UNIVERSITY FOR DEVELOPMENT STUDIES

AGRICULTURAL TECHNOLOGY TRANSFER MECHANISMS AND ADOPTION AMONG SOYBEAN FARMERS IN CHEREPONI DISTRICT OF NORTHERN REGION OF GHANA

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BY

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(BSC AGRICULTURE TECHNOLOGY)

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THESIS SUBMITTED TO THE DEPARTMENT OF AGRICULTURAL AND RESOURCE ECONOMICS, FACULTY OF AGRIBUSINESS AND APPLIED ECONOMICS, UNIVERSITY FOR DEVELOPMENT STUDIES, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF PHILOSOPHY (MPHIL) DEGREE IN AGRICULTURAL ECONOMICS

DECEMBER, 2019

DECLARATION

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

Abass Mahama	…….………………………	……………………
(Candidate)	Signature	Date

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

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ABSTRACT

Over the last decade, improved soybean production technologies have been tested and promoted among farmers using different technology transfer mechanisms. Whether the various agricultural technology transfer mechanisms are effective, and whether they have any effect on adoption of soybean production technologies and soybean yields remain unanswered. This study therefore focused on the effectiveness of agricultural technology transfer mechanisms (ATTMs) on adoption and soybean yields in the Chereponi District in the Northern Region of Ghana. Primary data from 300 soybean farmers using a multi-stage sampling approach was deployed. Descriptive statistics was used to present the perceived effectiveness of ATTMs and constraints to adoption of soybean production technologies (SPTs). The multivariate probit and the generalized Poisson regression models were used to analyze factors that influence adoption of SPTS and intensity of adoption respectively. While the effect of ATTMs on adoption of SPTs and soybean yields was analyzed using the recursive conditional mixed process framework. Results showed that demonstration and farmer to farmer methods were perceived by farmers as the most effective in terms of influence on adoption of SPTs. Age of farmer, educational level, household extension method, extension visits, cost of technology and distance to input market affects adoption of SPTs. Age of farmer, education, farming experience, distance to input market, household extension method were among variables that influence intensity of adoption of SPTs. Also, intensity of exposure to ATTMs, soybean project beneficiary and extension visits influenced intensity of adoption of SPTs. The intensity of adoption of SPTs, certified seeds and insecticide use had effects on soybean yields. High cost and non-availability of technologies were the major constraints affecting adoption of SPTs in the study area. The study recommends that stakeholders in the soybean sub-sector should focus on using demonstration and farmer-to-farmer methods in the dissemination of SPTs since these two methods were found to be effective. Agricultural extension agents should play a strong supervisory role in farmer-to-farmer methods of disseminating SPTs to avoid distortion of information. Also, access to education, extension services, mass media, credit and cost of technologies should be improved to promote rapid adoption of soybean production technologies. Furthermore, the study recommends that stakeholders should introduce soybean farmers to different agricultural technology transfer mechanisms so that adoption of multiple technologies can be enhanced. Government should tackle the high cost of triple super phosphate and certified seeds, and the non-availability of inoculants at local input markets by including these technologies in subsidized input packages under the Planting for Food and Jobs initiative.

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DEDICATION

I dedicate this work to Almighty Allah for His guidance and protection during the course of my study. I also dedicate this work to my lovely mother, Zenabu Charity Lansah and my close siblings Aliu Mahama, Zakaria Mahama, Munkaila Mahama and Aisha Mahama.

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LIST OF ABBREVIATIONS

ADVANCE	Agricultural Development and Value Chain Enhancement
AIC	Akaike's Information Criterion
ATT	Agriculture Technology Transfer
ATTMs	Agricultural Technology Transfer Mechanisms
BIC	Bayesian Information Criterion
CRMP	Conditional Recursive Mixed Process
CS	Certified Seeds
CSIR	Council for Scientific and Industrial Research
F2F	Farmer to Farmer
FFS	Farmer Field Schools
FTF	Feed the Future
GDP	Gross Domestic Product
GH¢	Ghana Cedis
GPR	Generalised Poisson Regression
GSS	Ghana Statistical Service
Ha	Hectares
ICT	Information and Communication Technology
IITA	International Institute for Tropical Agriculture
IPM	Integrated Pest Management
IRM	Imazapyr Resistant Maize
MEDA	Mennonite Economic Development Associates
MOFA	Ministry of Food and Agriculture
MT	Metric Tones
MVP	Multivariate Probit
NGOs	Non-Governmental Organisations
OLS	Ordinary Least Square

PDCM	Pest and disease Control Measure
PFJ	Planting for Food and Jobs
RING	Resiliency in Northern Ghana
SARI	Savannah Agriculture Research Institute
SPTs	Soybean Production Technologies
SRI	System of Rice Intensification
SRID	Statistics, Research and Information Directorate
TSP	Triple Super Phosphate
TV	Television
T&V	Training and Visit
USAID	United State Agency for International Development
VSLA	Village Savings and Loans Association

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Agriculture is the main driver of growth and economic development of most developing countries, it is essential because it provides food for non-agricultural labour force, raw materials for the industrial sector and also provides revenue and savings to support economic growth (Todaro & Smith, 2011; Pruburaj, 2018). Achieving a sustainable agricultural growth and development requires a wide range of approaches that meet the needs and priorities of farmers. In the past, the development of agriculture technologies were targeted at increasing yields, productivity and farm profits. However, in recent times the focus is on achieving higher production levels, productivity and profits sustainably. Therefore, it would be important for farmers to change their farming practices by adopting or using improved and sustainable technologies.

Notwithstanding the efforts by the Government of Ghana through the Ministry of Food and Agriculture (MoFA) and Non-Governmental Organizations (NGOs) in providing improved agricultural technologies to farmers, the sector is still faced with a major challenge of low productivity or yields especially for crops like soybeans, maize and rice. According to MoFA (2017), the average soybean yield stands at 1.3Mt/ha as against potential yield of 3.0Mt/ha. This means that soybean yields in Ghana are still far below its achievable potential. This underperformance is attributed to lower capacity to adopt and use improved technologies coupled with poor technology development and transfer mechanisms as well as poor crop management practices (MoFA, 2017).

Crop production pattern in Ghana vary markedly in accordance with the agro climatic conditions. A number of leguminous grain crops are widely cultivated in the northern part of Ghana. Legume base crops are the second abundant crop both in production and consumption next to cereals and are a major source of dietary protein, fiber, carbohydrates and essential minerals (Mohammed, Al-Hassan & Amegashie, 2016). Soybean is considered as one of the valuable legumious crop in the world and can grow successfully on soils low in nitrogen and has the capacity to fix valuable source of atmospheric nitrogen into the soil including its lower susceptibility to pests and diseases (Ugwu & Ugwu, 2010). Soybean is an important cash crop in Northern Ghana and its cultivation is dominated by small scale farmers equipped with traditional tools coupled with low or no adoption of improved soybean production technologies.

The earlier models of agricultural technologies transfer mechanisms were largely a non-participatory and top-down approaches (MoFA, 2016). This is because such models had limited farmer participation in the design and testing of technologies and only allocated farmers passive roles in the implementation of new technologies. A range of agricultural technology transfer methods have been implemented since the 1970s. These methods have combined outreach services in the form of extension agent visits to adults education (such as lectures and workshops), training and visit (T&V) model introduced by the World Bank (Anderson et al., 2006) and participatory methods such as demonstrations, workshops, exhibitions and farmer field schools. Also, extension methods such as ICT- based delivery system that provide advice to farmers on-line, voice calls and text messaging via the use of mobile phones have been implemented; other methods such as the establishment of model farms where farmers learn best agronomic practices have also been implemented (Birner et al., 2006). Diffusion of knowledge and promotion of agricultural technology adoption can be improved by the active participation of governments, NGOs and international research organizations in the operation of extension services.

1.2 Problem Statement

Agriculture extension delivery services plays a critical role in the timely dissemination of improved technologies that can trigger the desire change among farmers (Asiedu-Darko, 2013). The adoption of any new technology particularly agricultural technologies has largely been dependent on a number of key factors including the agricultural technology transfer mechanisms through which these technologies are transferred. Over the last decades, a number of technology transfer mechanisms aimed at stimulating adoption of agricultural technologies have been introduced or implemented in Ghana (MoFA-DAES, 2011). Some of these mechanisms have often resulted in failure. For instance, the training and visit model introduced in Ghana by the World Bank was criticized for its non-participatory approach where farmers generally play passive roles resulting in little or no behavioural change that could stimulate adoption (Anderson et al., 2006).

The Ministry of Food and Agriculture (MoFA) introduced a number of new approaches that seek to involve farmers in various stages of technological implementation (MoFA-DAES, 2011). Some of these new approaches included farmer field schools, farmer to farmer, demonstration methods and mass media (through ICT, radio, mobile phones and television). Despite the introduction of these new approaches, adoption of various agricultural production technologies particularly improved soybean production technologies have been low and disappointing (Mohammed et al., 2016). In fact, many development professionals and organizations have attributed the failure of farmers to adopt technologies due to the "wholesale" approach adopted by MoFA in transferring technologies to farmers (Kate et al. 2018). Anandajayasekeram et al. (2008) stipulates that the decision to implement a technology transfer mechanism should consider the socio economic characteristics of the target beneficiaries, organization of community, availability of resources access and crop type. Evidence points to the fact that, most of these transfer mechanisms have often involved relatively small number of farmers (Savanah Agriculture Research Institute (SARI), 2013), who in most cases do not share the new acquired knowledge with colleague farmers.

Many Non-government organizations (for instance, International Fertilizer Development Center) have made efforts in filling the existing challenges in technology transfer by introducing new innovative approaches such as; exhibitions, workshops, farmer to farmer and gifts methods in order to increase farmers participation in technology transfers and adoption. However, the effectiveness of these approaches in terms of stimulating adoption of soybean production technologies and enhancing soybean yields have not been explored by many empirical studies. However, only handful of research (Khaila et al., 2015; Mulwafu & Krishnankutty, 2012; Pemsl et al., 2006; Rathod et al., 2013 and Azumah et al., 2018) have focus on the effectiveness of some extension models on adoption of agricultural technologies in Ghana with no special emphasis on the soybean crop.

Therefore, this study will be important in assessing and analyzing the various agricultural technology transfer mechanisms in order to know the context each of the mechanisms can be successfully implemented to trigger adoption of soybean production technologies, and lead to some reforms in Ghana extension delivery services.

1.3 Research Questions

The study seeks to address the following research questions:

1. What are the perceived effectiveness of agricultural technology transfer methods on adoption of soybean production technologies in the Chereponi District?
2. What factors influence adoption of soybean technologies?
3. What are the effects of agricultural technology transfer mechanisms on adoption of soybean production technologies and yield of farmers?
4. What are the constraints to adoption of soybean production technologies in the Chereponi District?

1.4 Research Objectives

The general objective of the study is to assess the effectiveness, adoption and yield effects of agricultural technology transfer mechanisms among soybean farmers in the Chereponi District of the Northern Region of Ghana.

Specific objectives:

The specific objectives are to:

1. assess the perceived effectiveness of agricultural technology transfer mechanisms on adoption of soybean production technologies in the Chereponi District.
2. identify factors that influence the adoption of soybean production technologies through:
   a) analyzing factors influencing the adoption of soybean production technologies.

b) measure the intensity of adoption of soybean production technologies by farmers.

3. estimate the effect of agricultural technology transfer mechanisms on adoption of soybean production technologies and yield.
4. identify the constraints affecting adoption of soybean production technologies.

1.5 Significance of the Study

Assessing agricultural technology transfer mechanisms and adoption among soybean farmers will serve as an important addition to existing adoption studies. This study transcends a dimension similar to Azumah et al. (2018), by identifying sources of information on soybean production technologies and also assessing farmers' perceived effectiveness of technology transfer mechanisms on soybean production technology (s) adoption. The study also examined and document key factors that influence farmer exposure to agricultural technology transfer mechanisms in the Chereponi District. Many adoption studies have often discussed soybean production technology adoption in relation to one technological type (Mbanya, 2011; Miruts, 2016; Omodona, 2016 and Yitbarek, 2017).

A novel addition of this study is to assess factors that influence adoption of multiple soybean technologies and intensity of adoption of these technologies. Also, extant literature has not well documented the effectiveness of the various agricultural technology transfer mechanisms on adoption intensity and yields of soybeans. Another novel addition of this study is to fill the existing gap in the analysis of the joint effect of agricultural technology transfer mechanisms on adoption and soybean yields. Also, the study set out to identify and document major constraints that affect adoption of soybean production technologies among farmer in the Chereponi district. The outcome of this study will provide useful recommendations to international and national research institutions, donor supported projects and the MoFA to formulate policies that seeks to promote effective uptake of soybean production technologies while considering the socio-economic background of farmers.

The study also seeks to provide a comprehensive analysis of existing agricultural technology transfer mechanisms and also the adoption of soybean production technologies among farmers in the Chereponi District as well as provide useful policy recommendations to agricultural policy makers, policy implementers, international and national research institutes as well as non-governmental organizations. This study will also serve as a springboard for future detail research in legume grain farming in Ghana and beyond. This research will enhance efficiency in value chain development toward productivity.

1.6 Organization of the Study

The organizational structure of this study is in five chapters. Chapter one discusses the background of the study including a problem statement, research questions, research objectives and justification. Chapter two presents a review of relevant literature where definitions of important terms used in this study are presented. Also discussed in this chapter include agricultural technology transfer mechanisms, soybean production in Ghana, various soybean production technologies, factors influencing soybean technology adoption, empirical review of adoption studies, conceptual and theoretical framework of the study. Chapter three presents the methodology of the study. In this chapter a description of the study area, sampling and sampling technique, method of data analysis and empirical specification of analytical models are presented. Chapter four presents the results of the various objectives while chapter five presents a summary, conclusion and recommendations of the study.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter reviews literature on adoption (Concepts and overview of adoption). The chapter proceeds by looking at the historic and current state of soybean production in Ghana. A brief description of the various soybean production technologies is done under this chapter. Also, the chapter reviews literature on some conventional and popular agricultural technology transfer mechanisms relevant to this study. Factors that influence adoption of agricultural technologies are discussed under this chapter. Furthermore, the conceptual framework of the study as well as theoretical framework of econometric models used in this study are discussed. Last but not the least, the chapter concludes by looking at some empirical studies on agriculture technology adoption.

2.2 Review of Key Concepts

2.2.1 Technology

The cross cutting nature of technology has led to varied definitions depending on the area of research or discipline. It is dynamic in nature and therefore the definition can be modeled around a researcher's area of interest. The concept of technology is very important in examining the nature of technology and what it seeks to achieve or address. Technology is defined from different perspectives (Sazali, Raduan & Suzana, 2012) and it is very difficult to have a clear cut definition. Technology is the use of scientific knowledge in performing or executing a task better, it is often used to simplify a process or activity (Dardak & Adham, 2014).

Yitbarek (2017) defines technology as the practical application of knowledge and skills with the aim of causing change to human life and the environment. Technology could either consist of physical component such as machinery, products, tools, processes and techniques; or informational component such as technical knowledge, production, quality control and skilled labor (Kumar, Kumar and Persaud, 1999; Sazali et al., 2012; Rogers, 2003). As reported by Carroll (2017), technology can be defined as "a system created by humans that uses knowledge and organization to produce objects and techniques for the attainment of specific goals". Following the definitions of the various authors, technology can be defined in this study as a human invention that involves the use of new ideas to enhance production and efficiency of a particular system.

2.2.2 Agricultural technology

The evolution of agricultural production has been largely influenced by the introduction of modern agricultural technologies. Duruiheoma et al. (2015) define agricultural technology as any production technique (s) that increases the yield and income of farmers. Similarly, agricultural technology has been viewed by Duss and Kolb (2016) as the combination of several or individual production techniques such as farm machinery, inputs, farm management practices that increases yields of farmers.

In this study, agricultural technology is defined as the production of new techniques/practices that are environmentally and economically sustainable. Agricultural technology development in recent times has included yield enhancing technologies such as fertilizers, improved crop management practices and infrastructure such as irrigation. However, many including Harwood (2013) report the unfriendly nature of most agriculture technologies to smallholder farmers and that these modern agricultural technologies are suited for commercial farmers.

2.2.3 Adoption

Adoption has been defined in several ways in previous studies. The definition of adoption has been related to time and the willingness to use a technology or innovation continuously without abandonment or rejection. Most adoption studies consider the behaviour of individuals in relation to the use of technology. According to Rogers (2003), adoption is defined as the full use of a technology or innovation that gives the desired benefit or the best possible alternative that is available. Doss (2003) defines adoption as the use of improved technology while continuously using old or local technology. Similarly, Loevinsohn et al. (2013) and Feder et al. (1985) defines adoption as a process that integrates improved or new innovations, practices or technology into already existing technologies which is often characterized by a period of testing and subsequently adapting to these new technologies.

Kaine (2008) defines adoption of agricultural technology as an action accompanied by the intent to use provided it offers the best possible benefit over existing technologies. Many reasons account for farmer's decision to adopt technologies and this is often linked to the definition of adoption. Technology Uptake

2.2.4 Agricultural technology transfer mechanisms

Several adoption studies focusing on technology transfer mechanisms have used different terms to describe technology transfer methods (extension methods) used in delivery of new production practices, techniques and innovations. Technology transfer mechanism or extension approach is defined as a procedure that involves a series of steps such as planning, organization and management of institutions (delivery technologies) that engages in implementation of new practices coupled with high technical knowledge and delivery skills that are context based (MoFA-DAES, 2011).

Leeuwis (2004) defines agricultural extension as a philosophy adopted by an organization to delivery improved technologies to farmers. Hagmann and Shultz (2000) describes agricultural technology transfer mechanisms as context based approaches that meets the needs of different farmers and generally applied in situations requiring specific solutions.

Pontius et al. (2002) and Godtland et al. (2004) defines agricultural technology transfer mechanisms as tools that are used to transfer skills and knowledge to farmers with the intention of enhancing the knowledge of farmers on improved agricultural technologies or practices. Anand et al. (2018) also defines agricultural technology transfer mechanisms as means through which near technologies are released to farmers especially when these technologies are to be used in the future.

In this study, agricultural technology transfer mechanisms is defined as a procedure that involves a series of extension methods (i.e. demonstration, farmer-to-farmer, farmer field school, household methods etc.) used in the delivery of agricultural based information which includes improved agricultural production technologies, market linkages etc. to achieve a specific target.

2.2.5 Technology Transfer

According to Molnar and Jolly (1988) technology transfer is defined as "a multi-level process of communication involving a variety of senders and receivers of ideas and materials". Ramanathan (2007) defines technology transfer as a process which involves the movement of technology either machinery or human from one place to another. Technology transfers is regarded as a learning process which usually involves sharing of knowledge as well as technical expertise and hardware devices such as farm equipment, tools and machinery (Altalb et al., 2015).

2.3 Overview of the Concept of Adoption

The fundamental forces driving our culture, lifestyle and future is dependent on technological change and innovation (Kaine, 2008). Usually the benefit of any new innovation or technology is often realized when adopted by farmers (Ugochukwu & Phillips, 2018). However, the expected benefit is dictated by the adoption rate after diffusion and learning about the new technology for a period of time. In most technology adoption studies, a clear distinction between adoption and diffusion of technologies has been made.

Diffusion and adoption are often considered as two interrelated concepts that generally explain farmers desire over a time period either to accept or not to accept and propagate a particular technology. In fact, diffusion theory has been applied to technology adoption many years back (Ernst & Tucker, 2002). Many researchers have defined these two concepts in line with their research disciplines or fields including agriculture, education, sociology and health. However, the most widely used is the definition given by Rogers (2003), he considers not only technology but goes further to look at new ideas, practices or objects which makes his definition widely applicable in diverse research fields.

Rogers defines diffusion as the communication of innovation or technology among members of a particular social grouping via appropriate communication channels over a time period. The definition of diffusion brings to the fore, four key elements and these include; innovation, communication of new ideas, time and social system. These elements are considered the drivers to the adoption of any given technologies (Sheng Tey et al., 2011). Diffusion often starts when a new technology has passed through design and on-farm experimental test and ready for use by farmers (Ayele et al., 2001).

The focus of diffusion is the communication of new ideas among farmers of a social system; diffusion is therefore considered a special type of communication. Adoption of technologies is often considered as a result of diffusion (Tey et al., 2011 and Rogers, 2003). Adoption is the intent to use a practice or technology as long as it provides more advantage than alternative technologies (Kaine, 2008).

Again, Rogers (2003) defines adoption as the acceptance and non-acceptance of any new technology by a farmer over a specified period of time. From the definitions of adoption, it is clear that no given technology is adopted permanently and can be abandoned or rejected when a new technology is perceived to have relative advantage over the other. Following this, Rogers (1995 and 2003) identifies five key attributes of a new technology or innovation that influence the rate of adoption and these include; relative advantage of technology, compatibility with culture values and beliefs, complexity of technology, trialability and observability.

According to Sunding and Zilberman (2001) other factors such as age, credit and risk can influence the rate of adoption of technologies either positively or negatively. Additionally, other factors such as farm size, educational background, membership of a group, access to extension services and cost of technologies can influence the rate of adoption of technologies (Saurer & Zilberman 2010 and Millar 2010). Generally, the adoption of new technologies or innovation is not a one step process but follows systematic steps and include; awareness of technology, persuasion of potential adopters, information on technological characteristics, benefits of technology, cost of technology, decision, implementation or use of technology and confirmation of adoption (Rogers, 2003). The speed of adoption of technologies can be measured by computing the number of farmers who adopt or use a new technology during a specified period of time. And as explained by Rogers (2003), adoption rate is the speed with which members of a group adopt a given set of technologies.

2.4 Overview Soybean Production in Ghana

Glycine max (L.), soybean, is a leguminous crop that grows well in varied climatic conditions preferably in temperate, tropical and subtropical climates. Production of soybean crop for domestic consumption and industrial use is not new in Ghana. According to Plahar (2006), soybean was first introduced in Ghana around 1910 which was mainly used by local farmers in the northern sector in their traditional foods.

During the late 1960's and early 1970's, soybean research was intensified with a number of government led research institutions such as CSIR-Crop Research Institute and University of Ghana agriculture research station spearheading the process with the aim of improving human and animal nutrition. Despite this positive initiatives, utilisation of the crop was low, prompting the establishment of an inter-sectoral national committee on soybean production and utilisation in the 1980's, with the mandate of stimulating policy formulation to shore up production and utilisation of the soybean crop.

The agro-climatic condition of northern Ghana makes it well suited for the production of soybean and as such the cultivation of the soybean crop is concentrated in the north of Ghana (Mohammed et al., 2016; Dogbe et al., 2013 and Plahar, 2006). An earlier report by the MoFA-SRID (2013) reveals that northern Ghana produces about 77% of the total soybeans produced in Ghana yet represents about 30% of the overall national output (Dogbe et al., 2013). The soybean crop is regarded as an important leguminous crop because of its huge potential in developing the agriculture, health and industrial sectors of the economy (Plahar, 2006). In recent years, soybean demand has increased steadily prompting interventions from both the Government and NGOs/donor supported projects in the areas of capacity building, technology awareness and promotion, agricultural extension delivery services and input support. For instance, a recent initiative by the Ghana government known as the planting for food and jobs implemented in 2017 which is designed to improve agricultural growth by providing input, market, technological and extension support to farmers at subsidize rates is yet to meet fully its intended target especially for the soybean sub sector.

NGOs and other donor supported projects have instituted various support mechanisms in area of soybean production, for instance IITA and SARI through the N2Africa project over the last few years have carried out experimental research in soybean productivity including the development of improved varieties such as "Jenguma" and "Salintuya", crop management practices such as row planting, pest and disease control, rotation with other crops etc. in a number of districts in northern Ghana (Martey et al., 2015). Also, the USAID-feed the future through ADVANCE and RING projects in the last ten (10) years have supported female soybean farmers with inputs, market linkages, credit and extension services in the production and utilisation of soybean in northern Ghana. Similarly, the GROW project implemented by Menonite Development Associates (MEDA) has supported women soybean farmers in the Upper West region of Ghana with input, technical and market link support (MEDA, 2015). Furthermore, the USAID ATT project has been instrumental in the promotion of improved soybean production technologies such as inoculants, TSP, certified seeds and pest and disease control measures in northern Ghana through collaborations with SARI and ITTA.

Despite the critical roles played by stakeholders soybean yields is still low (Mohammed et al., 2016). A report by MoFA-SRID (2017) shows that the average soybean yields in

Ghana is 1.3Mt/ha as against a potential yield of 3.0Mt/ha, meaning that efforts made by organisations especially NGOs and donor supported projects have yielded minimal impacts. Recently, four soybean production technologies namely; certified seeds (for instance, Jenguma, Salintuya and Favour), inoculants, triple super phosphate and pest and disease control measures were promoted for adoption in northern Ghana (USAID RFA- FTF Ghana ATT project, 2016). These improved technologies have the capacity to improve yields of soybean. However, low adoption of improved soybean production technologies have been recorded among farmers in northern Ghana and this has contributed to the stagnant under-performance of the soybean crop (Tamimie, 2017 and Osman et al., 2018). It is estimated that adoption of soybean production technologies could potentially lead to a double increase in soybean yields (Awuni and Reynold, 2016) which can translate to a triple increase in incomes of soybean farmers (USAID RFA- FTF Ghana ATT project, 2016), therefore it will be important farmers adopt improved soybean productions technologies to achieve this feet.

However, the production of soybean in Ghana is often constrained by a number of factors that affect adoption of improved soybean production technologies and soybean productivity. For instance, Adraki, Allotey and Arthur (2018) in their study reported non-availability of inoculants in most local markets in northern Ghana and was found as the primary reason soybean farmers were not adopting inoculant technology. Similarly, earlier studies by Mbanya (2011) and Dogbe et al. (2013) found that inoculant use in northern Ghana was curtailed by low level of awareness and availability of the technology at rural farming communities in most parts of northern Ghana. Low use of certified soybean seeds among farmers in Ghana has been linked to two key issues, that is availability and affordability (Mbanya, 2011), which means that high level promotion of soybean production technologies without addressing the above mentioned constraints will continue to limit adoption. Even though it may be entirely unfair to overlook the efforts made by Government and other stakeholders in addressing these issues, priority should be given to the soybean seed sector by promoting seeds that are well suited for farming conditions of targeted farmers, for instance farmers have reported high shattering of some soybean varieties (e.g., Songda and Salintuya) which makes it entirely difficult for continuous usage of these seed varieties. Aside adoption challenges, Dogbe et al. (2013) identified other key factors that affects soybean production, notably among them are; i) land use rights which for a very long time has been a major constraint to land ownership for agricultural purposes ii) the unwillingness of farmers to join sustainable farmer based organisations and iii) poor access to extension delivery and soybean training services. Most of these challenges have not been given priority in most soybean interventions and may well be contributing factors limiting adoption efforts of soybean farmers in Ghana.

2.5. Soybean Production Technologies

2.5.1 Certified Seeds

Certified seeds are seeds that are sourced from known and reliable institutions such as research organisations, private seed producers/traders and agro-input dealers after passing inspection and testing. Certified seeds are high quality seeds that are not broken, diseased, wrinkled and shrunken (Micheal, Kevin & Matt, 2001; Seed Services Austrialia, 2013 and Bogdanović, Mladenov & Tubić, 2015).

2.5.2 Inoculants

Inoculants are bacteria that form a symbiotic relationship with the soybean roots to stimulate nodules formation that enhances nitrogen production and biological fixation throughout the entire growing season (Bala et al., 2011 and Thilakarathna et al., 2019).

2.5.3 Triple Super Phosphate (TSP)

TSP is a phosphorus based fertilizer that contains zero nitrogen. TSP is very soluble in water, making it readily available for uptake by plants. It is suitable for leguminous crops by supplementing the biological fixation of nitrogen by leguminous crops (Noor-Us-Sabah et al., 2016).

2.5.4 Crop Management Technologies

Crop management is a group of good agricultural technologies used to enhance the growth and yield of crops. Depending on the type of crop and biological characteristics (e.g. spring or winter crops) different technologies may be applied.

2.6 Agricultural Technology Transfer Mechanisms

Adoption of improved agricultural technology can be enhanced through effective and efficient technology transfer mechanisms. Several agricultural technology transfer mechanisms such as demonstrations, farmer to farmer, mass media (mobile phone, TV and radio) and farmer field schools have been discussed in literature in relation to adoption of agricultural technologies (Rathod et al., 2013, Davis et al., 2010, Pemsl et al., 2006, Ali, 2011, Dinpanah et al., 2010, Azumah et al., 2018 and Kenya, 2016). In this study eight agricultural technology transfer mechanisms are identified namely; demonstration, farmer to farmer, farmer field schools, mass media, exhibitions, workshops, household extension and gifts methods. However, due to limited literature on some of the technology transfer mechanisms, the study focused on four technology transfer mechanisms under this section for literature review and its effects on adoption of improved soybean production technologies and yield.

2.6.1 Demonstration Method

Demonstration methods is one of the technology transfer methods that are used widely by research scientists, agricultural departments, and organizations among others. Demonstration method is usually carried out either on farmer's fields or research managed fields using improved technologies and good agricultural practices to show the effectiveness of improved technologies and potential constraints on different conditions of farming (Choudhary & Suri, 2014). Choudhary and Suri used the demonstration method to show the effectiveness of technologies in oilseeds production with the aim of increasing farm productivity, profit and closing the extension constraints. According to Rathod et al. (2013), demonstration methods have increased the popularity of many improved agricultural technologies since new technologies are often implemented on farmer's farm under their own farming conditions. Demonstration methods have become a source of data generation by analyzing factors that influence increased crop yields, production constraints under different farming conditions (Anand et al., 2017).

2.6.2 Farmer Field School Method

The FFS can best be described as a non-formal school or a community-based learning center that generally applies practical participatory training methodology, interactive and engaging sessions where there is knowledge sharing between facilitators (extension agent) and participants (farmers) (Dinpanah et al., 2010). The farmer field schools bring together farmers and extension agents to learn, share knowledge/ideas and collectively adapt to improved agricultural technologies or practices.

Farmer field schools (FFS) is one of the most popular and innovative technology transfer method that is used worldwide by many organizations including government agriculture departments (Davis et al., 2010). According to Davis et al. (2010) the FFS approach is used by many countries in sub-Saharan Africa and was first started in Indonesia in 1989 where farmers were trained on integrated pest management (IPM). FFS is used in Ghana in a number of agricultural related activities such as technology transfer in food crop production, livestock keeping as well as water and soil conservation and management.

The basic concepts defining farmer field schools is based on Mwaseba et al. (2008), they define FFS as a class of adult farmers with many years of farming experience and accumulated knowledge. The FFS concept requires that the extension agent (facilitator) has in-depth knowledge of various technologies that are meant to be transferred to farmers and must be confident in his/her delivery of knowledge to farmers. The farmer field schools are usually a season long practical training program organized for small number of farmers. According to Kabir (2006), farmer field schools are implemented based on a number of principles including; a) farmers are regarded as experts in their own fields b) use of improved or certified seeds of good quality and c) application of good crop management practices.

2.6.3 Mass Media Method

Mass media commonly referred to as information communication technology (ICT) can be used to describe any tool or application such television, radio, mobile phone and computer as well as soft and hardware materials/tools, that has the capacity to communicate or create awareness of improved agricultural technologies among farmers (Aker, 2011 and Ali, 2011). The use of ICT has been an evolutionary break through especially in response to information gap that exist among many poor farmers in developing countries (Aker, 2011).

Different communication tools are used at different locations to address specific situations; in most developing countries like Ghana where investment in infrastructure such as electricity, internet and landline connections in many rural communities are low, it is difficult to use communication tools that demand the availability of these services. One of the most popular communication tools that have over the last decades caught up with many rural farmers is the mobile phone (Aker & Mbiti, 2010). Mobile phones usage perhaps has a huge potential of improving farmers access to information on improved agricultural technologies (Aker, 2011). This is attributed to the fact that, communication related cost are significantly reduced and most of the information delivered to farmers via mobile phone can be kept for future reference.

The use of radio is one of the earliest forms of mass media/ICT technique in the dissemination of agricultural technologies to farmers in rural communities. According to Azumah et al. (2018), the use of radio in the transfer of rice production technologies among farmers in northern Ghana was perceived to be effective relative to other mass media techniques. Similarly, as observed by Ali (2011), the use of radio in the dissemination of agricultural technologies was found to be very effective among other mass media techniques in India.

2.6.4 Farmer to Farmer Method

Farmer to farmer (F2F) extension approach is one of the oldest extension methods used by many countries across sub-Saharan Africa. The farmer to farmer approach basically engages farmers who are trained as lead or master farmers by extension agents or agriculture experts, these lead farmers then train other farmers within the communities they find themselves.

Depending on the country, different names are given to lead farmers (Karuhanga, Kiptot & Franzel, 2012), for instance they are called farmer advisors in Burkina Faso (Lenoir, 2009), farm promoters in Nicaragua (Hawkensworth & Perez, 2003), farm teachers in Kenya (Amudavi et al., 2009) and the USAID-ATT project refer to them as local implementing partners in Ghana (USAID RFA- FTF Ghana ATT project, 2016). The F2F complements efforts of extension agents in the transfer of improved agriculture technologies. The use of F2F has become very necessary due to the low numbers of extension agents available to serve the needs of rural poor farmers (Kaunda, 2011).

It is reported by Khaila et al. (2015) that most farmers find it convenient to access agriculture information from lead farmers within their communities since they are the closest source, especially if they have to make quick decisions on their production needs. Furthermore, Mulwafu and Krishnankutty (2012) and Meena et al. (2016) enumerates several benefits of the farmer to farmer approach that utilizes lead farmers, they included in their findings a) lead farmers serve as contact persons through which technologies are introduced to farmers b) lead farmers serve as facilitators for farmers capacity building c) lead farmers serve as a source of motivation to farmers by helping to change the mindset of farmers in the adoption of agricultural technologies and d) farmer to farmer approach can also reduce significantly extension agents workload and also reduce cost of providing extension services.

2.7 Factors Influencing Adoption of Agricultural Technologies

Extant adoption studies have explored factors that determine adoption of improved agricultural technologies (Awuni et al., 2018; Donkor et al., 2019; Kibrom et al., 2016, Varma, 2016, Diro and Mulugeta, 2015 and Diro et al., 2017). These factors are used to model the effect on adoption behavior of farmers and have either had positive or negative effect on adoption of improved agricultural technologies. These factors under this section are broadly categorized as technological, household specific, institutional and farm specific factors and discussed based on findings of past studies.

2.7.1 Institutional Factors

Institutional factors are important determinants of adoption of improved agricultural technologies. Institutional factors such as extension services, credit services and membership of farmer groupings are found in many adoption studies as having important effects on the adoption of agricultural technologies.

Access to extension services in many studies have had positive and significant impact on adoption of improved agricultural technologies (Diro et al., 2015, Donkoh & Awuni, 2011, Doss et al., 2003, Doss, 2003, Mensah-Bonsu et al., 2017, Kibrom et al., 2016 and Varma, 2016). As reported by Donkoh and Awuni (2011), extension agents serve as change makers by enhancing the adoption of improved agricultural technologies by making contacts, providing input and technical advisory support to farmers. Farmers contact with extension agents creates pressure among farmers to apply technologies or practices (Moser & Barrett, 2006).

Access to credit has been reported to have a positive and significant influence on adoption of improved agricultural technologies (Omodona, 2016, Doss et al., 2003, Doss, 2003 and Mensah-Bonsu et al., 2017). According to Omodona (2016) credit is one of the most important determining factor that explains the adoption behavior of farmers. Additionally, lack/inadequate access to credit has been identified as a major constraint to adoption of many agricultural technologies especially technologies that requires high initial capital (Doss, 2003). Contrarily, Gregory and Sewando (2013) found access to credit to have negative but significant influence on adoption of quality protein maize in Tanzania.

Membership of farmer groups is significant and has positive influence on the adoption of improved agricultural technologies (Varma, 2016, Uaiene, 2005, Omodona, 2016 and Mignouna, 2011). However, Mensah-Bonsu et al (2017) reported that, membership to farmer groups had negative influence on intensity of adoption of land and water management practices among maize farmers in Ghana.

2.7.2 Household Specific Factors

A number of household specific factors have been discussed in literature as very important determinants of adoption of improved agricultural technologies by farmers. These include age, gender, educational level, household size and income earned (wealth of farmer).

Age of a farmer can either have a negative or positive influence on improved agricultural technologies adoption. As reported by Abdulai and Huffman (2005), improved agricultural technologies adoption is higher among older farmers because of many years of farming experience and accumulated wealth. However, it is observed by Doss (2006) that young farmers are innovative and tends to be risk takers as a result will always like to try new technologies. Divergent findings from Mignouna (2011), Bruce et al (2014), Kibrom et al (2016) and Idrisa et al (2010) showed that age was negative and had insignificant effect on adoption of improved IRM technology, improved rice variety, multiple technologies adoption and soybean technologies respectively. However, contrary to this finding, age was found to be positive and significantly influence adoption of improved agricultural technologies (Omodona, 2016 and Fitsum, 2016).

Gender composition of farmer was statistically significant and had positive influence on adoption of improved agricultural technologies (Kibrom et al., 2016, Varma, 2016, Mensah-Bonsu et al., 2017, Berihun et al., 2014 and Akudugu et al., 2012). Also, Idrisa et al. (2010) found gender to be positively related to adoption of improved agricultural technologies but had insignificant influence on adoption of technologies in Nigeria.

The educational level of a farmer often than not may be used to predict the level or extent to adoption of improved agricultural technologies, it is assumed that, farmers with higher educational level are more likely to adopt new technologies (Doss, 2006). Many adoption studies have found educational level to be positive and significantly influence adoption of improved or new technologies (Doss, 2006, Akudugu et al., 2012, Kibrom, 2016, Diro and Mulugeta (2015), Diro et al., 2017 and Bruce et al., 2014). However, Mignouna (2011) found education to be negative and had insignificant influence on adoption of IRM technology. Deviating slightly from Mignouna (2011), Idrisa et al (2010) found education to be positive and had insignificant influence on adoption of soybean seed technology in Nigeria.

Larger households are often assumed to be adopters of new or improved technologies. Larger households serve as incentive to increase production and as a result any technology that meets this need is wholly adopted (Mignouna, 2011, Donkoh & Awuni, 2011, Bruce et al., 2014, Kibrom et al., 2016 and Varma, 2016). Household size was reported to have a significant and positive influence on adoption of IRM seed in Kenya (Mignouna, 2011). Diro and Mulugeta (2015) found household size to be significant but negatively influence adoption of soybean technologies in Ethiopia. However, Idrisa et al. (2010) found household size to be insignificant but positively influencing adoption of soybean seeds.

Adoption of new agricultural technologies is usually expected to be high among wealthier or high income earning farmers. It is presumed that wealthier farmers have readily available resources at their disposal and are able to assume more risk than farmers with less wealth (Doss, 2006). According to Kibrom et al. (2016) and Varma (2016) high income status of famers had a positive and significant influence on adoption of improved agricultural technologies.

2.7.3. Farm Specific Factors

Farm size and farmer experience are farm level factors that can either influence adoption of soybean production technologies positively or negatively. Many adoption studies have discussed these factors and their effect on adoption of improved technologies (Mignouna, 2011, Kibrom et al., 2016 and Varma et al., 2016). As observed by Doss (2006), having a large farm size does not necessarily cause adoption but may have an effect on adoption.

Farm size has a negative influence on adoption of improved technologies and significantly related to adoption (Diro & Mulugeta, 2015; Donkoh & Awuni, 2011 and Idrisa et al., 2010). According to Omodona (2016) farm size was significant and positively related to adoption of soybean technologies in Nigeria. Mignouna (2011) found farm size to be insignificant and negatively impacted on adoption of IRM technology in Kenya.

Measuring farm experience has been discussed in literature; Doss (2006) observes that measuring farm experience can be a bit difficult and therefore defining in specific terms what farming experience is will be very important. However, many adoption studies have found farming experience to be insignificant and positively related to adoption of improved agricultural technologies (Diro & Mulugeta, 2015, Idrisa et al., 2010).

However, farming experience was found to be positive and significantly related to adoption of improved agricultural technologies (Mignouna, 2011; Omodona, 2016 and Donkoh & Awuni, 2011).

2.7.4 Technological Factors

Technological factors have been found in many adoption technologies as important determinants of adoption. Rogers (2003) identified five attributes that influences the adoption of improved technologies, these include relative advantage, observability, compatibility, complexity and trialability.

Relative advantage is defined as "the degree to which an innovation is perceived as being better than the idea it supersedes". The extent of relative advantage is usually expressed in several ways including profitability of technology, social stature, or in many other ways.

Compatibility is the "degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters". A technological idea which is consistent with farmer's cultural values are most certain to be adopted.

Complexity is the "degree to which an innovation is perceived as relatively difficult to understand and use". Generally, farmers will usually prefer technologies that are relatively simple to use or apply. Adoption of any new technology will largely depend on its simplicity or low complexity.

Trialability is the "degree to which an innovation may be experimented with on a limited basis". According to Rogers (2003), the speed of adoption is usually enhanced when farmers can have pieces or packages of technologies to try on their farms.

Observability is the "degree to which the results of an innovation are visible to others" (Rogers, 2003). As observed by Rogers when results of some technological innovations are observed easily and communicated appropriately to farmers, it leads to adoption of such technologies.

2.8 Conceptual Framework of the Study

Agriculture has played substantial role in the development of the Ghanaian economy including the overall improvement of the welfare of the Ghanaian farmer. For a very long time, agriculture was the leading contributor to the gross domestic product of the Ghanaian economy but in recent times has dwindled with a sectoral contribution of 12.2% in 2016 (GSS, 2016) possibly to due lack of or inadequate use of agricultural technologies. Development of agriculture technology, transfer and adoption are the fundamental drivers to ensuring sustainable increase in agricultural productivity.

Increase in agricultural productivity is attainable when farmers adopt technologies through transfer channels or mechanisms that are more engaging, interactive and overall more productive. Agricultural technology adoption can be regarded as an ecosystem of activities which are interdependent which leads to the final adoption of technologies. The conceptual frame work (Figure 1) shows that the adoption of soybean production technologies depends on the characteristics of the farmer (s), whether or not the farmer has ever or still benefiting from a soybean project intervention. It is usually anticipated that farmers who are often exposed to technologies and given the needed technical assistance are more likely to adopt technologies than those who are not exposed. Again, it is often expected that once a section of farmers are part of a project and acquire new skills, it should be replicated on their farms and also share their new or enhanced skills with farmers who are not privileged to be part of the project beneficiaries.

Additionally, the framework shows factors that influence technology adoption could either be positive or negative and have been grouped as household specific, farm specific, institutional and technological factors. The adoption of improved agricultural technologies requires an effective and efficient transfer mechanism (s) that addresses the needs of its intended target. An earlier approach such as the training and visit method has been regarded as less participatory because of the top-down model used with very minimal farmer involvement in the design and implementation of new technologies. Recent approaches such as participatory methods which includes farmer field schools, demonstrations, workshops etc. are more engaging and interactive which encourages knowledge sharing among agricultural experts and farmers.

Introducing new technologies requires the consideration of different characteristics specifically household, farm level, institutional and technological characteristics in order to appropriately assess and address the constraints in the use of the technologies. The adoption of new technologies will therefore require that the general knowledge, simplicity, quality and perception of the new technologies by the farmers should be considered. The introduction of soybean technologies to farmers is often expected to be adopted and once adopted, the expected impact on farmers is increased soybean productivity and yield, increased use of certified seeds, inoculants and triple super phosphate, ensure farmer group cohesion (knowledge sharing) and the practice of good agronomic practices.

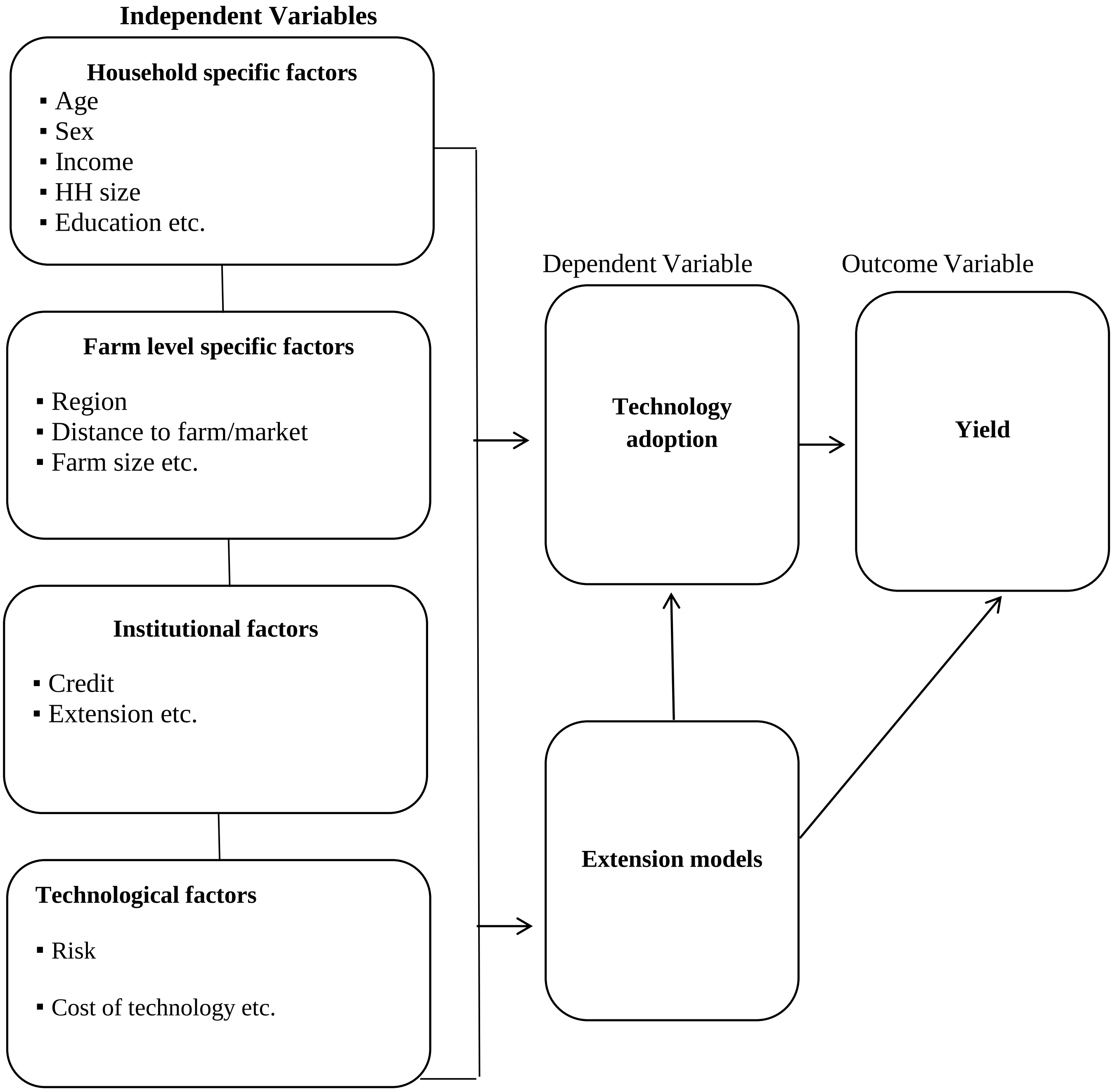

Figure 1: Conceptual framework of the study

Source: Students' own construct (2019)

2.9 Theoretical Framework

In this section, the study presents the theoretical framework for adoption of improved soybean production technologies as it pertains to this study. This study aligns with the utility maximization theory similar to previous studies on agricultural technology adoption behaviour, to explain adoption decision where the utility of a soybean farmer is specified as a linear function of the household socioeconomic, technological, institutional and farm-specific characteristics as well as a stochastic component (Marenya and Barret, 2007). Famers will adopt an improved soybean production technology or a combination of technologies that can provide maximum satisfaction to them. The probability of choosing a particular improved technology or a combination of the technologies is equal to the probability that the utility of that particular alternative is greater than or at worse, equal to the utilities of all competing alternatives in the set of choices. In order to maximise the utility U_{ij}, an i^{th} rice farmer will compare alternatives technologies and combinations. Conversely, an i^{th} soybean farmer will choose a technology j, over any alternative technology, k, if $U_{ij} > U_{ik}$, $k \neq j$. soybean farmers' choice of different interrelated improved technologies is modelled using a multivariate probit model (MVP) which allows for modelling binary choice outcomes together that are correlated. Also, the factors that influence the extent of combinations of improved soybean production technologies was modelled using generalized Poisson regression (GPR) which is used when the data under observation is underdispersed.

2.10 Empirical Studies on ATTMs and Technology Adoption

The adoption of improved soybean production technologies can contribute massively to improving soybean productivity in Ghana and beyond (Awuni and Reynolds, 2016; Mbanya, 2011 and Dogbe et al., 2013). The introduction of these improved technologies has increased significantly the yield and income of many smallholder farmers in Ghana. According to the USAID-Feed the Future project (2015), application of improved soybean production technologies such as inoculants, triple superphosphate and improved seeds increased yield by 76% and income by 677%. A number of factors are identified in many adoption studies in Ghana as major determinants of adoption of these improved production technologies. Additionally, adoption of improved production technologies is usually facilitated through awareness creation by implementing appropriate technology dissemination mechanisms that meets the needs of farmers (Dogbe et al., 2013). Some empirical studies conducted in the past on technology transfer mechanisms and factors influencing the adoption of improved soybean production technologies are reviewed under this section.

Kibrom et al. (2016) examined farmer's technology adoption decisions in Ethiopia and the results from their analysis showed that households visited frequently by extension agents were likely to adopt chemical fertilizer indicating strong knowledge transfer from extension agents to households. They also found that farmers with high educational qualification, large household size, high income status, large farm size and males had high adoption rate of multiple technologies. Varma (2016) also analyzed factors influencing the adoption of system of rice intensification (SRI) technologies in India and found that access to extension services, membership of farmer group, farmer experience, household size, and farm size, gender of farmer and income status of farmer were significant and positively impacted the likelihood of adoption of the various SRI technologies.

A study that analyses the effect of socio-economic variables on the adoption of soybean technologies in Nigeria found that, educational level and farming experience was positive and had significant influence on the adoption of improved soya bean production technologies (Mustapha et al., 2012). They also showed that age and farm size were negative but significantly influenced the adoption of improved soybean production technologies. However, they found gender and household size to have positive but insignificant influence on adoption of improved soybean production technologies.

Bruce et al. (2014) conducted a study on improved rice variety adoption and its effects on farmer output in Ghana and found household size and education of farmer had positive influence on the adoption of improved rice variety. Results from their analysis also showed that, farm size and extension visits had negative influence on adoption of improved rice variety. Also, Herbert et al. (2015) in a study on improving the adoption of agricultural technologies and farm performance through farmer groups in the Great Lakes Region of Africa, they found that membership of a farmer group and extension visits had significant influence on adoption of agricultural technologies.

A cross sectional analysis of data on the determinants of agricultural technology adoption in Mozambique shows that membership of farmer group and access to credit had positive and significant impact on adoption of agricultural technologies (Uaiene, 2006). He also found educational level and gender to have significant and positive influence on adoption of agricultural technologies. As observed by Paxton et al. (2011), educational level of farmer and farming experience influence adoption of precision agriculture technology by cotton producers positively and significantly. However, age and farm size had negative and insignificant influence on adoption of precision agriculture technology.

Mndzebele (2013) in a study that analyzed the effect of perceived relative Advantage, compatibility and complexity in the Adoption of electronic commerce in the Hotel Industry in South Africa found perceived relative advantage had negative influence on the adoption of electronic commerce. However, compatibility and complexity had positive impacts on the adoption of electronic commerce. Mairura (2016) observed that perceived relative advantage was positive and had significant influence on adoption of automobile on micro and small enterprises in Kenya. Mignouna (2011) in study on adoption and impact of improved agricultural technologies in Kenya found complexity and perceived relative advantage insignificant and negatively related to adoption of IRM technology. However, risk taking was found to be positive and significantly influenced adoption of IRM technology. Ogada (2009) studied a number of factors relating to the role of production risk in farm technology adoption in Kenya. The study showed that risk taking had a positive and significant influence on adoption of farm technologies such as fertilizer.

A study on the analysis of farmer field school on adoption of biological control rice producers in Iran show that, farmer field school has significant influence on the adoption of biological control techniques by rice producers (Dinpanah et al., 2010). Kenya (2016) in a study that analyze the role of farmer field schools on adoption and adaptation of recommended rice production practices in Tanzania found farmer field schools had significant influence on adoption of recommended rice practices. Choudhary and Suri (2014) focused on demonstration of technology; they observed that demonstration programs were an effective technology transfer tool for adoption of oilseed production technology in India. Also, Rathod et al. (2013) found that demonstration had a significant impact on adoption of seed treatment technology in soybean in India. Azumah et al. (2018) observed in their study on the perceived effectiveness of agricultural technology transfer methods found, individual method, group method and demonstrations as effective tools for adoption of rice production practices in northern Ghana.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter captures the study area which consists of climate and vegetation, socio economic characteristics of the respondents, agriculture and map of the study area. Additionally, this chapter also discusses the sampling approach, sample size, data instruments and method of data analysis, which includes empirical models that were used to analyze the study objectives.

3.2 Study Area

The study was conducted in the Chereponi District of Northern Region of Ghana (now part of newly created North East Region). The District lies between latitudes 10^0 10" and 10^0 20" N eastwards and longitude 10^0 10" N and 10^0 20^1 northwards. The district shares boundary with four districts in the northern region, to the west is Gushegu District, Bunkpurugu and Yunyoo districts to the North, Saboba and Yendi districts to the South –West. It has a total land area of 1,374.7 Sq. km.

Chereponi district is part of the savannah ecological zone of Northern Ghana. The climatic condition of the District is characterized by wet and dry seasons. The wet season spans from May to October and the peak of the wet season is from August to September with some occasional rainfall in the month of October. The district records an annual rainfall that range from 1000mm to 4000mm (GSS, 2014). From November to April, the district is characterized by total dryness with minimal or no cropping activities except some few irrigation farming in isolated areas. Generally, the temperature is high throughout the year and ranges between 21^0 C and 41^0 C. The district records the highest of 35^0 C and the lowest temperature levels of 21^0.

The vegetation of the district is generally the guinea savannah type dominated by mostly grass growing alongside some drought resistant trees and shrub species. The commonest tree species of economic value to the people of the district are Parkia, Baobab and Shea trees. The vegetation is mostly very green in the rainy season and very dry and brownish in the dry season (harmattan period).

The different characteristics of urban and rural areas across the globe make it difficult to have a global definition (Dijkstra and Poelman, 2014). The classification of a locality as urban or rural in Ghana is based on population size (GSS, 2014). This classification type is not different from what is used by the European Commission (Dijkstra and Poelman, 2014). Localities with population of 5,000 or more are classified as urban. The share of the population among urban and rural localities are 7,968 (14.9%) and 45,426 (85.1%) respectively (GSS, 2014). This statistic show that the district has majority of its population residing in rural areas.

The 2010 Population and Housing Census revealed that the Chereponi district has a population of 53,394, of which 26,206 representing 49.1% are males while the remaining 50.9% are females. The sex composition in the district shows there are more females than males.

Agriculture is the major economic activity of the people of Chereponi District. An estimated 40 percent of the total land area is used for agricultural purposes with a greater portion of the land left uncultivated (GSS, 2014). It is estimated by GSS (2014) that nine out of ten households (90%) in the rural areas are agricultural households. In the urban localities, six out of ten (60%) of households are into agriculture. This shows clearly that agricultural activities are dominated by rural households. Farming in the district is largely done on subsistence basis with many small farm holdings done across the entire district with an average land size of about 0.8ha. However, some farmers are engaged in commercial farming cultivating large areas of soybeans, maize, yam and rice. The district is known for its production of soybeans and other leguminous, cereals as well as root and tuber crops (GSS, 2014).

Available soybean yield data from MoFA shows that the district recorded yield figures of 1.76Mt/Ha in 2017 with a total production figure of 7,086MT, 1.00MT/Ha in 2016 with a total production yield of 3,246MT and 1.65MT/Ha in 2015 with a total production of 1,381MT. Also, a total of 4,026 hectares of land was put under soybean production in 2017, 3,264 hectares in 2016 and 837 hectares in 2015. It is observed that the total production in terms of yield and area put under cultivation has increased steadily providing a perfect case for the district to be selected for this study.

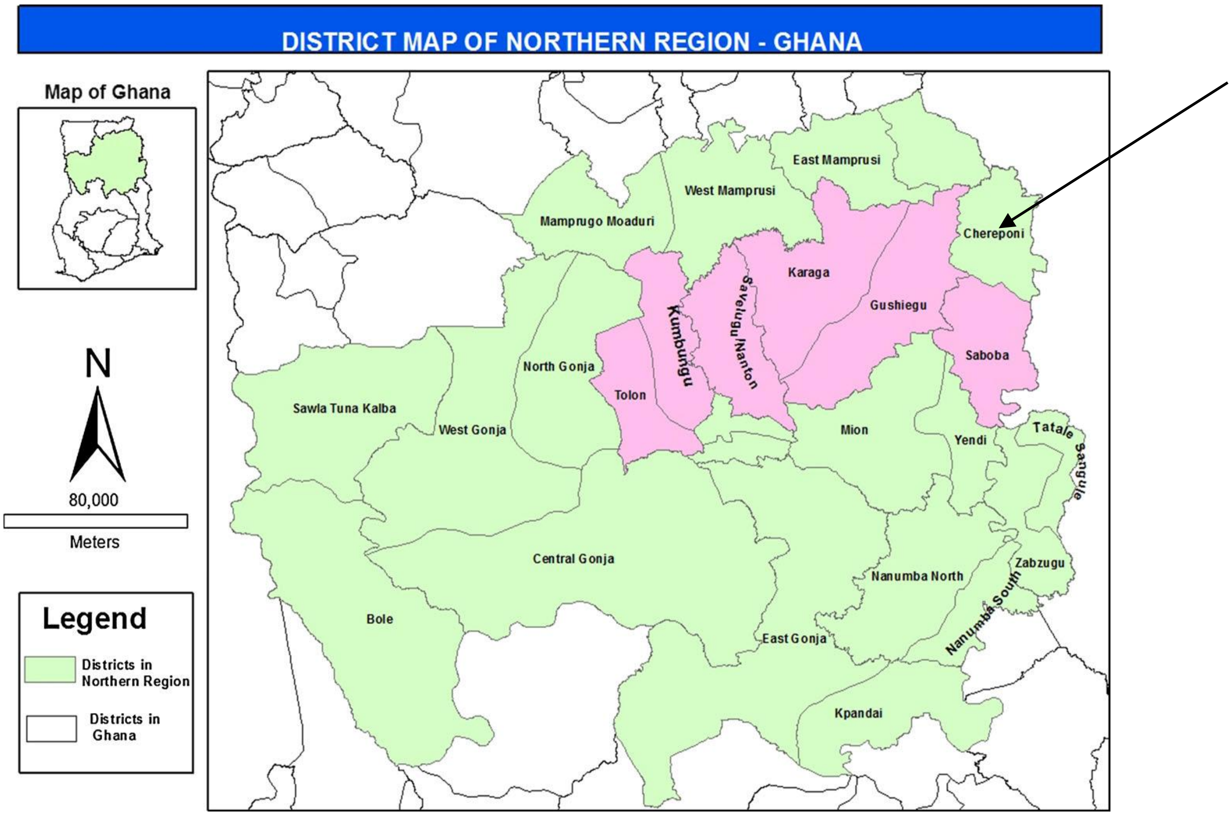

Figure 2: District map of Northern region and the study area

Source: Azumah et al. (2017)

3.3 Sampling Procedure

3.3.1 Sample Size

The sample size for this study was determined by adopting a statistical procedure used by Israel (1992). The sample size was calculated based on the assumption that the population is large and the actual number of soybean farmers is not known. Also, we do not know the variability in the proportion of farmers that adopt a given set of soybean technologies. Therefore, an approach based on precision rate and confidence level was used and the estimation formula for the sample size is given as:

$$n_0 = \frac{z^2 pq}{e^2} = \frac{1.96^2(0.5)(0.5)}{0.06^2} = 266\, farmers \qquad (23)$$

Where,

Z= confidence level at 95% which corresponds to 1.96 z-critical value

n_o= sample size

p= maximum variability (assumed 50% or 0.5 because the entire population of soybean farmers is not known and assumes maximum heterogeneity)

q= 1-p

e= accuracy desired, set at 0.06

Based on the mathematical computation, the sample size was 266 soybean farmers. However, a total of 300 soybean farmers were targeted to form part of the study, this is consistent with Tabachnick and Fidell (2007) who reports that for inferential analysis, a sample size of 300 is adequate.

3.3.2 Sample Technique

The choice of an appropriate sampling technique (s) is very important in ensuring a true reflection of the entire population of soybean farmers in the study area. A true representation of the sample is important in determining the accuracy of the data collected. It also gives an insight to future policy decisions that influence the kind of technologies to introduce and agriculture technology transfer mechanisms used in the dissemination of soybean production technologies and adoption behavior of farmers in the Chereponi district. With limited or no data on the population of soybean farmers in the district, the decision of an appropriate sample technique is a tough hurdle.

A multistage sampling technique was used. The study area was divided into five zones, namely; North, West, South-West, East and Central using cluster sampling method. A simple random sampling technique was used to sample two communities from each of the five zones which are known for soybean production and have benefited from soybean project intervention (either in the past or present). Thus, ten communities were sampled as follows: Jakpa, Banjani, Famisa, Kpaboku, Namariku, Sangbana, Tombu, Tusunga, Akromabila No. 1 and Ando-Kajura. A list of soybean farmers was obtained from MoFA and opinion leaders in the communities and a simple random sampling technique was employed in selecting the respondents. These respondents included beneficiaries and non-beneficiaries of soybean project interventions.

3.4 Data Collection

3.4.1 Types of Data Instruments and Data Collection Methods

The research data was obtained from primary sources. The primary data was collected using semi-structured questionnaires in a face to face interview of the soybean farmers in the selected communities for the study. The flexibility of a questionnaire is important to ensuring quality data is collected, therefore the questionnaire used for this study was segregated into various sections corresponding with the set objectives of the study. Additionally, the questions in the questionnaire were devoid of technical terms that are not common with farmers and enumerators. Also, the questionnaire was designed in such a way that reflects the way of life of the people in the study area such that, questions that may be provocative are avoided as much as possible. The questionnaire administration was conducted in a language that the target respondents understand and can speak, therefore enumerators who are fluent in the language of the farmers were recruited to assist in data collection.

The data collection exercise was conducted in close collaboration with the Chereponi District Agriculture Development Unit (DADU). The unit assisted with production data such as district soybean yield, community level yield, existing technologies and technology transfer mechanisms and adoption behaviour of farmers in communities that are of interest to this study. The data served as a springboard to identifying true respondents who can respond intelligently to the questionnaire administered to them.

3.5 Data Analyses

The study deployed qualitative and quantitative methods to analyze the data. The results are presented in tables. The data was processed and analyzed by using STATA 14 econometric software. Descriptive statistics and econometric models were used to address each objective as explained below

3.5.1 Perceived effectiveness of agricultural technology transfer mechanisms

The study employed descriptive statistics and summarized as means and standard deviations. Basically, the measures of central tendencies such as means and standard deviations were essential in analyzing the sources of information on soybean production technologies; the agricultural technology transfer mechanisms used by farmers and assessing the perceived effectiveness of agricultural technology transfer mechanisms.

3.5.2 Analytical framework for factors influencing adoption of improved soybean production technologies

3.5.2.1 Multivariate probit model

Usually in analyzing a farmer's decision to adopt a technology, the farmer must first cope with discrete or binary dependent variables (Studenmund, 2014). According to Studenmund (2014) discrete dependent variables are typically dummy variables, meaning that the dependent variable is limited by only two choices 0 and 1. The dependent variables specified in this study are discrete in nature, assuming that a farmer either adopts (1) or does not adopt (0) a given set of soybean technologies. The frequently used models to estimate discrete dependent variables are the linear probability and the binomial logit or probit models.

However, there are some identifiable problems with these above stated models. For instance, the major problems encountered using the linear probability model arises from the fact that, the goodness of fit is usually not an accurate measure of fit of the model. Additionally, the probabilities of the predicted values are either smaller than zero or larger than one. The use of binomial probit or logit is often limited in the sense that, it deals with single equation system and becomes impossible to use when there are several equations to analyze simultaneously. The generalization of the binomial probit model is based on an approached developed by Chib and Greenberg (1998) known as the Multivariate Probit Model. Farmers' choice of different soybean technologies to adopt is solely multivariate in nature.

The multivariate probit model is used estimate outcomes of binary outcomes simultaneously. For example, a farmer must make a decision on the adoption of one or more of the soybean technologies based on a number of explanatory factors, the multivariate probit model would be appropriate in predicting these adoption decisions jointly. The multivariate probit model is appealing because it allows for a free correlation of the dependent variables (Jacques, Florian & Alberto, 2009) and it is often preferable especially when more than two dependent variables are to be measured. According to Christina, Matthew and Eleni (2013) there are several forms of correlated discrete choices and the multivariate probit model is another form of this discrete choice regression model and it simultaneously identifies the factors that determines the choice of one or more of dependent variables and also allows for the error terms to be correlated freely. Correlation between the unobserved or dependent variables may be positive or negative (Solomon, Federica & Leslie, 2016).

In this study our dependent variables represent a discrete choice, which could either be negative (non-adoption 0) or positive (adoption 1) regarding how each of the explanatory variables determines the adoption of a particular soybean technology. A number of factors are considered very important in determining the decision to adopt soybean technologies and these factors are grouped under Institutional, technological, household and farm specific factors. It is recommended by most discrete choice studies (Greene, 2003 and Christina et al., 2013) that, the multivariate probit model is premise on multivariate normal distribution and it is dependent on independence among a collection of unimportant alternatives.

Suppose an i^{th} soybean farmer $(i = 1 \ldots . N)$ facing an adoption decision, to adopt or not to adopt the available soybean production technologies (SPT) on its farm f $(f = 1 \ldots F)$

.We can let U_0=Z_a represent the benefits to the farmer for no adoption and let U_k represent the benefit of adopting the K^{th} technology: *(k = INO, TSP, CS and PDC*) representing the soybean production technologies, inoculants (INO), Triple Super Phosphate (TSP), certified seeds (CS) and pest and disease control (PDC). The decision of the farmer to adopt the k^{th} technology can be expressed as;

$$Y_{ik}^{*} = X_{ik}'\beta_k + U_{ik}, \text{ where (k = INO, TSP, CS \& PDC)} \quad (1)$$

Y_{ik} = 1 if Y_{ik}^{*} > 0 and 0 otherwise

U_{ik}, *k* = 1, . . . *4* are error terms distributed as multivariate normal, each with a mean of zero, and variance–covariance matrix *V* , where *V* has values of 1 on the leading diagonal and correlations ρ_{jk} = ρ_{kj} as off-diagonal elements.

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

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

$$Y_k = \begin{Bmatrix} 1\, if\ Y_{ik}^{*} > 0 \\ 0\, if\ otherwise \end{Bmatrix} \quad (2)$$

Where *k* = 1….4 represents the type of SPT technology. The assumption is that the rational farmer has a latent variable, Y^*_{ik} which accounts for the unobserved preference associated with the k^{th} choice of SPT technology. U_{ik} are the error terms having a multivariate normal distribution with mean vector zero and a covariance matrix ∑ with a unit diagonal matrix as shown in

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

The parameters of the MVP model are estimated using the maximum likelihood procedures. Where M = 4, the log likelihood function for a sample of N independent observations is given by

$$L = \sum_{i=1}^{N} \varpi_i \log \Phi_4(\mu_i, \Omega) \tag{4}$$

Where w_i is an optional weight for observation $i = 1. . .N$, and $\Phi_4(.)$ is the multivariate standard normal distribution with arguments μ_i and $\mathbf{\Omega}$ where

$$\mu_i = (K_{i1}\beta'_{i1}, K_{i2}\beta'_{i2}, K_{i3}\beta'_{i3}, K_{i4}\beta'_{i4}) \tag{5}$$

with $K_{ik} = 2y_{ik} - 1$, for each i, $k = 1, . . . , 4$. Matrix Ω has constituent elements Ωjk,

where

$$\begin{aligned} \Omega_{jj} &= 1 \text{ for } j = 1,\ldots\ldots,4 \\ \Omega_{21} &= \Omega_{12} = K_{i1}K_{i2}\rho_{21} \\ \Omega_{31} &= \Omega_{13} = K_{i3}K_{i1}\rho_{31} \\ \Omega_{41} &= \Omega_{14} = K_{i4}K_{i1}\rho_{41} \\ \Omega_{32} &= \Omega_{23} = K_{i3}K_{i2}\rho_{32} \\ \Omega_{42} &= \Omega_{24} = K_{i4}K_{i2}\rho_{42} \\ \Omega_{43} &= \Omega_{34} = K_{i4}K_{i3}\rho_{43} \end{aligned} \tag{6}$$

The log likelihood function depends on the multivariate standard normal distribution function $\Phi_4(.)$. The most popular simulation method for evaluating multivariate normal distribution functions is the Geweke–Hajivassiliou–Keane (GHK) smooth recursive conditioning simulator.

3.5.2.2 Count data models

A number of methods have been used to examine the nature of technology adoption by farmers as explained in literature. Technology selection and adoption can be analyzed or modeled using multivariate probit or logit, bivariate probit or logit and multinomial probit or logit, in which case the dependent variable is a categorical variable which takes different values depending on the technologies selected (Mensah-Bonsu et al., 2017). In many statistical analyses, the dependent variables or response variables of interest (y) may be limited by being count data, taking on only nonnegative or positive integer values or counts which can be analyzed in terms of a set of covariates (x) (Baum, 2010; Erdman et al., 2008 and Cameron & Trivedi, 1999). Count data models focus on adoption intensity, which employs parametric specifications such as Poisson or generalized Poisson regression models depending on the relationship between the conditional mean and variance.

Standard Poisson regression model

The starting point for count data analysis is the Poisson (log-linear) regression model which specifies the conditional variance to be a function of the mean (Erdman et al., 2008 and Cameron & Trivedi, 1999). Let Yi be the random variable which takes non negative values, i = 0,1, 2, …, n where n is the number of observations. If Yi is the number of counts for the i^{th} occasion and follows a mass probability density function for the Poisson regression of Yi conditional upon Xi is specified as:

$$f(y_i) = \Pr(Y_i = y_i) = \frac{\exp(-\lambda_i)\lambda_i^{y_i}}{y_i!}, y_i = 0,1,2,\ldots\ldots \quad (7)$$

Poisson model assumes the variance as equal to the mean, as follows:

$$E(Y_i) = Var(Y_i) = \lambda_i \tag{8}$$

Where $E(Y_i / X_i) = \lambda = \exp X_i^{'} b$, is the intensity-of-rate or mean parameter, X_i is the i^{th} row of covariate matrix, and b= unknown parameters to be estimated. The mean of Y_i is given by $E(Y_i / X_i)$ and the variances of Y_i is given by $Var(Y_i / X_i)$.

The Poisson model may be estimated by Maximum Likelihood Estimator (MLE), where the parameter estimates are the solutions to the first order conditions,

$$L(\beta) = \prod_{i=1}^{n} \frac{\exp(-\lambda_i)\lambda_i^{y_i}}{y_i!} \tag{9}$$

The log-likelihood function is given by:

$$\begin{aligned} \ln L(\beta) &= \sum_{i=1}^{n} [-\lambda_i + y_i \ln \lambda_i - \ln y_i!] \\ &= \sum_{i=1}^{n} \left[y_i (X_i^{'}\beta) - \exp(X_i^{'}\beta) - \ln y_i! \right] \end{aligned} \tag{10}$$

By differentiating equation (4) with respect to β

$$\frac{\partial 1 \ln L(\beta)}{\partial \beta_j} = \sum_{i=1}^{n} \left(y_i - \exp(X_i^{'}\beta) X_i \right) = 0, \; j = 1, 2, \ldots\ldots, k \tag{11}$$

Yields k nonlinear equations and solve these equations by Newton-Raphson method or by iteratively weighted least square procedure the parameters are estimated.

Generalized Poisson regression model

Most real life data is often characterized by under-dispersion, over-dispersion and excess zeros therefore the equality of the conditional mean and variance of the distribution has been rejected (Erdman et al., 2008; Greene, 2002 and Cameron &

Trivedi, 1999). Most variables that comprise of count data are usually modelled or analyzed with basic count data models such as the Poisson regression model (Harris, Yang & Hardin, 2012). The underlying assumption of the Poisson regression model is that, variance is equal to the mean (equidispersion). This assumption of equidispersion is usually not reflective of most count data. The most likely occurrence in count data is overdispersion that is, where the variance is greater than the mean. In other cases where the variance is less than the mean, the data is said to be underdispersed.

According to Harris et al. (2012), dealing with underdispersed data will required that, the best models are used to avoid cases where the standard errors are overestimated and inferences misleading. Few models have been developed to deal with the incidence of underdispered data (Yang et al. 2007). Normally for under-dispersed data, a model that is based on the generalized Poisson distribution may be appropriate.

Suppose Y_i is a count response variable that follows a generalized Poisson distribution. The probability mass function (PMF) of Y_i, i = 1, 2,…, n is given by Famoye, Wulu and Singh (2004), Famoye (1993), Wang and Famoye (1997):

$$f(y_i) = \Pr(Y_i = y_i) = \left(\frac{\lambda_i}{1+\alpha\lambda_i}\right)^{y_i} \frac{(1+\alpha y_i)^{y_i-1}}{y_i!} \exp\left[\frac{-\lambda_i(1+\alpha y_i)}{1+\alpha\lambda_i}\right], y_i = 0,1,2,\ldots \quad (12)$$

The mean and variance of Y_i are mathematically given as:

$$E(Y_i|x_i) = \lambda_i, Var(Y_i|x_i) = \lambda_i(1+\alpha\lambda_i)^2 \quad (13)$$

The generalized Poisson regression model is by far an extension or generalization of Poisson regression model. Where α = 0, the probability mass function in reduces to the standard Poisson regression model. In practice, this assumption is often not reflective of real life data because the conditional variance could either be lesser or greater than the conditional mean. However, if there is inequality of the variance and mean, the estimates in Poisson regression model are still consistent but are inefficient, leading to overestimation or invalidation of standard errors and wrong inference (Famoye et al. 2004).

When $\alpha > 0$, it is assumed the variance is greater than the mean and which case the Generalized Poisson regression (GPR) model represents count data with over-dispersion. Also, when $\alpha < 0$, the variance is assumed to be less than the mean and therefore GPR model represents count data with under-dispersion. The dispersion parameter (α) is called the dispersion parameter can be estimated along with the regression parameters in the GPR model. The maximum likelihood method is used to calculate the estimates of α and β in the GPR model.

A number of non-parametric test can be used to measure the goodness-of-fit of Generalized Poisson Regression model based on the deviance or Pearson test statistic (Famoye, 1993). The test based on the deviance or Pearson statistic is approximated by the distributional effect of the chi-square when μ_i's are large. Usually, computing the deviance or Pearson test statistic with the Stata command can be complex. Therefore, the log-likelihood value is often used to measure the goodness-of-fit of the Generalized Poisson regression model. In comparing the Standard Poisson and the Generalised Poisson regression models, the model with large log-likelihood value is often considered the best.

The log likelihood (L) for the Generalised Poisson model is specified as:

$$\ln L(\beta,\alpha)=\sum_{i=1}^{n}\left[y_i \ln\left(\frac{\lambda_i}{1+a\lambda_i}\right)+(y_i-1)\ln(1+\alpha y_i)-\ln y_i!-\frac{\lambda_i(1+\alpha y_i)}{1+\alpha\lambda_i}\right] \quad (14)$$

A test of hypothesis of adequacy of the generalized Poisson regression model over the Standard Poisson Regression is given by:

$$H_0 : \alpha = 0 \text{ against } H_a : \alpha \neq 0 \qquad (15)$$

The test of H_0 is an indication of significance of the dispersion parameter. Therefore, when H_0 is rejected, the appropriate model to use is the generalized Poisson Regression model. To carry out the test in, one may use the asymptotically normal Wald type't' statistic defined as the ratio of the estimate of α to its standard error. An alternative test for the null hypothesis in is to use the likelihood ratio test statistic, which is approximately chi-square distributed with one degree of freedom when the null hypothesis is true.

According to Bozdogan (2000), one other way of choosing the best count data model is by considering the value of the AIC. Mathematically the AIC is presented as follows.

$$AIC = -2 \ln L\left(\tilde{\theta}\right) + 2k \qquad (16)$$

Where the L ($\tilde{\theta}$) is defined as the log likelihood value, and k denotes the number of parameters considered for estimation. Usually, the model with smaller AIC value is considered the best model.

3.5.3 Analytical framework for analysing effect of ATTMs on soybean production technologies adoption and yields

Ordered probit and multiple linear regression models were essentially the two estimation techniques deployed for the analysis in the conditional mixed process framework.

3.5.3.1 The Ordered Probit model

The ordered probit is modelled around a latent regression just as the binary probit model. Let:

$$Y^* = X^i \beta_i + \varepsilon \tag{17}$$

Where Y^* is a latent variable (either intensity of adoption of soybean production technologies or exposure to agriculture technology transfer mechanisms) and exhibits ordinal categories coded as $0,1,2,\ldots m$. The outcome category m is observed only when the underlying continuous responses falls in the $m-th$ interval as:

$$Y^*_i = \begin{cases} 0 if Y^* \leq 0 \\ 1 if\, 0 < Y^* \leq \mu_1 \\ 2 if \mu_1 < Y^* \leq \mu_2 \end{cases} \tag{18}$$

Where $Y*(i = 0,1,2)$ are the unobservable cut-off parameters estimated with other parameters specified in the model. In this case, the probability of a farmer to either adopt soybean technologies or exposed to agricultural technology transfer mechanisms was modelled by ordering the outcome responses to obtain discrete outcome values such that a finite set of ranges with each outcome corresponding to a particular range. In this ordered probit model, the thresholds are made free parameters defining the regions into which an outcome response may fall i.e. 0, 1, and 2. A value close to zero shows low adoption or exposure, likewise a value close to one shows moderate and that of two indicates high adoption or exposure, this is specified as:

$$prob(Y = 0) = P(Y^* \leq 0) = P(\beta' X + \varepsilon_i \leq 0) = \phi(-\beta' X) \tag{19}$$

$$prob(Y = 1) = \phi(\delta 1 - \beta' X) - \phi(-\beta' X) \tag{20}$$

$$prob(Y = 2) = 1 - \phi(\delta 1 - \beta' X) \tag{21}$$

Where, $0 < Y^* 1 < Y^* 2 \ldots < Y^* m - 1 .. n$ is the standard normal cumulative distribution function such that the total sum of the above stated probabilities is equal to one. The ordered probit model was estimated with the Maximum Likelihood Method which is appropriate for handling nonlinear models.

3.5.3.2 The Multiple Linear Regression Model

The Multiple linear regression was another method used to measure the impact of agricultural technology transfer mechanisms and adoption on soybean yields, expressed below as:

$$\Re_i = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \ldots.. + \beta_n x_n + e_i \quad (22)$$

Where $\Re_i$ is a continuous variable (soybean yields); *i* represents a soybean farmer, β_0 is the intercept and β_{1-n} are the parameter estimates of the $X's$ (household specific, farm level specific, technological and other institutional factors) and e_i is the error term.

3.5.3.3 The Conditional Recursive Mixed Process Model

Measuring the effect of agricultural technology transfer mechanisms on adoption and yields will require a joint estimation of multiple equation systems which analyses the relationship between improved technology selection and crop productivity (i.e., soybean technologies adoption and yield). In this regard, the necessary estimating equation for the adoption/yield model is given by equation (22). To estimate the impact of agricultural technology transfer mechanisms on technology adoption and yields of soybean farmers in Chereponi district, equations 17 and 22 as specified above were jointly estimated.

The decision by a soybean farmer to participate in different transfer mechanisms is potentially an endogenous variable, and therefore failure to account for endogeneity may likely produce inconsistent estimates. The potential endogeneity of agricultural technology transfer mechanisms may be probably due to the purposive selection of farmers to participate in technology transfer mechanisms. This selection bias if not considered may exaggerate the real effect of agricultural technology transfer mechanisms in the above specified regression model. Also, soybean farmers may not be exposed to technology transfer mechanisms due to inadequate extension contacts or simply because they are not beneficiaries of these technology transfer mechanisms. In this case, the inability to account for endogenity bias may underestimate the positive effect of technology transfer mechanisms.

Usually controlling for endogeneity will require that the endogenous equation is estimated with instrumental variables for agricultural technology transfer mechanisms. Variables that are highly correlated with the endogenous factor, in this case agricultural technology transfer mechanisms and uncorrelated with the unobserved variables that have the tendency of influencing the outcome variables are often described as instrumental variables (Makate et al., 2016).

The CRMP usually assumes a seemingly unrelated regression, where there is a high level independence among the different equation systems (Roodman, 2009; Asfaw, Di Battista & Lipper, 2016 and Fernandez-Cornejo & Wechsler, 2011) and will generally avoid the incidence of endogeneity, however a high possibility of correlated error terms is envisaged.

3.5.4 Empirical Specification of Models

Multivariate Probit Model

The factors influencing the adoption of multiple soybean technologies was analysed using the Multivariate probit model. Let Y_i be the improved soybean technologies and

X_i the explanatory variables that determine the adoption of any given soybean technologies.

The empirical specification of the Multivariate Probit Model is given as:

$$Y_{ik} = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \beta_4 X_{4i} + \beta_5 X_{5i} + \beta_6 X_{6i} + \beta_7 X_{7i} + \beta_8 X_{8i} + \beta_9 X_{9i} + \beta_{10} X_{10i} + \beta_{11} X_{11i} + \beta_{12} X_{12i} + \beta_{13} X_{13i} + \varepsilon_i \quad (24)$$

Where Y_{ik} define a set of dependent variables (adoption of inoculants, Triple Super Phosphate, certified seeds and pest and disease control measures technologies) as binary outcome; 1 if adopted and 0 otherwise; X_i's are a set of explanatory variables for each outcome equation (age, educational level, household size, soybean project beneficiary, exposure to demonstration method, exposure to household extension method, cropping system, cost of technology, distance to input dealer, credit access, extension contacts, membership of farmer group and risk of technology); β_0 define the constant term for each outcome equation.

$\beta_1, \beta_2, \beta_3 \ldots\ldots\ldots\ldots\ldots\ldots\ldots \beta_{13}$ are the parameters of the explanatory variables in the model. Where the ε_i's are the joint normal with means zero, variances one, and correlation ρ.

Generalized Poisson Regression Model

The generalised Poisson regression model was used to analyse the extent of adoption of improved technologies by soybean farmers and specified empirically as;

$$\ln Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + \beta_{11} X_{11} + \beta_{12} X_{12} + \beta_{13} X_{13} \quad (25)$$

Where;

$\ln Y$ = intensity of adoption of soybean production technology

The explanatory variables in the model are defined below.

X_1 = Age (in years)

X_2 = Education (number of years in formal education)

X_3 = Distance from farm to input dealer (in kilometers)

X_4= Income earned from soybean production (in GH¢)

X_5 = Exposure to demonstration method

X_6 = Exposure to Household method

X_7 = Experience in soybean production (in years)

X_8= Cropping system (1 if farmer practices mono-cropping, 0 if not)

X_9= Exposure to mass media

X_{10}= Credit access (1 if farmer had access to credit, 0 if not)

X_{11}= Extension contacts (number of contact times with extension agent)

X_{12}= Soybean project beneficiary (1 if respondent was a beneficiary, 0 if otherwise)

X_{13}= Risky nature of technology (1 if respondent perceive technologies as risky, 0 if not)

β_1,β_2, β_3………………… $\beta_{13}$are the parameter of the explanatory variables in the model.

Conditional Recursive Mixed Process Framework

The analysis of the effect of agricultural technology transfer mechanisms on soybean technology adoption and yield was determined simultaneously using the Conditional Recursive Mixed Process (CRMP) model proposed by Roodman (2009). The theoretical specification of the CRMP model is discussed under chapter two section 2.8.6. The study employed two estimation techniques namely multiple linear regression and ordered probit models to analyze the two equations (equations 2.17 and 2.22).

Soybean farmer's adoption of soybean production technologies can be analyzed using count data regression, multinomial and/or binary models (Mensah-Bonsu et al., 2017). However, the decision to use ordered probit model to estimate the effect of agricultural technology transfer mechanism was motivated by the potential increase in efficiency of estimates leveraging on the correlation between the dependent variables in the two equations when jointly estimated with CRMP (Ramirez & Shultz, 2000). Therefore, the outcome response was modelled to produce ordered outcome response. This ensured that the probabilities of responses were constrained in a set of finite ranges. The individual models were first estimated to explain the effect of the explanatory variables on exposure to agricultural technology transfer mechanisms using the ordered probit model, also the ordered probit model again was used to estimate the effect of agricultural technology transfer mechanisms on soybean technology adoption. Lastly, the multiple linear regression was then used to measure the effect of agricultural technology transfer mechanisms and adoption on soybean yields. However, estimating these models in single equations instead of joint estimation may likely produce inconsistent and inefficient estimates (Haji & Anam, 2013). To address this, the study opted for a procedure that can jointly estimate the mixed equation systems i.e. ordered probit model and OLS, hence the use of conditional recursive mixed process model. In the second estimation stage, the joint effect of the models were estimated by the CRMP model which checks for selection bias. In order to settle on a more reliable results, a comparison of individual estimates and that of CRMP joint estimates was necessary.

The empirical specification in a recursive form of these models are represented in equations 26a, b and c.

$$\Pr ob(ATTM = \gamma / X) = X_{i1}\beta_i + \varepsilon \qquad (26a)$$

$$\Pr ob(ASPT = \gamma / X) = X_{i2}\gamma_i + ATTM_2\partial_2 + e \qquad (26b)$$

$$SY = \alpha_0 + X_{i3}\alpha_i + ASPT_3\partial_3 + \mu \qquad (26c)$$

Where α_0 is the constant; X_{i1} defines matrix of variables (soybean project beneficiary, membership of FBO, educational level, extension visits, cropping system, farm size);

X_{i2} is a set of variables (cropping system, distance to input market, income, educational level, membership of FBO, extension visits, sex of farmer, soybean project beneficiary, household size, farming experience, access to credit, risk); X_{i3} is also a set of variables (cropping system, distance to input market, educational level, membership of FBO, extension visits, sex of farmer, farm labour, soybean project beneficiary, household size, farming experience, access to credit, quantity of seed used, quantity of TSP used, quantity of inoculants used, quantity of weedicide used, quantity of insecticide used); ATTM, SY and ASPT as earlier defined; γ is the cut-off points; β_i, α_i, ∂_3 and γ_i are estimated parameters and ε, μ and e are the equations error terms.

3.5.5 Constraints to Adoption of Improved Soybean Technologies

The constraints to adoption of the various soybean technologies was analyzed descriptively, the measure of central tendency such as means and standard deviations were used to present the various challenges that confronts farmer's ability to adopt key soybean production technologies in the study area. Also, in order to understand specific constraints that is associated with the adoption of a particular technology, the constraints were measured based on each of the three key soybean production technologies identified (inoculants, certified seeds and triple super phosphate).

3.6 Statement of Research Hypothesis

Three hypothesis were stated and tested for their significance. The first hypothesis: the soybean production technologies are not complementary.

$$H_0 : Y_i = 0 \text{ against } H_a : Y_i \neq 0$$

The second hypothesis: there more zero number of adoption of soybean production technologies by farmers. $H_0 : \alpha = 0$ against $H_a : \alpha \neq 0$

The third hypothesis: the probability of intensity of exposure to agriculture technology transfer mechanisms has no effect on intensity of adoption of soybean production technologies. $H_0 : \beta_1 = 0$ against $H_a : \beta_1 \neq 0$

3.7 Definition of variables

Table 1 presents a summary of definitions for the variables used in this study. In all, there are thirty-two (32) variables out of which two (2) are the main dependent variables. Column one presents the variable name. Column two indicates the definition of the variables in this study and how the variables were measured. Column three indicates the expected sign/direction of the variable in the various models and defines the a priori expectation.

Table 1: Definition of variables

Variables	Definition/measurement	Expected sign
Soybean project	Dummy: 1 for beneficiary farmer , 0 if otherwise	+
Age	The total number of years of farmer from birth.	+/-
Education	The total number of years spent in formal schooling.	+/-
HH size	Total number of people in housing unit that feed from the same source	+
Income	Revenue generated from soybean production	+/-
Experience	The total number of years a farmer has been cultivating soybean	+/-
Sex	Dummy: 1 for male, 0 if otherwise	+/-
Distance	Distance travelled by farmer to input dealer market	-
Farm size	Measured in the total hectares of land under soybean production	+/-
Cropping system	Dummy: 1 for farmers engaged mono-cropping, 0 if otherwise	+/-
Cost	Dummy: 1 for farmers who see technology as expensive, 0 if otherwise	+/-
Labour	Total number of persons available that worked on the farmers field during the farming season	+/-
Credit	Dummy: 1 for access to credit in the last growing season, 0 if otherwise	+/-
Extension	Total number of extension contacts in the last growing season	+
FBO	Dummy: 1 for if the farmer belongs to a farmer group, 0 if otherwise	+
Risk	Dummy: 1=technology is risky, 0= otherwise	-
Demos	Dummy: 1 for a farmer who accessed information via demonstration method, 0 if otherwise	+
HH ext. method	Dummy: 1 for a farmer who accessed information via HH extension method, 0 if otherwise	+
Mass media	Dummy: 1 for a farmer who accessed information via radio, 0 if otherwise	+
Moderate exposure	Dummy: 1 for a farmer exposed to 3-5 ATTMs, 0 if otherwise	+/-
High exposure	Dummy: 1 for a farmer exposed to 6-8 ATTMs, 0 if otherwise	+/-
Moderate adoption intensity	Dummy: 1 for farmer who adopted 2-3 SPTs, 0 if otherwise	+
High adoption intensity	Dummy: 1 for a farmer who adopted 4 SPTs, 0 if otherwise	+
Weedicide	Quantity of weedicides (measured in litres) used	+
Insecticide	Quantity of insecticides (measured in litres) used	+
Inoculants	Quantity of inoculants (measured in grams) used	+
TSP	Quantity of Triple Superphosphate (measured in kilograms) used	+
Seeds	Quantity of certified seeds (measured in kilograms) used	+
Yields	Quantity of soybean harvested per unit area (t/ha)	n/a
Adoption intensity	Number of improved soybean production technologies adopted (from 1 to 4)	n/a

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

The results and discussions of the study are presented in this chapter and divided into six major sections. Section one presents a description of the socio-demographic and institutional characteristics of sampled soybean farmers. Section two discusses the existing agricultural technology transfer mechanisms available to farmers by examining the technology transfer mechanisms used to transmit technologies. Soybean farmers level of exposure to the various technology transfer mechanisms and the perceived effectiveness of these technology transfer mechanisms in influencing adoption of soybean production technologies are discussed in sections three and four respectively.

Section five discusses the factors that influence the adoption of the various soybean production technologies, by examining factors that simultaneously influence the adoption of these technologies. Also, section six presents factors that influence the intensity of adoption of the soybean production technologies. The sixth section discusses the effect of agricultural technology transfer mechanisms on adoption and yields of soybean farmers in the study area, by estimating the joint effect of the technology transfer mechanisms and some key explanatory variables on adoption intensity and soybean yield. The seventh section presents the constraints to adoption of soybean production technologies, by critically examining the constraints in relation to each of the key production technologies.

4.2 Description of Household, Farm Specific, Institutional and Technological Specific Factors

Summary statistics of the 13 independent variables used in the study are presented in Table 2. About 50% of respondents had benefited from some form of soybean production project in the past either from government or NGOs operating in the area. The average age of soybean farmers in the study area was found to be 34.8 years. This means that, majority of farmers in the study area are largely youthful and are in the bracket of economically active age group. MoFA (2013) had reported the average age of farmers in Ghana to be 55 years. The finding is good for agricultural development in northern Ghana considering that agricultural activities around the area involves much labour as mechanisation and intensification mechanisms are slow.

Also, about 39% of the respondents were males while the remaining 61% of farmers contacted were females. This suggest that females are actively involved in soybean production than their male counterpart and therefore giving the necessary support more females will go into soybean production, which can help reduce the rural-urban migration.

The average years spent schooling was low at 1.66 years. This implies that a large section of soybean farmers had extremely low levels of education. Averagely, farmers in the study area have a substantial experience in soybean production (15 years). This implies that with the huge experience attained by farmers, it is expected that adoption of improved technologies could either be high or low since farmers would have tried similar technologies in the past and would have seen the impact of these technologies on their yields.

Income entails revenue generated from the sale of soybean. The average income earned per hectare from soybean production was estimated at GH¢752.17 (about US$ 140 at the time of the study).

The average distance covered by soybean farmers from their farm to input market was 6.38km. This meant, farmers travel relatively short distances to acquire inputs from dealers and this could influence the adoption of improved soybean production technologies positively. Extension is an important and critical source through which many farmers acquire information, either indirect contact with colleague farmers who have experience transferring agricultural information to other farmers, or directly, through contact with extension agents (Azumah, Donkoh, and Awuni, 2018). On average farmers have received approximately 3 number of extension visits from agricultural extension agents in the last season.

About 41% of farmers had access to farm credit for farm production purposes. Accessing farm credit is largely influenced by the intervention of NGOs and Village Savings and Loans Associations operating in the study area. Low involvement of commercial financial institutions was attributed to the risky nature of farming, low yields, low profit margins, and relatively small farm sizes cultivated by farmers' couple with the lack of collateral security to present for credit facilities.

A wide range of mechanisms have been used to expose or introduce improved technologies to farmers. In this study, three technology transfer mechanisms namely; Mass media (most through radio), technology demonstrations and household extension methods were identified as major sources through which farmers accessed information on soybean production technologies.

About 13% of farmers accessed information on improved soybean technologies through the mass media via radio. Also, about 79% of farmers were exposed to improved soybean technologies by participating in technology demonstrations field days. Meanwhile, 26% of the farmers accessed information on improved soybean technologies via household extension method. The results from Table 2 also reveals that about 79% of farmers think that soybean production technologies are risky to adopt since they may not improve yields.

The average household size of soybean farmers was 8.37, this is higher than the national and regional averages of 4 and 5.4 members per household respectively (GSS, 2014). This finding is however similar to that of Aidoo et al. (2013), who reported an average household size of 8.88 among soybean farmers in Northern Ghana. The relatively large household size recorded in the study area indicated a large production capacity of the farmers coupled with cheap source of labour that can potentially increase the application of good agronomic practices and labour intensive technologies.

The large household size had an impact on the number of hired labours (2.36) engaged to support in farming activities, this is similar to finding of Imoru and Ayamga (2015) who reported an average hired labour of 2.28 in the Northern region of Ghana. However, the number of household members engaged actively in farming activities on the average was 7.73. This implied, majority of household numbers were in the economically active age group.

Majority of soybean farmers constituting about 57% belong to farmer based organizations, farmers who belong to this groups have relatively short periods of engagements of less than 3 years.

The average number of technologies adopted by soybean farmers was 2.01, giving the complementary nature of soybean production technologies it can be concluded that adoption was low. The average soybean yield in the study area was 0.80ton/ha, higher than the finding of Dogbe et al. (2013), who reported an average soybean yield between 0.50ton/ha and 0.64ton/ha in Chereponi and Saboba Districts of northern region.

Also, the average farm size was 0.72ha, slightly lower than 0.80ha reported by GSS (2014), meaning that soybean farmers were cultivating relatively small farm sizes reflecting the fact that soybean is not a traditional staple crop in the study area therefore effective use of the soybean crop is low. Additionally, most of the sampled farmers were women who are entitled to smaller farm sizes usually less than one hectare. Dogbe et al. (2013) reports of high cost of land rent to women in Chereponi District as a result reduces their capacity to expand the land put under soybean production.

Table 2: Summary Statistics of Variables

Variable	Mean	Std. Dev.
Household specific factors		
Age (in years)	34.84	9.79
Sex	0.39	0.48
HH size	8.37	3.26
Education	1.66	3.73
Soybean project beneficiary	0.50	0.50
Farm specific factors		
Farming experience	15.27	9.92
Income	752.17	402.88
Distance	6.38	2.93
Cropping system	0.58	0.49
Farm size	0.72	0.54
Institutional specific factors		
Extension	2.77	1.97
Credit	0.41	0.49
FBO	0.57	0.49
Mass media (radio)	0.133	0.34
Demo	0.79	0.40
Household ext. method	0.26	0.44
Technological specific factors		
Risk	0.79	0.64
Cost	0.54	0.49
Other factors		
Adoption intensity (number of SPTs adopted. i.e. from 1 – 4)	2.01	1.33
Hired labour	2.36	1.42
HH labour	7.73	2.30
Seed	5.94	1.56
Insecticide	0.85	1.06
TSP	5.76	14.56
Weedicide	2.13	0.71
Inoculants	31.50	48.21
Soybean yield	0.84	0.41

Source: Computed from field data, 2019

4.3 Existing Agricultural Technology Transfer Mechanisms in Chereponi District

Eight technology transfer mechanisms were identified namely; farmer to farmer, demonstration, household, workshops, mass media, gifts, farmer field schools and exhibition methods.

Generally, farmers were more familiar with farmer to farmer and demonstrations methods used in the study area. On the average, about 74% of farmers in the study area were exposed to farmer to farmer method of technology delivery as presented in Table 3, supporting findings of Khaila et al. (2015), Azumah et al. (2018), Nakano et al. (2018), Mulwafu and Krishnankutty (2012) and Meena et al. (2016). Also, about 79% of farmers were aware of improved soybean technologies via the demonstration method, and this is in line with finding of Rathod et al. (2013). The authors in a study titled "Impact of Front Line Demonstration on Adoption of Seed Treatment in Soybean" in Wardha district of Maharashtra State of India identified the demonstration method as one method that has the tendency of increasing the popularity of most improved technologies since trials are mainly conducted on farmers own field. Also, 26% of farmers were exposed to improved technologies via the household method.

Surprisingly, just 13% of farmers were exposed to technologies via mass media (radio). The results slightly deviate from finding of Azumah et al. (2018) who found technology transfer through radio was ranked fourth among other technology transfer mechanisms like demonstration, household and farmer to farmer methods in northern Ghana. It is observed that most radio programmes on agricultural technologies in Ghana in most cases often are not able to exhaust discussions on improved technologies for the different crops cultivated coupled with inconsistency in information delivery on radio.

This, implied any attempt to introduce new technologies via radio could potentially receive low patronage unless appropriate measures are put in place.

However, a very small number of farmers are exposed to the other types of agriculture technology transfer mechanisms, gift method recorded 13%, workshops 16%, farmer field schools 1% and exhibitions 9%. This was because, this technology transfer mechanisms generally involved selection of a small number of the farmer population to participate or benefit. This meant that any attempt to introduce soybean production technologies via any of these methods may not have a wider coverage in terms of the number of farmers who can participate.

Table 3: Subscription to ATTMs among soybean farmers

Technology transfer method	Mean	Standard dev.
Farmer to farmer	0.74	0.43
Demonstration	0.79	0.40
Household	0.26	0.44
Workshop	0.16	0.37
Mass media (radio)	0.13	0.34
Gifts	0.13	0.34
Farmer field schools	0.01	0.11
Exhibitions	0.09	0.29

N=300
Source: computed from field data, 2019

4.4 Channels of Information Delivery on Soybean production Technologies

Table 4 below shows the specifics in terms of the organizational and individual delivery of information on the various soybean production technologies in the study area. In terms of the source of information on inoculants, about 59% of farmers sourced information from MoFA extension agents operating in the area. Also, 39% and 31% sourced information on inoculants from NGOs and colleague farmers respectively. While 12% of farmers received information from input dealers. For Triple Super Phosphate, 63% of farmers sourced information from MoFA extension agents, while 36% of farmers received information from NGOs. Also, about 24% and 25% of farmers sourced information on TSP from colleague farmers and input dealers respectively.

About 80% of farmers received information on certified seeds from MoFA extension agents, while 46% of farmers sourced information from input dealers. In terms of crop management practices (CMP), about 85% of farmers received information on improved practices from MoFA extension agents, while 25% and 24% sourced information from colleague farmers and NGOs.

The results from Table 4 below was not surprising because extension agents are expected to act as change agents serving as a link between farmers and development partners. In Ghana, NGO intervention in the agricultural sector have in most cases engaged MoFA extension agents to serve as local implementers to introduce and popularize new technologies among farmers. NGOs usually complement the efforts of extension agents by organizing training workshops, exhibitions and at times offer new technologies as gifts to farmers. However, the findings of this study contradicts that of Azumah et al. (2018), where they found MoFA extension agents as the least source of information on improved agricultural technologies among rice farmers in northern Ghana. Perhaps, the divergence could be as a result of differences in crop and technologies and also the study area since the authors covered a wider area with a relatively large sample size.

Table 4: Source of Information on SPTs

Source of information	Soybean production technologies							
	Inoculants		TSP		Certified seeds		CMP	
	Freq. (Yes)	Percent	Freq. (Yes)	Percent	Freq. (Yes)	Percent	Freq. (Yes)	Percent
Colleague farmers	94	31.3	71	24	19	6	74	25
Researchers	6	2	2	0.7	3	1	6	2
NGOs	117	39	106	36	58	19	70	24
Radio	16	5	15	5	10	3	9	3
MOFA extension agents	178	59	190	63	240	80	256	85
Input dealers	37	12	75	25	138	46	29	10

N=300
Source: Computed from field data, 2019

4.5 Perceived Effectiveness of Agricultural Technology Transfer Mechanisms

Under section 4.2, a number of agricultural technology transfer mechanisms used in the study area were discussed. This section discusses the perceived effectiveness of the various technology transfer mechanisms on the adoption of improved soybean production technologies. A 5 point likert scale was used to measure the perception of soybean farmers, 5 being very effective and 1 being the least effective technology transfer mechanism. Of the eight mechanisms identified in this study, demonstration (mean of 4.45) was ranked 1st in terms of influencing the adoption behavior of farmers. According to Choudhary and Suri (2014), demonstration method is effective in influencing the adoption of technologies by soybean oilseed farmers because of its effectiveness in ensuring better understanding of technologies that enhances yield. Azumah et al. (2018), also analyzed the effectiveness of agricultural technology transfer mechanisms among rice farmers and they found that demonstration method was the most perceived method that influence adoption of improved rice production technologies.

The second best ranked technology transfer mechanism was the farmer to farmer method. This method was perceived as having a significant effect in influencing the adoption of improved soybean production technologies (mean of 4.01). The farmer to farmer method is one of the low cost methods used in the transfer of many agricultural technologies around the world (Franzel, Kiptot & Degrande, 2019). The farmer to farmer methods complement the works of extension agents by filling the gap of inadequate extension agents by serving the extension needs of rural farmers (Kaunda, 2011). According to Mkwambisi et al. (2013), lead famers are key in influencing the adoption of agricultural technologies among colleague farmers. Lead farmers adopt various extension methods in the dissemination of new technologies. As reported by Khaila et al. (2015), lead farmers employ community led approaches such as community meetings, supervision of colleague farmers and establishment of demonstrations among others.

Most of the technology transfer mechanisms namely; household extension, workshop, farmer field schools, mass media, gifts and exhibitions methods with corresponding mean values of 2.98, 2.88, 2.51, 2.45, 2.38 and 2.18 respectively were perceived by farmers to be moderately effective in influencing the adoption of improved soybean production technologies. The moderately effectiveness of these technology transfer mechanisms did not come as a surprise since these mechanisms were less used in the study area to transmit soybean production technologies. This suggest that, any effort that seeks to ensure adoption of technologies should consider a mechanism that has a wide coverage where a large section of the population can participate.

During the face to face interview, a couple of challenges associated with these mechanisms came to forth. For instance, the household method was characterized for its one sided discussions which in most cases dominated by the extension agent with minimal or no contributions from farmers. Also, this method was considered time consuming since the extension agent will have to visit individual households. The difficulty of technologies transmitter via mass media (radio) and exhibitions was that trainings on improved technologies were not consistent and therefore farmers doubt on the applications of certain technologies could not be resolved on time for farmers to adopt such technologies. Participation in workshop and gifts method was characterized by selection of few farmers, therefore many of the farmers could not benefit from technologies transferred through these mechanisms, hence, contributing to the less effectiveness of these mechanisms. However, farmer field schools establishments were considered far from farmers communities and therefore posed a serious challenge in terms of their movement to training centers.

Table 5: Perceived effectiveness of ATTMs

Transfer method	**Mean**	**Standard deviation**	**Rank**
Demonstration	4.45	0.88	1st
Farmer to farmer	4.01	1.10	2nd
Household	2.98	1.19	3rd
Workshop	2.88	1.16	4th
Farmer field schools	2.51	1.02	5th
Mass media (radio)	2.45	1.17	6th
Gifts	2.38	1.27	7th
Exhibitions	2.18	1.16	8th

N=300. *The mean is measured on a 5-point Likert scale. The rank 5 being most effective and 1 being least effective*
Source: Computed from field data, 2019

4.6 Factors influencing adoption of soybean production technologies

Multivariate Probit model (MVP) was used to estimate the maximum likelihood of adoption of soybean production technologies and results are presented in Tables 6 and 7. The model deals with farmer's decisions to adopt multiple soybean production technologies that have a binary outcome. In the MVP model, the outcome variable is binary in nature with the value 1 representing a farmer's decision to adopt improved soybean technologies/practices and 0 for non-adoption. Overall, the model explained or fitted the data significantly well. The Wald chi square test of the hypothesis that the regression coefficients specified in each of the equations are jointly equal to zero was rejected. Additionally, the likelihood ratio test strongly rejected the null hypothesis that the error terms in all the specified equations do not correlate (Table 6).

Table 6 again shows that the estimated correlation coefficients of the dependent variables were statistically significant in all the six paired cases. All the six coefficients were positive and therefore different from zero. Furthermore, the use of the Multivariate probit model was justified in the sense that the results showed the interdependency between the soybean production technologies, suggesting that the probability of adopting a technology depended on whether or not another technology in the pairing was been used or not.

The results from Table 6 further showed that the adoption of inoculants, TSP, certified seeds and pest and disease control measures were all found to complement each other (positive sign). The correlation coefficient between TSP and inoculants was strongly positive, indicating the highest complementarity among the other paired cases (73%). The strong positive nature of the correlation between TSP and inoculants indicated that given the declining rate of soil fertility of most farmlands in northern region, high-cost yield enhancing technologies are not yet substitutes but still complements. This finding is highlighted in the study of Antwi et al. (2016) who used geospatial approach to study the spatial distribution of major soil nutrients in the northern region of Ghana, they found that of 120 locations, 97% of the area was deficient in nitrogen, 72% in phosphorus and only 12% in potassium. The use of multiple soybean technologies also indicated that for many farmers, different constraints were associated with the different soybean production technologies.

The results presented in Table 6 also indicated that the decision of farmers to adopt the different soybean production technologies differ quite marginally, indicating factors that influenced adoption of each of the technologies were also disparate and therefore implying some heterogeneity in the adoption of soybean production technologies.

Table 6: Pairwise correlation from Multivariate probit analysis

Pairwise correlation matrix		
Soybean production technologies	**Corr. Coefficient**	**Standard error**
TSP*Inoculants	0.7832***	0.0632
Certified seeds*Inoculants	0.2130*	0.1332
Pest and disease measures*Inoculants	0.4786***	0.1149
Certified seeds*TSP	0.2118*	0.1265
Pest and disease measures*TSP	0.6202***	0.0926
Pest and disease measures*certified seeds	0.6197***	0.1403
Number of observations (N)	300	
Likelihood ratio test of rho21 = rho31 = rho41 = rho32 = rho42 = rho43 = 0: $Chi^2(6) = 111.824$ Prob > $chi^2 = 0.0000$		

*Note: * and *** indicate significance at 10% and 1% levels respectively.*
Source: Computed from field data, 2019

Results from Table 7 below shows the significance of household specific, farm specific, institutional and technological factors in explaining the probability of soybean farmers' in adopting the various soybean production technologies. A total of 13 explanatory variables were estimated with the MVP model, seven variables were statistically significant in explaining the decision of farmers to adopt inoculants and TSP respectively. While six and nine variables were statistically significant in explaining the probability of adoption of certified seeds and pest and disease control measures respectively.

Results from Table 7 further showed that age had a positive effect on adoption of inoculants, TSP and pest and disease control measures (PDCM). However, age was statistically significant but negatively associated with adoption of certified seeds. This implied that, as farmers grow older, their likelihood of adoption of technologies increases. The finding corroborates with Mignouna (2011), where adoption of IRM seed was found to be higher among older farmers in Western Kenya. Doss (2006) found that in East Africa adoption was high among younger farmers mainly due to their innovativeness and risk taking ability. However, the finding contradicts Bruce et al. (2015), Kibrom et al) and Idrisa et al. (2010).

Education was significant and positively related to adoption of inoculants, TSP and PDCM, similar to findings of Doss (2006), Akudugu et al. (2012), Kibrom (2016), Samuel and Wondaferahu (2015), Diro et al. (2017) and Bruce et al. (2014). However, in sharp contrast, educat. (2016ion was found to be insignificant and negatively associated with adoption of certified seeds, corroborated by Mignouna (2011) who reported a negative and insignificant relationship between education and adoption of IRM seeds in Western Kenya. The finding therefore implied, farmers with some educational background are most likely to adopt soybean production technologies like inoculants, TSP and PDCM. The finding is in line with the *aprior* expectation since some technologies with application specifications may require some ability to read while the application of other technologies are just straight forward.

From the results, distance to input market was significant and negatively related to adoption of all the soybean production productions, corroborating with Teklewold et al. (2013) who found a negative relationship between distance to input shop and adoption of improved varieties in Ethiopia. The finding of this study generally reflects the non-availability of soybean production technologies in local input markets, where farmers are required to travel outside of their communities to access these technologies. With the associated impact of transaction cost and time relating to distance covered to access technologies pose a disincentive to farmer's adoption/implementation of soybean production technologies. A number of adoption studies (Richard, 2015; John et al., 2009; Berihun et al., 2014 & Admassie and Ayele, 2009) points to the fact that, farmers who access technologies from nearby input dealer shops are more likely to adopt agricultural technologies than farmers who travel far distances to access these technologies.

The choice of cropping system generally reflects the extent to which farmers adopt multiple technologies and quantity of such technologies to apply. Contrary to the *aprior* expectation, the result showed that cropping system negatively influenced the adoption of inoculants, TSP and PDCM. This is probably because soybean is not a traditional staple crop, hence the utilization of this crop by farmers is often limited, and to large extent influence the farmers' decision to incorporate soybean crop with other traditional staples.

Demonstration methods plays an important role in popularizing new technologies especially when the trial of technologies are carried out on farmers own field. As expected, demonstration method was statistically significant and positively associated with adoption of TSP and PDCM, consistent with finding of Awuni, Azumah and

Donkoh (2018). This means that farmers who participate in demonstration methods will have a higher chance of adopting the technologies than farmers who do not participate in demonstration methods.

The household extension method, even though regarded as one of the best technology transfer mechanisms is often constrained by inadequate extension agents who spend little time with farmers resulting in failure of the agent to inspire the needed change among farmers. The results showed that household extension method was statistically significant but negatively influenced adoption of all the soybean production technologies. The finding is supported by Awuni et al. (2018). This finding is of particular interest in Ghana where the role of extension agents in agricultural technology transfer is not recognized widely. Logistical and staff constraints have been attributed to the inefficient extension delivery services in Ghana, suggesting therefore that technology transfer via the household method might not necessarily produce the desired impact in terms of adoption of soybean production technologies because of high cost associated with this method (Anandajayasekeram et al., 2008).

Farmers' contact with agricultural extension services when using the various soybean production technologies was generally high. Adoption of technologies is largely influence by the extension agent ability to make frequent contacts with farmers. The results showed that the number of extension visits received by farmers was statistically significant and positively influenced adoption of inoculants and certified seeds, this finding is supported by Mensah-Bonsu et al. (2017), Kibrom et al. (2016) and Varma (2016). This implies, as farmers make more contacts with extension agents, it creates pressure among them to adopt new technologies.

Access to credit in the study area for farming purposes was relatively low since most farmers relied on NGO and VSLA support. Also, it was observed that credit given to farmers was mainly cash. The results presented in Table 7 showed that credit access was significant but negatively influenced adoption of certified seeds and PDCM, diverging from findings of Omodona (2016) and Mensah-Bonsu et al. (2017). However, the finding is in tandem with Gregory and Sewando (2013) who reported a negative relationship between credit access and adoption of quality protein maize in Tanzania. This means that as farmers credit access increases, the adoption of soybean production technologies decreases. This finding is reflective of the fact that farmers who receive cash credit to support in their farming activities usually divert credit to non-farm related activities and therefore do not use credit obtained for the acquisition of technologies needed to enhance production and yields. Motin et al. (2015) observed that diversion of farm credit to non-farm related activities in the Upper West region of Ghana was attributed to the inadequate amounts received by farmers and in other cases credit offered is usually huge for farmers to use for only farming activities. Also, Hamidi and Sabbaghi (2016) reported that families with large household sizes, low levels of education and low income earned from production were potential causes of credit diversion among farmers. This means that any attempt to increase adoption via credit assistance, should consider giving input credit to farmers other than cash credit.

Also, risk associated with soybean technologies showed a positive and significant relationship with adoption of inoculants, TSP and pest and disease control measures, similar to findings of Mignouna (2011), Brick and Visser (2015), Blanca et al. (2018) and Ogada (2009). As discussed in literature, higher risk technologies tend to give higher expected returns (see López, 2009). The finding therefore suggest that the higher the risk associated with technologies the higher the probability of adoption of technologies. Also, young farmers are perceived to be risk takers and innovators who have the ability to try new technologies that are perceived risky (Doss, 2006; Albert and Duffy, 2012 & Simtowe et al., 2009). This finding is motivated by the fact that the average age of respondents in the study was 34 years and therefore considered youthful, meaning that they are more likely to adopt riskier technologies.

The cost of technology was found to be statistically significant and negatively associated with adoption of certified seeds and pest and disease control measures. This is similar to finding of Imoru and Ayamga (2015). This is also consistent with *aprior* expectation of a negative relationship with adoption of soybean technologies. This means that as cost increases, the probability of adoption of some soybean production technologies decreases.

Table 7: Estimates of Multivariate Probit regression

Variable	Inoculants	TSP	Certified seeds	Pest and disease ctrl
Soybean project beneficiary	0.2440	0.1921	0.2685	0.2329
	(0.1966)	(0.1974)	(0.2237)	(0.1947)
Age	0.0168*	0.0308**	-0.0184*	0.0541***
	(0.0106)	(0.0099)	(0.0107)	(0.0097)
Education	0.0626**	0.0382*	-0.0071	0.0695**
	(0.0242)	(0.0239)	(0.0277)	(0.0238)
HH size	0.0193	-0.0241	-0.0027	-0.0207
	(0.0292)	(0.0284)	(0.0340)	(0.0279)
Distance	-0.2917***	-0.376***	-0.0984**	-0.2831***
	(0.0446)	(0.0445)	(0.0434)	(0.0380)
Cropping system	-0.6797***	-0.4349**	0.3539	-0.3580*
	(0.2015)	(0.1971)	(0.2607)	(0.1963)
Demos	0.3336	0.5365**	0.1380	0.3923*
	(0.2543)	(0.2526)	(0.3000)	(0.2567)
Household ext. method	-0.3249*	-0.4347**	-0.4811**	-0.6659**
	(0.2057)	(0.2063)	(0.2393)	(0.2246)
Extension visits	0.1080**	-0.0271	0.1011*	0.0304
	(0.0510)	(0.0452)	(0.0602)	(0.0447)
Credit	0.2858	-0.1386	-0.3474*	-0.4013*
	(0.2041)	(0.1943)	(0.2378)	(0.1937)
FBO	0.1514	-0.0629	-0.0348	-0.1938
	(0.2147)	(0.2091)	(0.2426)	(0.1986)
Risk	0.2353**	0.2016*	-0.1065	0.2409*
	(0.1190)	(0.1257)	(0.1293)	(0.1322)

Cost	0.2863	-0.0188	-0.4097*	-1.0358***
	(0.2021)	(0.1985)	(0.2362)	(0.2115)
Constant	-0.477	0.9688**	2.4422***	0.0588
	(0.4933)	(0.4747)	(0.5466)	(0.4610)

*Note: *, ** and *** indicate significance at 10%, 5% and 1% levels respectively. Standards errors in parenthesis*

Source: computed from field data, 2019

4.7 Factors influencing intensity of adoption of soybean production technologies

The study identified four key soybean production technologies that are important to achieving sustainable higher yields. Targeted farmers were required to indicate the soybean production practices they adopted and have continuously used for the past three years. The dependent variable was then modelled around the number of technologies adopted by farmers. The intensity of adoption of soybean production practices is presented in Table 8.

From Table 8, results show that 10.33% of farmers did not adopt any of the soybean production technologies and therefore recorded a zero count, whereas 19.67% of farmers adopted three technologies. Also, about 13.33% of farmers adopted two soybean production technologies while 37% (majority) of farmers adopted only one soybean production technology. However, all the four soybean production technologies were adopted by about 19.67% of the sampled farmers. The mean adoption intensity was about 2, with a variance of about 1.8.

The various soybean production technologies adopted by farmers is shown in Table 9. The results show that majority (86.67%) of farmers adopted certified seeds, while 32.33% of farmers adopted inoculants. Also, Triple Super Phosphate was adopted by 41.67% of farmers with 40.67% of the farmers also adopting pest and disease control measures that improve production.

Table 8: Intensity of adoption of SPTs

Intensity of soybean production technologies	Freq.	Percent
0	31	10.33
1	111	37.00
2	40	13.33
3	59	19.67
4	59	19.67
Mean adoption	**2.01**	
Variance	**1.77**	

Source: Computed from field data, 2019

Table 9: Soybean production technologies

Soybean production technology	Freq. (No. of farmers who adopted)	Percent
Inoculants	97	32.33
Triple Super Phosphate	125	41.67
Certified seeds	260	86.67
Pest and disease control	122	40.67

N=300

Source: Computed from field data, 2019

In Table 10, the results of the factors that influence the adoption intensity of soybean production technologies are presented. Model diagnostic tests were performed to determine the appropriate functional model to use. The parametric estimates across the two models are quite uniform (see Table 10). A few diagnostic tests performed revealed the existence of few zero counts (under dispersion). A goodness of fit test using the log-likelihood value was used to compare the count data models, i.e. Generalized Poisson (GP) and Standard Poisson (SP) model.

The log-likelihood values indicate the GP model to have the largest value, implying that the generalized Poisson model fit the data significantly well. The test of hypothesis of adequacy of the generalized Poisson over the standard Poisson shows that the dispersion parameter is less than zero (-0.30), suggesting evidence of significant under dispersion of the data. Therefore, the null hypothesis of equi-dispersion is rejected. Also, a test of AIC and BIC revealed the generalized Poisson model had marginally lower values than the standard Poisson model, providing significant justification for the choice of the generalized Poisson model over the other count data model to estimate the intensity of adoption of soybean production technologies. The proceeding discussion of the results in Table 10 is therefore based on estimates of the generalized Poisson regression model.

About thirteen variables were estimated with the generalized Poisson regression model, ten (10) variables were statistically significant in explaining the intensity of adoption of soybean production technologies. Age, education, extension contacts, mass media (radio) and risk associated with technologies are statistically significant and positively influence the number of soybean technologies adopted farmers in northern Ghana. Also, farmers experience in soybean production, cropping system used by farmers, distance from farm to input dealer market, exposure to household extension method and access to production credit are significant but bear inverse relationship with the number of soybean technologies adopted.

The results from Table 10 imply that as a farmer's age increases, it is assumed that they become more responsible for themselves and their immediate family members. As a result, they tend to have a strong desire to adopt a combination of technologies that can enhance their yields to improve their incomes to be able to take care of their families. This finding is in tandem with the *apriori* expectation of positive relationship and corroborates with Fitsum (2016) and Mustapha et al. (2012). However, the result diverges from Awuni et al. (2018) and Pokhrel et al. (2018) who reported an insignificant effect of age on intensity of adoption of improved rice technologies and irrigation technologies respectively. Nkegbe and Shankar (2014) also found a negative and insignificant relationship between age and intensity of adoption of soil and water conservation practices. The plausible explanation to these divergences could be as a result of differences in technologies measured. Some technologies require some experience in their use while others may require some amount of physical strength in their application.

Education explained as the number of years spent in formal schooling was also significant and positively impacted on adoption intensity. This suggest that as farmers spend more years in school, their understanding of the benefits of applying sustainable techniques in production improves. Awuni et al. (2018) made a diverging finding where education had an insignificant but a positive relationship with intensity of adoption of improved rice production technologies by rice farmers in northern Ghana. However, the findings of Dhraief et al. (2018), Charles et al. (2017), and Paxton et al. (2011) support *apriori* expectation of a positive relationship of age with intensity of adoption of soybean production technologies.

Also, farmers contact with extension agents during soybean production had a positive impact on the intensity of adoption, a result that highlights the important role extension services play in disseminating improved agricultural technologies. The finding is consistent with that of Awuni et al. (2018) who reported extension contacts to have a positive and significant impact on intensity of adoption, and that of Nkegbe and Shankar (2014), also in northern Ghana, who reported a positive effect of extension contacts on intensity of adoption of soil and water conservation practices. In a similar study, Danso-Abbeam et al. (2017) also reported a significant and positive effect of extension contacts on the adoption of improved maize variety in northern Ghana.

Contrary to findings of Awuni et al. (2018), mass media through radio had a significant and positive effect on the number of technologies adopted by farmers in the study area. This means that transfer of technologies via mass media can reach and impact more farmers in adopting soybean production technologies. The wider audience reached using radio cannot be underestimated. Transferring technologies via this platform has been found by many researchers to be very effective in influencing adoption of many agricultural technologies (Aker, 2011 and Ali, 2011). For instance, Azumah et al. (2018) observed that the use of radio was perceived to be effective among other media platforms in terms of its influence on adoption of improved technologies among rice farmers in upper east and northern regions of Ghana.

Farmer experience in soybean production was anticipated to have a positive effect on intensity of adoption of soybean production technologies. Experienced farmers are thought to have accumulated technical know-how over time and therefore are positioned better to adopt technologies. A good count of empirical studies has found a positive effect of farming experience on adoption of agricultural technologies (Awuni et al., 2018; Pedzisa et al., 2015; Mazvimavi and Twomlow, 2009). Experience in farming (in this study) was found to have a significant but inverse relationship with intensity of adoption, corroborating with Kunzekwegutaa et al. (2017). This finding highlights the fact that many experienced farmers feel rather comfortable and secured with conventional technologies which they have practiced over time.

Similarly, distance covered from farm to input market is significant and negatively related to adoption intensity of soybean production technologies in the study area. This means that if distance to input dealer shop increases by one kilometer, the intensity of adoption of soybean production technologies decreases by 12%. This is consistent with *aprior* expectation of negative relationship with adoption intensity. This is also consistent with the finding of Berihun et al. (2014) and Tefera et al. (2016). This therefore suggest that any efforts aimed at increasing adoption intensity of technologies must ensure easy access to these technologies by bringing input dealers closer to farmers.

As reported by Awuni et al. (2018), household extension method enables farmers to have close contact with extension agents by clarifying techniques that are not well understood. However, the high ratio of extension agent to farmer in Ghana as reported by GSS (2014) presents a great challenge in terms of the capacity of the agent to visit individual households to influence change. Household extension method is negative and a significant determinant of intensity of adoption of soybean production technologies in the Chereponi District. This means that the household extension method contributed less in terms of the number of technologies adopted by soybean farmers. This finding is in tandem with Awuni et al. (2018), who reported household extension method had negative impact the intensity of adoption of improved rice production technologies in northern Ghana.

Access to credit is considered as one of the most important steps in dealing with the constraints associated with adoption of agricultural technologies (Doss, 2003). However, results from Table 10 show a negative effect of credit on intensity of adoption of improved technologies. This implied that, as farmers access to credit increases, their desire to venture into other non-farm profit making enterprises increases rather than investing same in soybean production. The reason could be ascribed to the risky nature of farm enterprises in northern Ghana which is prone to climatic risks of unpredicted rainfall and temperature patterns. Also, traditionally soybean is not a staple food crop and therefore the utilization of the crop is often low in the study area. Farmers will therefore either invest more of acquired credit in the production of staple crops that improve their food security status or other non-farm activities that will stabilize their incomes. This observation is consistent with Motin et al. (2015) and Hamidi and Sabbaghi (2016) who reported diversion of farm credit to non-farm activities by farmers. The negative effect of credit diverges from that of Mensah-Bonsu *et al.* (2017) and Ullah *et al*. (2018) who reported significant and positive impact of credit on intensity of adoption of land conservation practices in Ghana and improved peach cultivars in Pakistan respectively.

Table 10: Factors that influence the adoption intensity of SPTs

Model	**Generalized Poisson**			**Standard Poisson**		
Variable	Coef.	Std.Err	dy/dx	Coef.	Std.Err	dy/dx
Soya project beneficiary	0.050	0.064	0.092	0.079	0.087	0.145
Age	0.037**	0.015	0.069	0.032**	0.019	0.059
Education	0.023**	0.008	0.043	0.015*	0.011	0.020
Experience	-0.029**	0.015	-0.05	-0.025	0.019	-0.046
Income	8.020	0.000	0.000	8.900	0.000	0.000
Distance to input market	-0.12***	0.011	-0.22	-0.13***	0.016	-0.245
Cropping system	-0.185**	0.066	-0.34	-0.174**	0.088	-0.322
Demo	0.140	0.091	0.247	0.115	0.125	0.202
Household ext. method	-0.262**	0.084	-0.45	-0.286**	0.113	-0.488
Extension visits	0.030**	0.016	0.056	0.035**	0.021	0.063
Credit access	-0.112**	0.066	-0.20	-0.153**	0.092	-0.275
Mass media (radio)	0.200**	0.096	0.397	0.279**	0.124	0.564
Risky	0.113**	0.044	0.208	0.088	0.056	0.161
Constant	0.367	0.349		0.578	0.454	
LR Chi^2 (13)	161.39			118.73		

Prob>Chi^2	0.0000	0.0000
Pseudo R^2	0.1611	0.1182
Log likelihood	-420.125	-442.907
AIC	870.25	913.81
BIC	925.80	965.66
Dispersion	-0.30	
Likelihood-ratio test of delta=0: chi^2(1) = 45.56 Prob>=chi^2 = 0.0000		

Note: *, ** and *** indicate significance at 10%, 5% and 1% levels respectively.
Source: Computed from field data, 2019

4.8 Effect of Agricultural Technology Transfer Mechanisms on Adoption and Yield

4.8.1 Determinants of intensity of exposure to ATTMs

The results in Table 11 presents estimates for the conditional recursive mixed process model (CRMP). The antahrho reported here (Table 11) basically measures selection bias. The atanhrho values of equations 26a*26b, 26a*26c and 26b*26c were all significant at 10%, 5% and 1% respectively, implying correlations between the error terms of the three equations. The negative values of atanhrho_12, antahrho_13 and antahrho_23 shows that there might be some omitted variables that affects both the outcome variables and intensity exposure to agricultural technology transfer mechanisms (ATTMs) negatively. A positive sign of atanhrho can be said in the reverse.

Also, the results shows that the likelihood test ratio and its associated p-value strongly rejects the null hypothesis of no endogeneity. This means that individual estimation of the models would have probably led to biased estimates. Therefore, the CRMP estimates are relatively more efficient and reliable.

Intensity of exposure of farmers to ATTMs can be influenced by institutional, household and farm level specific factors. The results in Table 11 presents factors that determine intensity of exposure to ATTMs. About six factors were analyzed, four factors were significant in explaining farmer's intensity of exposure to ATTMs. Education exhibited a significant and positive influence on intensity of exposure to ATTMs. This is similar to finding of Pan (2014) that Chinese rice farmers who spend considerably more years in formal school participated more in agricultural extension education than farmers with less years spent in formal schooling.

Similarly, cropping system was negatively related to intensity of exposure to ATTMs and significant at 1%. This implied that, farmers who practice other cropping systems instead of mono-cropping of soybean may feel reluctant to participate in ATTMs since trainings may be entirely focused on soybean production. This result deviates from finding of Pan (2014), who found a positive and significant relationship between cropping system and participation in agriculture extension education in China.

The positive effect of FBO on intensity of exposure to ATTMs suggests that once farmers are organized into groups, the probability of been engaged by technology dissemination institutions increases and therefore increases their exposure to ATTMs. Another important observation was the negative and insignificant relationship between extension visits and intensity of exposure to agricultural technology transfer mechanisms. The finding highlights the fact that farmers who receive extension visits from MoFA extension agents tend to participate less in technology transfer mechanisms used by other institutions such as NGOs, research institutions and donor supported projects.

4.8.2 Effects of ATTMs on adoption intensity of SPTs

Table 11 also presents results of the ordered probit used to determine the effect of intensity of exposure to ATTMs on intensity of adoption of soybean production technologies (SPTs) in the Chereponi district. As stated earlier, three categories were used to explain the intensity of exposure to ATTMs i.e. 0, 1 and 2 for low, moderately and high intensity of exposure to ATTMs respectively. Nine variables out 14 explanatory variables included in the model were statistically significant in explaining intensity of adoption of SPTs.

Moderate and high intensity of exposure to ATTMs were both statistically significant at 1% and positively impacted farmers intensity of adoption of SPTs. This implied that, farmer's participation in more than two ATTMs increases their probability of adopting more SPTs than those who participated less. This highlights the importance of participating in different ATTMs since each mechanism comes with an entirely different set of technologies.

Again, there was a positive and significant relationship between soybean project beneficiary variable and intensity of adoption of SPTs. This implied that, farmers who were beneficiaries or have ever benefited from any soybean project have a higher likelihood of adoption of more of the SPTs than non-beneficiary farmers.

Similarly, farmer experience was significant and had a positive effect on adoption intensity of soybean technologies. This result reflect the important role experienced farmers play in terms of their decision to adopt a combination of technologies. It is often assumed that farmers with many years of production experience are exposed to a wide range of technologies coupled with their perception of technologies and accumulated wealth which gives them an upper edge to make decisive choices that brings maximum returns. This result is in line with findings of Amusa and Simonyan (2017), Meijer et al. (2015) and Awuni et al. (2018).

There was a positive relationship between Income earned from soybean production and intensity of adoption of SPTs. The result implied that, soybean farmers who earn more income from soybean production have a higher probability of adopting more SPTs. Distance covered by farmer to input market was significant and negatively influenced intensity of adoption of SPTs. This implied that, when input dealer shop are situated far from farmer's location it limits their ability to readily access technologies for use and therefore may likely influence the number of technologies they adopt. This finding is consistent with *aprior* expectation of a negative relationship and that of Berihun et al. (2014).

The result in Table 11 showed a negative relationship between cropping system and intensity of adoption of SPTs. The implication of this finding is that when soybean farmers use other cropping systems (i.e. either intercropping or mixed cropping) instead mono-cropping their likelihood of adopting more SPTs will be low.

The coefficient of extension visit was significant at 5% and positively influenced intensity of adoption of soybean technologies. This suggest that farmers who receive more visits from extension agents are better able to clarify and understand technologies transferred to them better and therefore are best placed to adopt more SPTs. It is also observed that farmers with little or unclear knowledge of the effects of technologies on their productivity are reluctant to adopt multiple technologies. This finding is in tandem with Nkegbe and Shankar (2014) and consistent with *aprior* expectation of a positive relationship.

The positive and significant relationship between risk and adoption intensity of SPTs explains the desire of farmers to increase their productivity and yields. Risk has a direct relationship with returns (profit), risky technologies tend to give higher expected returns and therefore farmers with the intent of generating enough income from soybean production often tend to be risk 'lovers' and will adopt technologies that can propel higher yields. This result agrees with Blanca et al. (2018) who found a positive relationship between risk and adoption of agricultural technologies in Mexico and diverges from *aprior* expectation of a negative relationship with intensity of adoption of SPTs.

4.8.3 Effects of SPTs adoption intensity on yields

As expected, moderate and high intensity of adoption were statistically significant at 1% and positively related to soybean yields. This result reveals the complementarity that exist among the soybean production technologies such that adoption of a single technology doesn't really give the desired yields. This implied that, when farmers adopt multiple technologies the probability of getting increased yields is high. This finding is conforms with Ogada and Nyangena (2015), who observed that adoption of technologies either complete or partial resulted in higher maize yields in Kenya, suggesting that improved technologies contributed significantly to increasing yields.

The coefficient of education was significant and negatively influenced soybean yields. This implied that, as farmers' educational level increases, the probability of committing time and resources on soybean production decreases. This result can further be explained by the general lack of interest by educated people in farming as they find opportunities in the formal sector more lucrative than being engaged in farming in the rural areas. This result contrast finding of Urassa (2015) who found a significant and positive effect of education on yields in Tanzania.

Similarly, a negative relationship between farmer experience and soybean yields was found (significant at 1% level). This result came as a surprise because it was expected that as farmers gain more experience in soybean production, they tend to learn lessons from their previous productions and then make improvements in their next productions. Besides it is expected experienced farmers are better able blend a set of techniques/practices that could improve yields than farmers with less experience in soybean production. This implied that, accumulated wealth of experience does not necessarily reflect in higher yields unless the right production technologies are adopted.

Contrary to *aprior* expectation, distance to input market was positive and significantly impacted soybean yields. A plausible explanation to this result is that distance does not really matter provided the technologies will translate to higher yields. This implied that, effective technologies that increases productivity and yield can propel farmers to travel at length to access them. This result disagrees with Kamara (2004), who observed a negative impact of distance to input market on yield in Kenya.

Generally, the type of cropping system a farmer practices determines the quantity of harvest of a particular crop. In this study, cropping system was significant at 1% and positively impacted soybean yields. This implied that, farmers who practice mono-cropping system were more likely to have higher yields than farmers who practice other cropping systems. This is similar to observation of Kandeyang et al. (2010) as they found sole okro production (mono-crop) resulted in maximum yield due to efficient utilization of nutrients, space and sunlight.

Extension visit variable negatively influenced soybean yields of farmers in the study area at a 5% significance level. This means that frequent extension visits contributed less to increasing yields of farmers. This result contradicts finding of Minai et al. (2014), who reports of significant and positive effect of extension on coffee yields in Kenya. They argue that frequent extension visits enables farmers to do what needs to be done which increases yields. Also, Nyagaka et al. (2010) observed that when extension agents contact farmers frequently, they are able to provide information on new techniques and resource availability that support production.

The result in Table 11 also showed that quantity of certified seed used had a significant and positive effect on soybean yields. This result conforms with other findings (Bogdanović et al., 2015; Zaimoglu et al., 2004 and Clayton et al., 2009) that certified seeds do not only ensure high germination rate, disease free etc. but gives yields that out-performs farmers own seeds or those sourced from other places other than certified seed outlets.

Insect pest is one of the most important constraint in legume crop production (Karungi et al., 2000). Insecticide application was significant and exerted a positive effect on soybean yields. This finding corroborates with Dzemo et al., (2010) and Ndiso et al. (2017) of significant yield increases due to application of insecticide.

Table 11: Estimates of CRMP framework

Variable	**CRMP estimation**	
Intensity of exposure to ATTMs	**Coefficient**	**Std. Err**
Education	0.0490***	0.0187
Farm size	-0.1824	0.1266
Soybean project beneficiary	0.0283	0.1502
Cropping system	-0.4855***	0.1576
Extension visits	-0.0173	0.0376
FBO	0.2989**	0.1538
Adoption intensity of SPTs		
Moderate exposure to ATTMs	0.6975***	0.2612
High exposure to ATTMs	1.7172***	0.5079
Soybean project beneficiary	0.2847**	0.1491
Sex	-0.0994	0.1104
Education	0.0218	0.0198
HH size	-0.0001	0.0170
Experience	0.0345***	0.0073
Income	0.0001***	0.0000
Distance to input market	-0.2194***	0.0274
Cropping system	-0.3656**	0.1656
Extension visits	0.0781**	0.0365
Credit access	-0.1210	0.1503

FBO	-0.0729	0.1606
Risk	0.1192**	0.0612
Soybean yields		
Moderate adoption intensity	0.7096***	0.0988
High adoption intensity	1.1224***	0.1843
Certified seed	-0.0302*	0.0167
TSP	0.0023	0.0015
Inoculant	-0.0003	0.0005
Weedicide	0.0254	0.0308
Insecticide	0.1539***	0.0295
Labour	-0.0069	0.0171
Soybean project beneficiary	-0.0421	0.0642
Education	-0.0204**	0.0082
Experience	-0.0154***	0.0034
Distance to input market	0.0889***	0.0146
Cropping system	0.2957***	0.0699
Extension visits	-0.0437**	0.0173
Credit access	0.0330	0.0699
FBO	-0.0369	0.0718
Constant	0.0722	0.1986
Insig_3	**-0.6920*** **	**0.0825**
atanhrho_12	-0.3616*	0.2018
atanhrho_13	-0.1756**	0.0771
atanhrho_23	-1.1050***	0.2475
Sig_3	**0.5005**	**0.0413**
rho_12	-0.3466	0.1776
rho_13	-0.1738	0.0748
rho_23	-0.8022	0.0882
CMP model		
LR χ^2 =260.62;P> χ^2 =0.000; Log likelihood = -566.00		

Note: *, ** and *** indicate significance at 10%, 5% and 1% levels respectively.
Source: Computed from field data, 2019

4.9 Constraints to Adoption of Soybean Production Technologies

A number of constraints associated with the adoption of agricultural technologies have been identified by many researchers (Azumah et al., 2019; Omodona, 2016 & Dogbe et al., 2013). This section presents the constraints pertaining to the adoption of soybean production technologies. A number of soybean production technologies have been discussed in literature (Mohammed et al., 2016; Mbanya, 2011 and Dogbe et al., 2013), however three technologies important to this study were extracted to give an understanding of the extent to which the identified constraints affect adoption. The extracted technologies are inoculants, Triple Super Phosphate and certified seeds. The result from Table 12 showed that non-availability, limited amounts and high cost of soybean production technologies are the major constraints that affect adoption of in the study area. The following discussion put into context the constraints relative to each of the SPTs.

4.9.1 Adoption Constraints for inoculants

An assessment of constraints to adoption of inoculant technology revealed that non-availability of inoculants at the local input market dominated (63%) the list of constraints to adoption. This finding is consistent with Adraki et al. (2018), among other constraints identified by the authors, unavailability of inoculant in community open market in northern region was reported as a major challenge. The result is not surprising because many input dealers are unable to keep inoculants because of the storage condition it requires (i.e. effective when stored under cooler conditions). Also, inoculant sales have been linked to research institutions like the IITA and the SARI all based in Tamale. This means that farmers who desire to use inoculants will have to travel to Tamale to access them. This brings about issues of transaction cost and time spent to access the technology. Also, soybean farmers (31%) indicated the limited availability of inoculants at their local communities inhibits their adoption of inoculants. This means that farmers should be linked to input markets to enable dealers to know the demand for the technology and therefore supply to farmers at the right time and in the right quantities.

Contrary to initial expectation, inadequate labour was perceived by 1% of farmers as constraint affecting adoption of inoculants, implying that farmer's inability to purchase or access inoculants meant that labour needs for inoculant application was not peculiar task.

4.9.2 Adoption Constraints for Triple Super Phosphate

The results in Table 12 below shows about 71% of farmers consider TSP as expensive and therefore inhibits the adoption of the technology, similar to findings of Jahiruddin et al. (2010) and Agada (2014). It was observed that TSP demand in Ghana is met by import. Importation of TSP fertilizer is dominated by the private sector who control the distribution, sale and pricing, they create a monopolistic market and dictate the price of the fertilizer. This phenomenon presents a great difficulty to farmers especially smallholders who usually have minimal capacity to afford fertilizer. This means that any intervention that seeks to promote the adoption or use of TSP fertilizer should be accompanied by some form of subsidy or price reduction to enable farmers to purchase the fertilizer at a reasonable price.

About 36% of farmers indicated TSP fertilizer is not available to serve their production needs. This finding may be attributed to the centralized sale of TSP fertilizer and the fact that government subsidy for TSP is non-existent, hence a disincentive to input dealers.

4.9.3 Adoption Constraints for Certified Seeds

Table 12 also shows the constraints that affect adoption of certified seeds by soybean farmers. Among all the seven constraints that were identified, high cost of certified seed (proxies as technology is expensive) was reported by 60% of soybean farmers. This result is contrary to finding of Owusu (2016), who reports high cost of improved maize seeds was ranked by farmers in the Kwahu Afram Plains as the least constraint that hinders adoption of maize technology. The finding of this study explains the potential implication on seeding rates and the fact that many farmers may be applying below the recommended rate of 37.5kg/ha. This observation is similar to finding of Mbanya

(2011) who reports of low adoption of certified seeds among soybean farmers in northern region. Mbanya observed that about 33% of farmers obtained seeds from certified seed agents, while majority of farmers acquired their seeds from friends, local markets and their own storage. Similarly, a report by USAID RFA- FTF Ghana ATT project (2016) indicates that the use of certified soybean seeds in northern Ghana was limited with just 4.6% of the area covered by certified soybean seeds. This shows that more efforts need to be made to increase farmers' usage of certified soybean seeds by tackling associated constraints.

Table 12: Constraints to adoption of SPTs

Constraint	Inoculants		TSP		Certified seeds	
	Mean	**Std. Dev**	**Mean**	**Std. Dev**	**Mean**	**Std. Dev**
Technology not available locally	0.636	0.481	0.366	0.482	0.116	0.321
Inadequate amounts of technology	0.316	0.465	0.263	0.441	0.360	0.480
Technology is expensive	0.453	0.498	0.710	0.454	0.600	0.490
Inadequate labour	0.010	0.099	0.020	0.140	0.006	0.081
Inadequate credit access	0.053	0.225	0.150	0.441	0.213	0.410
Technology is too complex	0.033	0.179	0.020	0.140	0.006	0.081
Technology is risky	0.020	0.140	0.046	0.211	0.016	0.128

N=300

Source: Computed from field data, 2019

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND POLICY RECOMMENDATIONS

5.1 Introduction

The summary of findings, conclusions, policy recommendations as well as suggestions for future studies are presented in four sections under this chapter. Summary of the key findings of the study are reported in section 5.2. Sections 5.3, 5.4 and 5.5 entails the conclusions, policy recommendations and suggestions for future studies respectively.

5.2 Summary

This study assesses the effectiveness of adoption and yield effects of agricultural technology transfer mechanisms among soybean farmers in Chereponi District. Semi-structured questionnaires were administered to three hundred (300) soybean farmers using a multi-stage sampling technique.

Analysis of the study objectives were done using both descriptive statistics and econometric models. The perceived effectiveness of agricultural technology transfer mechanisms and constraints to adoption of soybean technologies were analyzed descriptively using means and standard deviations to explain the distributions. The multivariate probit and generalized Poisson regression models were used to analyze factors that determine adoption of multiple soybean production technologies and intensity of adoption of soybean technologies respectively. Lastly, the effect of intensity of exposure to agricultural technology transfer mechanisms on adoption intensity of soybean production technologies and soybean yields was analyzed using the CRMP framework by estimating two ordered probit and a multiple linear regression models.

The study identified eight (8) agricultural technology transfer mechanisms used by MoFA, NGOs and donor supported projects to transfer agricultural technologies to soybean farmers in the study area. Two out of these agricultural technology transfer mechanisms; demonstration and farmer to farmer methods were perceived by soybean farmers as most effective in influencing adoption of soybean production technologies. Also, high cost of technology (proxies as technology is expensive) was a major constraint to adoption of TSP and certified seeds in the study area. Non-availability of technology was a major constraint associated with adoption of inoculants.

In this study, four broad factors were identified as determinants of adoption of soybean production technologies and this entailed household, farm level, institutional and technological specific factors. The findings of the study showed that intensity of exposure to agricultural technology transfer mechanisms had significant effect on intensity of adoption of soybean production technologies.

In the MVP model, age of farmer, distance to input market and household extension method had significant effect on adoption of all four soybean production technologies (inoculants, TSP, certified seeds and pest and disease control measures). Educational level, cropping system and risky nature of soybean technologies had significant influence on adoption of three soybean technologies (inoculants, TSP and pest and disease control measures. Demonstration method had significant influence on adoption of only TSP and pest and disease control measures; extension visits significantly influenced only the adoption of inoculants and certified seeds; while access to credit and cost of technology had significant effect on the adoption of certified seeds and pest and disease control measures.

Also, in the generalized Poisson model, age of farmer, educational level, distance to input market, cropping system, mass media method, household extension method, extension visits, access to credit, risky nature of technologies and farming experience significantly influence intensity of adoption of soybean production technologies.

Furthermore, the results of the joint estimation (CRMP) revealed that educational level, cropping system, membership of FBO and farm size were significant determinants of intensity of exposure to agricultural technology transfer mechanisms. Also, moderate and high exposure to agricultural technology transfer mechanisms, farming experience, distance to input market, extension visits and risky nature of soybean production technologies had significant influence on intensity of adoption of soybean production technologies. yields of soybean was significantly determined by moderate and high intensity of adoption, educational level, farming experience, income, distance to input market, cropping system, extension visits, certified seeds and quantity of insecticide.

5.3 Conclusions

Among the various agricultural technology transfer mechanisms, demonstration and farmer to farmer methods were found to be most effective in influencing adoption of soybean production technologies. This could be attributed to the unrestrictive nature of these methods, which generally accommodates as many farmers as possible. It also highlights the effectiveness of farmer to farmer and demonstration methods in popularizing technologies among farmers.

MoFA extension agents were the main source through which soybean farmers acquired information on soybean production technologies. This highlights the importance of public extension services among the soybean farmers.

Among the various factors considered in the multivariate probit model, adoption of all soybean production technologies are likely to be influenced by age of farmer, distance to input market and household extension method.

Age of farmer, educational level, extension visits, mass media method and risky nature of technologies will increase intensity of adoption of soybean production technologies.

Among various factors examined in the CRMP framework, educational level and membership of FBO were likely to significantly increase farmer exposure intensity to ATTMs. Also, effect on intensity of adoption will be influenced by farming experience, extension visits, risk, soybean project beneficiary and intensity of exposure to ATTMs (moderate and high). Soybean yields was influenced by distance to input market, cropping system, extension visits, certified seeds use, insecticide use, moderate and high intensity of adoption of SPTs.

Adoption of TSP and certified seeds are likely to be constrained by high cost of technologies. Non-availability of technology is identified as a major constraint to adoption of inoculants. This means that if these constraints are effectively addressed, adoption of soybean technologies will be higher.

5.4 Recommendations

Information delivery efforts by MoFA extension agents on soybean production technologies should be complemented with the use of mass media method (e.g. radio, TV and mobile phones) since this method can be an effective information delivery tool in terms of reaching larger audience.

Stakeholders in the soybean sub-sector should focus on using demonstration and farmer to farmer methods in the dissemination of SPTs. Agricultural extension agents should play a strong supervisory role in farmer to farmer methods of disseminating SPTs so as to avoid distortion of information.

Access to education, agricultural extension services and mass media method should be improved in order to promote rapid adoption of SPTs among farmers.

The use of multiple agricultural technology transfer mechanisms will be relevant in increasing adoption intensity of soybean production technologies. Farmers should therefore be encouraged to participate in different agricultural technology transfer mechanisms. Also, farmers should adopt multiple soybean production technologies to increase their yields.

To tackle the constraints of high cost and non-availability of technologies, the study recommends inoculants and TSP should be included in subsidized input packages under the government Planting for Food and Jobs initiative.

5.5 Recommendations for Future Studies

This study looked at a combination of soybean production technologies that are adopted by farmers in Chereponi district in the northern region. Budget and time constraints limited the focus of the study to a single legume crop i.e. Soybean. Results from the MVP revealed high complementarity between inoculants and triple superphosphate. This finding is consistent with numerous experimental trials conducted by Savanah Agricultural Research Institute and International Institute of Tropical Agriculture both on-station and off-station with results pointing to potential higher yields and incomes when a combination of inoculants and TSP are adopted by farmers. In fact, USAID RFA- FTF Ghana ATT project (2016) revealed that when farmers adopt a combination of these technologies, their yields could increase by 76% and incomes by 67.7%.

Therefore, future studies should examine the impact of adoption of inoculant/TSP combination on legume grain productivity and income on wider areas in order to obtain empirical evidence of the impact of these technologies.

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APPENDICES

Appendix 1: Research Questionnaire

Type of farmer: 1=Beneficiary of soya project [ ] 2 = Non-beneficiary of soya project [ ]

1. Name of respondent……………………………………………
2. Name of community…………………………………………………..

SECTION A: HOUSEHOLD AND FARM SPECIFIC FACTORS THAT INFLUENCE ADOPTION OF SOYABEAN TECHNOLOGIES

Household Specific Factors

1. Sex: 1=Male [ ] 0= Female [ ]
2. Marital status: 1=Married [ ] 2= Single [ ] 3= Divorced [ ] 4= Widowed [ ]
3. Educational level: 1= No education [ ] 2= Primary [ ] 3=JHS/Middle school [ ] 4= SHS [ ] 5= Tertiary [ ] 6= others (please specify)……………………………….
4. Household size…………………..
5. What is your main occupation: 1= Farming [ ] 2= Others [ ]
6. Which other occupations are you engaged in? 1= None [ ] 2= Livestock rearing/sale [ ] 3= Trading [ ] 4= Fishing [ ] 5= Artisan [ ] 6=Employed by government [ ] 7= Employed by private company [ ] 8= Others (please specify)……………………………………

Farm Specific Factors

1. Farming experience………..years
2. Total farm size used for soyabean production……………..acres
3. For what purpose do you cultivate soyabean? 1= Home consumption [ ] 2= Market [ ] 3= Home consumption and market [ ] 4= others (please specify)……………………………
4. Which of the following is your soyabean farm prone to? 1= Floods [ ] 2= Drought [ ] 4=bush fires [ ] 5= Animal destruction [ ] 6= others (please specify)…………………….
5. Distance of farm to input dealer: ………………………………. Km
6. Distance of farm to house…………………………………Km
7. Which cropping system do you use?1= Mono cropping [ ] 2= Intercropping with cereals [ ] 3= Mixed cropping [ ]
8. What are your reasons for choosing a particular cropping system? ………………………………………………………………………………………..

SECTION B: AGRICULTURE TECHNOLOGY TRANSFER METHODS AND THEIR PERCEIVED EFFECTIVENESS

1. What is/are your source (s) of information on improved agricultural technologies? ***Choose as many as possible***
   1= [ ] Colleague farmers [ ] 2= Researchers [ ] 3= NGOs [ ] 4= Media [ ] 5= MoFA extension agents 6= [ ] Input dealers [ ] 7= others

2. What is/are the agricultural technology transfer methods you are exposed to? ***Choose as many as possible***
   1= [ ] farmer to farmer [ ] 2= Demonstrations [ ] 3= household [ ] 4= Workshops [ ] 5= Mass media [ ] 6= Gifts [ ] 7= Farmer field schools 8= [ ] Exhibitions [ ]
3. What is the effectiveness of the various technology transfer methods in terms of influencing your adoption of improved soya production techniques? *(Choose from a scale of 5-1). 5 being very effective and 1 being least effective.*

Transfer methods	**Perceive effectiveness**				
	5	**4**	**3**	**2**	**1**
farmer to farmer					
Demonstrations					
Household					
Workshops					
Mass media (radio, TV)					
Gifts					
Farmer field schools					
Exhibitions					

4. Challenges associated with any of the above technology transfer methods:
   ………………………………………………………………………………...

SECTION B: EXTENT OF ADOPTION OF IMPROVED SOYA TECHNOLOGIES BY FARMERS

Factors determining adoption of improved soya technologies

Institutional factors

1. Do you have access to extension services when using soya technologies on your farm?
   1= Yes [ ]   0= No [ ]
2. If your answer is yes, for the question #1, how often did the extension agent contact you per season?..
   ..
3. If yes for Q#1, how can the extension agent help you for the effective application of technology?
   1= Practical assistance at farm [ ] 2= Demonstration [ ] 3= Training at workshops [ ]
   4= other (please specify)………………………………………..
4. If yes for Q#1, how do you evaluate the assistance given by the extension agent for the successful adoption of technologies (*certified seed, inoculants, TSP, crop management techniques etc*)?

   1= Excellent [ ] 2= Very good [ ] 3= Good [ ] 4= Poor [ ] 5= other source (please specify)..
5. Do you have access to farm credit? 1= Yes [ ] 0= No[ ]
6. If Yes for Q#5, where do you source your farm credit from?

1= Commercial bank [ ] 2= Savings and loans institutions [ ] 3=Village savings and loans [ ] 4= money lenders [ ] 5= NGOs [ ] 6= other source (please specify)...

7. If No for Q#5, what are the major problem (s) you face to get farm credit?
   a) Absence of the credit facility [ ]
   b) High interest rate [ ] (Interest rate..... %)
   c) Problem of timely affording the credit [ ]
   d) Bureaucratic nature of the credit process [ ]
8. Do you belong to any farmer group in your community? 1= Yes [ ] 0= No[ ]
9. If Yes to Q#8, what benefit (s) do you get from the group?
   a) Learning of new technologies and innovations from each other [ ]
   b) Group members work for each other [ ]
   c) It makes credit/input acquisition easy [ ]
   d) Others (please specify)...
10. Do you expect any risks to be driven due to devoting technologies in soyabean production? 1= Yes [ ] 0= No[ ]
11. If yes for Q# 10, what are the failures (risks) noticed in the adopting technologies in soyabean production?
    1= Reduction in yield [ ] 2= increase in cost of production [ ] 3= Loss output market [ ] 4= Pollution of environment [ ] 5= other (*please specify)* ________________

Technological factors

12. Are technologies introduced to you compatible with local culture? 1= Yes [ ] 0= No[ ]
13. If yes to Q# 12, why are they compatible?..
    ....
    ....
14. If No to Q# 12, why are they not compatible?..
    ....
    ....
15. Are you comfortable with the cost of technology introduced to you? 1= Yes [ ] 0= No[ ]
16. What was your level of satisfaction?1= High [ ] 2= Moderate [ ] 3= Low [ ]
17. Are you able to access technologies to achieve expected output? 1= Yes [ ] 0= No[ ]
18. What was your level of accessibility? 1= High [ ] 2= Moderate [ ] 3= Low [ ]
19. Are you comfortable with technical complexity of technologies to achieve expected output? 1= Yes [ ] 0= No[ ]
20. What was the level of complexity of technologies? 1= High [ ] 2= Moderate [ ] 3= Low [ ]

Measurement of adoption rate

1. Have you adopted any of the soyabean technologies? 1= Yes [ ] 0= No[ ]
2. If Yes to Q#1, which of the following technologies have you adopted
   a) Inoculants [ ]
   b) Triple super phosphate (TSP) [ ]

c) Certified seeds [ ]
d) Crop management [ ]

3. If Yes to Q#2, for each of the technologies why did you adopt it? (indicate those that apply)

Soyabean Technology	**Reasons for adopting technology** 1=High yields 2=Less expensive 3=Readily available 4=Easy to manage 5= Improves soil fertility 6= Increasing incomes 7= Reduction in cost of production
Inoculants	
Triple super phosphate (TSP)	
Certified seeds	
Crop management	

Crop management: crop spacing, planting time, weeding, planting method, fertilizer application method, herbicide and weedicide application, pest and disease control.

4. Are you aware of the following soyabean technologies?

Soyabean technologies	Aware with technology? 1=Yes 0= No	If aware, current use status Currently using =1 Abandoned= 0	Number of years since adoption
Inoculants			
Triple super phosphate (TSP)			
Certified seeds			
Crop management			

Crop management: crop spacing, planting time, weeding, planting method, fertilizer application method, herbicide and weedicide application, pest and disease control.

5. From Q# 2, where did you obtain the technologies you adopted or use?

Technologies	Source of technologies Farmers in the village=1 Farmers in other villages=2 Local input dealers=3 Extension agents=**4** Local NGOs=5 International research institutes =**6** National research institute (SARI)=7 MOFA=8 Others (specify) =9…………………
Inoculants	
Triple Super Phosphate (TSP)	
Certified seeds	
Crop management	

Crop management: crop spacing, planting time, weeding, planting method, fertilizer application method, herbicide and weedicide application, pest and disease control.

SECTION C: ESTIMATED IMPACT OF IMPROVED TECHNOLOGY ADOPTION ON OUTPUT

1. How would you rate the price/cost of adopting the improved technologies? ***Please tick.***

Technologies	**High**	**Moderate**	**low**	**No price**
Inoculants				
Triple Super Phosphate (TSP)				
Certified seeds				
Crop management				

Crop management: crop spacing, planting time, weeding, planting method, fertilizer application method, herbicide and weedicide application, pest and disease control.

2. Would you expect that use of soyabean technologies like certified seed, TSP, inoculants and crop management has improving role on yield of soyabean? 1= Yes [ ] 0= No[ ]
3. Kindly indicate your level of agreement on the following practices as they help improve crop output *(5 being strongly agree and 1 being strongly disagree)*

Soyabean technologies	**Level of agreement**				
	5	**4**	**3**	**2**	**1**
Inoculants only					
TSP only					
Crop management only					
Certified seeds only					
Inoculants + TSP					
Crop management + inoculants + TSP + certified seeds					

Crop management: crop spacing, planting time, weeding, planting method, fertilizer application method, herbicide and weedicide application, pest and disease control.

4. Kindly indicate your level of agreement on the following practices as they help improve income *(5 being strongly agree and 1 being strongly disagree)*

Soyabean technologies	**Level of agreement**				
	5	**4**	**3**	**2**	**1**
Inoculants only					
TSP only					
Crop management only					
Certified seeds only					
Inoculants + TSP					
Crop management + inoculants + TSP + certified seeds					

Crop management: crop spacing, planting time, weeding, planting method, fertilizer application method, herbicide and weedicide application, pest and disease control.

5. What are the challenges to the adoption of these improved technologies?

……………………………………………………………………………………..

SECTION D: INPUTS USED IN SOYABEAN PRODUCTION

1. Hired labour

Activities	Males			Females		
	No. of people	Wage	Hours	No. of people	Wage	Hours
Land clearing						
Ploughing and harrowing of land						
Making ridges						
Sowing						
Weeding						
Fertilizer application						
Insecticide application						
Harvesting						

2. Family labour

Activities	Males			Females		
	No. of people	Wage	Hours	No. of people	Wage	Hours
Land clearing						
Ploughing and harrowing of land						
Making ridges						
Sowing						
Weeding						
Fertilizer application						
Insecticide application						
Harvesting						

3. Quantity of seed used per acre…………………………………………………
4. Units of seed used per acres 1= bowls[ ] 2= mini bags [ ] 3= maxi bags[ ] others[ ]
5. What is the total cost of seed?...
6. Capital for soyabean production activities

Activities	Cost per acre (GHC)

Land rent	
Land clearing	
Ploughing and harrowing of land	
Making ridges	
Sowing	
Weeding	
Fertilizer application	
Insecticide application	
Harvesting	

7. Capital for fixed inputs

Inputs	Unit price (GHC)	Quantity	Useful life	Number of years used
Hoe				
Cutlass				
Tampoli				
Knapsack sprayer				
Tractor				

8. Quantity of TSP fertilizer and Inoculants used

Yield enhancer type	Quantity used per acre	Unit cost (GHC)	Total cost (GHC)
TSP			
Inoculants			

9. Quantity of weedicides and insecticides used

Agro chemical type	Quantity used per acre	Unit cost (GHC)	Total cost (GHC)
Weedicides			
Insecticides/rodenticide			

SECTION E: OUTPUT AND REVENUE

1. Quantity of soyabeans harvested in
   Mini bags (50kg)…………………………
   Maxi bags (100kg)……………………….
2. Price of soyabean sold at the market in
   Mini bags (50kg) GHC…………………………
   Maxi bags (100kg) GHC……………………….
3. Quantity of soyabean consumed at home
   Mini bags (50kg)…………………………
   Maxi bags (100kg)……………………….
4. **Quantity of soyabean given as gift**
   Mini bags (50kg)…………………………
   Maxi bags (100kg)……………………….

SECTION F: CONSTRAINTS TO ADOPTION OR USE OF SOYA TECHNOLOGIES.

1. Do you face any challenge in adoption process of soyabean technologies? 1= Yes [ ] 0= No[ ]
2. What are according to you the most important constraints in applying soyabean technologies?

Constraints	Rank
Technologies not available locally	
Very small amount of the technologies are available	
Technologies are expensive	
Farm size	
Inadequate labour supply	
Inadequate credit access	
Technologies are too complex	
Technologies are not compatible with culture	
Technologies are too risky to apply	
Educational level	

3. Which of the following ways is/are better to address soya technologies to the farming community? Please rank the ways of inputs dissemination from best (first) to worst (the last)

Input dissemination institutions	Rank
MOFA	
Research institutions (SARI)	
NGOs	
Farmer based organisations	
Agro-input dealers	
Nucleus farmers	
Aggregators/buyers of soyabeans	

Thank you for your participation

Appendix 2: Matrix of the study

Table 13: Matrix of objectives, methods, key findings, conclusions and policy recommendations

Objectives	**Method of data analysis**	**Key findings**	**Conclusions**	**Policy recommendations**
Assess the perceived effectiveness of agricultural technology transfer mechanisms on adoption of SPTs	Descriptive statistics	Demonstration and farmer to farmer methods were perceived as most effective in terms of influencing adoption of SPTs	Demonstration and farmer to farmer methods are more likely to be most effective in influencing adoption of soybean production technologies.	Stakeholders in the soybean sub-sector should focus on using demonstration and farmer to farmer methods in the dissemination of SPTs
Analyzing factors influencing the adoption of improved soybean production technologies.	Multivariate probit model	Age of farmer, distance to input market and household extension method were variables that influenced adoption of all SPTs	Adoption of all SPTs is likely to be influenced by age of farmer, distance to input market and household extension method.	Access to education, agricultural extension services and mass media method should be improved in order to promote rapid adoption of SPTs
Measurement of intensity of adoption of soybean production technologies by farmers.	Generalized Poisson regression model	Age of farmer, educational level, extension visits, mass media method and risk had significant effect on intensity of adoption of SPTs	Age of farmer, educational level, extension visits, mass media method and risk will increase intensity of adoption of SPTs	Access to education, agricultural extension services and mass media method should be improved in order to promote rapid adoption of SPTs
Estimate the effect of ATTMs on adoption and yield.	CRMP framework (ordered probit and OLS	Education, cropping system and membership of FBO influenced exposure intensity of ATTMs. Intensity of	Educational and membership of FBO is likely to significantly increase farmer exposure intensity to	The use of multiple ATTMs will be relevant in increasing adoption intensity of soybean production technologies. Farmers should therefore be

		exposure to ATTMs (moderate and high), soybean project beneficiary, extension visits and farming experience were among factors that influenced adoption intensity of SPTs. Intensity of adoption of SPTs (moderate and high), distance to input market, extension visits, insecticide use, certified use were among factors that influence soybean yields	ATTMs. Also, effect on intensity of adoption will be influenced by farming experience, extension visits, risk, soybean project beneficiary and intensity of exposure to ATTMs (moderate and high). Soybean yields was influenced by distance to input market, cropping system, extension visits, certified seeds use, insecticide use, moderate and high intensity of adoption of SPTs.	encouraged to participate in different agricultural technology transfer mechanisms. Also, farmers should adopt multiple soybean production technologies to increase their yields.
Identify the constraints to adoption of SPTs.	Descriptive statistics	High cost of technology was a major constraint to adoption of TSP and certified seeds, while non-availability of technology was the biggest constraint to adoption of inoculants	Adoption of TSP and certified seeds is likely to be constrained by high cost of technologies. Non-availability of technology will be a major constraint to adoption of inoculants.	To tackle the constraints of high cost and non-availability of technologies, the study recommends inoculants and TSP should be included in subsidized input packages under the government Planting for Food and Jobs initiative.

Appendix 3: Factors Influencing Farmers' Exposure to Agriculture Technology Transfer Mechanisms

Table 14: Estimates of ordered probit model analysis

Variables	Coefficients	Std. error	z	P
Education	0.0479	0.0190	2.52	0.012
Farm size	-0.2281	0.1524	-1.50	0.134
Soybean project beneficiary	0.0238	0.1511	0.16	0.875
Cropping system	-0.4894	0.1599	-3.06	0.002
Extension visit	-0.0302	0.0396	-0.76	0.446
Membership of FBO	0.3004	0.1546	1.94	0.052

LR χ^2 (6) = 24.09, Prob> χ^2 =0.0005, Pseudo R^2 =0.049, log likelihood= -229.39

Appendix 4: Effect of Agricultural Technology Transfer Mechanisms and Other Factors on Intensity of Adoption

Table 15: Estimates of ordered probit analysis

Variables	Coef.	Std. error	z	P
Moderate intensity of exposure to ATTMs	0.3187	0.155	0.21	0.837
High intensity of exposure to ATTMs	1.4001	0.380	3.68	0.000
Soybean project beneficiary	0.2489	0.169	1.47	0.141
Sex	-0.3190	0.184	-1.73	0.084
Education	0.4921	0.020	2.35	0.019
Household size	-0.0344	0.250	-0.14	0.891
Farming experience	0.0379	0.008	4.69	0.000
Income	0.0000	0.000	0.49	0.627
Distance to input market	-0.2189	0.029	-7.31	0.000
Cropping system	-0.4308	0.164	-2.66	0.008
Extension visits	0.0944	0.038	2.42	0.015
Credit access	-0.3383	0.164	-2.06	0.040
Membership of FBO	-0.0146	0.166	-0.09	0.930
Risk	0.2829	0.108	2.62	0.009

LR χ^2 (14) = 142.74, Prob> χ^2 =0.0000, Pseudo R^2 = 0.228, log likelihood= -240.54

Appendix 5: Effect of ATTMs, Adoption Intensity and Other Factors on Soybean Yields

Table 16: Estimates of multiple linear regression

Variables	Coefficient	Std. error	t	P> [t]
Constant	0.8217	0.1492	5.51	0.000
Moderate adoption intensity	0.0643	0.0789	0.82	0.416
High adoption intensity	-0.0934	0.1206	-0.77	0.439
Farm Labour	-0.0220	0.0165	-1.33	0.186
Soybean project beneficiary	0.0728	0.0457	1.59	0.112

Education	-0.0053	0.0058	-0.91	0.364
Farming experience	-0.0053	0.0025	-2.13	0.034
Distance to input market	0.0280	0.0097	2.88	0.004
Cropping system	0.1334	0.0492	2.71	0.007
Extension visits	-0.0099	0.0128	-0.77	0.439
Credit access	-0.0915	0.0517	-1.77	0.078
Membership of FBO	-0.0527	0.0544	-0.97	0.333
Quantity of certified seed	-0.0347	0.0183	-1.90	0.058
Quantity of TSP	0.0025	0.0018	1.40	0.163
Quantity of inoculant	0.0003	0.0006	0.56	0.575
Quantity of weedicide	-0.0035	0.0319	-0.11	0.913
Quantity of insecticide	0.1738	0.0360	4.82	0.000
R^2	0.274			
Adjusted R^2	0.233			
F- ratio	6.68			
Prob>F	0.0000			

Appendix 6: Farmer's Awareness of Soybean Production Technologies

Table 17: Awareness of Soybean Production Technologies

Soybean technology	Percent Aware	Percent Unaware
Inoculants	84.33	15.67
TSP	87.33	12.67
Certified seeds	99.00	1.00
Pest and disease control measure	98.67	1.33

Appendix 7: Plagiarism Check Originality Report

Turnitin Originality Report

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PLAGIARISM CHECK ANALYSIS ***for*** *Agricultural Technology Transfer Mechanisms and Adoption among Soybean Farmers in Chereponi District of Northern Region of Ghana* **by ABASS MAHAMA (UDS/MEC/0005/17)**

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