitization.
3. In the recommended model, Value chain actors namely; aggregators, financial institutions and input dealers are jointly linked with double-edged arrows. Signaling that these actors would have to work more closely as a unit in the production chain and be concerned about the entire FBO

enhancement. Value chain actors should also work much closely with farmers and farmer groups and assist farmers to strengthen their FBOs.

4. In the recommended model, there is a double-edged connection between Value chain actors and farmers. This will require value chain actors to move their services to farmers beyond the mere exchange of goods and services and be concerned about FBO formation and farmer capacity building.
5. There is also a double-edged relationship between the (impact of farmer's adoption of CSA practices) and (farmers, NGOs and value chain actors). In the previous model, impact of farmer's adoption of CSA practices was a concern of NGOs to improve project styles. It is important for example for the financial institutions who play a very important role in the production as well as farmers adoption of CSA practices to be concerned about how farmers have benefitted from their adoption of CSA practices.
6. In the model, indigenous and introduced CSA practices are jointly considered when looking at the impact of CSA. In the previous model, indigenous CSA were not considered.
7. Definition of CSA practices should be expanded to include all innovations from all stakeholders including NGOs, MoFA, farmers and all value chain actors since their activities influence one another

The study also revealed a number of challenges facing the activities of these stakeholders in the production value chains that affect the effective provision of services to farmers. Prominent among them had to do with unsustainable production credit system and FBO systems that can be addressed using the Multi Stakeholder Credit System. The findings further reveal that the CSA model in the Sissala East District was limited in promoting of indigenous CSA even though a combination of indigenous and introduced CSA proved to have a greater impact on farm productivity and proposed a model that includes indigenous wisdom in CSA project designs. Even though NGOs played an important role in the promotion of farmer's to CSA practices, the study suggest it would be better if NGOs play much more of facilitations in the CSA model and create much platforms for farmers, financial institutions, Input dealers and aggregators to interact to build a strong synergy.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

5.0 Introduction

This chapter of the study summarizes the major findings with the corresponding conclusion and recommendations. The study used the adoption quotient to establish differences in farmer's adoption of various CSA practices. Based on the adoption levels, the researcher furthers examined the relationship between CSA practices adoption and farm productivity of maize, soya beans, beans and groundnut using the robust least squares estimation. Reasons and factors affecting farmer's adoption these CSA practices were also established using a probit regression. A qualitative was used to pair indigenous and introduced CSA practices that have the potential of achieving much positive results. These permutations were then converted to numbers and percentages to give understanding on the best areas of synergies between indigenous and introduced CSA practices. The following are the summary of the findings.

5.1.1 Farmers adoption of CSA practices

Generally, the adoption levels of CSA practices among farmers are low. Out of the fourteen (14) CSA practices, 42.8% of them recorded low adoption among farmers while 28.5 percent of the practices recorded high levels of adoption according to the FAO (2015) standards. In addition, it is observed that the use of improved seed is more adopted among farmers. This was directly attributed to the activities of CSA interventions in the study district. However, some other practices susch as use of mocuna cover crops and crop insurance were least adopted despite the fact that they are being promoted under CSA interventions.

5.1.2 Factors influencing farmers Adoption of CSA practices

Farmers level of education, access to farm extension, access to financial service, age of the farmer, experience of the farmer, farm size access to aggregator service and farmer's belongings to FBOs are all significant in explaining farmers adoption of CSA practices. For example, farmers who were educated adopted indigenous and introduced CSA practices 7% and 6% respectively. The results showed that, farmers who had access to extension services had a probability of adopting introduced CSA practices at 9% less than farmers who had access to extension services. Finally, the results reveal that, farmers who belonged to active FBOs have a probability of adopting introduced CSA practice 14 percent higher than farmers who do not belong to active FBOs. The revelations emphasized the need for an integrated approach to promoting farmers adoption of CSA practices.

5.1.3 Impact of CSA adoption on Farmers' Productivity

Farmers adoption of indigenous and introduced CSA practices were significant in explaining the difference in farmer's crop yields per acre. Farmer's adoption of indigenous CSA practices was significant at 1 percent in defining the differences in yield of maize for the 2015 and 2016 cropping seasons as well as the yield of groundnut in the 2015 cropping season. The results showed that the adoption of indigenous CSA propelled an increase in yield of maize by 0.26kg and 0.41kg in

2015 and 2016 cropping seasons respectively. Adoption of introduced CSA practices also had a significant impact on the differences in yield of farmers at 1 percent in explaining the differences in crop yield for maize in the 2015 and 2016 cropping seasons and significant at 10 percent for soya in the 2015 cropping season. The results show that, the adoption of introduced CSA practices propelled an increase in yield of maize per acre by 0.32kg and 0.72kg for the 2015 and 2016 cropping seasons. The results further show that farmer's adoption of introduced CSA practices propelled an additional increase in the yield of soya by 0.12kg per acre. In addition, adoption of indigenous CSA practices was significant at 1 percent in explaining the difference in groundnut yields for the 2015 cropping season. The results showed that adoption of indigenous CSA practices rather a negative influence on the yield of groundnut by 0.58kg. Farmers did not however select groundnuts and beans as targets for adopting introduced CSA practices.

The joint effect of adopting both indigenous and introduced CSA practices was significant at 1 percent in explaining the difference in yield of maize and significant at 10 percent in explaining the difference in the yield of soya for the 2015 and 2016 cropping seasons. The results show that, adopting indigenous and introduced CSA practices jointly propelled an additional increase in yield of maize per acre by 0.26kg and 0.54kg for the 2015 and 2016 cropping seasons respectively. For soya, the joint adoption of indigenous and introduced CSA practices propelled an increase in yield by 0.12kg per acre in the 2015 cropping season.

5.1.4 Areas for synergies in introduced and indigenous CSA practices.

There exist areas of synergies between the indigenous and introduced CSA practices among farmers. 12 areas for were for potential for strong synergies representing 24.5 percent of the total counts was made between indigenous and introduced CSA practices. This implies that, there is great potential for achieving multiple results from the conscious blending of indigenous with introduced CSA practices. Below are the areas for synergies identified;

1. Mocuna cover crops with soaking of maize before planting
2. Planting soya and reducing plant spacing
3. Planting soya and use of powdered neem leaves for inoculants
4. Practicing minimal tillage after rotating yam for cereals
5. Applying new organic fertilizer on maize farms and using sulpahte mixed with glyphosate weedicide for weeds control.
6. New organic fertilizer used on a yam farm rotated for maize
7. Applying multi action weedicide on soya fields and also reducing the planting space
8. Use of muti action weedicide on maize farms after yam rotation
9. Applying multi action weedicide on a maize field soaked before planting
10. Using ponded neem fruits as weedicide on a farm where improve seed is used
11. Use of improve seed on farms previously used to cultivate yam but rotated for maize

12. Applying new organic fertilizer on farms that maize was soaked before planting.

5.1.5 Getting the right CSA model for enhanced synergy

The study revealed that the current CSA model being used by NGOs and MoFA does not consider indigenous CSA practices and the role of indigenous knowledge in achieving sustainable increase in farm productivity. The model therefore does not make conscious efforts to promote activities that seek to link introduced CSA practices and indigenous practices and the best ways to blend them. Meanwhile a combination of indigenous and introduced CSA practices promise a greater impact in farm productivity. Based on the weaknesses of the current model, an all-inclusive CSA model is proposed. In the model, indigenous and introduced CSA practices are jointly considered when looking at the impact of CSA.

5.2.1. Conclusions

Base on the findings; the following conclusions have been arrived;

Firstly, it is concluded that, adoption of CSA practices among farmers in the Sissala East District is generally low despite several project interventions aimed at advancing smallholder farmer adoption of CSA practices. Adoption of CSA agricultural practices is motivated by a number of factors that are different form farmer to farmer and from community to community on which basis farmers adopt specified CSA practices. However, a number of constraints still impede farmer’s quick uptake of CSA practices that include cost of technologies for introduced CSA practices while the processes involved in preparing indigenous inputs discourage farmer's advancement in the adoption of these practice. Some indigenous CSA practices would have to be repackaged to become more users friendly to increase the upscale of such CSA practices.

In addition, adoption of introduced CSA has the positive potential of contributing to increasing crop production especially for maize and soya in the study area. Indigenous practices alone do not propel much positive benefits at the farm level in the area of increase in productivity. For this reason, a great need for synergies to be built between indigenous CSA practices and Introduced CSA practices.

For CSA interventions to achieve effective synergies between indigenous and introduced CSA practices, there is the need for NGOs and MoFA to move from their current CSA model where there is a disconnect between indigenous practices and introduced CSA practices to a more inclusive model which puts farmers involvement in project designs and implementation very keen. For a much sustainable CSA model in the Sissala East District, there is need for a sustainable FBOs and input credit systems which are not been effectively addressed in the current CSA model. Finally, Stakeholders in the production vale chain should take interest in farmers adoption of CSA practices since their activities directly impact on one another.

5.3.1 Recommendations

The results revealed that adoption of introduced practices is robust to all crops being practiced on namely maize and soya. It is therefore recommended that farmers increase their uptake of CSA practices to achieve the needed results on their farms.

It was further revealed that most introduced CSA interventions concentrated much on maize, which is a common crop for men. It is recommended that introduced CSA interventions should target practices for promoting groundnuts, beans and soya beans to enhance farm productivity.

Some indigenous CSA practices that are common among farmers need to be further studied to establish a scientific backing for their perceived advantages or other wise to farming and the environment. For example, the use of some pesticidal plants for pests control should be encouraged through further research to further build on farmer's knowledge and encourage local level resources for farming.

Even though farmers prefer improve seed for adapting to climate change, access to improve seed is low especially among women in the study area. It is recommended that NGOs and government work closely to develop competitive seed markets to provide widespread access to improve seed at affordable prices.

Generally, farmers do not consider the CSA interventions such as farm insurance, minimal tillage and mocuna cover crops appropriate for their local certain. It is recommended for CSA interventions promoting these practices to substitute with much preferred practices.

CSA project designs should include activities that create platforms for joint discussions by all institutions promoting CSA interventions to assess activities to reduce instances of duplications and conflicting project activities. The extensive uptake of CSA practices in the study area will happen with increased capacity development for stakeholders at all levels of the production value chain. Unfortunately, farmers, aggregators, financial service providers and inputs dealers' awareness and knowledge about promising CSA initiatives is limited.

This coupled with conflicting advice provided by different extension services under different project designs leads to poor uptake of CSA practices. It is recommended that CSA projects and interventions in the study area consider capacity development at all levels of the value chain to ensure a holistic uptake of CSA practices. It is recommended for input dealers and aggregators to be involved with FBO formation and development since FBOs enhanced farmer innovations adoption. Input dealers should have a register of FBOs and to aid in making their market assessment. Input dealers and aggregators should facilitate trainings such as market dynamics trainings even if they are to be sponsored by NGOs. This would further deepen the relationship between farmers and these stakeholders. In the old module, aggregators and input dealers did not have concerns for FBO development. Aggregators should be consulted for market availability during selection of farmers for loans. Farmers who are registered under particular aggregators should be given priority during the selection of farmers for credit facilities.

In addition, it is recommended for the District Assembly to make conscious efforts backed by monetary support to finance CSA initiatives. The study revealed that majority of CSA interventions in the study area are financed through donor aid. Considering the significance that CSA interventions promise for sustaining food production in the nearest future, the District Assembly and Government need to sponsor CSA by allocating internally generated resources to promising CSA interventions.

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APPENDIX

Field questionnaire

This study is a partial fulfillment for the award of an M.Phil degree in Environment and Resource management from the University for Development Studies WA Campus. You have been randomly selected and we would be grateful if you could kindly participate in our survey. Your participation is completely voluntary and you have the right NOT to participate in this survey at all or stop participation at any point in time during the survey. Apart from your time, there is no cost or remuneration involved. This survey would take some time of yours to administer and it includes information on your household characteristics and farming activities. All finding of the study will be held in confidentiality. Thank you.

General information

1. Community ……………………………………………… (Code ………)
2. Household code ……………………………………..
3. Sex of respondent: [ ] 1=Female 0=Male
4. Age of respondent ………………………….
5. Highest level of formal education of respondent: [ ]
0=None 1=Basic (Primary/JHS/Middle) 2=SHS 3=Tertiary
(Training college/Polytechnic/University)
6. Marital status of respondent: [ ]
0=Single 1=Married 2=Divorced/Separated 3=Widowed
7. Are you the head of the household? (If man is away >6months/yr, then woman is
Head)? [ ] 1=Yes 0=No,

Household composition

8. How many people are you in your household? Total [ ] male [ ] female [ ]
9. Number of persons with ages below 15 years. Total [ ] male [ ] female [ ]
10. Number of ages between 15 and 65 years. Total [ ] male [ ] female [ ]
11. Number of ages above 65 years Total [ ] male [ ] female [ ]
12. Number of ages who are literate or attended school total [ ] male [ ] female [ ]

Income generation

13. What is your major occupation [ ] 1=Agriculture 2=Petty
Trading 3=Craftsmanship 4=Salaried work (formal sector) 5=other
14. If [1] How many years of experience to you have in farming (*indicate number of years as well as range*) [ ] - [1] 1-5 [2] 6-10 [3] 11-15 [4] 20+
15. What is the size of your personal farm ………………….
16 Are members of your household engaged in any off-farm income generating activities?
[ ] 1=Yes 2=No.

17. If yes mention them

Activity	Number of people	Average monthly income	Average annual income

Objective one: To assess how the adoption of climate smart agricultural innovations is contributing to food production in the Sissala East district?

Knowledge and experience of climate variability

18. Have you experienced changes in the way rains and temperature patterns in the past years? 1. Yes 2. No

19. If yes what indicators do you see that confirm that rainfall and temperature patterns have changed?

[1] Reduced rains [2] Late start of rains [3] reduced yield [4] other *specify……………………………….*

Note multiple choices is allowed

20. How does the changing climate affect your agricultural work?

[1] Reduce yield [2] increased pest [3] increased cost of production [4] other *specify………………………………. Note multiple choices is allowed*

Adaptation practices using indigenous knowledge

21. Which of these traditional practices do you undertake on your farm?

Practice	Number of acres where practice is used	Type of crops	Any reasons for adoption
[1] Early planting			
[2] crop rotation with cereal/legumes			
[3] intercropping			
[4] mixed cropping			
[5] use of animal manure			
[6] use of fertilizer			

22. Have you adopted new practices besides the above? [1] Yes [2] no *(if no continue from que 27)*

23. If yes which other practices do you carry out besides these traditional agricultural practice due to the perceived changing climate at the farm level?

practice	mark	Number of acres where practice is used	Type of crops
[1] using Soora for insects control			
[2] using neem leaves as inoculant			
[3] Sulphate + weedicide mixture			
[4] Soaking of maize seed over night			
[5] rotation of cereals with yam			
[6] using neem fruits to control insects			
[7] reduce planting space			
[8] other			

24. Why do you adopt the above mentioned new practices? (Please tick)

Practice	[1]Reduced cost	[2] Effective for soil fertility improvement	[3] Have much knowledge on it	[4] Very common with my household	[5] Promotion of practice by NGOs
1					
2					
3					

25. How long have you been practicing these innovations?

Practice	Less than year	1 year	2 years	3 years	4 years	4+years
1						
2						
3						

26. Where did you learn this knowledge from?

Practice	From friends	From my own experience	From FBO meetings	From Radio	Other (specify)
1					
2					
3					

27. Which of these introduced agricultural practices to you adopt due to the perceived changing climate at the farm level?

practice	mark	Total number of acres	Number of acres where practice is used
[1] use of improved seed			
[2] use of mocuna cover crops			
[3] planting soya			
[4] minimal tillage			
[5] farm insurance			
[7] use of new fertilizer			
[8] use of new weedicide			

28. Why do you adopt the above mentioned practices? (Please tick)

Practice	[1]Reduced cost	[2] Effective for soil fertility improvement	[3] Have much knowledge on it	[4] Very common with my household	[5] Promotion of practice by NGOs	others
1						
2						
3						
7						
8						

29. For how long have you been adopting the above practices?

Practice	Less than year	1 year	2 years	3 years	4 years	4+years
1						
2						
3						

30. Where did you learn this knowledge from?

Practice	From friends	From my own experience	From FBO meetings	From Radio	NGO	Other (specify)
1						
2						
3						

Objective Two: To estimating the effect of climate smart agricultural innovations adoption on food crop production.

31. What is the size of land for your farming purposes? (*Indicate both number and range*)
[ ] [1] 1-5 [2] 6-10 [3] 11-15 [4] 16+
32. How long has this land been used for farming ……………………..
33. What is the mode of ownership of this land?
[1] From family [2] rented [3] bought [4] other (………………………..)
34. For how long would be allowed to work on this land …………………..
35. Do you have other lands that you can move to for farming [1] Yes [2] No
36. How many laborers are you able to employ on your farms in a season? …………..
37. Do you use inputs on your farm (e.g. Fertilizer, weedicides)? [1] Yes [2] no
38. If yes kindly give quantities

Input	Quantity per acre	Estimated total cost	N.o of acres
fertilizer			
weedicide			
seed			

39. What total amount of money do you spend on your farms for a season [1] 100 and below [2] +100-500 [3] 500+ -1000 [4] 1000+

40. Please indicate your cost of producing an acre of the following crops if applicable to you?

Item	Maize	soya	groundnut	White Beans
Cost of land preparation				
Fertilizer				
weedicide				
Cost of seed				
Cost of labor for planting				
Cost of labor for weed control				
Cost of labor for harvesting				
Total cost				
Average yield per acre				
Unit price/Revenue				
profit				

41. What was your average yield for the following crops if applicable for the 2015 and 2016 production seasons?

Crop	No. of bags (100kg) /2014	No. of bags (100kg) /2015	No. of bags (100kg) 2016
Maize			
Groundnut			
Beans			
Rice			

42. What quantity of food (produced and purchased) do you require to be sufficient in a month?

Crop	No. of bags	Estimated price
Maize		

Groundnut		
Beans		
Rice		
Yam		

43. Does your household have adequate monthly food requirement throughout the year from own production and Purchases? 1=Yes 2=No
44. If yes how many months [ ] Name the months. Jan [1] Feb [2] ………… Dec [12] […………………………………………….]

45. What quantity of your actual energy comes from your farm where any of the introduced practices is being adopted?

crop	Quantity used	Quantity from farm	Quantity purchased
Maize			
Groundnut			
Beans			
Rice			
Yam			

Objective three: To examine how synergies can be built in the various CSA models

Farmer's perspective
46. Do you have relations with any financial institution to aid your production activities?
[1] Yes [2] no
47. If yes, what kind of benefits do you get from them
[1] Ability to save [2] financial counselling [3] take loans

48. If no why don't you have any relations with any financial institution?
[1] they are far from my community [2] high interest rates [3] afraid of loan default [4] it is difficult to access loans
49. How does your non relations with the financial institutions affect your ability to undertake your farm production? [1] Cannot cultivate in large acres [2] I am unable to purchase farm inputs timely [3] I am unable to assess tractor services [4] others
50. How do you prepare your land for cultivation? [1] Tractor [2] herbicides only [3] hand plough

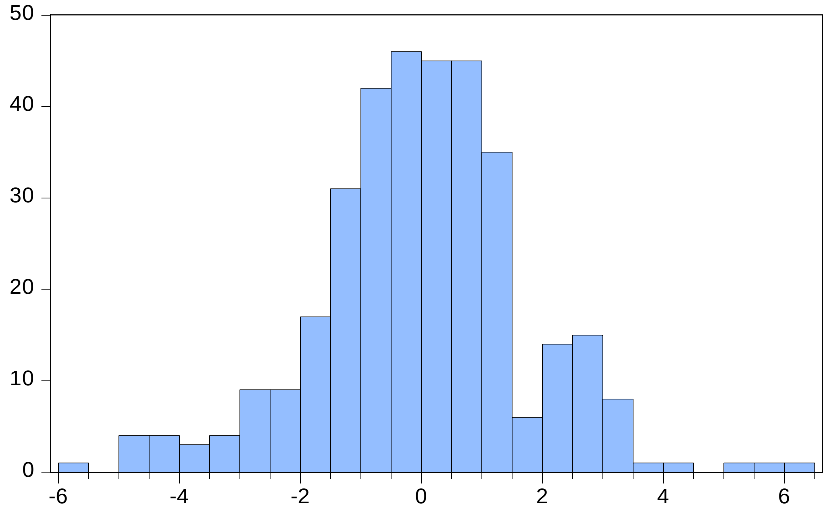
51. If tractor, how do you access your ability to access tractor services
[1] Difficult [2] easy [3] averagely easy
52. Do you have any relations with any extension officers from NGOs or MoFA
[1] Yes [2] no
53. If yes how often do you meet? [1] once a week [2] once a month [3] once a year [4] anytime when services is required
54. How long have you being receiving extension support from NGOs/MoFA ………………..
55. Do you have difficulties selling the produce from any of your crops that you cultivate?
[1] Yes [2] no
56. If yes which crops…………………………………..
57. Do you have access to aggregator services [1] yes [2] No
58. Does your FBO still meet [1] yes [2] no
59. Do you get any benefits from your FBO [1] yes [2] no
60. If yes, what benefits do you get [1] get financial support for farming [2] get technical training [3] savings from VSLA for production [4] able to attract market from aggregators and external market [5] others ………………………………………………
61. What process of information dissemination do you get your information from on climate change adaptation innovations?
[1] farmer field days [2] from extension officers [3] radio discussion [4] community forum [5] other *specify* ……………………………………………………………………….
62. Which information transmission channels do you deem effective for reaching out to you.
[1] farmer field days [2] from extension officers [3] radio discussion [4] community forum [5] other *specify* ……………………………………………………………………….
Multiple choice is allowed
63. Do you have easy access to inputs dealers (seed, weedicide etc) [1] yes [2] no
64. Do they give you enough satisfaction (price, quality) [1] yes [2] No
65. What role do you think farmers can play to complement the efforts of other originations eg NGOs and MoFA to promote the adoption of climate smart agricultural practices/ new practices for climate change adaptation?

Summary of regression results

Dependent Variable: YIELDMZ2015
Method: Least Squares
Date: 07/10/17 Time: 08:51
Sample: 1 394
Included observations: 343

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ADPMZ2015	0.189738	0.088070	2.154390	0.0319
AGE	0.170222	0.066107	2.574942	0.0105
AGESQUARED	-0.001972	0.000766	-2.576049	0.0104
AGGSEV	-0.476930	0.271216	-1.758487	0.0796
EXOFF	0.857553	0.311562	2.752433	0.0062
FARMSIZE	-0.043681	0.027905	-1.565367	0.1185
FBO	-1.210998	0.294796	-4.107915	0.0001
FINSEV	0.330225	0.342210	0.964978	0.3353
INPUTDEALERS	0.799921	0.275068	2.908088	0.0039
LABOUR	0.024700	0.032880	0.751194	0.4531
TRADMZ	0.041135	0.089103	0.461659	0.6446
IPMZ201501	0.307868	0.083833	3.672404	0.0003
DGENDER	-0.067234	0.257120	-0.261491	0.7939
C	4.052693	1.437512	2.819242	0.0051

R-squared	0.184495	Mean dependent var	8.682216
Adjusted R-squared	0.152272	S.D. dependent var	1.905948
S.E. of regression	1.754847	Akaike info criterion	4.002601
Sum squared resid	1013.152	Schwarz criterion	4.159243
Log likelihood	-672.4460	Hannan-Quinn criter.	4.064996
F-statistic	5.725472	Durbin-Watson stat	1.733138
Prob(F-statistic)	0.000000		



Series: Residuals	
Sample 1 394	
Observations 343	
Mean	1.18e-15
Median	0.027204
Maximum	6.328924
Minimum	-5.596331
Std. Dev.	1.721172
Skewness	-0.040601
Kurtosis	4.141507
Jarque-Bera	18.71684
Probability	0.000086

Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	1.641381	Prob. F(13,329)	0.0726
Obs*R-squared	20.89102	Prob. Chi-Square(13)	0.0751
Scaled explained SS	30.19057	Prob. Chi-Square(13)	0.0044

Dependent Variable: YIELDMZ2015
Method: Robust Least Squares
Date: 07/10/17 Time: 08:53
Sample: 1 394
Included observations: 343
Method: M-estimation
M settings: weight=Bisquare, tuning=4.685, scale=MAD (median centered)
Huber Type I Standard Errors & Covariance

Variable	Coefficient	Std. Error	z-Statistic	Prob.
ADPMZ2015	0.260831	0.080891	3.224484	0.0013
AGE	0.235381	0.060718	3.876632	0.0001
AGESQUARED	-0.002661	0.000703	-3.784041	0.0002
AGGSEV	-0.697235	0.249106	-2.798946	0.0051
EXOFF	0.940289	0.286163	3.285854	0.0010
FARMSIZE	-0.056210	0.025630	-2.193158	0.0283
FBO	-1.158444	0.270764	-4.278425	0.0000
FINSEV	0.309490	0.314313	0.984655	0.3248
INPUTDEALERS	0.990575	0.252644	3.920837	0.0001
LABOUR	0.014409	0.030200	0.477114	0.6333

TRADMZ	0.072482	0.081839	0.885665	0.3758
IPMZ201501	0.320694	0.076999	4.164925	0.0000
DGENDER	-0.289199	0.236159	-1.224594	0.2207
C	2.571689	1.320325	1.947770	0.0514

Robust Statistics

R-squared	0.213182	Adjusted R-squared	0.182091
Rw-squared	0.355468	Adjust Rw-squared	0.355468
Akaike info criterion	477.8621	Schwarz criterion	532.5657
Deviance	720.9484	Scale	1.264568
Rn-squared statistic	121.5745	Prob(Rn-squared stat.)	0.000000

Non-robust Statistics

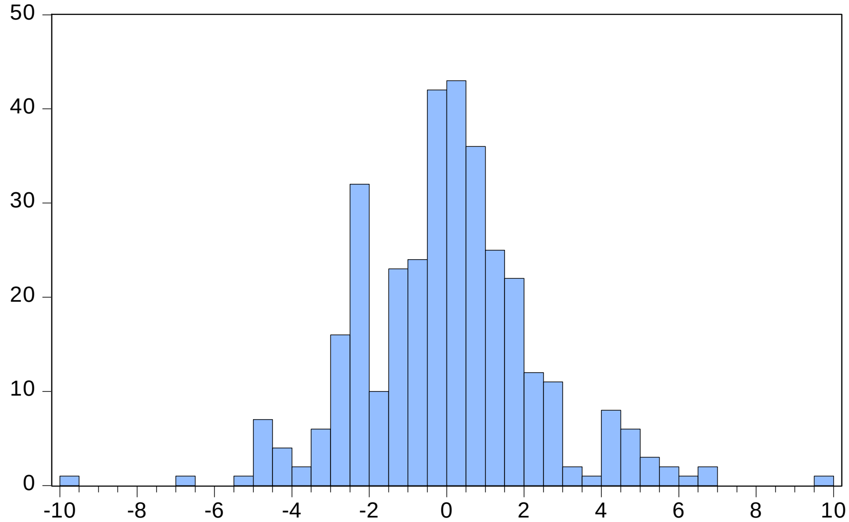
Mean dependent var	8.682216	S.D. dependent var	1.905948
S.E. of regression	1.767631	Sum squared resid	1027.966

Dependent Variable: YIELDMZ2016
Method: Least Squares
Date: 07/10/17 Time: 08:54
Sample: 1 394
Included observations: 344

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ADPMZ2016	0.428295	0.121195	3.533948	0.0005
AGE	0.214910	0.088486	2.428739	0.0157
AGESQUARED	-0.002586	0.001025	-2.523785	0.0121
AGGSEV	-0.341569	0.365332	-0.934955	0.3505
EXOFF	1.160981	0.417849	2.778470	0.0058
FARMSIZE	-0.069516	0.037561	-1.850773	0.0651
FBO	-1.256326	0.395766	-3.174413	0.0016
FINSEV	0.521836	0.464512	1.123407	0.2621
INPUTDEALERS	1.150229	0.369248	3.115061	0.0020
LABOUR	0.020861	0.044153	0.472460	0.6369
TRADMZ	-0.148526	0.119381	-1.244134	0.2143
IPMZ201601	0.667390	0.114835	5.811748	0.0000
DGENDER	-0.472243	0.345027	-1.368711	0.1720
C	3.401291	1.923269	1.768495	0.0779

R-squared	0.268731	Mean dependent var	9.703488
Adjusted R-squared	0.239923	S.D. dependent var	2.698534
S.E. of regression	2.352646	Akaike info criterion	4.588805
Sum squared resid	1826.531	Schwarz criterion	4.745110
Log likelihood	-775.2744	Hannan-Quinn criter.	4.651059

F-statistic	9.328489	Durbin-Watson stat	1.566695
Prob(F-statistic)	0.000000		



Series: Residuals	
Sample 1 394	
Observations 344	
Mean	5.68e-16
Median	0.033493
Maximum	9.670907
Minimum	-9.942000
Std. Dev.	2.307632
Skewness	0.215180
Kurtosis	4.861564
Jarque-Bera	52.32572
Probability	0.000000

Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	1.216910	Prob. F(13,330)	0.2653
Obs*R-squared	15.73658	Prob. Chi-Square(13)	0.2636
Scaled explained SS	27.96113	Prob. Chi-Square(13)	0.0092

Dependent Variable: YIELDMZ2016
Method: Robust Least Squares
Date: 07/10/17 Time: 08:56
Sample: 1 394
Included observations: 344
Method: MM-estimation
S settings: tuning=1.547645, breakdown=0.5, trials=200, subsmpl=14,
refine=2, compare=5
M settings: weight=Bisquare, tuning=4.684
Random number generator: rng=kn, seed=1089791345
Huber Type I Standard Errors & Covariance

Variable	Coefficient	Std. Error	z-Statistic	Prob.
ADPMZ2016	0.407014	0.108878	3.738240	0.0002
AGE	0.136409	0.079494	1.715960	0.0862
AGESQUARED	-0.001719	0.000920	-1.867438	0.0618
AGGSEV	-0.597767	0.328206	-1.821319	0.0686
EXOFF	1.229553	0.375386	3.275435	0.0011
FARMSIZE	-0.084656	0.033744	-2.508793	0.0121
FBO	-1.456957	0.355548	-4.097784	0.0000
FINSEV	0.610632	0.417307	1.463267	0.1434
INPUTDEALERS	1.421329	0.331724	4.284677	0.0000
LABOUR	0.050515	0.039666	1.273503	0.2028
TRADMZ	-0.161337	0.107249	-1.504327	0.1325
IPMZ201601	0.715155	0.103165	6.932157	0.0000
DGENDER	-0.245851	0.309965	-0.793157	0.4277
C	4.845150	1.727821	2.804196	0.0050

Robust Statistics

R-squared	0.293935	Adjusted R-squared	0.266121
Rw-squared	0.429942	Adjust Rw-squared	0.429942
Akaike info criterion	416.1241	Schwarz criterion	474.2118
Deviance	1329.405	Scale	1.840520
Rn-squared statistic	180.1169	Prob(Rn-squared stat.)	0.000000

Non-robust Statistics

Mean dependent var	9.703488	S.D. dependent var	2.698534
S.E. of regression	2.368282	Sum squared resid	1850.891

Dependent Variable: YIELDMZ2015
Method: Robust Least Squares
Date: 07/10/17 Time: 09:02
Sample: 1 394
Included observations: 347
Method: M-estimation
M settings: weight=Bisquare, tuning=4.685, scale=MAD (median centered)
Huber Type I Standard Errors & Covariance

Variable	Coefficient	Std. Error	z-Statistic	Prob.
AGE	0.234812	0.061427	3.822596	0.0001
AGESQUARED	-0.002643	0.000711	-3.714705	0.0002
AGGSEV	-0.646764	0.250983	-2.576919	0.0100
CSAIPMZ2015	0.263152	0.049870	5.276752	0.0000

DGENDER	-0.225244	0.235585	-0.956106	0.3390
EXOFF	0.928796	0.288057	3.224346	0.0013
FARMSIZE	-0.055395	0.025510	-2.171507	0.0299
FBO	-1.241112	0.271358	-4.573712	0.0000
FINSEV	0.451612	0.282888	1.596434	0.1104
INPUTDEALERS	0.994041	0.254443	3.906732	0.0001
TRADMZ	0.104032	0.076613	1.357882	0.1745
LABOUR	0.024270	0.030127	0.805604	0.4205
C	2.472686	1.327291	1.862957	0.0625

Robust Statistics

R-squared	0.202847	Adjusted R-squared	0.174207
Rw-squared	0.315985	Adjust Rw-squared	0.315985
Akaike info criterion	421.9578	Schwarz criterion	475.2161
Deviance	780.2509	Scale	1.398091
Rn-squared statistic	111.6430	Prob(Rn-squared stat.)	0.000000

Non-robust Statistics

Mean dependent var	8.703170	S.D. dependent var	1.907111
S.E. of regression	1.768146	Sum squared resid	1044.197

Dependent Variable: YIELDMZ2016
Method: Robust Least Squares
Date: 07/10/17 Time: 09:17
Sample: 1 394
Included observations: 348
Method: M-estimation
M settings: weight=Bisquare, tuning=4.685, scale=MAD (median centered)
Huber Type I Standard Errors & Covariance

Variable	Coefficient	Std. Error	z-Statistic	Prob.
AGE	0.125748	0.080174	1.568447	0.1168
AGESQUARED	-0.001603	0.000928	-1.726649	0.0842
AGGSEV	-0.609691	0.330428	-1.845156	0.0650
CSAIPMZ2016	0.545319	0.067502	8.078602	0.0000
DGENDER	-0.147887	0.307974	-0.480192	0.6311
EXOFF	1.153820	0.376777	3.062339	0.0022
FARMSIZE	-0.073235	0.033345	-2.196264	0.0281
FBO	-1.633240	0.354956	-4.601252	0.0000
FINSEV	1.072278	0.372551	2.878207	0.0040
INPUTDEALERS	1.472291	0.333508	4.414564	0.0000
TRADMZ	-0.082723	0.100377	-0.824130	0.4099

LABOUR	0.059382	0.039424	1.506225	0.1320
C	4.726259	1.731280	2.729922	0.0063

Robust Statistics

R-squared	0.282228	Adjusted R-squared	0.256517
Rw-squared	0.424903	Adjust Rw-squared	0.424903
Akaike info criterion	450.0162	Schwarz criterion	502.6130
Deviance	1336.360	Scale	1.770047
Rn-squared statistic	171.5261	Prob(Rn-squared stat.)	0.000000

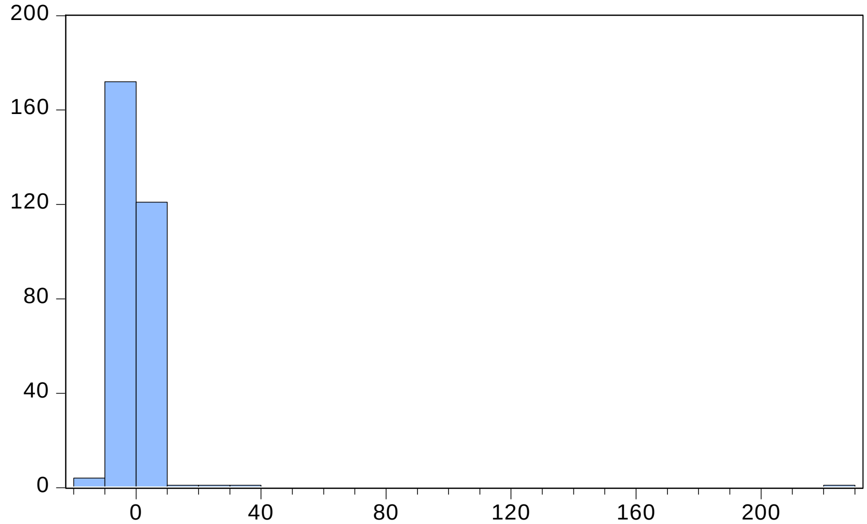
Non-robust Statistics

Mean dependent var	9.718391	S.D. dependent var	2.691861
S.E. of regression	2.379439	Sum squared resid	1896.679

Dependent Variable: YIELDSOYA
Method: Least Squares
Date: 07/09/17 Time: 02:27
Sample: 1 394
Included observations: 301

Variable	Coefficient	Std. Error	t-Statistic	Prob.
CSASOYA	-1.807159	1.156430	-1.562705	0.1192
AGE	0.164311	0.545971	0.300951	0.7637
AGESQUARED	-0.001702	0.006307	-0.269772	0.7875
AGGSEV	-3.732929	2.396551	-1.557625	0.1204
EXOFF	-0.614366	2.803665	-0.219130	0.8267
FARMSIZE	0.096136	0.258731	0.371566	0.7105
FBO	1.175136	2.658416	0.442044	0.6588
FINSEV	0.172180	2.746370	0.062694	0.9501
INPUTDEALERS	2.957635	2.561332	1.154725	0.2492
LABOUR	0.051307	0.270788	0.189473	0.8499
IPSOYA	-0.843585	0.903433	-0.933754	0.3512
TRADSOYA	2.438397	1.007658	2.419865	0.0161
DGENDER	1.521765	2.186353	0.696029	0.4870
C	1.924775	11.44293	0.168206	0.8665

R-squared	0.049173	Mean dependent var	6.712625
Adjusted R-squared	0.006104	S.D. dependent var	14.18031
S.E. of regression	14.13697	Akaike info criterion	8.180859
Sum squared resid	57358.06	Schwarz criterion	8.353283
Log likelihood	-1217.219	Hannan-Quinn criter.	8.249855
F-statistic	1.141729	Durbin-Watson stat	1.308577
Prob(F-statistic)	0.323451		



Series: Residuals	
Sample 1 394	
Observations 301	
Mean	2.60e-16
Median	-0.673542
Maximum	226.6552
Minimum	-11.63186
Std. Dev.	13.82728
Skewness	14.76204
Kurtosis	241.6505
Jarque-Bera	725230.9
Probability	0.000000

Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	1.206457	Prob. F(13,287)	0.2737
Obs*R-squared	15.59668	Prob. Chi-Square(13)	0.2716
Scaled explained SS	1706.160	Prob. Chi-Square(13)	0.0000

Dependent Variable: YIELDSOYA
Method: Robust Least Squares
Date: 07/09/17 Time: 02:29
Sample: 1 394
Included observations: 301
Method: M-estimation
M settings: weight=Bisquare, tuning=4.685, scale=MAD (median centered)
Huber Type I Standard Errors & Covariance

Variable	Coefficient	Std. Error	z-Statistic	Prob.
CSASOYA	0.028415	0.113937	0.249393	0.8031
AGE	0.079212	0.053792	1.472568	0.1409
AGESQUARED	-0.000954	0.000621	-1.534951	0.1248
AGGSEV	-0.168137	0.236120	-0.712085	0.4764
EXOFF	0.271542	0.276230	0.983028	0.3256
FARMSIZE	-0.018654	0.025491	-0.731777	0.4643
FBO	0.006620	0.261920	0.025276	0.9798
FINSEV	0.331289	0.270585	1.224340	0.2208
INPUTDEALERS	-0.303426	0.252355	-1.202378	0.2292
LABOUR	-0.022354	0.026679	-0.837866	0.4021
IPSOYA	0.185633	0.089011	2.085519	0.0370
TRADSOYA	-0.184609	0.099279	-1.859491	0.0630
DGENDER	0.131843	0.215410	0.612055	0.5405
C	4.267402	1.127412	3.785130	0.0002

Robust Statistics

R-squared	0.050595	Adjusted R-squared	0.007591
Rw-squared	0.120512	Adjust Rw-squared	0.120512
Akaike info criterion	451.0608	Schwarz criterion	505.6996
Deviance	534.8303	Scale	1.120741
Rn-squared statistic	28.51784	Prob(Rn-squared stat.)	0.007658

Non-robust Statistics

Mean dependent var	6.712625	S.D. dependent var	14.18031
S.E. of regression	14.54318	Sum squared resid	60701.71

Dependent Variable: YIELDSOYA
Method: Robust Least Squares
Date: 07/10/17 Time: 09:10
Sample: 1 394
Included observations: 303
Method: M-estimation
M settings: weight=Bisquare, tuning=4.685, scale=MAD (median centered)
Huber Type I Standard Errors & Covariance

Variable	Coefficient	Std. Error	z-Statistic	Prob.
AGE	0.077032	0.051907	1.484030	0.1378
AGESQUARED	-0.000918	0.000599	-1.533498	0.1252
AGGSEV	-0.197781	0.225431	-0.877347	0.3803
CSAIPSO	0.122729	0.069506	1.765742	0.0774
DGENDER	0.108741	0.207801	0.523293	0.6008
EXOFF	0.252346	0.266377	0.947327	0.3435
FARMSIZE	-0.018672	0.024568	-0.760004	0.4473
FBO	-0.087399	0.253043	-0.345391	0.7298
FINSEV	0.466030	0.249829	1.865396	0.0621
INPUTDEALERS	-0.507794	0.243205	-2.087926	0.0368
TRADSOYA	-0.174228	0.094846	-1.836960	0.0662
LABOUR	-0.023110	0.025657	-0.900728	0.3677
C	4.635774	1.086073	4.268380	0.0000

Robust Statistics

R-squared	0.048013	Adjusted R-squared	0.008621
Rw-squared	0.124310	Adjust Rw-squared	0.124310
Akaike info criterion	473.3020	Schwarz criterion	523.9313
Deviance	517.0668	Scale	1.072345
Rn-squared statistic	28.94319	Prob(Rn-squared	0.004017

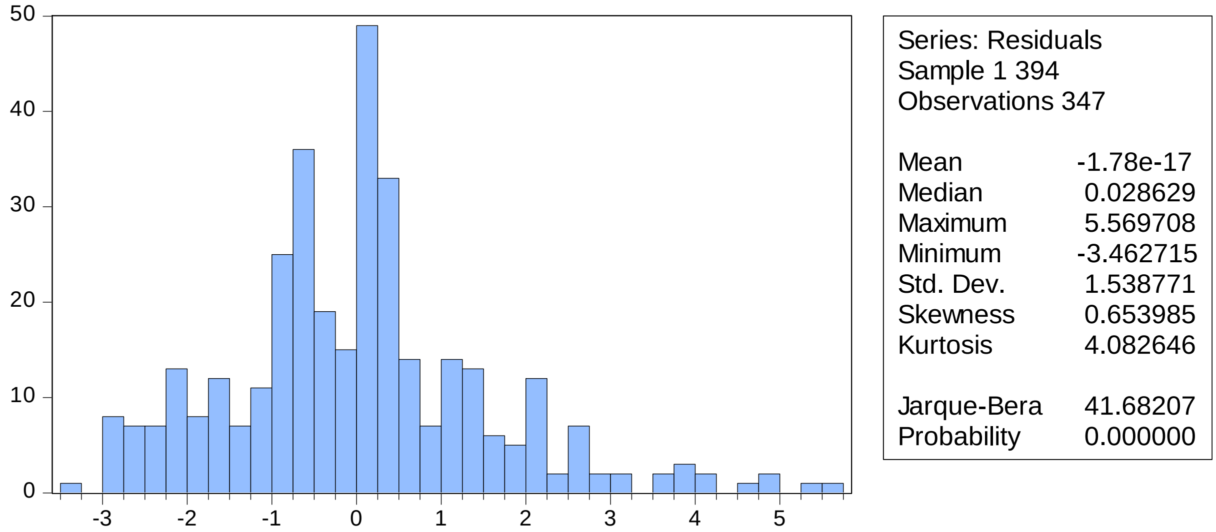
stat.)

Non-robust Statistics			
Mean dependent var	6.707921	S.D. dependent var	14.13340
S.E. of regression	14.47113	Sum squared resid	60729.98

Dependent Variable: YIELDGR2015
Method: Least Squares
Date: 07/09/17 Time: 02:20
Sample: 1 394
Included observations: 347

Variable	Coefficient	Std. Error	t-Statistic	Prob.
CSAGR2015	0.221723	0.178057	1.245234	0.2139
AGE	0.069798	0.059644	1.170246	0.2427
AGESQUARED	-0.001028	0.000688	-1.493862	0.1362
AGGSEV	0.200900	0.243273	0.825821	0.4095
EXOFF	1.160138	0.276360	4.197918	0.0000
FARMSIZE	0.023782	0.024267	0.980006	0.3278
FBO	-0.739016	0.259423	-2.848693	0.0047
FINSEV	0.080069	0.270729	0.295753	0.7676
INPUTDEALERS	-0.088617	0.249123	-0.355717	0.7223
LABOUR	-0.047652	0.029297	-1.626513	0.1048
TRADGR2016	-0.151163	0.127200	-1.188387	0.2355
DGENDER	-0.178333	0.229685	-0.776425	0.4380
C	4.571759	1.256620	3.638140	0.0003

R-squared	0.111311	Mean dependent var	5.798271
Adjusted R-squared	0.079382	S.D. dependent var	1.632296
S.E. of regression	1.566169	Akaike info criterion	3.771887
Sum squared resid	819.2640	Schwarz criterion	3.916098
Log likelihood	-641.4223	Hannan-Quinn criter.	3.829306
F-statistic	3.486199	Durbin-Watson stat	1.632425
Prob(F-statistic)	0.000072		



Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	3.454190	Prob. F(12,334)	0.0001
Obs*R-squared	38.30933	Prob. Chi-Square(12)	0.0001
Scaled explained SS	54.70565	Prob. Chi-Square(12)	0.0000

Dependent Variable: YIELDGR2015
Method: Robust Least Squares
Date: 07/09/17 Time: 02:23
Sample: 1 394
Included observations: 347
Method: M-estimation
M settings: weight=Bisquare, tuning=4.685, scale=MAD (median centered)
Huber Type I Standard Errors & Covariance

Variable	Coefficient	Std. Error	z-Statistic	Prob.
CSAGR2015	-0.576404	0.159518	-3.613402	0.0003
AGE	0.050222	0.053434	0.939896	0.3473
AGESQUARED	-0.000778	0.000617	-1.261167	0.2072
AGGSEV	-0.219086	0.217944	-1.005237	0.3148
EXOFF	0.851737	0.247586	3.440160	0.0006
FARMSIZE	0.021048	0.021741	0.968158	0.3330
FBO	-0.483850	0.232412	-2.081863	0.0374
FINSEV	0.005987	0.242541	0.024686	0.9803
INPUTDEALERS	-0.182152	0.223184	-0.816150	0.4144
LABOUR	-0.043832	0.026247	-1.670005	0.0949
TRADGR2016	-0.078813	0.113956	-0.691602	0.4892
DGENDER	-0.027018	0.205770	-0.131303	0.8955
C	5.239179	1.125784	4.653807	0.0000

Robust Statistics

R-squared	0.100127	Adjusted R-squared	0.067796
Rw-squared	0.205262	Adjust Rw-squared	0.205262
Akaike info criterion	528.5148	Schwarz criterion	577.3134
Deviance	545.0855	Scale	1.042787
Rn-squared statistic	59.22378	Prob(Rn-squared stat.)	0.000000

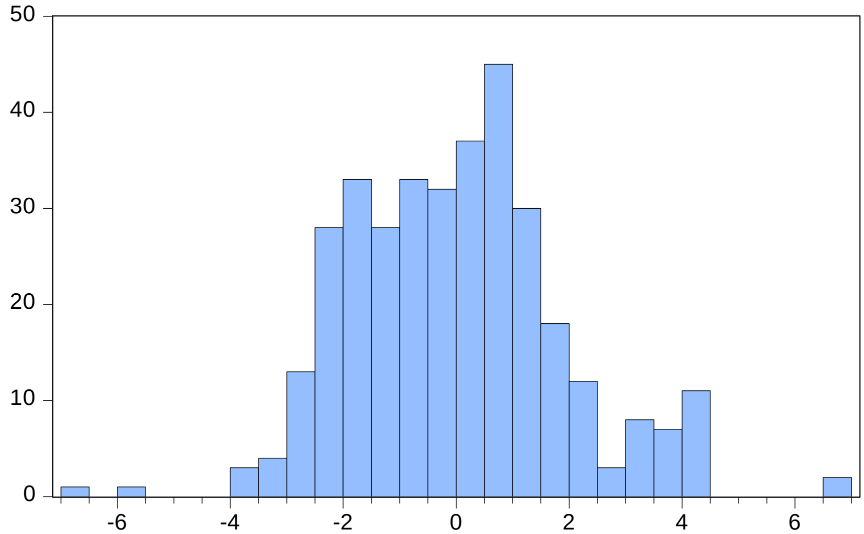
Non-robust Statistics

Mean dependent var	5.798271	S.D. dependent var	1.632296
S.E. of regression	1.634089	Sum squared resid	891.8628

Dependent Variable: YIELDGR2016
Method: Least Squares
Date: 07/09/17 Time: 02:34
Sample: 1 394
Included observations: 349

Variable	Coefficient	Std. Error	t-Statistic	Prob.
CSAGR2016	0.322167	0.221284	1.455900	0.1464
AGE	0.071499	0.072417	0.987320	0.3242
AGESQUARED	-0.001058	0.000837	-1.264072	0.2071
AGGSEV	0.159699	0.297287	0.537187	0.5915
EXOFF	1.266252	0.338963	3.735665	0.0002
FARMSIZE	0.007532	0.029769	0.253020	0.8004
FBO	-0.127046	0.318089	-0.399406	0.6898
FINSEV	0.393126	0.332279	1.183120	0.2376
INPUTDEALERS	0.086383	0.304499	0.283688	0.7768
LABOUR	-0.019559	0.035951	-0.544043	0.5868
TRADGR2016	0.010978	0.155776	0.070473	0.9439
DGENDER	-0.201957	0.281939	-0.716314	0.4743
C	4.671554	1.517747	3.077953	0.0023

R-squared	0.106407	Mean dependent var	6.653295
Adjusted R-squared	0.074493	S.D. dependent var	1.999316
S.E. of regression	1.923408	Akaike info criterion	4.182612
Sum squared resid	1243.031	Schwarz criterion	4.326211
Log likelihood	-716.8658	Hannan-Quinn criter.	4.239775
F-statistic	3.334181	Durbin-Watson stat	1.581894
Prob(F-statistic)	0.000134		



Series: Residuals	
Sample 1 394	
Observations 349	
Mean	2.54e-15
Median	-0.006103
Maximum	6.915731
Minimum	-6.525581
Std. Dev.	1.889955
Skewness	0.405461
Kurtosis	3.794496
Jarque-Bera	18.74158
Probability	0.000085

Heteroskedasticity Test: Breusch-Pagan-Godfrey

1.935781	Prob. F(12,336)	0.0295
22.56789	Prob. Chi-Square(12)	0.0316
29.22754	Prob. Chi-Square(12)	0.0036

Dependent Variable: YIELDGR2016
Method: Robust Least Squares
Date: 07/09/17 Time: 02:36
Sample: 1 394
Included observations: 349
Method: M-estimation
M settings: weight=Bisquare, tuning=4.685, scale=MAD (median centered)
Huber Type I Standard Errors & Covariance

Variable	Coefficient	Std. Error	z-Statistic	Prob.
CSAGR2016	0.001156	0.211564	0.005465	0.9956
AGE	0.028783	0.069236	0.415724	0.6776
AGESQUARED	-0.000442	0.000800	-0.551926	0.5810
AGGSEV	-0.172673	0.284230	-0.607512	0.5435
EXOFF	1.116952	0.324075	3.446585	0.0006
FARMSIZE	0.002077	0.028462	0.072981	0.9418
FBO	0.186529	0.304117	0.613346	0.5396
FINSEV	0.529824	0.317685	1.667765	0.0954
INPUTDEALERS	-0.007740	0.291124	-0.026588	0.9788
LABOUR	-0.008377	0.034372	-0.243705	0.8075
TRADGR2016	0.088372	0.148934	0.593366	0.5529
DGENDER	-0.279422	0.269556	-1.036604	0.2999
C	5.455978	1.451084	3.759932	0.0002

Robust Statistics

R-squared	0.111300	Adjusted R-squared	0.079561
Rw-squared	0.169656	Adjust Rw-squared	0.169656
Akaike info criterion	369.7141	Schwarz criterion	424.7195
Deviance	996.5759	Scale	1.690789
Rn-squared statistic	52.59669	Prob(Rn-squared stat.)	0.000000

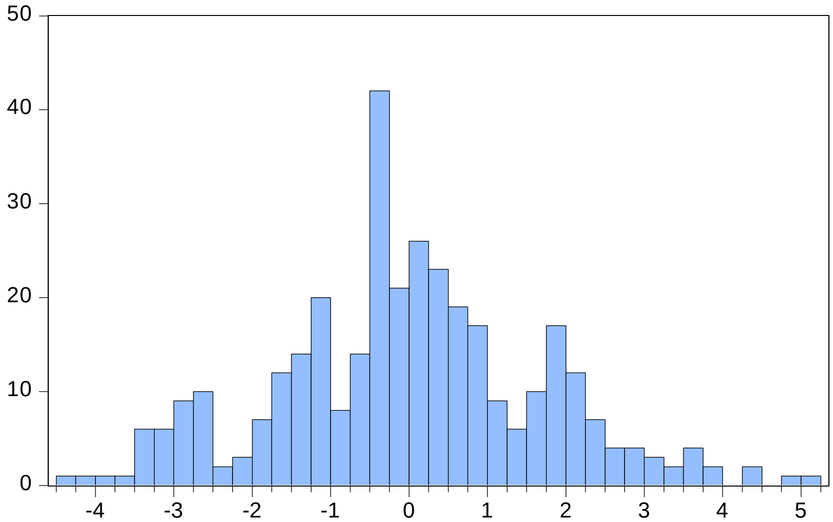
Non-robust Statistics

Mean dependent var	6.653295	S.D. dependent var	1.999316
S.E. of regression	1.944899	Sum squared resid	1270.964

Dependent Variable: YIELDBE2015
Method: Least Squares
Date: 07/09/17 Time: 02:38
Sample: 1 394
Included observations: 347

Variable	Coefficient	Std. Error	t-Statistic	Prob.
CSABE2015	-0.056089	0.093985	-0.596784	0.5511
AGE	0.076719	0.064797	1.183991	0.2373
AGESQUARED	-0.000915	0.000750	-1.220605	0.2231
AGGSEV	-0.145189	0.268584	-0.540573	0.5892
EXOFF	0.345232	0.307037	1.124399	0.2617
FARMSIZE	0.026214	0.026952	0.972632	0.3314
FBO	-0.100572	0.289958	-0.346849	0.7289
FINSEV	0.311107	0.291437	1.067494	0.2865
INPUTDEALERS	-0.091856	0.275576	-0.333323	0.7391
LABOUR	-0.046148	0.032563	-1.417164	0.1574
TRADBE	-0.009988	0.095704	-0.104364	0.9169
DGENDER	-0.143142	0.248869	-0.575170	0.5656
C	4.043166	1.358512	2.976171	0.0031

R-squared	0.040701	Mean dependent var	5.368876
Adjusted R-squared	0.006235	S.D. dependent var	1.729365
S.E. of regression	1.723965	Akaike info criterion	3.963875
Sum squared resid	992.6668	Schwarz criterion	4.108086
Log likelihood	-674.7324	Hannan-Quinn criter.	4.021295
F-statistic	1.180918	Durbin-Watson stat	1.634703
Prob(F-statistic)	0.295316		



Series: Residuals	
Sample 1 394	
Observations 347	
Mean	4.59e-17
Median	-0.065548
Maximum	5.118926
Minimum	-4.295288
Std. Dev.	1.693806
Skewness	0.131288
Kurtosis	3.087122
Jarque-Bera	1.106585
Probability	0.575053

Heteroskedasticity Test: Breusch-Pagan-Godfrey

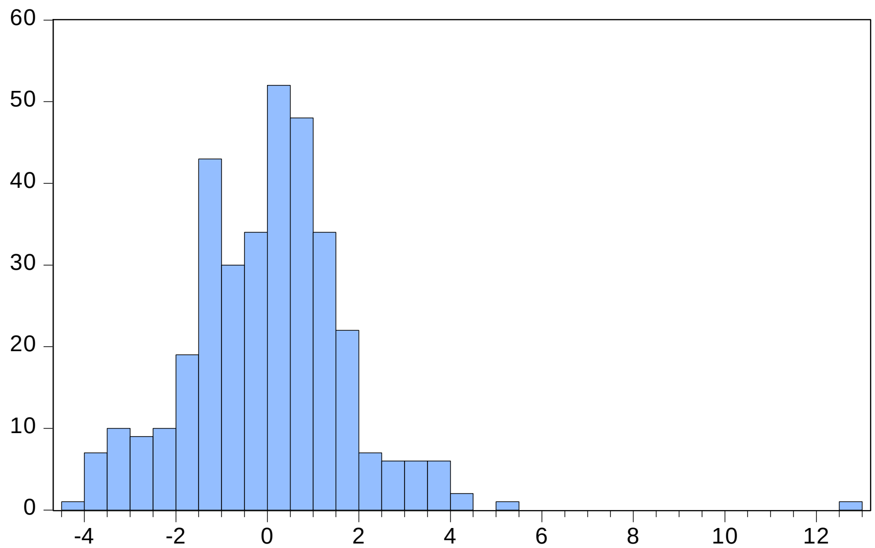
2.592519	Prob. F(12,334)	0.0026
29.56709	Prob. Chi-Square(12)	0.0032
28.58646	Prob. Chi-Square(12)	0.0045

Dependent Variable: YIELDBE2015
Method: Least Squares
Date: 07/09/17 Time: 03:05
Sample: 1 394
Included observations: 347
White heteroskedasticity-consistent standard errors & covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
CSABE2015	-0.056089	0.087023	-0.644528	0.5197
AGE	0.076719	0.086092	0.891120	0.3735
AGESQUARED	-0.000915	0.001036	-0.883749	0.3775
AGGSEV	-0.145189	0.258798	-0.561015	0.5752
EXOFF	0.345232	0.312185	1.105858	0.2696
FARMSIZE	0.026214	0.023312	1.124517	0.2616
FBO	-0.100572	0.284707	-0.353246	0.7241
FINSEV	0.311107	0.282751	1.100286	0.2720
INPUTDEALERS	-0.091856	0.314899	-0.291699	0.7707
LABOUR	-0.046148	0.027139	-1.700437	0.0900
TRADBE	-0.009988	0.104826	-0.095282	0.9241
DGENDER	-0.143142	0.222023	-0.644716	0.5196
C	4.043166	1.768598	2.286085	0.0229

R-squared	0.040701	Mean dependent var	5.368876

Adjusted R-squared	0.006235	S.D. dependent var	1.729365
S.E. of regression	1.723965	Akaike info criterion	3.963875
Sum squared resid	992.6668	Schwarz criterion	4.108086
Log likelihood	-674.7324	Hannan-Quinn criter.	4.021295
F-statistic	1.180918	Durbin-Watson stat	1.634703
Prob(F-statistic)	0.295316	Wald F-statistic	1.050570
Prob(Wald F-statistic)	0.401909		



Series: Residuals	
Sample 1 394	
Observations 348	
Mean	-1.70e-16
Median	0.094818
Maximum	12.59711
Minimum	-4.080545
Std. Dev.	1.774959
Skewness	0.985755
Kurtosis	9.685219
Jarque-Bera	704.3955
Probability	0.000000

Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	1.811700	Prob. F(12,335)	0.0451
Obs*R-squared	21.20774	Prob. Chi-Square(12)	0.0474
Scaled explained SS	85.34464	Prob. Chi-Square(12)	0.0000

Dependent Variable: YIELDBE2016
Method: Robust Least Squares
Date: 07/09/17 Time: 03:07
Sample: 1 394
Included observations: 348
Method: MM-estimation
S settings: tuning=1.547645, breakdown=0.5, trials=200, subsmpl=13,
refine=2, compare=5
M settings: weight=Bisquare, tuning=4.684
Random number generator: rng=kn, seed=560416332
Huber Type I Standard Errors & Covariance

Variable	Coefficient	Std. Error	z-Statistic	Prob.

CSABE2016	-0.090907	0.086602	-1.049710	0.2939
AGE	0.038335	0.062479	0.613568	0.5395
AGESQUARED	-0.000591	0.000724	-0.816151	0.4144
AGGSEV	0.027629	0.264643	0.104401	0.9169
EXOFF	0.063395	0.294012	0.215619	0.8293
FARMSIZE	0.065458	0.026134	2.504720	0.0123
FBO	0.800190	0.278078	2.877572	0.0040
FINSEV	-0.121995	0.282588	-0.431706	0.6660
INPUTDEALERS	-0.558220	0.258909	-2.156045	0.0311
LABOUR	-0.031164	0.031412	-0.992103	0.3211
TRADBE	-0.239018	0.092586	-2.581575	0.0098
DGENDER	0.002610	0.239773	0.010884	0.9913
C	5.467268	1.317712	4.149062	0.0000

Robust Statistics

R-squared	0.119624	Adjusted R-squared	0.088088
Rw-squared	0.184611	Adjust Rw-squared	0.184611
Akaike info criterion	407.7575	Schwarz criterion	460.4915
Deviance	771.6477	Scale	1.416807
Rn-squared statistic	55.37919	Prob(Rn-squared stat.)	0.000000

Non-robust Statistics

Mean dependent var	5.985632	S.D. dependent var	1.907764
S.E. of regression	1.823512	Sum squared resid	1113.940

probit AdoptionIn Exoff Aggsev Finsev Farmsize Age Inputdealers Dgender Dbasic Experience FBO

Iteration 0: log likelihood = -99.46877

Iteration 1: log likelihood = -68.611993

Iteration 2: log likelihood = -64.477138

Iteration 3: log likelihood = -64.282211

Iteration 4: log likelihood = -64.281064

Iteration 5: log likelihood = -64.281063

Probit regression Number of obs = 344

LR chi2(10) = 70.38

Prob > chi2 = 0.0000

Log likelihood = -64.281063 Pseudo R2 = 0.3538

AdoptionIn	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
Exoff	.1161816	.5084251	0.23	0.819	-.8803132	1.112676
Aggsev	-.3456384	.3648333	-0.95	0.343	-1.060698	.3694217
Finsev	-1.195079	.3366852	-3.55	0.000	-1.854969	-.5351879
Farmsize	.0572864	.0352078	1.63	0.104	-.0117197	.1262924
Age	.0549118	.0245145	2.24	0.025	.0068644	.1029593
Inputdealers	-.9188767	.6535317	-1.41	0.160	-2.199775	.3620219
Dgender	-.5612167	.3597786	-1.56	0.119	-1.26637	.1439364
Dbasic	-.7216344	.3158624	-2.28	0.022	-1.340713	-.1025555
Experience	-.0569944	.026656	-2.14	0.033	-.1092391	-.0047496
FBO	-.634409	.5269246	-1.20	0.229	-1.667162	.3983441
_cons	2.374913	1.059331	2.24	0.025	.2986614	4.451164

Average marginal effects Number of obs = 344

Model VCE : OIM

Expression : Pr(AdoptionIn), predict()

dy/dx w.r.t. : Exoff Aggsev Finsev Farmsize Age Inputdealers Dgender Dbasic Experience FBO

| Delta-method

	dy/dx	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Exoff	.0119832	.0524381	0.23	0.819	-.0907937	.11476
Aggsev	-.0356498	.0375199	-0.95	0.342	-.1091875	.037888
Finsev	-.1232626	.0336632	-3.66	0.000	-.1892412	-.057284
Farmsize	.0059086	.0035809	1.65	0.099	-.0011098	.0129271
Age	.0056637	.0025197	2.25	0.025	.0007252	.0106022
Inputdealers	-.0947746	.0671468	-1.41	0.158	-.2263798	.0368306
Dgender	-.0578849	.0369984	-1.56	0.118	-.1304004	.0146305
Dbasic	-.0744307	.0319508	-2.33	0.020	-.1370531	-.0118083
Experience	-.0058785	.002739	-2.15	0.032	-.0112468	-.0005102
FBO	-.0654341	.0542354	-1.21	0.228	-.1717335	.0408653

probit AdoptionIP Exoff Aggsev Finsev Farmsize Age Inputdealers Dgender Dbasic Experience FBO

Iteration 0: log likelihood = -87.04472

Iteration 1: log likelihood = -66.97202

Iteration 2: log likelihood = -61.292797

Iteration 3: log likelihood = -60.943497

Iteration 4: log likelihood = -60.94298

Iteration 5: log likelihood = -60.94298

Probit regression Number of obs = 344

LR chi2(10) = 52.20

Prob > chi2 = 0.0000

Log likelihood = -60.94298 Pseudo R2 = 0.2999

AdoptionIP	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Exoff	-.9303229	.4214827	-2.21	0.027	-1.756414	-.1042321
Aggsev	-1.042122	.455931	-2.29	0.022	-1.935731	-.1485139
Finsev	.245732	.4126568	0.60	0.552	-.5630604	1.054524
Farmsize	.2798905	.0753203	3.72	0.000	.1322654	.4275155
Age	-.0168868	.018535	-0.91	0.362	-.0532148	.0194412
Inputdealers	.4712467	.3747385	1.26	0.209	-.2632273	1.205721
Dgender	-.2460546	.3745331	-0.66	0.511	-.9801259	.4880168
Dbasic	-.5827487	.3003573	-1.94	0.052	-1.171438	.0059407
Experience	.0205768	.023061	0.89	0.372	-.0246219	.0657756
FBO	1.408152	.4832926	2.91	0.004	.4609162	2.355388
_cons	1.028366	.86944	1.18	0.237	-.6757046	2.732437

Note: 0 failures and 14 successes completely determined.

. margins, dydx(*)

Average marginal effects Number of obs = 344

Model VCE : OIM

Expression : Pr(AdoptionIP), predict()

dy/dx w.r.t. : Exoff Aggsev Finsev Farmsize Age Inputdealers Dgender Dbasic Experience FBO

	Delta-method					
	dy/dx	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Exoff	-.0911203	.0415836	-2.19	0.028	-.1726227	-.0096179

Aggsev	-.1020704	.0450564	-2.27	0.023	-.1903793	-.0137615
Finsev	.0240682	.0403154	0.60	0.551	-.0549486	.1030849
Farmsize	.0274138	.0074225	3.69	0.000	.012866	.0419617
Age	-.001654	.0018145	-0.91	0.362	-.0052102	.0019023
Inputdealers	.0461561	.0367422	1.26	0.209	-.0258573	.1181696
Dgender	-.0240998	.036589	-0.66	0.510	-.0958128	.0476133
Dbasic	-.0570772	.0290895	-1.96	0.050	-.1140917	-.0000627
Experience	.0020154	.0022542	0.89	0.371	-.0024028	.0064336
FBO	.1379212	.0477018	2.89	0.004	.0444273	.2314151