UNIVERSITY FOR DEVELOPMENT STUDIES

SOCIAL NETWORKS AND INTEGRATED SOIL FERTILITY MANAGEMENT ADOPTION: EFFECTS ON MAIZE YIELDS AND FOOD SECURITY OF FARMERS IN NORTHERN REGION

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UNIVERSITY FOR DEVELOPMENT STUDIES, TAMALE

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BY

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FEBRUARY, 2019

DECLARATION

Student

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

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

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ABSTRACT

Land degradation, unreliable rainfall, population growth and chronic poverty in sub-Saharan Africa challenge the sustainability of soil fertility, crop yields and general livelihoods (food security) for smallholder farmers. Several soil fertility management interventions have been introduced to farmers in groups over the years, but different levels of uptake, determinants and socio-economic effects have been reported in separate studies. However, the determining role of social networks in adoption and a comprehensive and systematic estimation of the effect of adoption on maize yields and food security requires further understanding. This study examines the effect of intensity of adoption of Integrated Soil Fertility Management technologies through social network on smallholder farmers' maize yields and food security in Northern Region. The study administered a semi-structured questionnaire to 300 sampled maize farmers selected through a multi-stage random sampling technique from three selected districts in the Northern Region. Multivariate probit model was used to examine the determinants of farmers' choice of sources of agricultural information. The models were estimated individually and also within Conditional Mixed Process (CMP) system for choice of appropriate estimation due to endogeneity. Results of the CMP estimation showed that age, educational status, maize farm size, access to mobile phone and radio significantly influence farmers' choice of source of agricultural technology information. The results also showed that age, educational status, farmers' innovativeness, moist land, family labour, perception of erosion, farm production cost, access to research institutions, trainings on ISFM and social networks significantly determine the intensity of adoption of ISFM. Furthermore, age, experience in farming maize, farm size, family labour availability, amount of fertiliser applied per hectare, burning of crop residue, perception of fertility of farmland, pest control, Tropical Livestock holding, wealth index, extension contacts, social networks and the number of ISFM practices adopted have significant impact on maize yields. Also, the results revealed that age, household size, education, informal credit, farm size, intensity of ISFM practices adopted and maize yields influence farm household food security. It is recommended that there should be enhanced collaboration between farmers and research through community level training on ISFM practices to promote soil fertility. MoFA and other research institutions should adopt the mass communication and training sessions through the use of mini vans and tricycles to disseminate information on ISFM practices. They should also promote diversification of farm enterprises to enhance food security.

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DEDICATION

I dedicate this academic output to my parents, Mr Yussif Fuseini and Hajia Mariam Haruna.

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LIST OF ACRONYMS

ADP	Agricultural Development Programme
AIC	Akaike Information Criterion
ANCOVA	Analysis of Covariance
ATT	Attitude Toward the Behaviour
BIC	Bayesian Information Criterion
CA	Conservation Agriculture
CAADP	Comprehensive Africa Agriculture Development Programme
CMP	Conditional Mixed Process
CSIR	Centre for Scientific and Industrial Research
EPA	Extension Planning Area
FAO	Food and Agriculture Organisation
FBO	Farmer Based Organisation
GART	Golden Valley Agricultural Research Trust
GDP	Gross Domestic Product
GSS	Ghana Statistical Service
IFDC	International Fertiliser Development Centre
IHYM	Improved, High Yielding Maize
IITA	International Institute of Tropical Agriculture
ISFM	Integrated Soil Fertility Management
MSV	Maize streak virus
MiDA	Millennium Development Authority
MoFA	Ministry of Food and Agriculture
OLS	Ordinary Least Squares
OPVs	Open Pollinated Maize Varieties
PBC	Perceived Behavioural Control
PCA	Principal Component Analysis
PHC	Population and Housing Census
SARI	Savannah Agricultural Research Institute
SCP	Soil Conservation Practices
SN	Subjective Norm
SNA	Social Network Analysis
TLU	Tropical Livestock Units
TPB	Theory of Planned Behaviour
WCA	West and Central Africa
UN	United Nations

CHAPTER ONE

INTRODUCTION

1.1 Background to the study

Enhancing growth in agricultural productivity levels is considered vital to economic growth in poor countries, especially in sub-Saharan Africa where productivity growth is on a downward trajectory compared to other continents (Evenson and Gollin, 2003). In developing countries, agriculture still contributes significantly to sustaining people's livelihoods of promoting food production, availability and accessibility, employment generation and income (Wilfrid and Edwige, 2004).

Over the years, attempts to propel rapid increment in food production across several African countries have emphasised reliance on farmland extension. The continuous practice of clearing these lands have negatively affected ecological and productive systems (Fearon, 2000). Within these challenges, smallholder farmers are highly affected by the deteriorating soil quality. Consequently, with the limited capacity of small farm owners to be resilient to the effects of climatic variability such changes have effects on their agricultural output and overall livelihood schemes causing even greater risks to their persistent poverty levels, predominant subsistent agriculture and worsening land degradation problems (Mango *et al*., 2017). Agricultural productivity can be enhanced either through the development and use of new technologies or through the efficient use of the existing technologies without damaging the natural resource base (Bhasin, 2002). However, the important food crops in Ghana are maize, rice, sorghum, millet, cassava and legumes such as groundnut and cowpea. Among the cereals, maize is the most relevant with an estimated 750,000 ha allocated to the crop every cropping year. Ghana satisfies only 51% of its maize needs, and only 25% of its rice supplies (Gloria *et al*., 2014).

Maize is not just the largest staple crop in Ghana but also the predominantly cultivated crop accounting for majority of total cereal production. Additionally, maize is the largest commodity crop in the country only next to cocoa. The significant contribution of maize to the economy of Ghana cannot therefore be overemphasised. The crop provides a key source of food, feed and cash for many households in Ghana (Martey *et al*., 2013).

Ghana's maize production has increased and continues to increase across the entire country for the past years as a result of its high potential grain yield. It is grown mainly for its energy-rich grains and its production continues to gain wider acceptability over other traditional cereal crops in sub-Saharan Africa, especially in the savannah of West and Central Africa (WCA). It has a wide range of uses than any other cereal. Maize high yield potential, wide adaptability, relative ease of cultivation, processing, storage and transportation have promoted the potential of the crop for eradicating food security challenges posed by population increase in WCA (Gloria *et al*., 2014). Regrettably production is seriously constrained by natural low soil fertility (low levels of Nitrogen), low investment in nitrogenous fertilisers, recurrent drought and *Striga hermonthica* parasitism. These stresses have an overwhelming importance to maize production in this region, affecting the livelihood of millions of people, food security and economic development. Yield losses in maize from *Striga* infestation in the area are often significant with estimates ranging from 16% to 100% (Alidu and Abdulai, 2013).

To overcome these challenges, it is required that the resilience of smallholder farmers to the adverse effects of land degradation and poor soil quality is placed on sustainable basis through the learning and adoption of soil and water enhancing technologies. These technologies for many years have been greatly promoted to minimise soil loss and falling agriculture productivity around the world (example Haiti**) (**Kokoye *et al*., 2016). These techniques largely target addressing soil erosion, supporting soil fertility, improving yields and enhancing farm income **(**Kokoye *et al*., 2016). Formally, these technologies are defined to include stone and soil bunding, composting, agroforestry, crop residues, use of legumes in crop rotations and through exact application (Dercon *et al*., 2010; Johansen *et al*., 2012)**.** For instance, from 2009 up to 2015, Savannah Agricultural Research Institute (SARI) disseminated many Integrated Soil Fertility Management (ISFM) practices in Northern Ghana to promote maize productivity. The goal of these field trials was to establish the effect of ISFM on the yield of maize. These field demonstrations encompass different ISFM technologies such as legumes rotation with maize, improved (drought resistant and high-yielding) maize varieties to various levels of fertiliser application, both organic and inorganic fertilisers.

Improved technologies are not adopted immediately, randomly or completely throughout a population (Maertens and Barrett, 2012). This implies that useful insights about the structure of African economies and the formulation of relevant economic policy are ensured by the recognition that people are engulfed in social networks (Udry and Conley, 2010). Therefore, to understand the diffusion of technology in agriculture, social networks have the potential to improve the effectiveness of conservation programmes across the world (Ramirez, 2013). Ramirez (2013) concluded that with an appropriate appreciation of the social determinants of knowledge flow and the adoption of new conservation technology in the agricultural sector, researchers and policy makers will be able to identify and minimise constraints to technology diffusion and adoption. Thus, they provide supporting services as social learning of new agriculture technologies, seeking and exchange of agricultural inputs, market information, finances among others that they would not normally readily access on sustainable basis from extension service agents, government, development partners and other financial institutions. They also offer these transaction services at no or amounts smaller than the average transaction fees charged by mainstream input suppliers and financial institutions. The wide array of agricultural technology exchanges offered by social networks has made their operations a subject of intellectual and academic discourse and research in recent times.

Social interactions are expressed in social network analysis via nodes and ties (Wasserman and Faust, 1994). A node is an (individual) actor in a network of relationships and a social tie represents the relation between nodes (actors) in a network (Hanneman and Riddle, 2005; Wasserman and Faust, 1994). A social network is the individual members (nodes) and the links among them through which resources such as information, money, goods or services flow (Maertens and Barrett, 2012).

1.2 Problem Statement

The fundamental concern of Ghana Government and other development partners in promoting national food security and some levels of job creation is to support the production and the promotion of staple crops. In Ghana, maize is viewed as the most significant cereal grain in the context of total production and utilisation.

Maize is a very important staple food in Ghana accounting for more than 50% of total cereal production in the country and grown in all agroecological zones (Akramov and Malek, 2012). The chunk of maize produced goes into food consumption and it is arguably the major food security crop (Abdulai *et al*., 2013). Over 85% of rural dwellers grow maize because it fits well into the varied systems of farming with a broad potential for raising yield given better management practices relative to other cereal crops (Alidu and Abdulai, 2013). The crop has a huge opportunity of eradicating food insecurity posed by growing national population given its high yield potential, wide adaptability and moderately ease of production (Alidu and Abdulai, 2013).

The concentration of food production in Ghana is located in the savannah and forest zones and the three northern regions contribute significantly to the national food basket. Food production potentials therefore abound in these regions (Nkegbe *et al*., 2012). Crop producers within Northern Ghana fail to obtain reasonable yields of a number of their cereal crops without the application of fertilisers because of poor soil fertility of the area. To address this problem of low soil fertility levels, various attempts by research institutions have been made including adopting liquid fertilisers. However, a couple of these products are produced and calibrated outside the country with different soil, climatic and environmental conditions (Gloria *et al*., 2014). To this end, Ministry of Food Agricultural (MoFA) and non-governmental organisations in Northern Ghana are channelling their efforts in propagating soil and water conservation technologies, including grass stripping, composting, stone and soil bunds, among farmers in the area. But rates of implementing these technologies are thought to be discouraging (Nkegbe *et al*., 2012).

Farmers' access to information on agricultural technology could be a panacea to improving adoption. Empirical studies, for instance, in Nigerian have indicated that challenges in accessing information through various information sources ameliorates the large positive effect of agriculture on the population. The inadequate information challenges in the country have been identified to be one of the key determinants that dampen the adoption of agricultural technologies. Information generally connotes refined data recorded in different forms (Yahaya, 2003). According to Farinde (1991), the consequent effect of the low agricultural information utilisation effect of low adoption of improved technologies has indirect repercussions on farmers' productivity and could deteriorate their overall wellbeing. Adoption of improved farm technologies is conditioned on sufficient information, which has to be effectively disseminated to allow the recipient to understand it and value it enough to warrant overt behavioural change. For instance, it is documented that farmers learn various agronomic practices, processing of farm output and storage through knowledge acquired from different information sources (Keregero, 1995). Therefore, agricultural extension organizations are fundamentally mandated to educate farmers and disseminate very recent agricultural technologies via various extension teaching methods including individual, group, and mass contacts (Hussain, 2005).

Interestingly, many adoption studies such as Nkegbe *et al*. (2012) and McCarthy (2015) try to explore the causes of the low uptake of improved soil conservation practices but there has rather been no study on the effect of social network on diffusing and adopting Integrated Soil Fertility Management (ISFM) practices in Northern Ghana. Hence, the significant contribution of social networks as a determinant of adoption is often largely ignored. Meanwhile, few studies by Bandiera and Rasul (2003), McCarthy (2015) and Mekonnen *et al*. (2018) maintain that social learning influences a farmer's initial choice to implement an innovation and that such decisions are often linked to the choices of his peers within his social network. Even farmers' new crop choices and cultivation have been empirically evidenced to be linked to that of the choices of others also cultivating the same crop (Conley and Udry, 2010). The effect of Soil Fertility Management (SFM) technology adoption, through social network, in promoting smallholder farmers welfare and sustainable agriculture remains critical to the promotion of agriculture in the area and this requires investigation.

More often than not, smallholder farmers strive to raise their farm productivity by adopting a mixture of ISFM technologies but it is always unclear whether these practices have sufficiently improved farm output. Should farmers be motivated to invest in these technologies if need be? To promote the adoption of ISFM techniques requires that adopting farmers ascertain a clearer, new and highly analytical perspective of the effect of these soil quality management practices on farm productivity. In this connection, an extensive analysis of the linkage between ISFM and farm output of small farm owners would largely benefit adoption, farm productivity and overall livelihoods activities. So, one of the main concerns of the MoFA and other research institutions (eg. SARI) in encouraging ISFM is to determine the estimated maize yield effects of adoption of Soil Fertility Management technologies of smallholder famers.

Then again, from welfare perspective, beyond the investigation of how much output farmers produce out of adopting ISFM practices is the need to analyse the food security effects of its adoption. This idea validates the argument for relevance of food self-sufficiency of smallholder farmers. But there is a gap as to whether adoption of

ISFM practices and farm productivity can improve food security concerns of smallholder farmer. Therefore, it is imperative to acquire information about the effect of adoption of Soil Fertility Management technologies in harnessing the food security so as to understand how it could further enhance the adoption of ISFM practices.

This study therefore seeks to explore the determinants of farmers' choices of sources of agricultural information. It assesses the social networks and other drivers of Soil Fertility Management technology adoption in order to ascertain the effect of Soil Fertility Management technology adoption through social networks and other determinants on smallholder farmers' maize yields and food security.

1.3 Research Questions

Main research question:

Has the adoption of Integrated Soil Fertility Management technologies through social networks any significant effect on farmers' maize yields and food security in Northern Region?

Specific research questions

The following questions were addressed in this study:

i. What are the factors influencing farmers' choice of social networks as a source of agricultural information in Northern Region?

ii. How has social network together with other drivers affected the intensity of adoption of Soil Fertility Management technologies in Northern Region?

iii. What is the effect of intensity of adoption of Integrated Soil Fertility Management on maize yields?

iv. What is the effect of intensity of adoption of ISFM practices on farm households' food security in Northern Region?

1.4 Objectives of the study

General objective:

To assess the effect of adoption of Soil Fertility Management technologies through social network on smallholder farmers' maize yields and food security in Northern Region.

Specific objectives

i. To examine the determinants of farmers' choice of social networks as a source of agricultural information in Northern Region.

ii. To analyse the effect of social networks together with other drivers on the intensity of adoption of Soil Fertility Management technologies in Northern Region.

iii. To examine the effects of adoption of Soil Fertility Management technologies on maize yields

iv. To estimate the effect of ISFM adoption intensity on farm households' food security in Northern Region.

1.5 Significance of the Study

Given the growing emphasis to transform the agricultural sector, there is the need for effective, cheaper and faster agricultural technology dissemination mechanisms to enhance increase yields and food sustenance despite challenges of sustainable adoption. In rural settings in Northern Ghana, settings within which most agricultural lands have been extensively cultivated and soil quality rapidly deteriorating, it then becomes imperative to analyse the social network and Integrated Soil Fertility Management adoption: impacts on productivity and food security of farmers. Also, sustainable adoption of ISFM practices has been generally recognised by many (eg. Toenniessen *et al*., 2008; Vanlauwe *et al*., 2010 and Lambrecht *et al*., 2014) as one of the major approaches to improving and sustaining soil quality for enhanced plant growth.

This study also informs stakeholders about the efficacy of ISFM practices in its contributions to maize yields of smallholder farmers. This could reduce the apathy among rural folk especially smallholder farmers which is an opening of reluctance on their part to fully participate in the dissemination, perhaps investment and consequent adoption of ISFM technologies that are critical to maintaining their soil quality and promoting agriculture growth. The study would not only involve smallholder farmers but MoFA and other research institutions to explore effectiveness of current ISFM technologies, assess effectiveness of social networks in disseminating agriculture technologies, and tackle the barriers that exclude rural people from improved ISFM technologies that have high agriculture growth potentials. Interventions that are required for promoting the institutional support needed by a rural economy at the national, district, community, and local levels will therefore be adequately informed by the findings of this study.

Also, it is imperative to indicate that this study took place on previous Savannah Agricultural Research Institute (SARI) projects on the promotion of ISFM technologies in some targeted districts in the Northern Region. It can therefore be an evaluation of SARI and other organisations' investments in disseminating ISFM technologies. For instance, from 2009 to 2015, SARI conducted field experiments on boosting maize cropping system productivity in Northern Ghana through widespread adoption of ISFM. These ISFM practices include; combined application of organic and mineral fertilisers with different tillage systems/bunding on nutrient (N) and water use efficiency to high maize yields. The results reveal significantly high maize grain yields in favour of the bunded fields especially in years of intermittent drought as compared to the plots not bunded but with the same quantity of nutrient applied. However, these have not been demonstrated extensively on farmers' fields (on-farm) for adoption (Kombiok *et al*., 2014). Therefore, the influencing factors of adoption of ISFM practices among the wider farmer population also require investigation. This study hence assesses the off-experiment adoption of these ISFM technologies and their effect on maize yields and farmers' food security in three selected project districts in the Northern Region.

Previous studies such as Shively (1998) and Abdulai (2016) have often made restrictive categorisation of farmers in adoption studies into adopters and non-adopters of conservation technologies. In most cases, the classification of the farmers into these binary categories is to meet the requirement and permit the utility of impact models such as Propensity Score Matching (Kassie *et al*. 2007 and Wu *et al*. 2009), Endogenous Switching models (see: Alene and Manyong, 2007 and Coulibaly *et al*., 2017) among others. These tendencies have often left single adopters of components of ISFM as if they are entirely non-adopters. Meanwhile, the intensity of the contribution of each component is different and labelling adopters of only fertiliser application for instance as non-adopters is flawed as its yield effect could be more than the other components (Mazvimavi *et al*., 2012). This methodological gap demands a novel approach to estimating the determinants of uptake of ISFM technologies where in practical farming situations farmers normally adopt at least one of the 'tools in the box' of ISFM package. This present study therefore also makes a theoretical contribution to the literature through the implementation of a zero-truncated Poisson regression model as well as use of Conditional Mixed Process (CMP) which corrects for endogeneity and rarely have studies simultaneously estimated determinants of adoption, yield and food security using this method.

In effect, this study bridges the literature gap and contribute to current debates on effectiveness of ISFM technologies in sustainable rural agriculture efforts in Ghana as well as the methodological issues in estimating the effects of adoption on maize yields and farmers' food security in the real context that at least every farmer adopts one of the ISFM practices. Therefore, this study which aimed to analyse the effect of the adoption of ISFM through social learning on smallholder farmers' maize yields and food security is indeed relevant.

It is envisaged that the output of the study will highlight the broader role of agricultural research institutions in promoting the agricultural sector especially in the Northern Ghana. It will also incorporate into adoption studies, the over-looked aspects of social networks that can help promote agriculture tremendously. This is also aimed at broadening the theoretical perspectives of social network since it will now examine these aspects which have been overlooked over the years.

1.6 Organisation of the Thesis

The Chapter One (1) presents an introduction covering the background, problem statement, research questions and objectives and significance of the study. Chapter Two (2) contains a review of literature. Chapter Three (3) presents the methodology of the study; this included model specification, detailed discussion of the variables and data utilised in the study. Chapter Four (4) results and discussions: the chapter discusses the results from the study. Finally, the conclusions of the major findings and recommendations, and suggestions for further research were discussed in Chapter Five (5).

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter reviews various literatures relevant to this study. It embodies a theoretical review which conceptualises Integrated Soil Fertility Management (ISFM), its components and evolution in Ghana; it examines the concept of social learning and presents the meaning of food security. Empirically, the review captures the determinants of farmers' choices of sources of agricultural information. Studies on the effect of social networks together with other drivers on the intensity of adoption of Integrated Soil Fertility Management technologies are also discussed. The literature review also extensively captures the impact of intensity of adoption of Integrated Soil Fertility Management technologies on maize yields of smallholder famers. Research studies on the effects of intensity of adoption of Integrated Soil Fertility Management technologies and maize yields on farm households' food security have also been reviewed. The chapter further looks at the theoretical framework as well as the conceptual framework that underpin this study. It ends with a conclusion highlighting the lessons derived from literature and how the literature reviewed is linked to this study.

2.2 Conceptual definitions

This section presents the conceptual definitions of major variables of the study. They include the concept of Integrated Soil Fertility Management and its components, social networks, food security and other related issues such as the brief history of ISFM practices in Ghana.

2.2.1 The concept of Integrated Soil Fertility Management and its components

A number of interesting papers have been published on Integrated Soil Fertility Management practices. The concept of ISFM is defined by Vanlauwe *et al*. (2010) as a combination of soil fertility management practices which relevantly consist of the use of fertiliser, organic inputs, and improved germplasm, combined with the technical know-how on how to adapt these practices to local settings with the motive of maximising the agronomic utilisation efficiency of the applied nutrients and improving crop yields. Similarly, within the setting of Northern Ghana, a more local flavour of ISFM definition by Denwar *et al*. (2011) posited that ISFM is a combined adoption of organics and minerals. Similarly, other numerous studies of ISFM provide a rich resource for understanding the workings of the process in particular contexts. For instance, Sanginga and Woomer (2009) offered a comprehensive work on the theme defining it as a means supporting farmers with enhanced investment benefits in fertiliser by its simultaneous adoption with local agro-minerals and available organic resources. Their work covers not just the meaning of ISFM but its practice in different climatic conditions, process of its implementation and its social dimensions with regards to its roles in promoting gender empowerment, food self-sufficiency and nutrition, reduction in the incidence of poverty among others. This partly motivates the current study to investigate the types of ISFM under the Guinea Savannah climatic zone and its social implications for farmers in the Northern Region.

2.2.1.1 Improved Crop Varieties

In terms of crop varieties adoption, studies (see: Amare *et al*., 2012; Mathenge *et al*., 2014 and Manda *et al*., 2016) verified that the use of improved crop varieties has potential for raising household consumption and income, and minimise the incidence of poverty and inequality. Consistent with this, a study by Abate *et al*. (2015) found evidence that the maize farms with improved varieties in Ethiopia went up from 14% in 2004 to 40% in 2013 remains a main factor in accelerating growth in maize production in Ethiopia. They are very relevant given its resilience to drought, major diseases, greater yield potential and wide adaptability. Relatedly, Ekboir *et al*. (2002) argued that the improved maize variety, *Obaatanpa*, which covers more than 50 % of the maize hectarage (650 000 ha) in Ghana, has good levels of resistance to the *Maize streak virus* (MSV), lowland rust (incited by *Puccinia polysora* Underw.), and reasonable levels of resistance to blight and therefore increases yield. Denwar *et al*. (2011*)* found that using *Striga*-tolerant maize varieties can reduce *Striga* infestation and raise maize yields which always follow legumes in crop rotation as adopted in Northern Ghana. Often adopted drought tolerant varieties and/or hybrids improved maize varieties suitable for various agro-ecological systems in Ghana especially in northern Ghana were developed and evaluated by the International Institute of Tropical Agriculture (IITA) in conjunction with national agricultural research systems and propagated by the SARI. They include, *Obatanpa, Abontem, Aburohemaa, Etubi*, *Dozdi*, *Omankwa* among others (Martey *et al*., 2013).

2.2.1.2 Covering with crop residue

Organic soil cover is a cropping system that maintains a ground cover of 30% from cover crops and crop residues retained including crop residue left after harvest (Abdulai, 2016). A study by Arslan *et al*. (2017) on Zambia, indicated that, cover crops are able to sequester CO_2 considering their large photosynthesis activities through the capture, conversion and store CO_2 in the soil. Conservation Agriculture (CA) practices that sequester soil organic matter contribute to environmental quality and the enhancement of agricultural systems on more sustainable basis. Nhamo *et al*. (2018) noted that crop residues are a transmission belt for getting nutrients back to fertile agricultural soils on condition that the process promotes soil carbon storage. However, where residues dominate the feed for livestock with high competing alternative uses, poor availability of crop residues can jeopardise their contribution in nutrient recycling. Burning and clearing of crop residues yearly after harvest are predominant farming practices with farmers for the motive of mainly smoothening the surface for ease of implements passage and weeds control (Bationo *et al*., 2011), which worsens nutrient loss and directly result in greenhouse gas emissions and contributes to the degrading soil biological properties (Pathak and Wassmann, 2007).

2.2.1.3 Organic Manure

Beyene (2010) defined farmyard manure as a combination of animal excreta, often including urine and litter used for bedding. Examples range from manure sourced from the habitations of dairy cattle and broiler chickens. This practice consists of applying manure (organic matter) to the field to enhance plant growth (Senkondo, 2014). Adding organic matter in the soil improves soil properties (Senkondo, 2014), and increases soil organic carbon (Riley, 2016).

Okorogbona and Adebisi (2012) in their article on the promotion of smallholder agriculture in South Africa using animal manure reiterated that in South Africa, the yearly amount of animal manure is high enough to satisfy 13.3%, 9.9% and 27.6% of the country N, P and K soil nutrients, respectively. Whereas 25% of the about 3 million tons of animal waste is utilised as fertilisers, significant amount of the remaining 75% is unused, with a minute amount utilised as available energy for heating. Animal manure is therefore not optimally used. Indeed, the challenge to many resource-poor farmers has been their inadequate knowledge on manure use. Animal manure which represents a source of organic nutrients is very important for the production of leafy vegetables especially for farmers with little resources. Manures from domestic animals such as cattle, goat and chicken remain widespread types of manure utilised as sources for soil nutrient. It is estimated that manure adoption positively affects crop growth and yield, whereby chicken manure is adopted at a rate less than those of ruminants for maximum yield. The estimated positive contribution of applying animal manure has been supported by Kihanda *et al*. (2004) as an element that improves growth and yield of crops as a consequence of plant uptake of the nutrients contained in the manure. Fatunbi and Ncube (2009) also emphasised that manure significantly result in raising organic matter components of cropped soils and hence improves their production capacity. These conclusions were earlier supported by Edmeades (2003) who proved that manure application causes major effect on improving soil organic matter composition and very much associated with soil features compared to chemical fertiliser when adopted at the same elemental nutrient rate especially given that manure is an external provider of organic matter.

2.2.1.4 Fertiliser Use

Several studies cover the experiences of particularly smallholder farmers on fertiliser application. Nhamo *et al*. (2018) opined that small farm owners in Africa are the least users of fertiliser inputs per unit area under agriculture. Figures suggest that adoption rates are still <20 kg/ha in many countries. Agricultural transformation and commercialisation of crop value chains require that application of mineral fertiliser efficiently is necessary to curtail low yields and to eradicate land degradation driven by nutrient mining. Fertiliser adoption is not a magic solution for all soil fertility-related problems. The use of mineral fertilisers has emerged unavoidable particularly on soils that are basically poor in fertility and those whose nutrients have been depleted through poor farming practices (Bationo *et al*., 2007). Fertiliser adoption by small-farm owners is restricted by lack of initial capital outlay and constrained availability (Bationo *et al*., 2007; Diouf and Sheeran, 2010; Nakano and Kajisa, 2013). In addition, they showed that poor formulations and lack of site specificity result to over- and/or under application of mineral nutrient elements, a technical bottleneck occasionally encountered by farmers. Non-conducive policy environment, e.g., lack of access to subsidies and credit facilities, does not encourage cash constrained farmers from using fertilisers. In these situations, the rates of mineral fertiliser applied on small farms are not consistent with meeting the requirements of plant and soil.

Earlier contributions by Diouf and Sheeran (2010) note that if fertilisers are applied under CA demands higher soil managing skills, then application costs could increase even in the context where application rates are not encouraging. A broader indication is that CA demands more managerial skills which could be quite costly for farmers to afford. As a result of these, the current study therefore examines the farmers' educational status and cost of adopting ISFM technologies as some of the influencing factors of adoption.

Ngwira *et al*. (2014) emphasise the critical contribution of applying fertiliser to enhancing maize yielding by concluding that it increased yield compared with non-fertilised plots, irrespective of whether tillage and residues are managed or not, across all locations and seasons. They revealed that without fertiliser, there exist no much difference between conventional tillage and no-tillage regardless of managing crop residue, suggesting that in case of farmer non-use of fertiliser, CA will fail to yield any positive benefits. Conversely, Carranca (2012) in his paper on nitrogen use efficiency by annual and perennial crops cautions that the amount of nitrogen fertiliser applied to plants is usually large. Only marginal components of this type of fertiliser, estimated around 6–50%, is absorbed by plants which depends on fertiliser, plant and soil type, climatic conditions, and agricultural practices. The unaccounted nitrogen can be released from the ecosystem as trace gas and ammonia volatilisation, or dissipate by leaching and runoff in the nitrate or ammonium form. The primary motive of minimising mineral nitrogen adoption will emerge to this twenty- first century what the aim of minimising pesticides usage was to the last century.

2.2.1.5 Composting

Sanginga and Woomer (2009) observed that domestic composting has a high potential to support nutrient concentration of organic resources even though it is usually insufficiently supplied and mainly used for home gardens or high value crops. They defined composting as the mixture of agro-minerals and manures with heavy crop residues and their partial decomposition, resulting in the production of high-quality compost. However, they pointed out strenuous efforts, cash investment, time and transport requirements make it unavailable and unattractive. An alternative to compost is vermicompost which Saha *et al.* (2012) studied and concluded that vermicomposting is a likely antidote to the problem of the depleting biodiversity emanating from the recycling of natural resources.

In spite of the idea that most soil processes are controlled and organised by soil microbes, the contribution of vermicompost in sustaining microbial diversity and promoting appropriate functioning of soil requires further understanding. The major benefits are the following: Extracellular enzyme activity is propelled after applying vermicompost in soil. There is an initial boosting of microbial growth explained by the initial activation of the microbial enzymes and intracellular enzyme activity. Upon aging of vermicomposting the enzymatic activity reduces. Higher microbial population in vermin-cast is observed compared to the surrounding soil. Significant transformations in bacterial and fungal communities are observed (Saha *et al*., 2012).

2.2.1.6 Crop rotation

It is reckoned that crop rotation mostly supports the enhancement of soil C and available N levels, but not necessarily all the time (Bagayoko *et al*. 1996). Crop rotation is an effective grain yield booster due to disrupting pest cycles (Mason *et al*., 2015). Crop rotation encompasses the alternating of crops of varied families, for instance, legumes and cereals every cropping season (Mazvimavi *et al*., 2012). The quality of the soil is also likely to increase due to the organic matter build up from crop residues, use of legumes in crop rotations and intensed fertiliser use efficiency through precise adoption (Dercon *et al*., 2010; Johansen *et al*., 2012).

2.2.1.7 Combinations of ISFM technologies

In adoption studies, the use of an agricultural technology could be partial or full depending on the substitutability or complementarity of the individual units within the ISFM package. The intent is often to encourage full adoption as it is envisaged to produce maximum outcomes.

Most studies rely on this two-dimension characteristic of adoption. Notably, the findings from Hogset (2005) support the argument that farmers prefer to adopt technologies gradually, one by one, to experiment with them on a small scale before applying them to the whole farm. But the ISFM practices that are required to resolve the challenges of natural resource depletion in Africa widely fit the description of complementary technologies (Fernandes *et al*., 2005). There are possibilities of a farmer adopting them individually, but the optimal benefits are achieved only upon their simultaneous adoption. Mango *et al*. (2017) study results provide a helpful coverage of the trend in adoption. From the use of Sustainable Agricultural Practices, 31% of the sampled farmers were using grain legume rotations on their farms, 60% were adopting inorganic fertilisers, 14% were using compost manure, 86% owned some livestock, and 44% were adopting farmyard manure, while 43% were utilising green manure.

2.2.1.8 Brief Evolution/History of Integrated Soil Fertility Management technologies in Ghana

Arslan *et al*. (2017) recount that historically, CA was birthed by ecological and economic hardships in the United States (U.S.) led to severe droughts during the 1930s and gained much attention from farmers for reasons increasing fuel prices during the 1970's (Haggblade and Tembo 2003). Large commercial farm owners adopted minimum tillage technologies to eradicate the drought-induced soil erosion and minimise fuel costs. An estimated 35% of total arable area in the U.S. was cultivated adopting minimum tillage technologies in the course of the 1980's (Haggblade and Tembo 2003). The CA experience in the U.S. gave impetus to the CA movement in South America (mainly Brazil) and Southern Africa (mainly South Africa and Zimbabwe), where government agricultural research centres established conservation tillage programmes to actively promote CA (*ibid*).

In Ghana, according to Ekboir *et al*. (2002), as early as in the 1990s, no-till with mulch, a conservational soil management practice, came into effect among Ghanaian farmers as a result of a joint agricultural programme between the Crops Research Institute in Kumasi, Ghana, Sasakawa Global 2000, and the Monsanto Company. The programmed package was disseminated to farmers in the Forest, Transition, and Guinea Savannah Zones and quickly got adopted. It is estimated that in 2000, no till was used by 100,000 small-scale farmers in 45,000 hectares of land.

2.3 Meaning of Social Network

There are myriads of definitions on social networks. The meaning of the concept of social network analysis therefore varies widely. In a widely used definition pioneered in earlier works on the nature of social networks consider it as all human actors participating in a social system composed of many actors who serve as reference points for each other's decision making. The type of the relationships in the network hinges on the main actor's perceptions, beliefs, and actions (Borgatti and Foster, 2003).

Generally, social networks are embedded in social capital. Distinctively, Borgatti and Foster (2003) argued that social capital equals the value of network connections. Similarly, social capital is defined as the social network link and the tangible and intangible resources acquired the through link (Gabbay and Leenders, 1999 and Greve and Salaff, 2003) and hence social capital encompasses variables including social networks. Consistent with this, Baron and Markman (2000) noted that social capital consists of social networks and the support gained from these. Bandiera and Rasul (2003) measured social networks at a level far smaller than the village. This distinguishes the effect of private social networks from correlated unobservables at the geographic or cohort level.

“A social network is the pattern of friendship, advice, communication or support which exists among the members of a social system” (Valente, 1996).

A social network is a social structure comprises individuals (or organisations) known as "nodes", which are connected by one or more particular types of interdependency, such as friendship, kinship, common interest, financial exchange, dislike, sexual relationships, or relationships of beliefs, knowledge or prestige (Kazienko *et al*., 2011). In a recent study, Maerteens and Barrett (2012) conceptualised social network as individual members (nodes) and the links among them through which information, money, goods or services flow. Social networks are collections of social or interpersonal relationships linking individuals in a social grouping (Scott, 2011).

2.3.1 Social Learning concept and agricultural technology adoption

Introducing agricultural innovations into a particular geographical area at a given period of time is usually carried through private and public initiatives (Hogset, 2005). Extensive studies have also examined social learning in different contexts and with different perspectives. Bandura (1978) took the theoretical perspective of social learning with the preposition that people learn from the observed behaviour of others. The socio-political characteristic of the learning process implies that knowledge and perceptions tend to be socially constructed. Social construction connotes socially created values and norms that comprise bedrock for human behaviour and adaptation.

The dissemination of innovations across the spectrum of social groups over a given time is considered the diffusion of innovations (Stoneman, 2001). Hogset (2005) subsequently conceived social learning as the “learning from others” model, where information on novel technologies spread from mouth to mouth through collective experimentation, discussion and persuasion or by direct observation of neighbours’ experiments.

Bandiera and Rasul (2003) however incorporates family members into social learning process and refers to family members as the farmer's extended family within the same village. Friends and neighbours refer to other individuals within the same village. These unique sets of individuals also have some influence on the adoption behaviour of farmers.

McCarthy (2015) outlined agricultural information source characteristics variables to include: the number of times the farmer has received an agricultural technology training in the last 12 months, the total number of an agricultural technologies adopters the farmer knows both in and outside of the village, and four composite variables for where the farmer learns agricultural information. The four composite variables for agricultural information sources are social networks (including learning agricultural information from relatives, neighbouring farmers, farmers' groups, and Integrated Pest Management Clubs), agricultural authorities (including learning agricultural information from agricultural officers and seed/pesticide/fertiliser salespersons), agricultural training events (including learning agricultural information from farmers' fairs, field days, and farmer's field schools), and media (including learning agricultural information from radio, television, newspapers/leaflets, and mobile phone providers).

Monge and Halgin (2008) argued that *innovation* from different schools of thought (e.g., Rogers, 2003 and Damanpour and Schneider, 2008) refers to diversed concepts—such as ideas, practices, products, services, processes, technologies, policies, structures, and administrative systems— that the adopting unit perceives as new. Perhaps quite conveniently and broadly, an innovation is best understood as anything new successfully incorporated into social or economic processes. Mugonola *et al*. (2013) maintained that adoption is conceived as an innovation decision process involving a number of steps through which decision-making units pass from the time of enlightenment about the new technology to the time they actually use the technology. Technology adoption is a continuous process of decision making. At each stage of the decision-making process economic agents get constrained by some interacting factors to inform the next step in the decision cycle (Bayard *et al*., 2007). Changing from one technology to another will require "double loop learning" (Kilelu *et al*., 2014) a farmer needs to learn how to deal with new management and a new network of people and institutions. In such context, feedback plays an important function in shaping human practices. Feedback is information that is obtained about the outcomes, characteristics, and/or consequences of our actions, and it enables us to assess these.

Nhamo *et al*. (2018) proved that communities and the networks that people have membership play an important role in influencing agricultural practices. It is, therefore, necessary to understand these and where possible incorporate them into a technology development and scaling process. A case in point is that community-based organisations are ideal for promoting local involvement and for sharing knowledge permitting communities to use existing networks and to use these to build up new networks. Farmer-to-farmer extension is grounded on the opinion that for a farmer "seeing is believing" and other farmers seen as the best educators.

2.4 Smallholder farmers food security issues

2.4.1 Meaning of food security

There is extant literature on the concept of food security. Earlier, the World Food Summit of 1996 conceived food security as existing when "all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life" (United Nations, 1996). Similar conceptual definition by Bandiera and Rasul (2003) argues that the number of months of food security - defined as the number of months of the year in which the household has stocks of food ready for consumption - does not differ by adoption status. The average household has insufficient food stocks for three months each year, exposing them to considerable risks.

Four conditions must be fulfilled simultaneously to ensure food security: food must be available, each person must have access to it, the food consumed must fulfil nutritional requirements, and access must be stable enough throughout the life of the person to ensure health. These elements are hierarchical and build on one another. Finally, availability, access and utilisation of food must be maintained throughout the life of each person for food security to be achieved (Brown, 2014). It is emphasised that availability and access to food are necessary but not sufficient conditions to enhance food security. Therefore, these should not be thought of as the sole determinants of food security; they only represent a subset of a much broader list of causal determinants of food security (Kalkuhl *et al*., 2016). What primarily remains key for the general well-being and specific health needs of individuals is the extent to which each person is able to meet their dietary needs (including micro- and macronutrients) and qualitative or subjective food preferences. This ability—subsumed under the utilisation dimension—is influenced by within-household allocation and distribution decisions, cultural or behavioural values, and complementary factors like diseases or other circumstances that require specific diets. While utilisation is the key dimension for food security on the individual level, measuring it is difficult and expensive, which hampers the utilisation of indicators focusing on food availability (e.g., per capita calorie provision) or accessibility (e.g., share of households with insufficient income to meet food and nutrition demands) (ibid).

2.4.2 Approaches to measuring food security

Over the past several years, global development policy concerns have highlighted the acuteness of food insecurity problems. As a result, several attempts have been made to measure food security so as to aid policy targeting at resolving world food security challenges. One of the earliest attempts was made by Haddad *et al.* (1994) who propounded the interaction approach. It is an overlapping method that aims at unravelling the degree to which a percentage of households that are insecure on one dimension turn out to also be insecure on another dimension. For instance, in the context of this approach, the concern will be, for individuals without proper access to water, what proportion of them are not food secured? Hence, a package of different indicators can be relevant determinants of food insecurity. However, though this approach combines different pointers of household food insecurity, it is limited by numerous combinations.

Consequently, Maxwell (1996) propounded a coping strategy technique for households in the midst of food shortages. It is an aggregated index structured on six food coping strategies. A scale was developed for the frequency of each individual strategy and was multiplied by the severity weighting factor based on ordinal ranking to derive the food security score. The relevance of this technique is that it enables deep understanding of household short-term food insufficiency. However, the disadvantage of the technique is that it overlooks specialized enumerators or any complex statistical procedures and hence fails to distinguish between short-term food insecurity from long-term vulnerability indicators

Again, a key growing indicator that has emerged over the year as an alternative measure of food security by incorporating food access is dietary diversity. This tool is especially useful to developing countries where diets are predominantly starchy staples, capture few or no animal products, and possibly contain high fats and sugars. In some developing countries, empirical evidence suggest that nutritional challenges are not the outcome of inadequate calories, but rather a lack of diet quality (Ruel, 2003). Therefore, the measurement of dietary diversity indicators has achieved currency, especially as the close relationship of dietary diversity with household per capita consumption and daily caloric availability as well as with anthropometric indicators of nutritional outcomes has been evidenced by previous empirical studies (see, for example, Hoddinott and Yohannes, 2002). The use of dietary diversity has been observed by few studies to be not just an indicator individual's dietary quality but that of the household as (Ruel, 2012). The measure is usually computed by summing the total number of foods or food groups consumed over a given reference period, usually ranging from one to three days. A basic dietary diversity indicator is the Household Dietary Diversity Score (HDDS), developed by the Food and Nutrition Technical Assistance (FANTA) project, which denotes the number of a total of 12 food groups consumed during the past 24h. The HDDS separates main staples into two groups, disaggregates meat, fish, and eggs, and also includes a group for miscellaneous food items. A primary problem associated with dietary diversity indicators concerns the difficulty involved in interpreting comparisons across studies, since the food groupings as well as the reference periods often vary between approaches. In an attempt to resolve this challenge further, validation exercises have been conducted involving dietary diversity indicators that group food indifferent ways or that prompt respondents about minimum quantities of each food group consumed. This informed the choice by the present study to adopt and modify the HDDS as a proxy for measuring farmers' food security.

2.5 Theoretical review

For years now, several studies have emphasised adoption of ISFM technologies (see: Vanlauwe *et al*., 2010; Mazvimavi *et al*., 2012; Mponela *et al*., 2016; Coulibaly *et al*., 2017 and Nhamo *et al*., 2018). More so, various theoretical frameworks have been employed to highlight the adoption behaviour of farmers. These include the theory of planned behaviour and reasoned action (Fishbein and Ajzen, 2011), diffusion of innovation (Rogers, 2003), social learning (Bandura, 1978), random utility and other quantitative theories. However, according to Bwambale (2015), as far as these studies are concerned and their theoretical underpinnings, there remains divergent points of view on the fundamental determinants of adoption.

Therefore, following Bwambale (2015), the current study adopted a holistic approach to examining the complexities of farmers' behaviour that characterise their adoption of soil fertility management technologies. This involves the combination of multiple factors from the theories of Planned Behaviour, Diffusion of Innovation, Social Learning and Random Utility Model. These factors include farmers' socio-demographic characteristics, social learning variables, institutional factors, farmland and tenancy characteristics, farmers' perception and other contextual variables that motivate farmers' adoption of specific components of integrated soil fertility management technologies.

2.5.1 Theory of Planned Behaviour

Ajzen's Theory of Planned Behaviour (TPB) (Ajzen, 1985) is a socio-psychological model which postulates that a person's (e.g., in a firm, a decision-maker's) intention to enact a given behaviour is the key determinant of that behaviour. In turn, intention depends on three principal determinants: attitude toward the behaviour (ATT), i.e., the level of an individual's positive or negative propensity towards a specific behaviour; subjective norm (SN), i.e., the extent of social pressure that people with influence exert on individuals, leading them to adopt or not adopt a specific behaviour; and perceived behavioural control (PBC), i.e., the individual's understanding of the ease or otherwise of accomplishing that specific behaviour. Each of these constructs derives from a combination of beliefs that respectively regards: the advantages vs. disadvantages associated with the considered behaviour (behavioural beliefs); the persons or organisations that may support it or not (normative beliefs); and the perceived ease versus difficulty of performing it (control beliefs). This model has been adopted to examine the cognitive factors determining farmers' adoption behaviour and, consequently, to assess farmers' crop yield and food security intentions.

Van Hulst and Posthumus (2016) explored the determinants of adoption of conservation agriculture or conventional farming, using the Reasoned Action Approach in Kenya among CA farmers and their neighbours in their field schools realised that the farmer's choice is explored by differentiating three elements in the decision-making process: the farmer's attitude towards CA, the farmer's perception of the social norms towards CA, and the farmer's perceived behavioural control (PBC) over practicing CA. They found strong evidence that attitude and PBC are motivating intentions to use CA techniques. It is implied that experimentation and learning are very important to promote intentions and use of CA, since they contribute both to realistic attitudes towards CA and an improved perceived behavioural control.

In effect, the three factors (subjective norm, perceived behavioural control and attitude), are informed by individuals' beliefs stemming from various sources, and are partly dependent on personal attributes and past experiences (Reimer *et al*., 2012).

Though this theory remains relevant in determining farmers' behaviour, the theory of social learning (Bandura, 1978) to understand how farmers' experiences in interpersonal exchanges and self-efficacy underpin adoption. This further relates the subjective norms component of the Theory of Planned Behaviour to Social Learning Theory where farmer-to-farmer extension or learning is detailed.

2.5.2 Social Learning Theory

Social learning is understood as the process through which groups of people learn, by jointly defining problems, searching for and implementing solutions, and evaluating the value of solutions for peculiar problems (Koelen and Das, 2002). This focus on social learning attracts attention to the contribution of social networks in farmers' learning and behaviour change, specifically on the tendency of networks to determine the adoption process at the micro level (Tran *et al*., 2017). This theory is grounded on the Social Learning Theory by Bandura (1978) who posited that learning occurs within a social environment which rests on various strategies such as observation (of neighbours), imitation (of associates/peers) or modelling (by friends). Such learning may or may not result in change in behaviour, depending on the extent of attention of the learner (cognitive capacity), ability to remember the observed behaviour (retention capacity), ability to replicate the observed behaviour (motor capacity) and desire to act the observed behaviour (motivation level), all of which are determined by the farmer's behaviour, attitudes and outcomes of such behaviours.

Kolb (1984) suggests that during the learning process, an individual undergoes four key stages: experiencing, reflecting, conceptualising, and experimenting. Concrete experience in and through action is the centre stage for the learning process. Individuals observe the consequences of their actions from which they learn deeply as they reflect upon such experiences. They, in turn, develop abstract concepts (analysis) and generalisations (conclusions) from these experiences and implement the knowledge acquired through active experimentation in subsequent situations resulting in new concrete experiences with a reflective feedback process on the outcomes of their actions (Keen *et al*., 2005 and Loeber *et al*., 2007).

2.5.3 Classical Diffusion Model

Diffusion means a process where an innovation is transmitted through given channels among members of a social system over time (Rogers, 2003). An innovation could connote an idea, practice or concept seen as novel by individuals or groups (Rogers, 2003). Classical diffusion model (ibid), which features diffusion as a phenomenon of contagion or information spread among potential users. Within the scope of this study of soil fertility management technology adoption, the 'hardware' of the technology represents the manure, compost, inorganic fertiliser, improved maize varieties, covering with crop residue etc and the 'soft' element of the technology is adoption which covers skills including mode and rate of application.

Consequently, Rogers (2003) and Nutley *et al*. (2002) propose five characteristics upon which the rate and tendency of adopting a technology is judged based on certain perceived features of a technology. Some of these features are intrinsic to the technology in hand while others concern the adopters' characteristics and their usage of the technology. They are: relative advantage, compatibility, complexity, trialability, and observability.

Relative advantage is understood as the way in which a given technology is seen as better than any technology it might replace (Rogers, 2003). It is dependent on a farmer's unique set of interests influenced by economic (costs, yields), social (current circumstances), and cultural (norms, beliefs) context within which the innovation will be applied (Pannell *et al*., 2006).

Compatibility refers to how the technology fits or is perceived to be consistent with farmers' available values and practices. Synchronisation of a new technology with an existing one brightens the chances of adoption since it makes the new technology relatively familiar. Complexity means the difficulty of understanding the application and actual use of a given technology. If potential adopters consider an innovation to be complex, its adoption likely gets low interest (Pannell *et al*., 2006).

Trialability means the opportunity for a likely user to try a technology (innovation) in an experimental setting. The targeted user can test the potentials and failures of a technology without necessarily committing to purchasing or adopting it (Rogers, 2003 and Pannell, *et al*., 2006). This contributes significantly to promoting persuasion and use of the technology by minimising uncertainty and risk associated with adoption of such a technology (Rogers, 2003 and Pannell, *et al*., 2006), and is dependent on the observability of results (Cary *et al*., 2001 and Pannell *et al*., 2006). Observability connotes how clear others perceive the use of the technology. Seeing, hearing and knowing that other individuals are using the technology significantly encourages adoption. This has an outright consequence on the type of social learning among farmers as well as the resultant adoption of ISFM practices (Reimer *et al*., 2012).

It can be deduced that, with the Classical Diffusion Model, all what is required for the occurrence of diffusion, in a virtually automatic fashion, is that users' information accessibility on innovations could be guaranteed. The selection of this framework is therefore appropriate since it clearly ties such social learning variables as membership of a community organisation among other community level social variables to adoption.

2.5.4 Random Utility Theory

Since farmers are exposed to a package of soil conservation and fertilisation management practices, they can adopt a bundle of practices that embodies all or any subset of the soil conservation and management practices offered. Thus, the use decision must take this into account because if, for estimation purposes, each adoption decision is treated independently, then valuable economic information may be lost (Cooper, 2003).

Similar to available research on agricultural technology utilisation behaviour, this current study adopts a random utility theory to understand technology use where the utility of a farm household is specified as a linear function of the household and farm-specific characteristics, institutional factors, attributes of technology as well as a stochastic component (Marenya and Barrett 2007). Farmers will usually use a technology or a mixture of a technologies that yields maximum utility to them.

Knowledge on the above theories makes it evident that understanding determinants of adoption goes beyond a single theory to a combination of theories by incorporating variables from the three attributes of Ajzen's Planned Behaviour Theory together with Roger's Diffusion of Innovation Theory to understand how differences in farmers' perceived controls and norms can determine their adoption. The Theory of Social

Learning provides social learning variables to understand the effect of farmer-to-farmer interactions on farmers' adoption decisions on Integrated Soil Fertility Management practices. On the flipside, the Random Utility Model reveals individual-specific variables that describe features of the decision maker. These variables could determine the relative attractiveness of the alternatives (Heiss, 2002).

2.6 Empirical review of past studies on study objectives

This section presents the findings from previous empirical studies that are linked to study objectives by highlighting their methodology, results, recommendations, determinants of key variables and the gaps in those studies.

2.6.1 Determinants of farmers' choice of agricultural information sources

Opara (2010) in an article explored the various personal and socio-economic determinants of the utilisation of agricultural information among farmers in the agricultural development programme (ADP) zones of Imo state, Nigeria. He used stepwise multiple regression procedure (backward solution) to investigate the linkage between the personal and socio-economic factors of farmers (independent variables) and farmers use of agricultural information (dependent variable). The study evidenced educational qualification, marital status, income and farmers preferred media of agricultural technology dissemination to major factors of farmers' decision on the use type of agricultural information (explaining 29.58% of the variation in the dependent variable). However, the study failed to give a comprehensive coverage of the utilisation of varied agricultural information sources including social networks.

Okoedo-Okojie (2015) in examining determinants of Constraints to Information Sources Utilisation among Maize Farmers in Edo State, Nigeria collected from 150 randomly selected maize farmers with the aid of structured instrument (questionnaire) validated by expert judgment, and assessed by employing frequency, percentage, mean and Chi-square for hypothesis testing. Results demonstrated that most preferred information sources were radio (M = 2.69), fellow farmer (M = 2.60), posters and bill board (M = 2.59), and books and leaflets (M = 2.58).

There was a significant relationship between access to credit (R2 = 7.416), farm ownership (R2 = 12.497), sex (X2 = 13.759) of respondents and constraints encountered in information sources utilisation at 0.05 level of significance. It was recommended that the Ministry of Agriculture should study time for broadcasting agriculture information in understandable language to attract maize farmers to listen, radio and television signals needs to reach rural areas to improve audience level of farmers for increased proven technologies information utilisation. Though various sources of agricultural information were adequately covered in his study, the study did employ a multivariate probit model to consider cases where a number of farmers may rely on several agricultural information sources.

Kughur *et al*. (2015) examined factors influencing farmers' access to various agricultural information sources in Gwer-East local government area of Benue State, Nigeria. They employed primary data for their paper from 116 respondents selected randomly across the study area. Using descriptive and inferential statistics (multiple regression) for data analysis, they showed that friends/relatives constitute 75.5% of farmers' agricultural information source, whereas 60.9% obtained information specifically on agricultural credit. The multiple regression analysis revealed formal education and yearly income as significant (at $p<0.10$ and $p<0.05$ respectively) determinants of agricultural information. They recommended improving farmers' access to credit schemes, promoting adult literacy to furnish farmers with reading and writing abilities and recruiting more extension agents in different areas of accessing agricultural information to support farmers with relevant and current information. Though their study was interesting, the sample size was not adequate compared to present study sample of 300 farmers.

Rehman *et al*. (2011) studied the factors affecting farmers' effective use of print media in the dissemination of agricultural information in Punjab. They used subscribers of three most circulated agricultural magazines as their study population. The results from 361 sampled respondents demonstrated that the print media were the main sources of information of the farmers. Some key determinants influencing their effective use were quality of information, newness, farmers' interest, in time publication, ease of accessing print media, usefulness of information, educational level of farmers, amount of information contained in it, and cost of acquiring print media. This study left out other major sources agricultural information including social networks and agricultural extension services.

Mittal and Mehar (2015) analysed influencing factors of farmers' tendency to use varied agriculture-related information sources. They examined the determinants by implementing a multivariate probit model and 1,200 farmer households primary survey data and highlighted that farmer's age, educational status and size of the farm inform farmer's decision in choosing varied information sources. The findings established that farmers adoption of several information sources, that could complement or substitute each other which indicates the implication that farmers' information requirements are met with numerous sources. This was a very comprehensive study in India and requires a similar study in Ghana which the present study intends to achieve.

Aonngernthayakorn and Sopart (2016) investigated the determinants rice farmers' utilisation of agricultural information in Central Thailand. They found from 240 sampled rice farmers that small farmers had more access to information on farming practices and post-harvesting activities, while large and medium farmers utilised more information on marketing, covering future market and farmgate prices. They employed multinomial logit model and estimated that length of farming experience, household labour size, distance to the Rice Research Center, and number of information sources, as well as the internet, television, extension programme, and relatives, significantly influence farmers' utilisation of agricultural information.

Mbanda-Obura *et al*. (2017) analysed the determinants of choices of agricultural information sources and pathways of a group of sorghum farmers in Ndhiwa Sub-County. Their research design was purely quantitative with a multi-stage sampling technique to collect cross sectional data from 379 sampled sorghum farmers. Results from their multinomial logit showed that gender, age, farming experience and education of household head, farm size, member and access to credit facilities are statistically significant. They recommend that a focal farmer be usually selected on criteria for further training to dissemination information or a centre by set up for farmers to visit to share information.

2.6.2 Analysis of the effect of social network and other drivers on the adoption of Integrated Soil Fertility Management technologies

Though there is some general consensus among scholars about determinants of agricultural technology adoption, the empirical results of earlier studies on off-farm income and technology nexus has been contradictory. For instance, the study by Gedikoglu and McCann (2007) showed that farmers' off-farm income significantly influences their decision to use improved technologies depending on capital and time that is required by the technology, the off-farm income can significantly be a determinant that promotes adoption or a factor that defers adoption. The outcome of the analysis using multivariate probit regression on farmers' overall farm in the U.S. income effect on farm technology adoption verifies that injecting manure into the soil, though capital-intensive practice, has significantly positive effect by off-farm work and adoption of record keeping, which is a labour-intensive practice, is negative and has a significant impact on off-farm work. While the early adoption theories focused on profitability, subsequent studies have emphasised that farm size, risk and uncertainty, information, human capital and labour supply also affect adoption. However, the study was carried out in the U.S and the present study provides empirical evidence of the significant impact of off-farm income on agricultural technology adoption decisions in the African setting.

Bandiera and Rasul (2003) presented evidence on how farmers' choices to use a new crop relate to the adoption choices of their network of family and friends. They found an inverse-U shaped relationship, implying that social effects tend to have positive outcomes when the network contains few adopters and get negative with many adopters. They also established that the adoption choices of farmers who have better information about the new crop are less sensitive to the adoption choices of others. Finally, they highlighted that adoption choices are highly related within family and friends than religion-based networks, and uncorrelated among individuals of different religions. They theorised an inverted U-shaped individual adoption curve, implying that network effects are positive at low rates of adoption, but negative at high rates of adoption.

Ali *et al*. (2007) studied the contribution of social capital to promoting the adoption of soil fertility management technologies in Tororo district, Uganda in a survey with 103 female and male farmers. Using Logit regression model, they highlighted that the tendency of presently adopting legume cover crops was more with farmers with memberships to groups relative to other community members. Some social capital variables that were found to have significant effect on increasing the probability of adoption of legume cover crops include the extent of cooperation, information diffusion and linkages with external agencies. Farmers' associations performed impressively on such indicators of social capital as cooperation, extent of trust, information sharing and participation in collective activities. They therefore suggested that strengthened local organisations and intensified multipurpose cover crops could raise adoption of soil fertility management technologies. This is a relevant recommendation but there are multiple soil fertility management technologies in the study and farmers could adopt some components or the full package and hence using a logit model bears some methodological shortcomings.

Genius *et al*. (2013) examined the role of information dissemination in promoting agricultural technology use and diffusion. They studied the effect of two information channels, namely extension services and social learning. They developed a theoretical model of technology adoption and diffusion, which they then empirically apply, using duration analysis, on a micro-dataset of across olive producers from Crete (Greece). Their study argued that both extension services and social learning are major factors that drive technology adoption and diffusion, whereas the efficacy of each typology of informational channel is strengthened by the existence of the other. They emphasised that informational transmission takes place not only through extension services but also between farmers themselves: a larger stock of adopters in the farmer's reference group induces faster adoption (-0.293 years), while a greater distance between adopters increases time before adoption (0.172 years). The effect of social learning is comparable to the effect of information provision by extension personnel (mean marginal effects on adoption times are -0.293 and -0.306 for the stock of adopters and exposure to extension services, respectively). In contrast, unlike with exposure to extension, geographical proximity is a very important determinant of informational transmission among the population of farmers. Finally, the interaction term between the two channels of information dissemination was found to have negative and statistically significant effect. This result indicates that extension services and intra-farm communication channels complement each other in information provision to olive-growers.

This finding might hinge on the nature of the transmitted information. The study was very comprehensive as it developed a theoretical model and tested it but focused on irrigation technology use and hence motivate further research to particularly examine these information channels in disseminating Integrated Soil Fertility Management technologies.

Langyintuo and Mungoma (2008) provided empirical evidence that examines a non-linear association between wealth and utilisation of new agricultural technologies so as to enhance understanding as to whether in a farming setting, farm households with a poorer wealth score act differently from their counterparts on a higher level. Employing data collected from a random selection of 300 households in three districts of Zambia, they first classified farm households into poorly- and well-endowed on the basis of their ownership of productive assets and implemented individual double-hurdle models for the use of improved, high yielding maize (IHYM) varieties separately for the two groups. They revealed that the influencing factors of intensity of adoption of IHYM varieties varies between the two groups. This highlights their recommendation of wealth targeted interventions to propagate the intensity of adoption of those varieties and its consequent effects on food security and general livelihoods of the households.

Monge and Halgin (2008) analysed the role of change agents and social capital to the use of innovations among small farm households through social networks in rural Bolivia. Three hundred and sixty farmers involved in the targeted networks and 60 change agents and other actors propagating the dissemination of innovations were interviewed. Their study found persuasion, social influence and competition to be statistically significant influencing factors of farmers' use of innovation. Their findings tend to engage policy attention especially the incorporation of social capital and networks in the design and implementation of policies on agricultural innovations. However, the study did not directly deal with the nexus between adoption of soil fertility management practices and social networks in Ghana.

Nkegbe *et al*. (2012) investigated the determinants of intensity of adoption of six conservation practices *viz*. stone bund, soil bund, grass strip, agroforestry, cover crops and composting using 445 households' data across 15 rural settings in northern Ghana. They employed univariate, bivariate and multivariate probit models and their findings showed the key adoption factors to be plot and cropping characteristics such as location; and socio-economic and institutional variables including number of contacts with extension officers, membership in farmer association and distance to major market. Their study implies that building the capacity of extension service in the area can greatly influence conservation adoption. However, the study, with the exception of farmer association membership variable, neglected the critical contribution of participatory extension approaches such as social networks in the diffusion of agricultural technologies. The paper, however, gives a good support to the development of the literature on adoption studies, especially in Northern Ghana.

Lambrecht *et al.* (2014) presented a study on gender distributed programme participation and concluded it leads to higher use rates with females not taking part in the use of capital-intensive technologies whereas females were not to be participating more in labour-intensive technologies. In their conclusion they noted that selecting female-headed households guarantees high effectiveness for technology use than selecting female farmers under male-headed households. Though this is a unique and one of the scanty studies that explored the gender dimension of adoption of agricultural technologies it did not consider the major technology dissemination channels such as social networks across the gender divide.

Mponela *et al*. (2016) investigated the factors influencing the adoption of integrated soil fertility management technologies small-scale farmers in the Chinyanja Triangle of Southern Africa. They employed cluster analysis to classify the technologies as well as ordered probit to investigate the tendency of several technology adoption. Their study revealed that adoption of ISFM is classified into 3 technological categories depending on complementarities. The nutrient dense category of technologies is inorganic fertiliser, compost and animal manure (ISFMset3). The other technological group consisting of fallow, rotation and grain legumes (ISFMset2) which promotes biomass accumulation and nitrogen fixation with complementary effects in cereal dominated farming system, has more potential to be used by farmers with land that needs high inputs, are relatively highly educated, have more bicycles and have higher financial capital. Other four technologies (ISFMset1 including mulch, lime, compost and agroforestry) are used by a few individuals to address specific constraints in nutrient and water retention, and acidity. Their study is very useful to the current study but did not deeply explore the consequence of social learning for ISFM adoption.

Kokoye *et al*. (2016**)** assessed the use and the socio-economic effect of adopting Soil Conservation Practices especially on farm income in Northern Haiti as a consequence of agricultural productivity increase. With data collected on 483 farmers in six watersheds in Northern Haiti, they used the Heckman two steps selection model for their analysis. Their study demonstrated from the probit model that gender of farmer, membership of farmer groups, land ownership, access to credit, the interaction between education and group, the size of the plot and the interaction between slope and the size of the plot are key determinants. The outcome model of the Heckman selection shows household size, access to credit and off-farm activities improve farmers' income as significant. But the study failed to make any policy recommendation on adoption and had some model identification challenges as the same explanatory variables were included in both the selection and outcome models which can impair the reliability of the estimates.

Abdulai (2016) adopted a discrete time duration model to understand the role of peer effects through farmers' social and institutional networks as well as farmers' risk attitude in the use and diffusion of conservation agriculture technology. The results from a principal components analysis revealed that farmers' years of education, risk appetite, social networks, access to credit, extension services and machinery as well as soil quality positively affect adoption and diffusion of conservation agriculture technology. This was very interesting but failed to capture the effect of the adoption of the conservation agricultural technology on crop yield which also influences adoption of the technology. In this current study, there is a link between soil fertility management adoption and crop yield.

Mango *et al.* (2017) studied the level of awareness and use of land, soil and water conservation practices in the Chinyanja Triangle, Southern Africa. Data for this study was collected from 312 households using a survey questionnaire. They used t-tests to categorise adopters and non-adopters of soil, land and water conservation measures and binomial logit models. Their study found the household head's age, education, agricultural advice reception, farmer group membership, pieces of land-owned or used in production and land-to-man ratio as major determinants of decisions to adopt. Based on the findings, they drew the conclusion that to maintain and enhance land productivity, emphasis should be placed on farmers' heterogeneity with regards to household head's age, level of education, extension services outreach, and socio-economic characteristics. This suggests that governments' policies initiatives should target improving farmers' level of education, extension delivery that will target the elderly and the youth, landownership, credit access, and social capital such as group formation. With respect to landholding, their results are consistent with Oostendorp and Zaal (2012) who concluded that earlier adoption studies employing duration or panel data have concentrated on the role of different changing village and household-level determinants and highlighted the importance of land ownership changes. As a corollary, the study proposes that policy-makers should focus on the important role of land market changes for investment in land. This informs the incorporation of land tenancy and plot characteristics as some of the influencing factors of adoption in the current study.

Moges and Taye (2017) analysed the significant influencing factors of farmers' perception which motivate their adoption and investment in Soil and Water Conservation (SWC) technologies in Ankasha District of Ethiopia. They surveyed 338 households drawn in a random selection from two rural sample kebeles (called villages here after). Descriptive statistics and results from logistic regression model demonstrated that educational status and level of access to trainings have a positive and highly significant relationship ($P < 0.01$) with farmers' perception. Likewise, household ownership of land, plot size, slope type, and extension contact have positive and statistically significant effect on farmers' perceived understanding on the need to use soil conservation practices at 5% level of significance. Likewise, the effect of farmers' age and distance to plot from the homestead have statistical significance and negative effect ($P < 0.05$). Overall, the findings suggest that the perceived need for farmers to incur investments in Soil and Water Conservation technologies is highly influenced by socioeconomic, institutional, attitudinal and biophysical determinants. Thus, regular contacts between farmers and extension agents and frequent agricultural trainings are also required to raise sensitisation on the impacts of Soil Water Conservation benefits. This recommendation forms the foundation of the present study to establish whether farmer-to-farmer extension and contacts with extension agents are critical factors that influence adoption of soil fertility management technologies or not.

Kpadonou *et al*. (2017) performed a joint analysis of the determinants of on-farm soil and water conservation technologies in West African Sahel by implementing a combined analytical approach of both multivariate and ordered probit models. They selected 500 farmers and their study emphasised that the significant determinants of farmers' adoption decisions and to emphasise the utilisation of most SWC practices are the presence of children (aged 6 to 14) within the household, land holding, land tenure, awareness and training on SWC and access to alternative – but non-agricultural labour constraining – cash sources such as remittances. Higher migrant household members raise the likelihood of the household increases the use of SWC practices, but only when this is in line with the household's land endowment and labour needs for farm activities. This comprehensive study will be of significance for a finer understanding of SWC practices in West African Sahel. Overall, they recommend the findings of their study should inform policy prescriptions on promoting SWC practices.

Mekonnen *et al*. (2018) examined the existence of social learning in agriculture in Ethiopia. They evidenced that kinship or group membership and organising regular meetings with network members are all related with an increased tendency of establishing an information link with a network member. Furthermore, they found evidence of the presence of positive and significant association between networks and the use of row planting and yields for both male and female networks. On the contrary, they provided evidence to suggest that the hypothesised inverse U-shaped association of social learning, that is, between the number of adopters in the network and the adoption of row-planting, is quite higher for female networks. The implication of their findings is that extension services and other related programmes that aim at promoting the adoption of agricultural technologies and seeking yield improvement can benefit from social networks but that their success depends on figuring out the ‘‘right” networks, such as those of female household members in the context of row-planting.

2.6.3 Studies on estimating the impact of adoption of Integrated Soil Fertility Management technologies on maize yield of smallholder famers

Mazvimavi *et al*. (2012) defined total factor productivity as increase in output that is unexplained by change in inputs. But generally, vast number of studies (see: Arslan, 2017; Abate *et al*., 2015; among others) on maize yield or productivity tend to measure yields by output per hectare or metric tonnes per hectare.

Braimoh and Vlek (2006) investigated some key determinants of maize yield in Northern Ghana. They created a soil quality index as a continuous variable with a social data set to study maize yield employing linear multiple regression. Five significant variables were identified ($P < 0.05$): soil quality index, fertiliser utilisation, household size, distance from main market, and the interaction between fallow length and soil quality index. The interaction between soil quality and fallow on maize yield was statistically significant and negative, implying the effect of litter quality and N immobilisation on improving the quality of the soils. Research and policy should focus on the promotion of site-specific, legume-based cropping, and the adoption farm-livestock integration system of farming in Northern Ghana in particular and similar areas across sub-Saharan Africa. The study captured only three soil fertility management practices (soil quality index, fallowing and inorganic fertility) and also using social data the use of these technologies could be driven by unobserved characteristics that also influence maize yields and so failed to consider potential endogeneity.

Alene and Manyong (2007) investigated the literacy effects on the outcomes of agricultural productivity with consideration to local and improved technology in northern Nigeria using endogenous switching regression analysis. They proved that there exist major productivity-inducing outcomes of education and extension services only under improved technology. Factors that enhance technology use will hence invariably increase the marginal roles of farmer schooling; these include education, participatory technology evaluation, improved seed supply, and market access. The results demonstrated that schooling not only enhances agricultural productivity following technology adoption but also promotes adoption itself. However, the study did not directly estimate the impact of ISFM practices on maize yield in Ghana.

Ngwira *et al*. (2013) studied the contribution of CA practices to crop productivity, profitability and improved soil under the conditions encountered by small-scale farmers in two farming communities from 2005 to 2011 in Malawi. The drier agro-environment of Lemu of Bazale Extension Planning Area (EPA) is featured by sandy, clay and loam soils and inadequate rainfall. Here, CA showed positive benefits on maize yield after the first season of experimentation, with highest increases of 2.7Mgha^{-1} and 2.3Mgha^{-1} high yield in CA monocrop maize and CA maize–legume intercrop, respectively, compared to the conventional tillage in the driest season of 2009/10. In the high precipitation environment of Zidyana EPA (featured by sandy loam soils), significant maize yield outcomes led to the fifth season of experimentation. In contrast, for rigorous use of CA by small-scale farm owners, cultural beliefs that crop production is possible without the clear adoption of ridge and furrow system and residue burning for mice hunting should be curbed. On the flipside, Kirkegaard (2008) argued that some soil fertility management practices such as crop rotation minimise the chance of infestation by pest and disease and consequently crop yield whiles Farooq *et al*. (2011) indicated that they also foster weed control.

Mazvimavi *et al*. (2012) performed productivity and efficiency analysis of maize cultivated under conservation agriculture in Zimbabwe. The analysis was conducted on a three-year panel sample of sampled small-scale farm owners and using a stochastic production frontier model compared productivity and technical efficiency between improved agricultural practices and that of conventional farming. Their findings revealed that CA technology is implemented on a small scale of plots than its counterpart conventional farming (0.36 ha relative to 0.85 ha) even though has a very important role to total maize production, on average 50% of output share. Similarly, it is reckoned that fertiliser application has a higher positive effect in CA than in conventional farming. Overall, returns to scale are similar for CA and conventional farming (0.84 and 0.89 respectively). These findings establish the major yield gains in CA practices and key effects on food production. CA saves land under cultivation, and this is a very critical concern for land or resource poor farmers since they can still ensure active food production on smaller area. But more labour requirements in CA poses some challenges in its utilisation, especially for the poorer farmers. Their study examined efficiency in the production of maize without directly analysing the factors determining maize yields.

Pedzisa *et al*. (2015) assessed determinants of intensifying (by the number of techniques used) technology utilisation of conservation agriculture (CA) techniques by small farm owners in Zimbabwe using count data analysis. They found that productivity has a direct association with the intensity of adoption. Farmers employing all the CA practices tend out to be highly productive, with about maize yield of 2.50 tons/ha, relative to a yield of less than 1 tons/ha for farmers using three or fewer techniques. Further, the previous season intensity of CA technologies adoption was also found to be positive and have statistically significant impacts on that for the present season adoption intensity. The implication is that propagating CA technologies adoption has a persistent effect, even subsequently when those propagations cease. The study provided empirical support that promoting conservation agricultural practices has raise maize yield potential in Zimbabwe but not necessarily in Ghana and hence also motivating the present study.

Okeyo *et al*. (2014) demonstrated in a paper on how reducing nutrient loss need for sustainable agriculture in the tropics (Kenya) can be a determinant of maize yields using experimental design. Results showed mulching had a direct effect on runoff and maize yields. Inadequate and erratic long rainfall pattern results in total crop failure in 2011. Amidst short rains in 2011 tied ridging and mulching raised maize yield by 94 and 75%, respectively, relative to control. They highlighted the relevance of analysing soil and water conservation techniques in rain-fed farming systems point of view in response to decreasing food production and buttresses attention on tied ridging and mulching. This emphasises the relevance of this present study as it tries to examine ISFM technologies in food production under rain-fed system in Northern Ghana in West Africa.

Banerjee *et al*. (2014) investigated the major determinants inhibiting maize (Zea mays L.) production in eastern India to frame useful crop and nutrient management techniques to curtail yield losses. Using of multivariate categorisation and regression tree analysis as well as Stochastic Frontier Analysis observed that intensifying farm input utilisation and eradicating socio-economic and structural challenges improve efficiency in maize production. Poor yields of farmers were attributed to farmer's ethnic origin, availability of family labour, amount of land owned, legumes in crop rotation, irrigation constraints, seed type, optimal plant population, labour and capital investment, and use of organic manure. A typology-specific farm support strategy may be formulated to offset this lack of entitlement among resource-poor farmers.

Gloria *et al*. (2014) provided an empirical evidence on maize cropping systems in Ghana and revealed that they are associated with low productivity due to continuous use of traditional low yielding open pollinated maize varieties (OPVs). Maize yields average approximately 1.7 MT/ha as against an estimated achievable yield of 6.0 MT/ha (MoFA, 2011). The development, adoption and commercial adoption of locally adapted maize hybrids in Ghana holds the key to increased output in the country, since hybrids are known to yield higher than OPVs. The successful use of improved varieties particularly hybrids depends on their comparative urge over local varieties commonly grown by farmers. Their study is useful in understanding the critical contribution of improved maize varieties especially the drought resistant varieties to enhancing maize yields but it did not comprehensively cover other components of ISFM practices including organic manure and inorganic fertiliser application and therein lies the justification of the present study.

Ngwira *et al*. (2014) performed an on-farm assessment of the contribution of principles and components of conservation agriculture boosting maize yield and weed biomass in Malawi. The interaction between site and treatment demonstrated that under the rainy environment of Zidyana, weed debris acquired under no-tillage and residues in addition to fertiliser (NT+F+R) was 0.6 mg ha^{-1} lower than under CP+F. Findings imply that an estimated 6.0 mg ha^{-1} of mulch is needed to have a similar effect as tillage in managing weeds. Fertiliser had significant effect on maize yield, irrespective of tillage and crop residue management. Mulching had a relatively higher benefit over tillage in the less humid environment of Manjawira, where maize yield acquired under NT+F+R was 1.2 mg ha^{-1} more than under CP+F. They verify that employing no tillage yields benefits on condition of accompanying it with fertiliser application, retention of crop residues as surface mulch, and improved weed control. Improving farmers' access to inputs (fertilisers and herbicides) is very key to the use of CA at scale in Malawi. On the contrary, their study used an experimental design and hence up-scaling to a broader community or setting requires a quasi-experimental study to establish the effect of adoption of ISFM on maize yields especially given the difficulty in conducting experimental research in social science.

Urassa (2015) explored the households' maize production levels and the factors influencing its productivity. Using survey data from Rukwa district, his study evidenced that maize crop remains very c- 50rucial to households' wellbeing. However, the crop production levels were low. Education was noted as a crucial determinant in increasing yields, implying that non-agriculture policy variables could also be useful in supporting productivity and welfare of farmers. Regardless of the relevance of maize crop to household welfare, a number of constraining factors were outlined as reducing productivity including access to fertilisers, improved seeds and other chemical inputs needed for better production, and extension services. Therefore, local and central government efforts are required to increase households' maize production and thereby increase the chances of improving their well-being.

Mason *et al*. (2015) reviewed soil and cropping system research in semi-arid West Africa as related to the potential for conservation agriculture. The review focused on the wealth of research on cropping systems, tillage, crop residue, nutrient, and weed management as related to conservation agriculture. It concluded that there exist some association between crop residue and grain yields, thus improving crop, soil, water, nutrient, and weed management efforts to raise grain yield would also promote the availability of crop residue with opportunity for 'left over' crop residue being supplied for soil mulching. Increased grain and stover yields and raised profit potential for resource-poor farmers in West Africa will be required before wide-scale adoption of conservation agriculture will be possible.

Latati *et al*. (2016) associated an increment in biomass and grain yield with higher levels of nitrogen fixation ability provided by beans when using a bean-maize intercropping system. This was buttressed by Abdulai (2016) who demonstrated that on average, farmers in Zambia produce about 2.6 metric tonnes per hectare (tons/ha) of maize with fertiliser and 1.4 tons/ha without fertiliser, which is far below the 5 tons /ha under Comprehensive Africa Agriculture Development Programme (CAADP). Maize yields with fertiliser in the Central, Eastern, Southern and Western provinces are about 2.5, 2.6, 1.9, and 2.0 tons/ha, respectively. For maize production without fertiliser, about 1.7 ton/ha is recorded for Central province, 1.6 tons/ha for the Eastern province, 1.2 tons/ha for the Southern province and 0.9 tons/ha for the western province. The authors provided evidence of a direct link between crop rotation and inorganic fertiliser application and that also constitutes some of the testable hypotheses of the present study.

Arslan *et al*. (2017) investigated the impact of various soil and water conservation techniques (SWC) on maize productivity under weather shocks in Tanzania. First, they estimated the factors influencing uptake of agricultural technology by applying a multivariate panel data model by incorporating their complementarities and/or substitutabilities of the technologies. They found high complementarities existing between agricultural practices both with regards to adoption as well as yield impacts.

Farmers in locations characterised by high rainfall variability and temperature have been unexpectedly high have significantly lower maize yields. SWC emerged as one of the key practices in increasing yields with significant benefits by itself, in combination with other practices, under normal weather conditions and during rainfall and temperature shocks. Overall, promoting the utilisation of SWC stands as a potential policy strategy to safeguard food security from worsening regular weather risks in Tanzania.

Ntabakirabose (2017) performed economic assessment of the factors determining of maize productivity and efficiency among farmers in Rwanda. Using multi-stage sampling technique to sample 168 maize farmers, his work adopted Stochastic production frontier model to examine technical, allocative and economic efficiency levels, whiles Tobit model was used to identify determinants of efficiency levels. The finding revealed that improved seeds, land size, organic manure, labour and inorganic fertiliser have a positive and statistically significantly effect on maize output. Factors including access to credit; extension services, work experience in the production of maize; and family income were statistically significant at 1% level as determinants of technical efficiency. However, household head age and distance to market showed a negative but statistically significant effect on technical, allocative and economic efficiency of the maize farms. They recommended that government agencies especially Rwanda Agriculture Board and local government and researchers should consider the above indicated production, socio-economic and institutional factors to promote productivity of maize in the study area.

Fujisao *et al.* (2018) studied productivity implications of cultivating maize in a continuum in Sainyabuli Province, Laos I. The time of the cultivation of maize in the separate fields ranged from 1 to 30 years. On the average, yields across the three sample sites in each field also ranged from 1.1 to 6.0 t ha^{-1} and with a high probability to much longer when the time of continuous cultivation was extended. ANCOVA and regression analysis for each topo-sequential position revealed that the diminishing yield trend in each field were mainly acquired from the upper position of sloped fields. Cost of 1.7 t ha^{-1}, with respect to maize yield, was required for buying inputs such as seed, herbicide, and outsourcing plowing in maize cultivation. The linear regression line fitting the yield depending on the time of continuous cultivation implied that maize production diminished at −0.06 t ha^{-1} $year^{-1}$; but it may be economically viable for 43 years. This contrast with the finding that yield in six of the 36 sampled fields emerged at lower than profitable levels, suggesting that immediate enhancement of soil quality in field and effective crop management are required to produce maize sustainably. Even though this was a field experimental study, it still provides some testable hypothesis for further testing of maize yield effects with data at farm level of ISFM adoption.

2.6.4 Studies regarding adoption of integrated soil fertility management technology on food security of smallholder farmers

There is empirical evidence that adoption of soil fertility management and increase in crop yields translate into promoting the food security of farm households. For instance, Shiferaw *et al*. (2003) investigated relevance of production and consumption side factors determining farmers' food security priorities using a logistic regression analysis in Southern Ethiopia. From data from 247 farmers, the major influencing factors of household food security were: innovation adoption, farming system, size of the farm, land quality, household size, per capita aggregate production and whether farmers have access to market or not. Of these, innovation adoption, farming system, size of the farm, and land quality are production-side determinants. Household size, per capita aggregate production, and access to market are consumption-side determinants.

Beyene and Muche (2010) researched on factors influencing household food security among rural households in the Ada Berga district in central Ethiopia. Household calorie acquisition was examined to measure the status of household food security. Based on the survey of 196 farm households, the logistic model was estimated. Variables related to experiences in farming activities, off-farm and non-farm incomes, land and livestock holding and soil and water conservation practices significantly affect household food security. A difference in the utilisation of chemical fertiliser contributes positively to the impact on food security where improved food security was observed as the intensity of fertiliser use increases. Results also indicated that developing interventions with the purpose to increase income diversification, improved supply of fertiliser, increasing land and livestock productivity will immensely contribute to the attainment of food security. In general, the results of the study produced the implication that attaining food security in the highlands of Ethiopia requires adoption of mixed strategies and policies.

Lawson (2011) established the factors determining food security among rural Ethiopian households, focusing mainly on food aid using unique panel from the Centre for the Study of African Economies. The data, covering 15 rural villages and 1477 households, were collected in four waves in 1994, 1995, 1997, and 1999. The analysis is cross sectional within each survey round with a rich set of controls for household and production characteristics. A fixed effects model using village variation as an instrument is used to estimate the effect of both short term, and long term, food aid on food security at the household level. Key findings are that while the amount of food aid received in the last year does not have significant effects on food security, participation in food for work might. Long term food aid can have a positive or no effect on commodity type. Also, the persistence of aid, as measured by how many years the household has received aid, has a significant negative effect on food security. It may be the case that the longer a household has received aid the less likely it is to reinvest in its factors of production.

Fisher and Lewin (2013) explored how socio-economic characteristics of households, local conditions, and public programmes are associated with the probability that a farm household in rural Malawi is food insecured. The statistical analysis uses nationally representative data for 8350 randomly selected households interviewed during 2004/05 for the second Malawi Integrated Household Survey. Regressions are estimated separately for households in the north, centre, and south of Malawi to account for spatial heterogeneity. Results of a multilevel logit model reveal that households are less likely to be food insecure if they have larger cultivated land per capita, receive agricultural field assistance, reside in a community with an agricultural cooperative and relatively high annual rainfall, and are headed by an individual with a high school degree. Factors that positively correlate with household food insecurity are price of maize, price of fertiliser, number of household members, and distance to markets. Implications of these findings for policy are discussed.

Tefera and Tefera (2014) identified major factors influencing farm household food security and coping strategies employed to cope with food shortfall. Households' daily calorie availability was measured to determine household food security status. A total of 130 randomly selected households from Mareko Woreda of Guraghe Zone in Southern Region were involved as source of information. The finding of the study shows that 62 % of sample households were food insecure. Despite the food secure households' acquisition of adequate kilo calories, they faced 2.46 food deficient months indicating the weekly calories availability per adult equivalent may not best describe food security status year-round. Logistic regression model resulted in eleven significant variables at less than 10% probability level among 17 variables. These were age of household head, level of education, household size, size of cultivated land, use of improved seed, number of contacts with development agents, size of credit received, size of livestock owned, and off-farm income per adult equivalent. The study recommends that proactive policy in family planning, strengthening extension support, incorporating coping strategy in the government regular projects and programmes, promoting land intensive and conservation agriculture should be integrated as food security efforts of the government.

Olabiyi and McIntyre (2014) used pooled data from the nationally representative Canadian Community Health Survey, spanning the years 2005–2010 and investigated risk factors for food insecurity in higher-income households. Food insecurity was increased among renters, single-parent households, and those with greater household size and where educational attainment was lower, unemployment benefits were received, chronic disease was present, and smoking and problem of gambling occurred. They recommended that consideration of these factors may inform policies and programmes that provide access to short-term income support for higher-income households as well as treatment for gambling and other addictions.

Abafita and Kim (2014) examined the factors influencing farmers' food security in rural Ethiopia by applying data acquired from the Ethiopian Rural Household Survey.

They employed self-reported food security situation and a multidimensional index using principal components analysis. Employing Ordinary Least Squares and Instrumental Variable estimation, they identified and examined the important determinants. Their study found that age of the house head, adequacy of rainfall, livestock possession, off-farm activities, soil conservation practices and per capita consumption expenditure had a positive and significant association with farmers' food security whereas having credit and remittances had a negative influence. They recommend income diversification opportunities in rural communities by promoting off-farm activities, education, capacity building and extension services, and improving livestock productivity to enhance farmers' food security. They also encourage the productive utilisation of credit in rural areas.

Mathenge, Smale, & Olwande (2014) analysed how using hybrid maize can influence household dietary diversity of family farms from Zambia. They estimated two-stage, instrumental variables, Poisson, and ordered logit regression models to test the hypothesis of the relationship between hybrid seed use and four indicators of dietary diversity: food group diversity (24-h), vitamin A diversity (7-day), food frequency (7-day), and frequency of consuming foods fortified with vitamin A (7-day). They argued that their findings stood robust to econometric method and sampled women investigated in the study and were involved in maize cultivation using maize hybrid seed had highly diverse diets.

Khonje *et al*. (2015) analysed adoption and welfare impacts of adopting improved maize varieties in eastern Zambia using data obtained from over 800 sampled farm households. Simultaneously implementing both propensity score matching and endogenous switching regression models, their study argued that adoption of improved maize varieties results in major benefits in crop incomes, consumption expenditure and food security. They concluded that improved maize varieties have a high potential to significantly reducing poverty in eastern Zambia.

Harris-Fry *et al*. (2015) examined the factors influencing farmers' food security in Bangladesh. They randomly took data from sampled 2,809 women within reproductive age. They estimated a Multinomial logistic regression model to establish the link between chosen influencing factors of household food security and months of sufficient household food provisioning, and a linear regression to estimate the relationship between the same factors and women's dietary diversity score. The results observed that land owned, relative wealth, women's educational status, access to media and women's freedom of accessibility to market all significantly mitigated the danger of food insecurity. Larger households increased the risk of food insecurity. Households with vegetable gardens, rich households and educated women had a higher tendency of improved dietary diversity scores. They recommended existing policies that relate to these determinants should be designed and monitored with the understanding that they could substantially influence the food security concerns and nutritional status of the population.

Domènech (2015) conducted an extensive review on improving irrigation access to combat food insecurity and undernutrition. The author noted that interventions designed to facilitate adequate water provisioning and accessibility for welfare and domestic activities create increased tendency to improve various factors influencing undernutrition, such as the quantity and diversity of foods consumed within the household, income generation, and women's capacity building. The review analysed the existing evidence concerning the contribution of irrigation to promoting nutrition and health benefits. Quite a number of the studies reviewed revealed a direct effect of irrigation schemes on food security. However, existing evidence is still insufficient to draw broad conclusions, largely because nutrition has not yet been considered an explicit objective of irrigation development. Nutrition-sensitive irrigation schemes are required to facilitate the realisation of the full potential of irrigation schemes and eradicate negative effects of the phenomenon to people's health and nutrition wellbeing. Again, the author maintained that even though it was empirically verified that there is a direct effect of irrigation on food security, this gives a reason for more studies to buttress the evidence. Hence, this justifies the current study even though with a focus to analysing the effects of ISFM practices, not irrigation, on food security of farm households.

Bidisha *et al*. (2017) attempted to analyse the association among credit, food security and dietary diversity in Bangladesh. They employed Household Income and Expenditure Survey with additional survey data of 1,200 households. They controlled for potential selection bias using propensity score matching and an instrumental variable technique by using distance to nearest financial institution in their estimates. They noted that credit access improves food security and allows households to achieve greater dietary diversity. Dietary diversity was measured using dietary diversity scores, including the food consumption score and the household dietary diversity score and households with having access to credit score more for those without according to such measures. The results were robust following correction for endogeneity issues, and the paper therefore provides empirical evidence in favour of policies supporting credit access by poor households in Bangladesh. However, their study emphasised credit accessibility and its effect on food security without establishing a direct association that might exist between agricultural technology use and its consequence for farmers' food security.

Coulibaly *et al.* (2017) analysed the implications of using fertiliser trees for household food security. They used primary data of 338 farmers in Malawi and adopted an endogenous switching regression to rigorously analyse adoption impacts. Econometric results revealed that fertiliser tree adoption promotes food crops values by 35%. Disentangling the impacts through categorisation by land ownership also revealed that farmers with farm ownership of up to 2 acres realised the more benefits. Furthermore, fertiliser tree used together with improved maize varieties further highly raised value of food crops. Their study offered preliminary insights that contribute to an unfolding area of research on quantitative assessment of agricultural interventions such as agroforestry practices using novel analytical approaches. They offered some policy prescriptions and proposed the necessity of subsequent studies to be conducted around development interventions that take into consideration variation in social, economic and ecological settings of farmers to promote adoption so as to enjoy the full benefits of agroforestry in enhancing soil quality and farmers' food security.

2.7 Conceptual Framework on ISFM technology adoption

The conceptual framework puts the study in a context and highlights study objectives and key variables in the study and their interconnectedness. The study was theoretically grounded on an extended form of Ajzen's (1985) Theory of Planned Behaviour with the Random Utility Theory, the Social Learning Theory and Roger's Diffusion of Innovation Theory as other sources of predictors of farmers' adoption decision making (Figure 2.1).

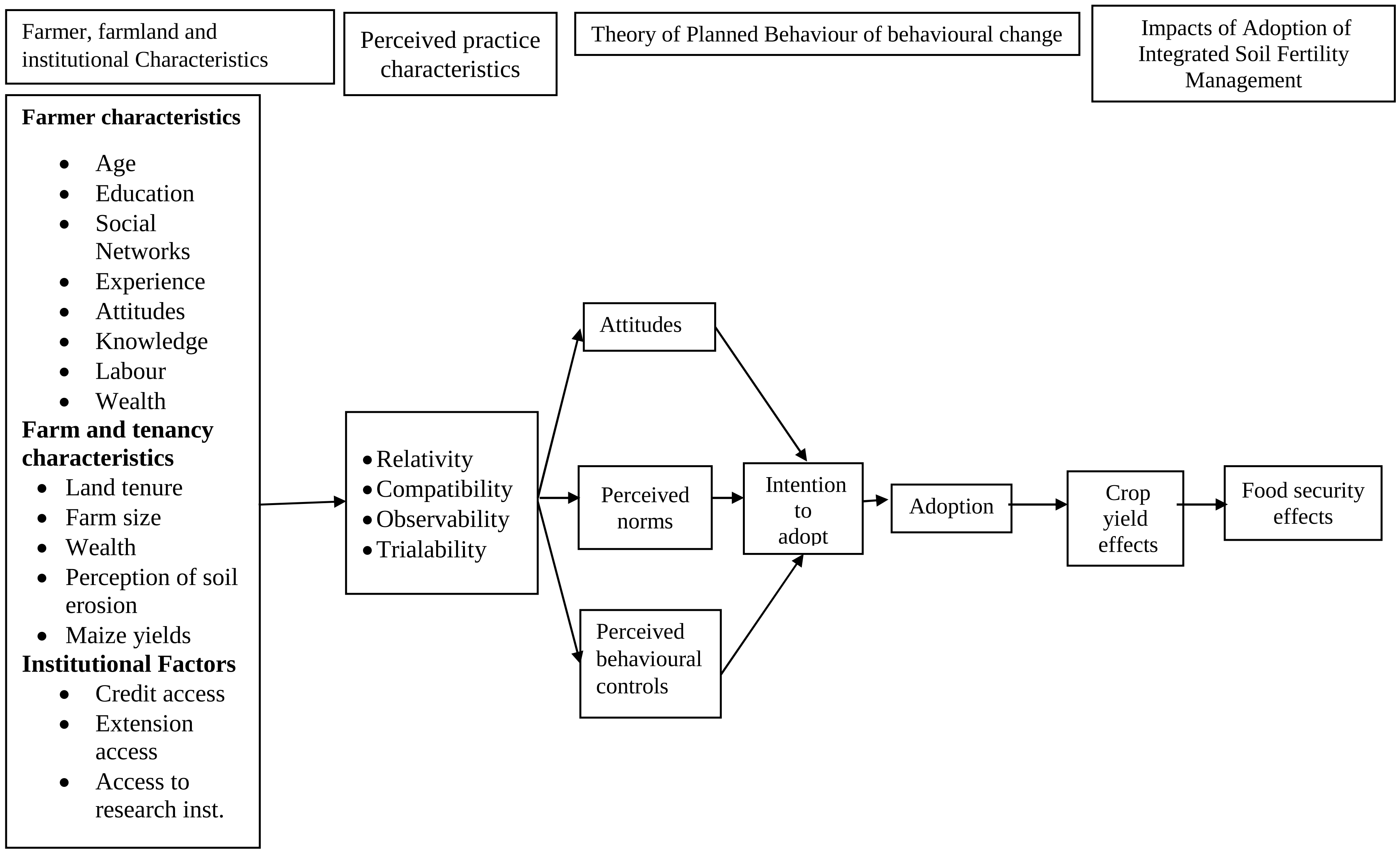

Figure 2. 1: Modified conceptual framework (Adapted from Bwambale 2015)

In this study, farmers' intentions to switch to ISFM practices are premised on different reasons. They may identify a highly efficient and profitable method to produce, or they may perceive a problem and in their quest for solutions discover a new practice, such as soil fertility management practices as they may find that immediate yield benefits or profits are attractive with clear financial incentive. This motivation for adoption is explained by the Classical Diffusion Theory. However, it may seem improper to depend only on the classical model as grounds for propagating the adoption of ISFM technologies (e.g. fertiliser application). This results from the fact that the adoption and diffusion model rests on "voluntarism on the part of the farmer's decision making and the economic gain attached to the new behaviour" (van Es, 1983) and may also lead to financial losses at the farm level.

The problems stimulating the possible shift in adoption of ISFM technologies are typically perceptions of soil degradation, soil erosion or declining crop yields and worsening food security as a result of deteriorating soil fertility. These views are related to farmer perceptions that are shaped by farmers' personal characteristics (e.g., age, education, soil fertility management attitude, norms beliefs), farmers' social networks (Social Learning Theory) and the physical characteristics of the farm plot (e.g., slope). This idea of farmers' perceptions towards technology attributes influencing their adoption behaviour of those technologies represents a transition from the Random Utility Theory (farmer characteristics influencing utility for soil fertility management practices) to Theory of Planned Behaviour (resultant formation of attitudes, perceptions and norms that affect intention to adopt and final adoption).

Moreover, in Figure 2.1, households embark on technology choices and decisions that influence the utilisation of their soil resources which are constrained by their socio-economic attributes and on-farm resources, alongside with higher level factors at the local and wider scales. For example, with poor land tenure and access to credit challenges, the farmer cannot invest in ISFM technologies if this needs a large capital outlay. Information about new technologies and financial conditions is a precursor to shifts in farm practices and obtaining it does not usually involve large financial outlays. Government credit and extension policies play a critical role here. Hence farmland tenancy and institutional factors have a more indirect influence. Nonetheless, all these factors affect the net returns and risk that drive the decision-making process.

When positive adoption decisions are made, it is expected that Integrated Soil Fertility Management practices together with other farm characteristics (eg. perceptions of soil erosion, degradation, topography, etc) and institutional factors (eg. access to extension, credit markets, etc) will enhance maize yields which may have a direct consequent effect on farm household food security.

The channels through which adoption and maize yield impact on food security are not clear especially as higher household sizes and commercialisation decisions may neutralise the effect of higher yields on food security. However, given that maize is a staple crop in the study area high household sizes providing more labour for agricultural production (Braimoh and Vlek, 2006), adoption and maize yields are expected to induce that direct linkage to food security. These positive effects of agricultural technology adoption and characteristics of the components of the Integrated Soil Fertility Management package will certainly influence the utility the farm household derives from these technologies and eventually lead to widespread adoption.

2.8 Summary of review and gaps identified

The reviewed studies used various methodologies to identify determinants of farmers' choice of sources of agricultural information on soil conservation practices. Apart from the work of Mittal and Mehar (2015) that did an extensive research on the influencing factors using multivariate probit, the other reviewed literature did not account for the complementarity and substitutability of the sources of agricultural information. Hence the current study follows the methodology of Mittal and Mehar (2015) to explore the factor influencing farmers' choices of sources of agricultural information.

Again, in practical farming circumstances, farmers are not randomly classified into two groups (adopters and non-adopters), rather farmers embark on their own technology utilisation choices, or are systematically picked into interventions by development agencies depending on their tendency to take part in technology adoption. Furthermore, farmers (or development agencies) have tendency to pick plots non-randomly depending on the quality attributes, which are usually unobserved to the researcher. For instance, Abdulai (2016) argued that famers may adopt the complete package or subsets of the package can be adopted individually. This is akin to D'Emden, Llewellyn, & Burton (2008) who defined an adopter as a farmer who uses a technology on all or portion of the farm. In their study, a farmer who practiced one or more of the global CA principles; minimum tillage, crop rotation and retaining crop residue, is termed an adopter, while a non-adopter is one who failed to adopt any of components of the CA principles. This has some methodological flaws as the number of the technology applied is entirely overlooked.

Clearly from the review, several studies (see: Shiferaw *et al*., 2003; Mathenge, Smale, & Olwande, 2014; Okeyo *et al*., 2014; Abate *et al*., 2015; Khonje *et al*., 2015; Abdulai, 2016; Moges and Taye, 2017; Arslan *et al*., 2017 and Mekonnen *et al*., 2018) have been done in most areas in East Africa especially in Ethiopia and Kenya on the factors influencing use of soil fertility management technologies, the consequence of soil management technologies on maize yields and food security. Hence in the context of Northern Region of Ghana, where ISFM technologies have been widely promoted and practised, there is the need for this study to examine the effectiveness of participatory extension approach (social networks) in adopting ISFM technologies and its implications on maize yield and food security of small farm owners.

Most of the studies (see: Ngwira *et al*., 2013 and Okeyo *et al*., 2014) on the consequences of various agricultural conservation practices have been field experiments in which context most on-farm conditions and farmer characteristics are particularly adequately controlled. From the review, previous studies have failed to estimate the maize yield outcomes of the number of ISFM practices adopted on a wide scale or community level adoption in Sub-Saharan Africa. The current study examines these effects in a non-experimental study over a wide geographical setting.

Overall, this review, though does not argue to be highly extensive, has highlighted research gaps from which the objectives of the current study emerged. It has shown several methodologies particularly data analytical methods and their shortcomings and so has informed the choice of the analytical methods for this study. In particular, the present study use of the CMP for the estimation of the combined effect of adoption and maize yields on food security closes a major methodological gap. Furthermore, the review has provided this study with lots of empirical and theoretical studies that will make the discussion of study results a lot easier.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This section covers a brief description of the study area, types and sources of data, sample size and sampling techniques, survey instruments, analytical methods and the computer packages used.

3.2 Study area

The study was conducted in the Northern Region which is characterised by an inherent long dry spell and highly unpredictable distribution and amount of rainfall spread over six months as well as water and wind erosion (due to bush burning) during the rainy and dry seasons. It has been evidenced that low maize yields are the result of poor soil quality particularly inadequate nitrogen. Consequently, farmers in Northern Ghana are record low yields of crops without the application of fertilisers. To resolve this challenge of low soil fertility, various soil fertility management interventions through on-station experiments and farmer field schools have been introduced by MoFA and SARI (Gloria *et al*., 2014). Clearly, there is therefore a critical need for research to understand the determinants of adoption of these soil management technologies and the effect of adoption and maize yields on food security so as to improve soil quality and farmers' wellbeing in the Northern Region.

The Northern Region, which assumes an estimated 70,384 square kilometres is the region with the largest land mass in Ghana. It is bordered with the Upper East and the Upper West regions to the north, the Brong Ahafo and the Volta regions to the south, Togo to the east, and Côte d'Ivoire to the west. Overall, the land mass low lying with exception in the north- eastern corner with the Gambaga escarpment and along the western corridor. The region's water resource is absorbed by the Black and White Volta Rivers and their tributaries such as the Nasia and Daka rivers (GSS, 2010).

There are relatively dry climatic conditions in the region and a unimodal rainfall season that starts in May and stops in October. The quantity of rainfall reported yearly ranges between 750 millimetres and 1,050 millimetres. The dry season starts in November and stops in March/April with maximum temperatures occurring towards the end of the dry season (March-April) and minimum temperatures in December and January. The harmattan winds, which occur from December to early February, have a considerable effect on temperatures in the region, making them vary between 14 ^{O}C at night and 40^{O}C during the day. Humidity is very low, aggravating the consequences of the daytime heat. The however harsh climatic conditions adversely affect economic activity in the region and in the health sector, enable cerebrospinal meningitis to thrive, almost to endemic proportions. The region also falls in the onchocerciasis zone. Despite the fact that the disease is presently firmly managed, a geographical setting is still not much populated and not much cultivated as a result of previous effects of river blindness. The main vegetation is grassland, interspersed with guinea savannah woodland, featured by drought-resistant trees including acacia, (*Acacia longifolia*), mango (*Mangifera*), baobab (*Adansonia digitata* Linn), shea nut (*Vitellaria paradoxa), dawadawa, and neem (Azadirachta indica)* (GSS, 2010).

In 2012, in the region, there was a creation of six more districts. The region had 26 constituencies before the new arrangement for the new districts in 2012. Five more constituencies were created in 2012 for the region following the creation of the new districts raising the counts of the constituencies in the region to 31.

The Tamale Metropolitan Assembly remains the most populous area in the region, with a population of 371, 351, representing 15 percent of the region's population. This large concentration may be that Tamale is the capital of the region and is also centrally located. Commercial activities, job opportunities and educational institutions in the metropolis are attracting people from other parts of the region. The Yendi Municipality is second largest as regards to population (199,592). The least populous districts are Chereponi (53,394) and Saboba (65,706) representing 2.2 percent and 2.7 percent of the region's population respectively. The two districts use to be one and known as Saboba/Chereponi District until 2004 when they were split into two (GSS, 2010).

The 2010 census estimated that a total of 2,503,006 households in Ghana are engaged in agriculture, of which 240,238 households are in the Northern region. This constitutes 9.6 percent of the national total. The Northern region's average agricultural household size is 8.5 relative to a national average of 5.3 persons (GSS, 2010).

Maize is grown in all the five major agro-ecological zones in Ghana, and it is regarded as the most useful cereal grain in terms of total production and consumption. In the Guinea and Sudan Savanna Zones of Ghana, maize is a predominantly produced crop and remains a key ingredient of the daily nutrition of the inhabitants of the area. The area has the huge opportunities in leading maize production (FASDEP, 2002).

Maize production in Ghana (like the rest of South Saharan Africa) is heavily dependent on rain-fed and characterized by erratic rainfall patterns both in amount and distribution. Drought therefore greatly influences maize production in Ghana, affecting people's livelihoods, food security and overall wellbeing. It has emerged as a critical impediment to agricultural productivity in SSA including Ghana as a result of climate change. The opportunities that abound the Guinea and Sudan Savanna zones of Ghana in leading maize production has been threatened by persistent drought, nitrogen stress and the prevalence of striga. Effective and sustainable approaches to resolve the menace of drought, striga and the looming threats of climate change are of great concern (FASDEP, 2002). It therefore emerged that this situation partly informed the introduction of ISFM technologies in the Northern region particularly in the Tolon, Savelugu and Karaga districts through the AGRA Soil Health Project in collaboration with SARI.

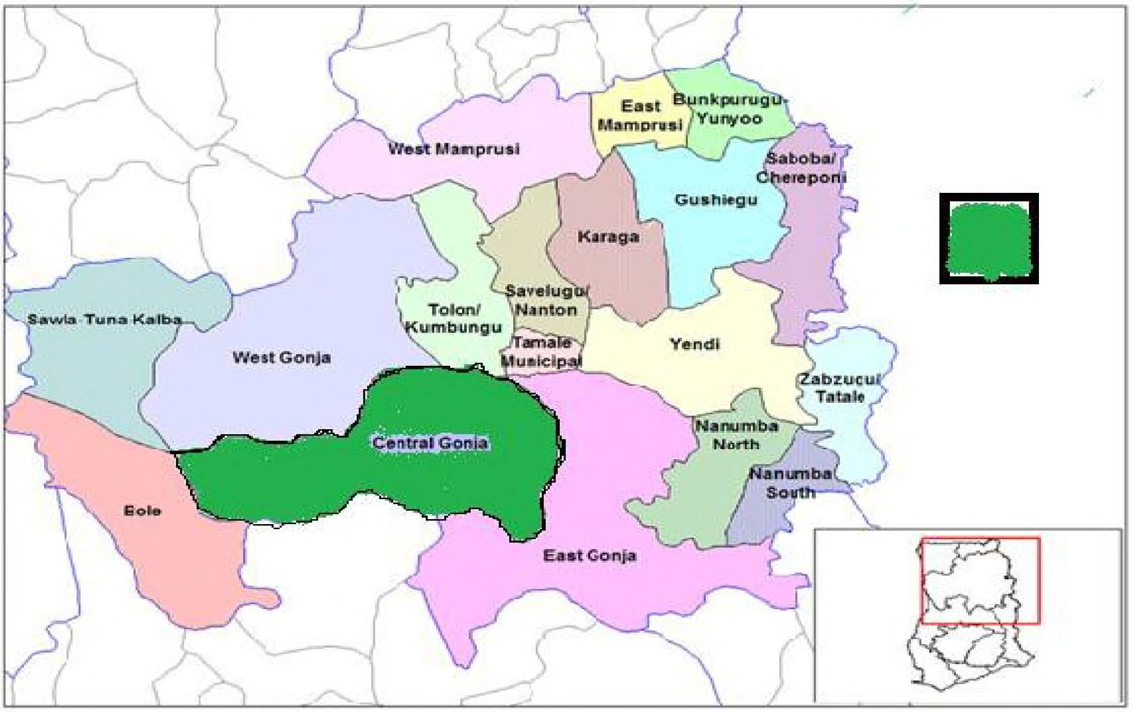

Figure 3. 1: Map of the Northern region and its districts

Source: 2010 PHC data from GSS.

3.3 Research design

The research was purely a cross-sectional study that collected data from maize farmers in selected districts in the Northern Region. Hence primary data was solicited for the thesis using semi- structured questionnaires containing both closed as well as open-ended questions. Other secondary information was gathered from SARI annual reports and other publications.

3.4 Sample size and sampling technique

The sample size was calculated using the following Cochran's (1977) sample size determination formula:

$$n = \frac{z^2 p(1-p)}{d^2} \quad \text{...(3.1)}$$

where n = the required sample size, z = the confidence level at 95% (standard value of 1.96), p = estimated population percentage under study (90%) and d^2 = margin of error at 3.4% (standard value of 0.034). Since according to the GSS (2010), an estimated average of 90% of households in across the three selected districts (Tolon, Savelugu and Karaga) in the Northern Region are farm households, the population percentage used in this computation is 90%. Therefore, assuming a margin of error of 3.4% and the total estimated population percentage of 90% or 0.90 on farming and adoption of ISFM practices, the formula above computed a sample size of 299 farm households. But with reference to Cohen's (1992) arguments of statistical accuracy of high sample size, 300 questionnaires were administered. Statistically, the sample size is large enough to study and generalise about the population.

In obtaining the sample for the survey, a multistage sampling technique was used. First, the districts in which ISFM technologies were first experimented were sampled using the CSIR-SARI 2012 Annual Report list of beneficiary districts including Chereponi, Karaga, Savelugu Municipal and Tolon Districts in Northern Region.

So, in effect, three districts were randomly selected. They are: Savelugu Municipal and then Tolon and Karaga districts. Second, a list of all communities in the three (3) selected districts that are predominantly in maize production was acquired from SARI and MoFA. The choice of the maize crop was motivated by the fact that the ISFM technologies promoted by SARI are mainly for maize production. Thereafter, five (5) communities were also randomly selected from each district. Third, farmers were finally randomly selected from each of the five (5) communities from each of the three (3) districts. In effect, 15 communities were sampled from the 3 districts of Tolon, Savelugu and Karaga. In sampling the ISFM adopters, a simple random sampling technique was finally used. Whiles on the field, a list of farm households was acquired from extension agents, various Farmer-Based Organisations (FBOs) and lead farmers who participated in ISFM technology training in the past in each sampled community. From that list, respective households were drawn randomly for interview in each of the selected communities.

To ensure representativeness, proportionate sampling techniques was employed to fairly allocate the sample size of 300 farm households to the randomly selected 3 districts given the total farm household population of each district. The result of the proportionate sampling procedure is shown in Table 3.1 below.

Table 3. 1: Population and sampled farm households

Selected districts	*Population of farm household*	*Proportion*	*Sampled farm households*
Tolon	11,437	$11,437 / 31,793 \times 300$	108
Savelugu	13,093	$13,093 / 31,793 \times 300$	123
Karaga	7,263	$7,263 / 31,793 \times 300$	69
Total	***31,793***		***300***

Source: Author's computations using 2010 PHC data from GSS.

3.5 Tools and techniques for data collection

A structured questionnaire was designed and administered to solicit detailed information about household, social networks, farm, crop production and institutions including the structure of the household, education, income sources, soil type and perception of soil erosion, maize yield, access to extension services, participation in credit market, confidence in extension services, land tenure, number of days per year of information sharing on ISFM technologies, membership of formal and informal organisations, use of ISFM practices among others. The study administered questionnaires in a face to face interview by experienced interviewers with close supervision. In all, 300 questionnaires were administered and duly completed for the data analysis.

The study respondents were household heads who were in charge of farm management decisions. Due to household ownership of different plots at different locations within and outside the communities, the farmers were allowed to choose their highest yielding farm plots.

3.6 Data analysis and presentation

The study employed quantitative techniques in the analysis. Descriptive statistics was computed on the socio-demographic and economic features of the respondents and on the factors influencing the implementation of ISFM technologies, farm yield and food security. To examine the determinants of farmers' choices of sources of agricultural information, a Multivariate Probit model was used. The remaining three objectives were achieved by comparing estimates of their individual models to that of their joint estimation in a Conditional Mixed Process system. This was done to enhance credibility of the estimates by accounting for the likely correlation of the error terms of the three equations.

Hence for the objective two, the zero-truncated Poisson model (model 1 in the CMP) was employed to examine social networks and other determinants influencing the intensity of adopting different Soil Fertility Management practices. Furthermore, for the objectives three and four, two Ordinary Least Squares regressions estimation (models 2 and 3 in the CMP estimation) were then used to ascertain the effect of adoption of ISFM practices on maize yields and the effect of intensity of adoption and maize yields on household food security.

3.7 Theoretical and Empirical Specification of Models

This section outlines the theoretical and empirical specifications of the econometric models that underpin the objectives of the study and the justification for their use in this study. It also indicates the various dependent and independent variables and their respective measurements.

3.7.1 Random Utility Theory

The tendency of selecting a specific practice or a combination of practices is equal to the chance that the utility of that particular alternative is greater than or equal to the utilities of all other alternatives in the choice set. In order to maximise the utility U_{ij}, an i th farmer will compare alternative practices and combinations. Accordingly, an i th farmer will choose a practice j, over any alternative practice, k, if $U_{ij} > U_{ik}$, $k \neq j$ (Varma, 2015).

Following Gitonga *et al*. (2013;) random utility models presume that the utility U_a derived by individual households from using the Integrated Soil Fertility Management technologies is composed of a deterministic component which can be calculated based on observed characteristics Z_i and a stochastic error component ε, which is unobserved, such that

$$T_i^* = \beta Z_i + \varepsilon_{1,} \quad T_i = 1 \text{ if } T_i^* > 0 \quad \text{.. (3.2)}$$

where T_i is a binary indicator variable that takes a value of 1 if household i adopts a component of Integrated Soil Fertility Management package and 0 if otherwise, β is a vector of parameters to be estimated, Z is a vector of explanatory variables and ε is the error term. The error component ε is never observed, hence there is no enough information to predict an individual's choice, but the study can predict patterns of households' adoption of any component of the Integrated Soil Fertility Management technologies. The conditional probability of adoption any of the Integrated Soil Fertility Management technologies by a household based on the observable characteristics can then be estimated using either binary probit or logit models:

$$\Pr(T_i = 1) = pr(T_i^* > 0) = 1 - F(-\beta Z_i) \quad \text{.. (3.3)}$$

where F is the cumulative distribution function for ε_i, which is assumed to have a normal distribution for the probit model, or logistic distribution for the logit model (Gitonga *et al*., 2013).

3.7.2 Examining determinants of farmers' choice of social networks as a source of agricultural information

To ascertain farmers' socioeconomic characteristics effect on their preference for social networks of a source of agricultural information in the Northern Region of Ghana, a Multivariate Probit regression model was used. With this, the choices of sources of agricultural information were based on preference and do not mean one was better than the other but farmers can have a combination of different sources.

A Multivariate Probit (MVP) model, simultaneously models the effects of a number of explanatory variables on every source of agricultural information, while allowing the observed and unmeasured factors (error terms) to be freely correlated (Mittal and Mehar, 2015). One source of correlation could be complementarities (positive correlation) and substitutability (negative correlation) between different agricultural information sources (Mittal and Mehar, 2015). Contrary to the Multivariate model (MVP) is the Univariate probit models which ignore the potential correlation among the unobserved disturbances in the equation and the relationships between the determinants of choice of agricultural information sources. From the above, farmers may consider combination of agricultural information source as complementary whiles others as competing, hence failure to capture the unobserved factors and the inter-relationships among the sources result into a bias and inefficient estimate (ibid).

The agricultural information source in recent time by farmers may be partly dependent on earlier information sources. Thus, the choice of agricultural information sources is inherently a multivariate one as well as trying univariate modelling does not contain relevant economic information contained in interdependent and simultaneous agricultural information sources.

The observed outcome of the various combination of sources of agricultural information model was modelled in a random utility framework. Consider the i^{th} farm household $(i = 1, \ldots N)$ which is to decide whether or not to choose any available agricultural information sources. Let U_0 be the utility the farmer enjoys when he chooses not to utilise a new agricultural source of information, and let U_k represent the utility received by the farm household when it selects the K^{th} agricultural source of information if the net benefit is greater than zero, say $Y_{ik}^* = U_k - U_0 > 0$. The net benefit (Y_{ik}^*) that the farm household gains from the K^{th} agricultural information source is, on the contrary a latent variable which is determined by observed household characteristics and the availability of information dissemination devices to the household (X_i) and unobserved characteristics (ε_i).

$$Y_{ik}^* = X_i \beta_k + \mu_i \quad \ldots\ldots (3.4)$$

The Multivariate Probit model is featured by a set of binary dependent variables K, that is equal to 1 if the i^{th} farmer chooses agricultural information source k, and zero otherwise, such that:

$$Y_k = \begin{cases} 1 \; if \;\; Y_{ik}^* > 0 \\ 0 \; otherwise \end{cases} \quad k(\text{SN}, \text{FE}, \text{TM}, \text{MIT}) \quad \ldots\ldots (3.5)$$

Where SN = Social networks; FE = Formal extension; TM = Traditional media; MIT = Modern ICT.

Since the study selected four agricultural information sources and they tend out not to be mutually exclusive, the multivariate probit model where the selection of several agricultural information sources at any point in time is a possibility, the error terms jointly assume a multivariate normal distribution (MVN) with zero conditional mean and variance normalised to unity (for identification of the parameters) where $(\mu_{SN}, \mu_{FE}, \mu_{TM}, \mu_{MIT}) \approx MVN(0, \Omega)$ and the symmetric covariance matrix Ω is given by:

$$\Omega = \begin{bmatrix} 1 & \rho_{SNFE} & \rho_{SNTM} & \rho_{SNMIT} \\ \rho_{FESN} & 1 & \rho_{FETM} & \rho_{FEMIT} \\ \rho_{TMSN} & \rho_{TMFE} & 1 & \rho_{TMMIT} \\ \rho_{MITSN} & \rho_{MITFE} & \rho_{MITTM} & 1 \end{bmatrix} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.6)}$$

The off-diagonal components in the covariance matrix are relevant since they are the unobserved correlation between the stochastic components of the various typologies of agricultural information sources. This assumption means that equation (3.6) gives MVP model that jointly represents decisions to choose a particular agricultural information source which is explained by the hypothesised explanatory variables. This specification with non-zero off-diagonal components permits correlation across the error terms of several latent equations, which represent unobserved characteristics that affect the choice of alternative agricultural information sources.

Empirically, the Multivariate Probit regression model is specified as:

$$AIS = \beta_0 + \beta_1 Age + \beta_2 Agesq + \beta_3 Edtnlev12 + \beta_4 Edtnlev13 + \beta_5 Edtnlev14 + \beta_6 MaizeCult$$
$$+\beta_7 Mobilephone + \beta_8 Radio + \beta_9 Tolon + \beta_{10} Savelugu + \alpha_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.7)}$$

Details of the variables' description, measurement and a priori expectations are detailed in Table 3.2 below.

Table 3. 2: Description of variables and a priori expectations of socioeconomic factors influencing farmers' choice of agricultural information sources

Explanatory variables	*Description*	*Measurement*	*Slope coefficient*	*A priori expectation*
AIS	Agricultural Information Source	1 if Social networks; 0 otherwise. 1 if Formal extension; 0 otherwise. 1 if Traditional media; 0 otherwise 1 if Modern ICT; 0 otherwise		
Age	Respondents' age	Years	β_1	+/-
Agesq.	Respondents' age square	Years	β_2	+/-
Edtnlev	Respondents' level of education	1 if 1 – 4 years; 0 otherwise. 1 if 5 – 8 years; 0 otherwise. 1 if 9 – 12 years; 0 otherwise	β_3 β_4 β_5	+/- +/- +/-
MaizeCult	Maize farm size in hectares	Hectares	β_6	+/-
Mobilephone	Household ownership of a mobile phone	1 if owned; 0 otherwise	β_7	+/-
Radio	Respondents' ownership of a radio	1 if owned; 0 otherwise	β_8	+/-
District dummies	Respondents' district of origin	(1 if Tolon; 0 otherwise) (1 if Savelugu; 0 otherwise)	β_9 β_{10}	+/- +/-

3.7.3 Examining the impact of social networks and other determinants of intensity of adoption of Integrated Soil Fertility Management practices

From the adoption literature, there have been several studies to analyse the determinants and particularly the intensity of adoption of agricultural technology. Pedzisa *et al.* (2015) treated the adoption process as potentially partial and incremental rather than a binary outcome variable. They considered each component of conservation agriculture as a discrete technique modelling intensity of adoption as the number of practices adopted using both a Poisson and a negative binomial model to account for the non-continuous nature of the dependent variable instead of measuring the intensity of adoption as the proportion of total cultivated land under conservation agricultural practices. In contrast, Mponela *et al*. (2016) estimated an ordered probit to analyse the factors influencing the ISFM practices use by small farm owners. In a new study by Kpadonou *et al*. (2017), they combined both multivariate and ordered probit models to analyse promoting climate-smart-agriculture in developing drylands. Gedikoglu and McCann (2007) employed Multivariate Probit regression to examine off-farm income analysis of agricultural technology adoption.

It is also observed that a critical shortcoming of count data models is that they fail to have reasonably sound theoretical basis, and there is very little guidance on the appropriate functional form, but they are still the best when modelling number of technologies adopted (Nkegbe and Shankar, 2014). In line with this, an initial check of the data for the current study revealed at least every farmer adopts one of the ISFM technologies. Hence, the current study adopted a zero-truncated Poisson regression model as the baseline estimation technique to analyse the factors influencing the intensity of adoption as a consequence of a natural truncation of the observed outcome variable, that is, utilisation of ISFM practices. This estimation did not truncate observations for the dependent variable unlike Tobit Truncated regression model that involves a dependent variable that is only observed beyond a specified threshold and hence reduces the dataset (Winkelmann, 1995).

Earlier studies that estimated count data models conceived the intensity of adoption of various technologies as the number of ISFM practices adopted. The number of conservation practices at any given time $\boldsymbol{y_i}$ which is an integer count variable, can be said to come from a Poisson distribution and could hence be estimated using the basic Poisson model as (Cameron and Trivedi, 2013; Greene, 2008; Winkelmann, 2008).

$$\text{Prob}(Y_i = y_i \mid x_i) = \frac{e^{-\lambda}\lambda_i^{y_i}}{y_i!}, \lambda_i \in \mathbf{R}^+, y_i = 0,1,2,... \qquad \text{.................................. .}$$

(3.8)

From the equation (3.8), the $\lambda_i = E(y_i \mid x_i) = \text{Var}(y_i \mid x_i)$ and the mean is usually represented by $\lambda_i = \exp(x_i\beta)$ where x_i is a vector of characteristics specific to household i, and β is a vector of unknown parameters to be estimated. The marginal (or partial) effects in the Poisson model given by:

$$\frac{\partial E(y_i \mid x_i)}{\partial x_i} = \lambda_i\beta \qquad (3.9)$$

This marginal effect, as in other count data models, is interpreted as the unit change in the intensity of adoption variable emanating from a variation in the explanatory variable (Cameron and Trivedi, 2013).

In other words, following Long and Freese (2014), given the exclusion of zero outcome from the sample, the zero-truncated Poisson model starts with the Poisson regression model:

$$\Pr(y_i = k|x) = \frac{\exp(-\mu_i)\mu_i^{y_i}}{y_i!} \qquad (3.10)$$

where $\mu_i = \exp(x_i\beta)$ and for any given x_i, the probability of observing a 0 is

$$\Pr(y_i = 0|x_i) = \exp(-\mu_i) \qquad (3.11)$$

Whiles the probability of a positive (that is, non-zero) count is

$$\Pr(y_i > 0|x_i) = 1 - \exp(-\mu_i) \qquad \text{...}$$

(3.12)

Now given that the counts are truncated at 0, the probability for each positive count given that that count is greater than 0 for it to be observed is by the conditional probability

$$\Pr(\mathrm{A}|\mathrm{B}) = \frac{\Pr(\mathrm{A} \& \mathrm{B})}{\Pr(B)} \quad \text{...} (3.13)$$

Hence the conditional probability of observing a specific value $y = k$ given that the count is not 0 is specified as:

$$\Pr(y_i = k | y_i > 0, x_i) = \frac{\Pr(y_i = k \,\&\, y_i > 0 | x_i)}{\Pr(y_i > 0 | x_i)} \quad \text{...} (3.14)$$

Again, with the probability that $y = k$ and $y > 0$ is just the probability that $y = k$, and substituting equation (X) generates the conditional probability

$$\Pr(y_i = k | y_i > 0, x_i) = \frac{\Pr(y_i = k | x_i)}{1 - \exp(-\mu_i)} \quad \text{...}$$

(3.15)

Despite the relevance of the basic Poisson model in practical research, estimating a Poisson regression model without considering the truncation gives biased estimates of the parameter vector *b*, and misleading inferences are drawn (Lord, Washington, & Ivan, 2005). Fortunately, the Zero-truncated model as a modification of the basic Poisson Regression model accounts for it.

Hence, the Zero-Truncated Poisson where the probability of a zero count $\exp(-\mu)$ based on the PDF was used. The value of the PDF needs to be subtracted from 1 and the remaining probabilities rescaled on that difference. To investigate determinants of intensity of adoption of ISFM practices in the study area, the number of ISFM techniques adopted by each farming household defines the dependent variable; it is thus a discrete nonnegative integer- valued count variable. The chosen Integrated Soil

Fertility Management technologies were crop rotation, mulching, composting, fertiliser application, organic manure application and cover cropping. The density function of a zero-truncated Poisson variable is outlined by (Johnson *et al*., 2005)

$$P[X_i = n] = \begin{cases} \dfrac{\lambda^n}{n!(e^{\lambda} - 1)} & \text{if } n \in \mathbb{N}_0 \\ 0 & \text{elsewhere} \end{cases} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.16)$$

with parameter $\lambda \in \mathbb{R}^+$. The difference with standard Poisson distribution lies in the correction factor $(1 - e^{-\lambda})^{-1}$, which reflects the observation that a value of 0 cannot occur. The basic parameter including the mean:

$$\mu_{X_i} = \frac{\lambda e^{\lambda}}{e^{\lambda} - 1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.17)$$

and variance $\sigma^2_{X_i} = \dfrac{\lambda e^{\lambda}}{e^{\lambda} - 1}\left[1 - \dfrac{\lambda}{e^{\lambda} - 1}\right]$ ………………………………..…………….. (3.18)

can, with ease, be derived outrightly (Johnson *et al*., 2005). The higher moments for this type of probability distribution can be acquired from the moment generating function:

$$M_{X_i}(t) = \frac{e^{\lambda e^t} - 1}{e^{\lambda} - 1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

(3.19)

while the cumulative distribution function is given by:

$$F_{X_t}(x) = \begin{cases} \dfrac{e_{\lfloor x \rfloor}(\lambda) - 1}{e^{\lambda} - 1} & \text{if } x \geq 0 \\ 0 & \text{if } x < 0 \end{cases} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.20)$$

with $\lfloor x \rfloor$ the integer part of x and $e_a(b)$ the exponential sum function defined as

$$e_a(b) \equiv \sum_{i=0}^{a} \frac{b^i}{i!}, \text{ with } a \in \mathbb{N}$$

For the Poisson pdf $h(y_i, \mu_i \mid y_i \geq r) = \dfrac{\mu_i^{y_i}}{[e^{\mu_i} - \sum_{j=0}^{r-1} \dfrac{\mu_i^j}{j!}] y_i !}$, $y_i = r, r+1, ...$ ……..

(3.21)

with its truncated mean (μ_{x_i}) and truncated variance ($\sigma^2_{X_i}$) given in equations (3.17) and (3.18) respectively after series of derivation (see: Cameron and Trivedi, 2013 for details), the maximum likelihood estimation (MLE) of left-truncated (since 0 practice is unobserved) Poisson models using equation (3.21) has a log-likelihood which is given by:

$$L(\beta) = \sum_{i=1}^{n} \left[y_i \ln(\mu_i) - \mu_i - \ln\left(1 - \exp(-\mu_i) \sum_{j=0}^{r-1} \mu_i^j / j!\right) - \ln(y_i !) \right] \text{………….(3.22)}$$

solving the log-likelihood equation (3.22) yields the MLE of β

$$\ell(\beta) = -E\left[\frac{\partial^2 L(\beta)}{\partial\beta\partial\beta'} \right] = \sum_{i=1}^{n} [\mu_i - \delta_i(\mu_i + \delta_i - r)]\mu_i^{-2} \frac{\partial\mu_i \partial\mu_i}{\partial\beta\partial\beta'} \quad \text{………………………..}$$

(3.23)

Empirically, the zero-truncated Poisson regression is specified as:

$$\Pr(Y_i > 0 | x_i) = f(X_i^{SE}, X_i^{FC}, X_i^{HA}, X_i^{IF}, X_i^{SL}) \text{ ………………………. (3.24)}$$

The Table 3.3 below indicates the various variable names and their descriptions.

Table 3. 3: Details of variables description

SE = Socio-demographic and economic characteristics	
Age	Respondents' age
HHS	Respondents' household size
Edtnlev	Respondents' level of education
Innovativeness	Respondent's level of innovativeness
Famlabour	Family labour availability
FC = Farmland characteristics and production	
Smallrrigation	Access to other water sources for crops
PercISFM	Perception of ISFM
ErosionInd	Perception of erosion index
Costprod	Cost of production
HA = Household assets	
AccessOFInc	Farmers' access to off-farm income
OffFarmInc	Farmers' off-farm income
TLU	Tropical Livestock Units
IF = Institutional factors	
AccessRes	Access to research institutions services
TrainingISFM	Farmers' access to training on ISFM

InforCredit	Amount of informal credit in GH¢
ExtCont	Annual number of extension contacts in 2016/2017 season
SL = Social learning	
Kinship	Total number of family and friends within and outside the community that the farmer shares information and other assistance with.
NoAgrmem	Number of agricultural associations the farmer belongs to
Meetings	Number of times farmers attend meetings in a year.
MeanSocLearn	Mean social learning
District dummies	(1 if Tolon; 0 otherwise) (1 if Savelugu; 0 otherwise)

3.7.4 Impact of intensity of adoption of Soil Fertility Management technologies on maize yield and food security of smallholder famers

Several research papers have tried modelling the outcomes of agricultural technologies on crop yields. The selection of the modelling technique, as expected, is contingent on the availability and data distribution of the study variables. Braimoh and Vlek (2006) used social data and estimated the maize yield effects of adopting soil fertility management practices by employing linear multiple regression without taking care of potential endogeneity challenges from endogenous regressors. Using panel datasets, Arslan *et al*. (2017) examined the outcomes of maize production of soil and water conservation practices adoption using a multivariate panel data model. Other studies by Alene and Manyong (2007) investigated the effects of education on agricultural productivity under traditional and improved technology using Endogenous Switching regression analysis. Other comprehensive studies by Mathenge, Smale, & Olwande (2014) estimated a two-stage, instrumental variables, Poisson, and Ordered Logit regression models to verify the relationship between hybrid seed adoption and four indicators of dietary diversity.

Therefore, the other individual model for separately estimating the effect of intensity of adoption of ISFM practices on maize yields and food security is multiple linear regression. Analytically, the multiple linear regression model is specified as:

$$Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \dots\dots\dots \beta_K X_K + e_i \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots \quad (3.25)$$

Where Yi is the value of the continuous dependent variable (maize yield and food security in this case), β_0 is the intercept term, which represents the average value of the variable, when all independent variables take the value of zero. The terms, $\beta_{1,} \beta_2, \beta_3 +++ \dots\dots \beta_k$ are the unknown parameters to be estimated corresponding to the explanatory variables, $x_{i1}, \; x_{i2} \; x_{\;i3}$ ------ x_{ik}. A single parameter, measures the change in the expected value of the dependent variable, upon a unit change in the value of the independent variable, assuming that all other regressors are held constant. This can be positive or negative, and is determined as *a priori* from economic theory. To maintain the data validity and robustness of the classical linear regression model (CLRM) the assumption of the model, the error term and the independent variable were considered.

3.7.5 CMP theoretical and empirical specification for the combined effect of intensity of adoption and maize yields on food security

In line with Braimoh and Vlek (2006), with modification to take into consideration endogeneity, the current study adopted the Conditional Mixed Process (CMP) to evaluate the effect of ISFM techniques on maize yields and food security. The individual model estimates were computed and then compared with that of the CMP system estimates for a choice of more credible results. The argument is that, from a methodological perspective, estimations of the effect of intensity of adoption of ISFM practices on maize yields and their combined effect on food security might therefore suffer from the challenge of endogeneity, as use of the agricultural practices, maize yields and food security determinants are arguably endogenous.

Hence, to take into consideration the likely influence of unobserved factors which can jointly impact on intensity of ISFM adoption, maize yield and food security, a recursive system with unidirectional dependency among the endogenous variables is defined and comprises three equations: (3.26) adoption, (3.27) maize yield and (3.28) food security. These were jointly performed to account for the potential influence of unobserved factors which can jointly impact on intensity of ISFM adoption, maize yield and food security. The main potential of using a recursive system is that it is unnecessary to worry about endogeneity issues of right-hand side dependent variables from the other equations. In fact, in a recursive system, the modelling can be done on the observed data of endogenous variables but not the predicted data (Roodman 2009, 2014).

The first equation describes intensity of adoption of Integrated Soil Fertility Management practices (*NumISFM)* as a count variable with *NumISFM* (1,2,3,4,5,6) which is dependent on institutional factors (*Insfactors*), farm characteristics (*farmcharact*), social network variables (*socinetwork)* and control variables *(control).* The second equation describes maize yield *(Maizeyields)* which depends on intensity of adoption of Integrated Soil Fertility Management practices *(NumISFM),* institutional factors (*Insfactors),* farm characteristics *(Farmcharact*) and control variables (*Control).* The third equation examines food security which is determined by the intensity of ISFM practices adoption *(NumISFM)*, maize yields *(Maizeyields)*, institutional factors (*Insfactors)*, farm characteristics *(Farmcharact*) and other control variables (*Control*).

Adoption of ISFM techniques are the selected number of innovations of fertiliser application, composting, crop rotation, organic manure, improved maize varieties and mulching. With the social network variables such as membership to farmer organisations, number of farmer organisations a farmer belongs to, the number of farmers within and outside the community that the farmer shares information on maize production with, attendance or otherwise of association meetings and the frequency of attendance of association meetings. The study controlled for age of household head, level of education of the household head, household size, farmer's experience in farming maize and available family labour per hectare. The institutional factors were access to credit, extension services, annual extension contacts, access to research institutions, training on ISFM and informal credit. The farm characteristics included farmland erosion, perception of soil fertility, moist land, rainfall, perception of ISFM, burning of residue on maize, pest control on maize plot and distance to maize plot. It is important to observe that the three equations below constitute a recursive equation system and the errors are allowed to be correlated across equations:

$$NumISFM = f(Insfactors, \ farmcharact, socinetwork, \ controls) + \in_i^a \text{ ……......... } (3.26)$$

$$Maizeyields = f(NumISFM, \ Insfactors, \ farmcharact, \ controls) + \ \in_i^b \text{ ……..…..... } (3.27)$$

$$Foodsecurity = f(NumISFM, Maizeyields, \ Insfactors, \ farmcharact, \ controls) + \ \in_i^c \text{ .... } (3.28)$$

Where *NumISFM*, *Maizeyields* and *Foodsecurity* are the endogenous regressors in a recursive system as explained and $\in_i^{a,b\&c}$ are the correlated error terms.

Given the OLS and zero-truncated Poisson regression model assumptions, the final empirical regression model for the CMP system that was estimated was in the form:

$$NumISFM = \delta_0 + \delta_1 Insfactors_{i1} + \delta_2 farmcharact_{i1} + \delta_3 socinetwork_{i1} + \delta_4 controls_{i1} + \in_i \text{ .. } (3.29)$$

$$Maizeyields = \beta_0 + \beta_1 NumISFM + \beta_2 Insfactors_{i2} + \beta_3 farmcharact_{i2} + \beta_4 socinetwork_{i2} + \beta_5 controls_{i2} + \alpha_1 \text{ .... } (3.30)$$

$$Foodsecurity = \gamma_0 + \gamma_1 Maizeyields + \gamma_2 NumISFM + \gamma_3 Insfactors_{i3} + \gamma_4 farmcharact_{i3} + \gamma_5 socinetwork_{i3} + \gamma_6 controls_{i3} + \mu_i \text{ .... } (3.31)$$

Where δ_0, β_0 and γ_0 are constant terms; δ_i, β_i and γ_i are estimated coefficients; *NumISFM*, *Maizeyields* and *Foodsecurity* are dependent variables as earlier indicated; $Insfactors_i$ is a matrix of institutional factors (extension services, access to credit and research institutions); $farmcharact_i$ is a matrix of farmland characteristics and production (perception of soil fertility, erosion, cost of production, etc), $socinetwork_i$ is a matrix of social network variables (FBO membership, kinship and number of FBO groups the farmer belongs to); $controls_i$ is a matrix of control variables (age, educational status, family labour, wealth, district dummies, etc) and $\in_i, \alpha_i$ and μ_i are the error terms. Details of the variables used in both the individual and system models, their descriptions, measurements and a priori expectations are presented in Table 3.4 below.

Table 3. 4: Description of variables and a priori expectations of the effect of intensity of adoption of ISFM practices on maize yields and food security

Explanatory variables	***Description***	***Measurement***	***Expected Signs***	***Slope coefficient***
Dependent variables				
NumISFM	Number of ISFM practices adopted	Number		
Maizeyields	Maize yields	Kg/acre		
Foodsecurity	Farmers' food security	Dietary diversity score		
Explanatory variables				
SE = Socio-demographic and economic characteristics				
Age	Respondents' age	Years	+/-	β_1
HHS	Household size	Number	+	β_2
Edtnlev	Respondents' level of education	1 if 1 – 4 years; 0 otherwise. 1 if 5 – 8 years; 0 otherwise. 1 if 9 – 12 years; 0 otherwise	+ + +	β_3 β_4 β_5
Innovativeness	Respondents' level of innovativeness	Difference in years between the year of knowledge and year of adoption of the ISFM practices	+	β_6
Famlabour	Family labour availability	Number of adult household members in farm work	+	β_7
FC = Farmland characteristics and production				
Moistland	Access to moist land	1 if maize plot is moist, 0 otherwise	-	β_8
PercISFM	Perception of ease of adopting ISFM practices	1 if yes, 0 otherwise	+	β_9
ErosionInd	Perception of erosion index	1 if low, 0 otherwise	+	β_{10}
Costprod	Cost of production	GH¢	-	β_{11}
HA = Household assets				
AccessOFInc	Farmers' access to off-farm income	1 if yes, 0 otherwise	+/-	β_{12}
OffFarmInc	Off-farm income	GH¢	+/-	β_{13}
TLU	Tropical Livestock holdings	Tropical Livestock Units	+	β_{14}
IF = Institutional factors				
AccessRes	Access to research institutions' services	1 if yes, 0 otherwise	+	β_{15}
TrainingISFM2	Farmers' access to training on ISFM	1 if yes, 0 otherwise	+	β_{16}
InforCredit	Amount of informal credit in GH cedis	GH¢	+	β_{17}
Extensioncont	Annual number of extension contacts in 2016/2017 season	Number of visits	+	β_{18}
SL = Social learning				
Kinship	Total number of family and friends within and outside the community that the farmer shares information and other assistance with.	Number	+	β_{19}
NoAgrmem	Number of agricultural associations the farmer belongs to	Number	+	β_{20}
Meetings	Number of times farmers attend meetings in a year.	Number	+	β_{21}
MeanSocLearn	Mean social learning	Number	+	β_{22}
District dummies	Respondents' district of origin	(1 if Tolon; 0 otherwise) (1 if Savelugu; 0 otherwise)	+/- +/-	β_{23} β_{24}

3.7.5.1 Measurement of selected variables

Innovative variable is proxied as the difference in years between the year the farmer heard of the ISFM technology and the year the farmer actually adopted the practice(s) whiles following Beyene and Muche (2010) Tropical Livestock Unit (TLU) is measured as an animal unit equivalent to live-weight of 250 kg. In this case, 1 head of cattle = 0.7 TLU, 1 camel = 1 TLU, 10 sheep or goats = 1 TLU, and a donkey = 0.5 TLU Tropical Livestock holdings. Also, following McCarthy (2015) MeanSocNetwork was measured as a simple arithmetic mean of total number of family and friends within and outside the community that the farmer shares information and other assistance with number of agricultural associations the farmer belongs to and number of times farmers attend meetings in a year.

Again, following Langyintuo and Mungoma (2008), Principal Component Analysis (PCA) was used to create the wealth index. The PCA is a combination of linear indicators that captures the highest quantity of information which is ubiquitous to all of indicators of wealth. Seven wealth indicators were used and included farm household access to TV, radio, motorbikes, knapsack sprayer, 'motor king' and mobile phones. However, ownership of bicycles was omitted as a result of its commonness among the farmers. For the combination of wealth indicators, they were labelled as a_{1j}^{*} to a_{kj}^{*}, representing farm household ownership of K assets by each farmers j. As the assets are measured in different units, their values are normalised by its mean and standard deviation to allow for uniform unit (scaling them from 0 to 1) of measurement for the computation. The normalisation is done as follows:

$$i = \frac{X_1 - X_{\min}}{X_{\max} - X_{\min}} \quad \text{..........} \quad (3.32)$$

with i being the index and X_1 being the level. In a like manner, $X_{\min}$ and $X_{\max}$ represent the minimum and maximum values of X. The components were then ordered and the first principal component which explains a large amount of the variation in the wealth data to represent household wealth index. To ensure the selected wealth indicators are effective in categorising relatively "wealthy" households and relatively "poor" ones, the rule of thumb is that if a variable/asset is owned by more than 95% or less than 5% of the sample, it should be taken out of the analysis. By this, hoes and cutlasses that were owned by more than 95% and thresher and tractor ownership owned by less than 5% of the sampled farmers were omitted.

Food security (Dietary Diversity Score)

The study quantitatively examined farmers' food consumption by estimating the number of eating occasions to understand their dietary diversity over a period (the past seven days). Dietary diversity proxy measure of household food security was used. A 7-day household eating frequency of diversified food groups (Kennedy *et al.*, 2010) was used to compute the mean dietary diversity score. The study represents it as HDDS. It is a self-reported score on eating habits calculated by summing over the frequency of eating of 12 food groups over the past 7 days and dividing it by 12 to arrive at the mean HDDS. After computing the mean HDDS, it was used as a dependent variable for estimating the effects of adoption of ISFM on food security. These food groups included in the computation of the HDDS indicator where: Cereals; Root and tubers; Vegetables; Fruits; Meat, poultry, offal; Eggs; Fish and seafood; Pulses/legumes/nuts; Milk and milk products; Oil/fats; Sugar/honey and Miscellaneous. The responses in the measurement of the food groups consumption were coded *Yes=1* if respondent consumed a particular food group and *No=0* if otherwise.

3.8 Computer packages used

The data analysis and presentation of the results were done using Stata 14.0 and Microsoft Excel.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents and discusses the results of the study. It describes the socio-demographic and economic characteristics of maize farmers in the sampled districts of the Northern Region. The chapter answers the research questions which the study sets out to achieve in the order in which they were presented in Chapter One. First of all, it examines the determinants of farmers' choice of agricultural information sources. Secondly, it explores the effect of social networks and other drivers on the intensity of adoption of ISFM practices as well as the effect of intensity of adoption on maize yields in farmers' drive to increase production. Lastly, it analyses the effect of adoption of ISFM practices on farmers' food security towards maximising welfare efforts.

4.2 Socio-demographic and economic characteristics, production, plot characteristics, household assets, institutional factors and social networks

4.2.1 Personal and household characteristics

From the results presented in Table 4.1 below, males dominated the sample with 298 (99.33%) out of the 300 sampled farmers whiles females were two (2) representing only 0.67% of the sample. Even though sex is an important variable in explaining agricultural technology adoption and broader household welfare issues such as food security, it was omitted from the estimated regression models due to non-variability in the distribution of its observations. With regards to age, it was measured in years with the mean age being 36 years.

It is generally hypothesised that younger people have high tendency to explore new sources of information, adopt new agricultural technologies to enhance yields and explore different off-farm income sources to enhance food security.

Educational status was measured both in years and in categories. In years, the maximum years of education was 9 whiles the minimum was 0 years. The mean years of education was 0.57. This suggest that a lot of the respondents do not have formal education. To capture the education effect on choice of information source, intensity of adoption, maize yields and food security, its categorical measure was used in the regression models. Categorically, farmers without any form of formal education were 215 (71.67%) whiles those with 1 – 4 years of education were the next highest group, 81 (27.00%) of farmers. Only 3 (1.00%) and 1 (0.33%) of farmers have 5 – 8 years and 9 – 12 years of education respectively. Household size captures the entire composition of the household or its strength. It was measured by the number of individuals within a home who share socio-economic characteristics and responsibilities together. The mean household size was 17.15. This is high but when the composition is mainly adults, they could be used as active family labour to support farm production. Related to the household size is dependency ratio which was measured by the number of dependants in the household divided by the number of adults. The mean household dependency ratio for a farmer with at least 17 years of experience in maize farming was 0.46 per household.

4.2.2 Production, plot characteristics and household assets

In terms of agricultural production, a farmer owns an average of 1.97 hectares of farm size and travels a distance of about 2.39 km to his maize plot. At least, 66% of the farmers perceive their farmlands to have gentle slope while 81% of them perceive their farmlands to be eroded even though 88% of them still believe their farmlands are fertile. The prevalence of pest infestation on maize plots reduces yields and so it is hypothesised that farmers who took steps to control pest on their farms reported higher maize yields. However, only 55% of the farmers sprayed their farms with pesticides which contributed to a farmer incurring an average of GH¢ 1345.95 cost of overall farm production.

Adopting ISFM practices depends on how simple it is for farmers to adopt and approximately 53% of the farmers perceived adoption of ISFM practices to be easy but adopting an average of 3 ISFM practices after almost 79% reported to have received training on ISFM practices. This implies that most of the sampled farmers have gone through some form of training on ISFM practices in the past and this explains their high innovativeness of 2 years. It should be recalled that farmers' innovativeness was measured by the time lag between the year the farmer heard or understood the technology and the year he actually practised it. To promote the adoption of ISFM practices reminds farmers of the cost implications but only 18% of them have access to off-farm income receiving approximately GH¢ 203.37 annually to complement their farm income.

Having access to a mobile phone widens a farmer's set of information sources and results show that about 60% of the sampled farmers had access to mobile phones. On the average, every farmer had available family labour of about 18.16 man-days per cropping season. Wealth index which was measured by applying PCA to the farmers' productive and non-farm assets revealed an average score of 4.66e-17 which is virtually 0 and suggests that in times of poor harvest farmers may be resource constrained which will affect their ability to adopt ISFM practices. For detailed discussions on the measurement of wealth index and tropical livestock holding in Tropical Livestock Units refer to the methodology. The tropical livestock holding was measured in Tropical Livestock Units to provide a common basis for the comparison of farmers with ownership of different types of livestock. Each famer on average owned 2.95 tropical livestock with a tropical livestock being equivalent to 250 kg body mass of a live-weight. It is hypothesised that farmers with more livestock have a high tendency to adopt ISFM practices from their animal resources.

Table 4.1: Socio-demographic and economic characteristics, production, plot characteristics, household assets, institutional factors and social networks

Variable	Mean	S D	Min	Max
Personal and household characteristics				
Gender (1=Male; 0=Females)	0.99	0.08	0	1
Age (in years)	35.57	11.20	17	70
Respondents' education in years	0.57	1.16	0	9
Household Size	17.15	8.98	2	51
Dependency ratio	0.46	0.17	0	2
Experience in maize farming (in years)	16.60	10.92	1	60
Production, plot characteristics and household assets				
Farm size in acres	1.97	1.90	0.40	6.48
Distance to maize plot (Km)	2.39	1.75	0	15
Perception of slope of farmland (1= Gentle; 0= Otherwise)	0.66	0.47	0	1
Perception of erosion of farmland (1 = yes; 0 = otherwise)	0.81	0.39	0	1
Perception of fertility of farmland (1= fertile; 0= otherwise)	0.88	0.33	0	1
Pest control (1 = yes; 0 = otherwise)	0.55	0.50	0	1
Cost of production in GH¢ (per acre)	1345.95	842.84	281	7110
Ease of adopting ISFM (1 = yes; 0 = otherwise)	0.53	0.500	0	1
Number of ISFM practices adopted	3.03	0.96	1	6
Training on ISFM (1 = yes; 0 = otherwise)	0.79	0.41	0	1
Innovativeness (years between knowing and practising ISFM technology)	2.09	2.86	-6	27

Access to off-farm income (1 = yes; 0 = otherwise)	0.18	0.39	0	1
Off-farm income in GH¢ (per annum)	203.37	618.06	0	5000
Mobile phone ownership (1 = yes; 0 = otherwise)	0.60	0.49	0	1
Family labour (in man-days)	18.16	11.87	1.38	98.84
Wealth index	4.66e-17	1	-2.39	6.71
Tropical livestock holding in Tropical Livestock Units	2.95	4.72	0	40.13
Institutional factors				
Access to extension (1 = yes; 0 = otherwise)	0.74	0.44	0	1
Extension Contacts (number of annual contacts)	9.59	8.43	0	50
Distance to nearest extension office in Km	3.18	1.24	1	8
Access to research institutions (1 = yes; 0 = otherwise)	0.31	0.46	0	1
Access to informal credit (1 = yes; 0 = otherwise)	0.68	0.47	0	1
Access to input assistance (1 = yes; 0 = otherwise)	0.54	0.50	0	1
Social network variables				
FBO membership (1 = yes; 0 = otherwise	0.50	0.50	0	1
Kinship	11.41	9.20	0	85
Number FBOs membership	0.67	0.79	0	4
Number of times meetings are attended	2.58	4.01	0	24

Author's estimations from field survey, 2018.

4.2.3 Institutional factors

Access to extension services is also hypothesised to have a positive effect on intensity of adoption of ISFM practices even though Pedzisa *et al*. (2015) found an inverse relationship. Approximately, 74% reported access to extension services but with low number of annual contacts (10). This indicates a wide extension officer – farmer ratio and still requires policy focus for improvement. Averagely, a farmer had a distance of 3.18 km to travel to the nearest extension office in the study area. Apart from extension services from MoFA, about 31% of the farmers also received research, extension and others forms of support services from research institutions. A similar study by Pedzisa *et al*. (2015) also reported positive effect of access to research institutions on intensity of adoption of ISFM practices. No farmer reported taking credit from formal banking institutions but 68% received informal credit from their families and friends which shows a potential for developing innovative agricultural financing using social networks. Access to input assistance mostly from recent government 'Planting for Food and Jobs' fertiliser subsidy has also been accessed by about 54% of the farmers.

4.2.4 Social Network

These variables are expected to influence agricultural technology diffusion. It includes FBO membership which 50% of the farmers had membership and actively sharing agricultural information with at least 11 family members and friends both within and outside the community. Averagely, a farmer belonged to only one FBO and attended meetings only 3 times in any given farming season.

4.3 An overview of ISFM practice adoption

The results presented in Figure 4.1 revealed that the intensity of adoption is predominant in Tolon district as it has a mean number of adopted ISFM practices of 3.35 out of the 6 practices in the present study. This may emanate from the low levels of education in the area. The next high adoption rate was noted in the Savelugu district with a mean of 3.16 adopted on cultivated farm plots. The lowest mean adoption intensity was observed in the Karaga district where the adoption rate was 2.59. The differences in the intensity of adoption across the districts is attributed to the activities of NGOs and research institutions that are operational in some of the districts. As an instance, the proximity of farmers to SARI, ADRA and UDS which are all located and have been operational in the Tolon districts induces adoption. These institutions within the districts have been engaged in collaborative research efforts since the early 2000s now and this greatly impacts on the adoption behaviour of the farmers. This contrast sharply with the Savelugu district where farmers observed that SARI and ADVANCE-USAID have been vigorously promoting agricultural technology use especially for soya beans. The Karaga district has not benefited much from such interventions apart from the activities of SARI and MoFA.

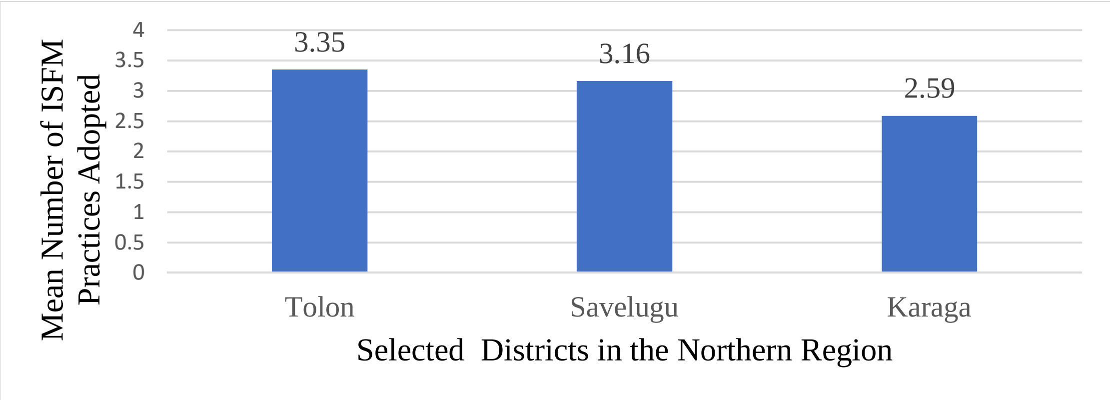

Figure 4. 1: Mean number of ISFM practices adopted, by district
Source: Computations from field survey, 2018.

The ISFM techniques for maize production predominantly consist of 6 technologies including the use of improved maize varieties, crop rotation, mulching, composting, organic manure and fertiliser application. It was noted that fertiliser application is the highest adopted practice with 98.33 % of the sampled farmers adopting the practice. Crop rotation followed with about 79% adopting farmers whiles improved maize varieties are adopted by 77% of the farmers. With regards to organic manure, only 36.33% of the sampled farmers adopted whiles the lowest adoption rates were reported for mulching and composting by 7.33% and 6.33% of the farmers respectively (see Figure 4.2). The poor adoption of mulching and composting stems from inadequate sensitisation about these practices and challenges in controlling the activities of hunters and neighbours from grazing crop residue and conveying the heavy animal droppings and kitchen left-overs for composting. It is revealing to observe that the use rates of the technologies are high for improved maize varieties as a result of the one-off buying behaviour of the seeds. This finding is emphasised by SARI in the following observation:

> *"Most of the recently developed and promoted maize varieties such as Obatanpa, Omankwa and Akomasa are from Southern Ghana. These improved maize varieties are expensive so the farmers don't frequently buy and they are usually acquired by farmers through field trials and demonstrations. Farmers' one-off buying behaviour of the improved seeds is determined by whether the variety high yielding, gives more flour, months of maturity etc" CSIR – SARI Annual Report, 2012.*

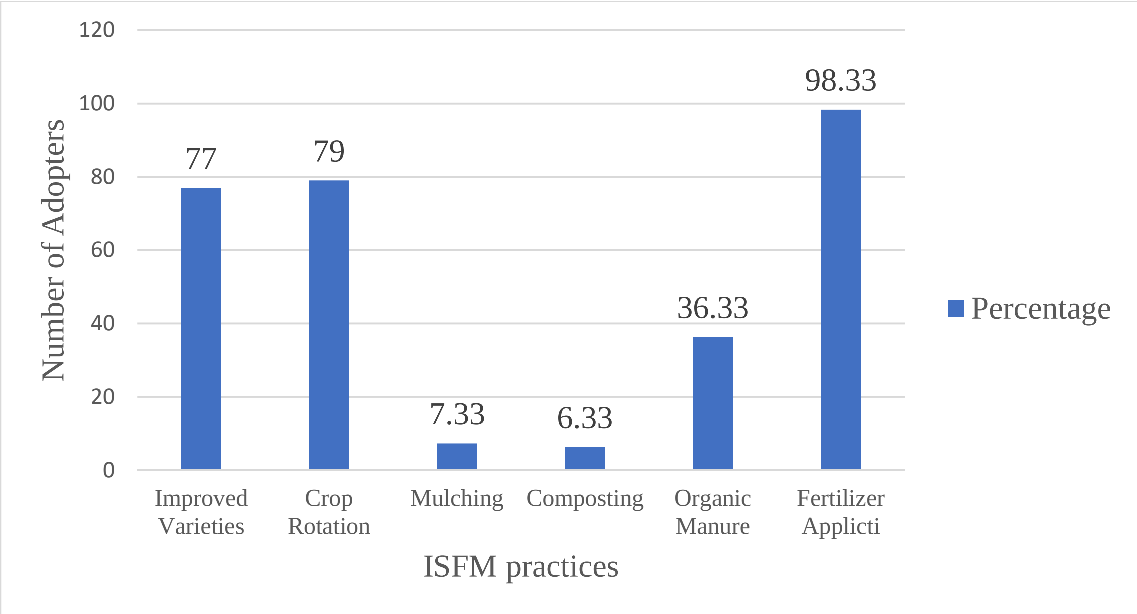

Figure 4. 2: Percentage of Adopters of ISFM practices
Source: Field survey, 2018.

As earlier noted from the mean number of ISFM practice adoption across the selected districts, Figure 4.3 shows the percentage of farmers who adopted various intensities from one practice, two practices through to six practices. It can be reported from Figure 4.3 that majority of farmers (42.33%) adopted 3 practices. This is followed by 4 practices (24.67%) and 2 practices (22.67%). However, the lowest percentage of farmers who adopted 1, 5 and 6 practices were 5%, 4.67% and 0.67% respectively.

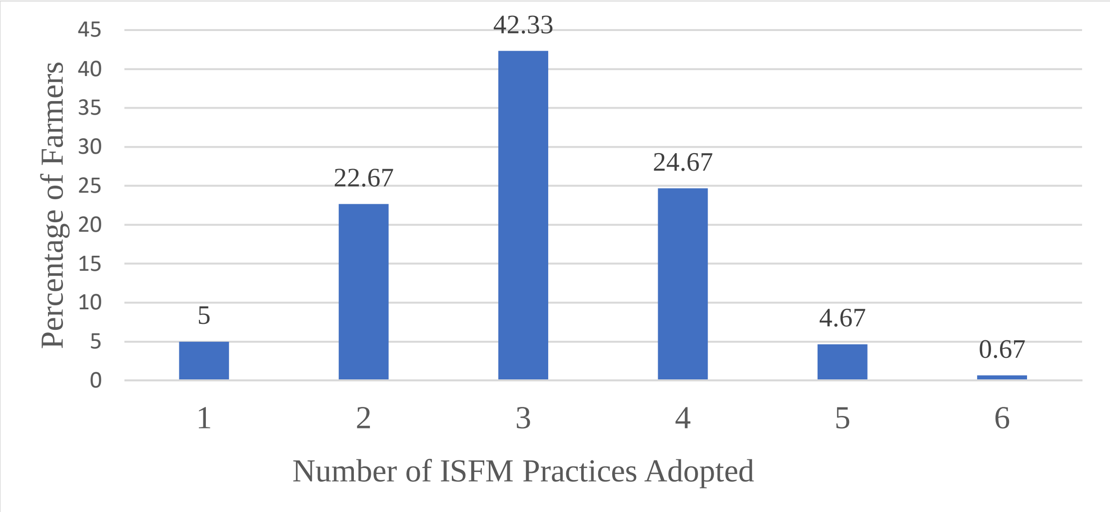

Figure 4. 3: Percentage of farmers by number of ISFM practices adopted
Source: Field survey, 2018.

In terms of implementing specific ISFM practices across districts, there were some variations. With regards to improved varieties, 85% practised it in Savelugu, 82% in Tolon and 64% in Karaga districts. Similarly, 91% of the farm households in Karaga district practised improved varieties whiles 77% of farmers practised improved varieties in Tolon district as well as 69% of farmers in the Savelugu district. The lowest percentage of farmers' adoption of ISFM practices was recorded for mulching – 18% for Tolon, 4% for Savelugu and no farmer adopted it in the Karaga district. This is indicative that farmers mostly allow their neighbours' animals to graze the crop residue while other farmers and hunters burn the residue. For composting, which recorded the lowest percentage of farmer adoption, only 10% and 9% of farmers in Tolon and Savelugu districts respectively adopt composting as Karaga did not report any adopters for composting. The adoption percentage of farmers for organic manure was 50% for Tolon and 50% for Savelugu districts whiles in Karaga only 9% of the farmers were shown to be adopters. Fertiliser use had the most adoption rate among farmers as 99% of contacted farmers in the Tolon district adopted it while 98% of the farmers separately in Savelugu and Karaga districts were adopters (see Table 4.2) below.

Table 4. 2: Distribution of farmers by ISFM practices adopted across districts (%)

Practice	Tolon	Savelugu	Karaga	All
Improved varieties	82	85	64	77
Crop rotation	77	69	91	79
Mulching	18	4	0	7.33
Composting	9	10	0	6.33
Organic manure	50	50	9	36.33
Fertiliser application	99	98	98	98.33

Source: Field survey, 2018.

Another important variable on which farmers were interrogated was the extent of application of fertiliser. Aside the need to adopt fertiliser, it is also very important to meet the quantity requirement for expected high maize yields. The mean fertiliser applied per hectare was 4.6 50kg bag/ha in Tolon district followed by Savelugu district at 3.6 50kg bags/ha. The Karaga district had the lowest mean fertiliser applied per hectare of 2.8 50kg bag/ha (see Figure 4.4).

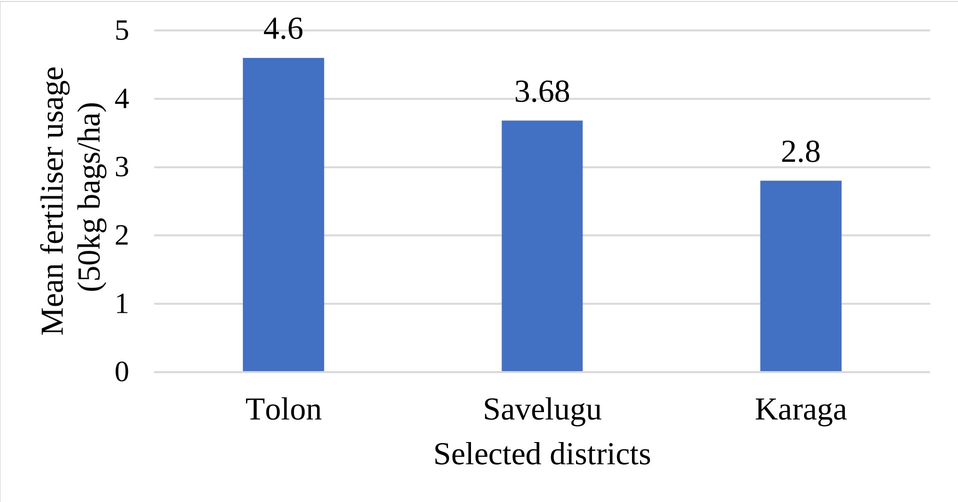

Figure 4. 4: Mean fertiliser usage (50kg bags/ha), by districts
Source: Field survey, 2018.

With regards to yield across districts, the Savelugu district reported the highest maize yields of 1055 kg/acre whiles the Tolon and Karaga districts recorded 978 kg/acre and 881 kg/acre respectively (see Figure 4.5).

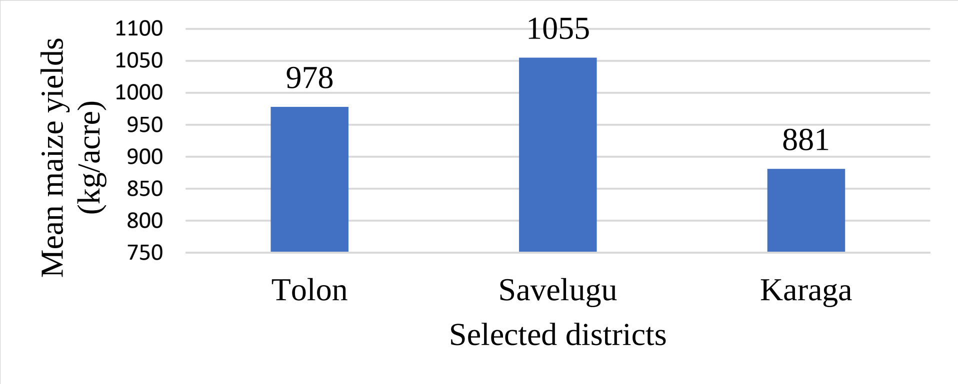

Figure 4. 5: Mean maize yields (kg/acre), by districts
Source: Field survey, 2018.

4.4 Examining the determinants of farmers' choice of social networks as a source of knowledge of ISFM technologies

The pair-wise correlation coefficients depict whether pairs of sources of agricultural information are complementary, substitutes, or do not affect each other in their adoption patterns. From Table 4.3 below, the results from the estimated correlation coefficients were statistically significant in two of the six cases, where three coefficients have negative and the other three have positive signs. In addition to supporting the implementation of the MVP, this also shows the interdependence of sources of agricultural information where the tendency of selecting a source is conditional on whether a source in the subset has been chosen or not. Since the correlation coefficient between social network and traditional media is negative it means the two sources are substitutes with a correlation coefficient of 20.37%. The association of formal extension with modern ICT is the highest (21.37%) with a positive sign which is suggestive of the fact that the two sources are complementary.

The substitutability of social network with traditional media is similar to the study results of Mittal and Mehar (2015) who found the two to be substitutes for rural farmers in India.

Table 4. 3: Pairwise correlation of farmers' sources of agricultural information

Source of Information	Correlation coefficient	Std. error
'Social network' and 'Formal Extension	-0.0670	0.2471
'Social network' and 'Traditional Media'	-0.2037*	0.0004
'Social network' and 'Modern ICT'	-0.0983	0.0893
'Formal Extension' and 'Traditional Media'	0.0154	0.7904
'Formal Extension' and 'Modern ICT'	0.2137*	0.0002
'Traditional Media' and 'Modern ICT'	0.0366	0.5279

* **Implies statistical significance at 5%. Source: Author's estimations from field survey, 2018.**

4.4.1 Distribution of farmers' choices of information sources

From the survey, farmers demonstrated that there are several information sources available depending upon whether the farmer's perceptions of its reliability, adequacy of the information, ownership of information transmission devices including mobile phone and radio which are ubiquitous in the study area. Table 4.4 below displays the different combinations of information sources to farmers.

Table 4. 4: Distribution of farmers' different combinations of farmers sources of agricultural information

Available combinations of information sources	Frequency	Percent
'Only social network'	24	8.00
'Only Formal Extension'	5	1.67
'Only Traditional Media'	11	3.67
'Only Modern ICT'	0	0.00
'Social network' and 'Formal Extension'	42	14.00
'Social network' and 'Traditional Media'	17	5.67
'Social network' and 'Modern ICT'	14	4.67
'Formal Extension' and 'Traditional Media'	7	2.33
'Formal Extension' and 'Modern ICT'	5	1.67
'Traditional Media' and 'Modern ICT	4	1.33
'Social network', 'Formal Extension' and 'Traditional Media'	12	4.00
'Social network', 'Formal Extension' and 'Modern ICT'	27	9.00
'Social network', 'Traditional Media' and 'Modern ICT'	13	4.33
'Formal Extension', 'Modern ICT' and 'Traditional Media'	21	7.00
All four	98	32.67
Total	**300**	**100**

Author's estimations from field survey, 2018.

4.4.2 Determinants of farmers' sources of information

The study estimated from the MVP model generated with maximum likelihood estimation on factors influencing farmers' choices of sources of agricultural information. The study results demonstrate model fitness for the data with the Wald test [χ^2 (38) = -653.821, p = 0.0000)] of the hypothesis that all regression coefficients in each equation are jointly equal to zero is rejected. Again, the likelihood ratio test [(χ^2(6) = 18.2376, p = 0.0057)] of the null hypothesis that the covariance of the error terms across equations are not correlated is also rejected (see Table 4.5 below). This is supported by the correlation between error terms of the sources of agricultural information equations shown in Table 4.4 above.

Age: The age variable was found to be statistically significant for social network information source but its negative sign implies that young farmers use less of social network as their source of agricultural information. Though age is not significant for the formal extension and 'Traditional Media' information sources but its positive effect on them shows that the youth have more tendency to listen to extension agents and radio for agricultural information. An earlier study by Mbanda-Obura *et al.* (2017) age has a positive influence on agricultural extension officers.

Agesq: The age square highlights the information source of the farmer as the farmer gets older. It was verified to be statistically significant at 5% and positive for the social network information source. This implies that as farmers get older they get more experience, fail to explore other sources of information and tend to share a lot of their experiences with their fellow farmers. Again, this is confirmed by Mbanda-

Obura *et al*. (2017) who found older farmers to be more reliant on their peers for agricultural information seeking.

Table 4.5: Estimated coefficients of determinants of farmers' choice of sources of agriculture information from a Multivariate Probit Model

Variables	Social network	Formal Extension	Traditional Media	Modern ICT
Age	-0.0874*	0.0565	0.0083	-0.0089
	(0.0461)	(0.0398)	(0.0355)	(0.0408)
Agesq	0.0013**	-0.0005	-0.0002	4.01e-05
	(0.0006)	(0.0005)	(0.0004)	(0.0005)
Level of Education (1 – 4 years)	0.1580	0.1850	-0.2540	0.4020**

	(0.2040)	(0.1920)	(0.1880)	(0.1920)
Level of Education (5 – 8 years)	4.2350***	4.5480***	4.4420***	-0.6180
	(0.2500)	(0.3230)	(0.2260)	(0.7380)
Level of Education (9 – 12 years)	-5.4900***	4.1220***	4.2890***	4.3530***
	(0.2760)	(0.2710)	(0.2610)	(0.2850)
Farm size (maize) (ha)	0.0203	-0.0014	-0.0292	-0.0985**
	(0.0437)	(0.0491)	(0.0426)	(0.0436)
Mobile phone ownership (1 = yes: 0 = otherwise)	-0.9900*	0.1060	0.2320	
	(0.5280)	(0.3110)	(0.2950)	
Access to radio (1 = yes: 0 = Otherwise)	-0.4730**	0.2590		0.7500***
	(0.2110)	(0.1860)		(0.1850)
Tolon (1 = Tolon: 0 = Otherwise)	1.1490***	-0.3900*	0.1350	-0.9130***
	(0.2260)	(0.2000)	(0.2010)	(0.2030)
Savelugu (1 =Savelugu: 0 =Otherwise)	0.7990***	0.1330	0.0121	-0.5660***
	(0.2090)	(0.2070)	(0.1970)	(0.2050)
Constant	2.8280**	-0.9720	0.2760	0.5580
	(1.1070)	(0.8810)	(0.7990)	(0.8370)
Observations	300	300	300	300
Wald χ^2 (38)	96.28			
Prob>chi2	0.000			
Log likelihood	-653.821			
Wald chi squared				

Source: Author's computations from field survey.

Note:

1. Karaga is used as the reference group.
2. The empty spaces in the respective regression are to eliminate multicolinearity. Robust standard errors in parentheses.
3. *** p<0.01, ** p<0.05, * p<0.1
4. Likelihood ratio test of $H_0 : \rho_{21} = \rho_{31} = \rho_{41} = \rho_{32} = \rho_{42} = \rho_{43} = 0$

   $\chi^2_{(6)} = 18.2376$, p-value = 0.0057

Level of education: At 1% level of significance, farmers with level of education within 5 – 8 years are more likely to resort to social networks, formal extension and traditional media as a source of agricultural information than their counterparts without education as it is significant and have a positive relation to these sources of information.

Also, those with 9 – 12 years of education was significant and a positive effect on formal extension, traditional media and modern ICT but with a negative relation to social networks than their counterparts. This implies that highly educated farmers explore various information sources but do not find any need to use social networks. That is, as farmers get more educated, they move from social networks to other sources of agricultural information sources. This is corroborated with that of Mittal and Mehar (2015) who found a similar result in India that as farmers get educated, they abandon social networks and rely on modern ICT for their information needs.

Farm size: Farm size proxied for economic status was found significant at 5% for only modern ICT (use of mobile phones). However, its negative sign implies that farmers with large farms do not find it useful to depend on modern ICT rather they likely depend on only social networks even though it is not significant for social networks. This could be indicative that most of the large-scale farms in the rural areas are owned usually by people with less education. However, this contradicts Mittal and Mehar (2015) who found farm size to be direct and significant for all information sources.

Access to mobile phone: Farmers having access to mobile phone are negatively and significantly (at 10%) related to social networks. This means that they are more active with other information sources and do not depend on social networks.

Access to radio: Okoedo-Okojie (2015) revealed that the most preferred information sources for farmers is radio. From this study, access to radio was significant at 5% but negative for social networks and significant but positive for modern ICT. Again, this suggests that farmers with radio have high tendency to shift from social networks towards the utilisation of modern ICT for agricultural information. It further suggests that traditional media (use of radio) and modern ICT are complementary as shown in Table 4.3 above.

District Dummies: Tolon and Savelugu districts were positive and significant at 1% for social networks and significant at 1% but negative for modern ICT. The implication is that due to effective spread of agricultural information through social networks, farmers in these two districts still heavily depend on social networks and rarely use modern ICT compared to their counterparts in the Karaga district which is the reference group. Mbanda-Obura *et al*. (2017) however indicate that irrespective of the broad variation across socio-economic background of states, the general farmer tries to still utilisation of the traditional media for agriculture information.

4.5 Determinants of Intensity of adoption of ISFM technologies

Results in Table 4.6 below shows the intensity of ISFM adoption intensity. It can be seen that at the minimum every farmer adopts one of the ISFM practices which justifies the use of the zero-truncated Poisson regression model.

Table 4. 6: Frequency of ISFM practices adoption among farmers

Number of practices	**Frequency**	**Percent**
0	0	0.00
1	15	5.00
2	68	22.67
3	127	42.33
4	74	24.67
5	14	4.67
6	2	0.67
Total	**300**	**100**

Source: Author’s computations from field survey.

Table 4.7 below shows the pair-wise correlation coefficients, which depict whether pairs of techniques are complementary, are substitutes, or do not have any association in their adoption patterns.

It can be observed that composting and mulching are complement because of the positive correlation coefficient (19%) between them. Also, composting and organic matter are complementary with a correlation coefficient of 20%. This implies that trainings and campaigns to promote ISFM practices adoption should jointly capture mulching, composting and organic matter.

Table 4. 7: Pairwise correlation of ISFM practices

Practices	Improved maize varieties	Crop rotation	Mulching	Composting	Organic manure	Fertiliser application
Improved maize varieties	1					
Crop rotation	0.0294	1				
Mulching	-0.0893	0.0509	1			
Composting	0.1096	0.1005	0.1893*	1		
Organic manure	0.1000	0.0832	0.0799	0.2019*	1	
Fertiliser application	0.0526	0.0607	0.0366	-0.0731	-0.0641	1

*** Implies statistical significance at 5%. Source: Author's estimations from field survey, 2018.**

4.5.1 Impact of intensity of adoption of ISFM technologies on maize yields and food security

4.5.1.1 Intensity of adoption of ISFM practices

In passing, from Appendix I, results from the Likelihood-ratio test of the restrictive assumption that the mean and variance of its parameter, λ, are equal, alpha coefficient = 0 (χ^2 (01)) = 0.000, *Prob* = 0.500), showed that the dispersion parameter for the zero-truncated negative binomial count data model was insignificant and hence the absence of over-dispersion at 1% level of significance. A formal test by Hilbe (2011) of AIC and BIC for the two models was also performed. The lower the estimates of these parameters, the more fit the model. The AIC and the BIC for zero-truncated Poisson model had 950.031 and 1027.810 respectively whiles that for the zero-truncated negative binomial model were 954.037 and 1039.26 respectively (see Appendix I).

This exhibited not just the absence of over-dispersion but the appropriateness of the zero-truncated Poisson model over the zero-truncated negative binomial model in an attempt to explain the intensity of adopting ISFM practices in both the baseline model and in the CMP framework.

4.5.2 Model choice between CMP system and individual model estimations

The second, third and fourth objectives of the study investigated the effect of intensity of adoption of ISFM technologies and other control variables on maize yields and food security. As already discussed in the methodology, the base line for the first stage equation is a zero-truncated Poisson regression model (the adoption model) whiles the second stage and third stage equations are OLS regressions to model the effect of intensity of adoption of ISFM technologies on maize yields and food security respectively.

This section of the analysis presents results of the CMP econometric estimation as shown in Table 4.8 below. The results include the coefficients of the ρ which show that at 1% level of significance there is a significant correlation of the error terms of the three equations, the intensity of adoption equation (Equation 1), the maize yield equation (Equation 2) and the food security equation (Equation 3). In other words, intensity of adoption was found to be significant in the maize yields model and then both intensity of adoption and maize yields were also simultaneously found to be statistically significant in the food security model. Comparing the CMP system estimation (Table 4.8 below) and the individual baseline model estimations (Appendix II), it was also observed that in the individual intensity model, ease of adopting ISFM practices and off-farm income were found significant but insignificant in the CMP system whereas within the intensity model in the CMP, family labour and perception of erosion of farmland were also significant but insignificant in the individual intensity of adoption model.

In the same vein, ill-health, social networks and main occupation were significant in the individual maize yields model but insignificant in the CMP system whiles perception of fertility of farmland and other district dummies were significant in the maize yields model in the CMP but insignificant in the individual maize yields model. Lastly, whiles extension contacts was significant in the individual food security model and insignificant in the food security model within the CMP, the reverse was the case for the age and level of education variables. The marginal effects of variables in the intensity of adoption in the CMP had significantly reduced compared to that in the individual intensity of adoption model.

The implication of these correlations and variations in the results (signs and significance of variables in the two models) is that there exists unobserved heterogeneity among the farmers and hence there is endogeneity implying that estimating the three equations separately, as has been done in the literature (see Braimah and Vlek, 2006), instead of as a structural equation system potentially leads to biased estimates. Therefore, estimating the three equations in a system of equation is justified and gives relatively reliable and more efficient estimates as that approach is able to account for endogeneity across the equations. As a result, the CMP system estimation results are discussed for the ensuing objectives whiles details of the results of the individual models can be referred to in Appendix II.

4.5.3 Effect of social networks and other drivers on ISFM technology Adoption Intensity

From the CMP estimated results, out of the 18 explanatory variables hypothesised to influence maize yields, 11 were statistically significant whiles 7 predictors including extension contacts, household size, ease of adopting ISFM practices, informal credit, access to off-farm and off-farm income and Tropical Livestock holding (TLU) were not found to have any significant influence on the intensity of adoption of ISFM technologies. The significant variables are discussed as follows:

Age: Age of farmers in the results was found to have a positive and significant effect at 5% on use intensity with a probability of 0.0001 for every one additional unit increase in the age of the farmer, other factors being constant. This finding is supported by that of Mango *et al.* (2017) who studied the awareness and use of conservation agriculture in the Chinyanja Triangle, Southern Africa. They demonstrated that a farmer's age significantly determined the probability of both awareness and use of conservation practices by farmers. A one-year increase in age is correlated with a 3% rise in the likely use of available land, soil and water conservation. They implied that age positively influenced both the knowledge and use of conservation practices and that older farmers relied on their experience to easily get information from extension officers and other sources.

Level of Education (5 – 8 years): Education is expected to enhance farmers' capacity to understand and easily adopt agricultural technologies and to freely interact with staff from agricultural and research organisations. Educated farmers could also confidently seek information from research organisations. Education was measured categorically and farmers with education between 5 – 8 years having a probability of 0.0161 at 1% level of significance of adopting more ISFM practices, *ceteris paribus*. The intuition is that the level of education positively influences the number of ISFM practices adopted. Hence farmers with more years of education have a higher tendency to adopt more ISFM practices than farmers who do not. Findings from Kokoye *et al*. (2016) found a strong linkage between adoption of soil conservation technologies and farmers level of education.

Innovativeness: Aside farmers' educational status, how innovative a farmer is also expected to be a significant influencing factor on how intense agricultural technologies are adopted. This expectation stems from the argument that even farmers without formal education maybe innovative with the tendency to adopt more ISFM practices than those with formal education. From Table 4.8 below, farmers' innovativeness was positive and with significant correlation with the intensity of using ISFM practices. In other words, *ceteris paribus*, when farmers are more innovative it increases the utilisation of about 0.0002 more ISFM practices.

Family labour availability: In times of labour shortages for agriculture, farmers usually resort to the family to supplement their labour needs. It is therefore expected that farmers with more available family labour will tend to adopt more ISFM practices. However, contrary to expectation, family labour availability was found to have a significant (at 10%) but negative effect on the intensity of adoption of ISFM practices. The results show that for every one of family labour available, the farmer reduces intensity of adoption by -0.000068. This implies that available labour may be available for other farming activities since the farm household maybe involved in the production of a wide range of crops and so engaged in a broad range of activities and not necessarily ISFM practices.

Moist land: Access to moist land for crops is suggestive of the adequacy of water or moisture available is necessary fulfil the requirements for effective maize growth. Though this variable is not quite strong in predicting the intensity of adoption of ISFM, it was discovered to be negatively and significantly correlated with intensity of ISFM practices adoption at 10%. Table 4.8 below shows that small farm owners with access to moist land in general are likely to adopt 0.0026 less of ISFM practices, other factors being constant.

This argument is corroborated by that of Mponela *et al.* (2016) who discovered some ISFM practices such as mulch, compost and agroforestry to be adopted by a few farmers to forestall peculiar challenges in improving nutrient and water retention as well as acidity. This implies that farm households having farm plots that have poor water retention have high tendency to implement ISFM practices whiles farm households with better access to moist land have a lower likelihood to use more ISFM practices. This is a plausible result as having improved access to moist land will address a number of farm plot constraints that ISFM practices seek to achieve.

Perception of erosion of farmlands: Results from Table 4.8 below show farmer perception of erosion of farmlands to be positive and significant at 10%. This meets an *a priori* expectation and farmers who perceive their farmlands to be eroded adopt 0.0020 more of ISFM practices than farmers who do not. Haggblade and Tembo

(2003) acknowledged that soil erosion is a key consideration in farmers' choice of conservation agricultural practices.

Cost of production: Relatively high input cost such as that of inorganic fertiliser constrains the level of profitability to induce the adoption of improved maize. This means that higher farm households' incomes are associated rather with a set of SAPs such as maize–legume rotation and residue retention (Manda *et al*., 2016). Cost of production was estimated to significantly, at 10%, and negatively influence the intensive use of adoption of ISFM practices. This result is expected as it hinges on the law of supply whereas the cost of inputs for production increases, the farmers being rational reduces adoption of ISFM practices. The key element of the farmers cost outlay is fertiliser acquisition as the most adopted ISFM practice. This evidence is therefore consistent with that of Diouf and Sheeran (2010) who noted that to successfully apply fertilisers in conservation agriculture requires both higher managerial skills and better access to fertiliser and these could be costly beyond reach for the farmers.

Access to research institutions: The intensity of adoption of ISFM techniques is hypothesised to be broadly promoted through field experiments and demonstrations if farmers have frequent access to research institutions such as SARI. The findings in Table 4.8 below shows that access to research institutions was significant at 1% and was positively associated with the intensity of adoption of ISFM practices, holding other factors fixed. That is, farmers with access to support services from research institutions tend to adopt 0.0031 ISFM practices more than their counterparts who do not. This result is supported by Pedzisa *et al.* (2015) who found that non-governmental input support has a significant effect on adoption intensity. This implies that research institutions play a major contribution to the promotion of ISFM practices adoption and deserves encouragement to complement the efforts of extension agents.

Training on ISFM: Various sources of knowledge on ISFM are available to farmers. McCarthy (2015) outlined agricultural information source characteristics variables to capture the number of times the farmer has received an agricultural technology training over the last 12 months, agricultural training events (including learning agricultural information from farmers' fairs, field days, and farmer's field schools) among others. The findings of the study report that farmers' access to training on ISFM significantly influenced (at 1%) the intensity of adoption of ISFM. That is, other factors of intensity of adoption held constant, farmers who attend training on ISFM practices tend to adopt 0.0052 ISFM practices more than farmers who do not. These results are consistent with Pedzisa *et al*. (2015), Kpadounou *et al*. (2017) and Moges and Taye (2017) who also found that training on how to apply Soil and Water Conservation (SWC) technologies creates awareness about it and its subsequent adoption.

Mean Social Network: Social network including learning agricultural information from relatives, neighbouring farmers, farmer groups, and farmer associations are very relevant in the dissemination of agricultural technology (McCarthy, 2015). Of the three proxies employed in this current study as measure of social network including membership of agro-based organisation, number of times farmers attend meetings in a year and the total number of an agricultural technology adopters the farmer knows both in and outside of the village, it was only the kinship (the total number of an agricultural technologies adopters the farmer knows both in and outside of the village) that significantly explained farmers' adoption intensity of soil fertility management practices. Results from the current study provides evidence that suggests that social work had a positive and significant effect on the intensity of adoption of ISFM practices. The general effect of social network is that, holding other factors fixed, farmers with high social capital adopt 0.0005 more ISFM practices at 0.01. In other words, for farmers with strong kinship ties, every additional family member or friend a farmer adds to his/her kinship increases the probability of adopting more ISFM practices by 0.0005 at 0.01 level of significance. This confirms Nkegbe and Shankar (2014) and Abdulai (2016) argument that membership to farmer organisation and engagement in mutual labour sharing arrangements, representing social capital, both have positive and statistically significant effect at the 0.01 level on intensity of adoption.

This finding represents a test of the Social Learning Theory by Bandura (1978) who posited that learning occurs within a social environment depending on various strategies such as observation (of neighbours), imitation (of associates/peers) or modelling (by friends). Such learning approach may or may not result in change in behaviour, depending on the level of attention of the learner (cognitive capacity), ability to remember the observed behaviour (retention capacity), ability to replicate the observed behaviour (motor capacity) and desire to put into practice the observed behaviour (motivation level), all of which are influenced by the model's behaviour, attitudes and outcomes of such behaviours.

District dummies: District dummies of being located in both the Tolon and Savelugu districts are reported to have a positive and statistically significant at 1% in both cases. This implies that farmers located in the Tolon and Savelugu districts have more tendency to increases the number of ISFM practices adopted by 0.0056 and 0.0045 respectively. This contradicts with Nkegbe and Shankar (2014) who acknowledged, applying count data models, that locational variations are also key to negatively determining the extent of intensity of adoption of soil conservation techniques within the Upper West Region of Ghana. The contradictions may have stemmed from the idea that their study combined both soil and water conservations unlike in this current study where the focus is on soil fertility management which are quite common. It also has an implication that there could be low degree of awareness and difficulty in managing water conservation practices.

Table 4. 8: CMP estimation of the impact of intensity of adoption of soil fertility management practices on maize yields

	CMP estimation		Marginal effects	
Variables	**Coefficient**	**Std. error**	**Coefficient**	**Std. error**
Equation 1				
Intensity of ISFM adoption				
Age	0.0122***	(0.0044)	0.0001**	(4.98e-05)
Household size	0.0035	(0.0055)	3.43e-05	(5.51e-05)
Edtnlev (1-4 years)	0.0085	(0.0946)	8.49e-05	(0.0009)
Edtnlev (5-8 years)	1.6200***	(0.4080)	0.0161***	(0.0048)
Edtnlev (9-12 years)	0.0503	(0.7860)	0.0005	(0.0078)
Innovativeness	0.0244*	(0.0140)	0.0002	(0.0002)
Family labour	-0.0068*	(0.0036)	-6.80e-05*	(3.94e-05)
Moist land	-0.2610**	(0.1320)	-0.0026*	(0.0014)
Ease of adopting ISFM	0.0791	(0.0946)	0.0008	(0.0010)
Perception of erosion	0.1980**	(0.0965)	0.0020*	(0.0010)
Access to off-farm Income	-0.1510	(0.1270)	-0.0015	(0.0013)
Cost of production	-0.0002***	(5.70e-05)	-1.47e-06**	(6.66e-07)
Off-Farm Income	0.0001	(9.13e-05)	1.00e-06	(9.45e-07)
TLU	0.0104	(0.0105)	0.0001	(0.0001)
Access to Research Institutions	0.3110***	(0.0983)	0.0031***	(0.0012)
Training on ISFM	0.5220***	(0.1060)	0.0052***	(0.0016)
Informal Credit	3.97e-05	(0.0002)	3.25e-07	(1.79e-06)
Extension contacts	0.0011	(0.0059)	1.14e-05	(5.92e-05)
MeanSocLearn	0.0514***	(0.0121)	0.0005***	(0.0002)
Tolon	0.5600***	(0.1400)	0.0056***	(0.0018)
Savelugu	0.4500***	(0.1260)	0.0045***	(0.0016)
Constant	1.4830***	(0.2600)		
Equation 2				
Maize yields				
Age	-20.2400***	(4.2380)		
Household size	-4.3840	(3.8660)		
Main occupation	-307.6000	(190.8000)		

Experience in maize production	14.3600***	(4.0300)
Ill-health	114.7000	(72.1500)
Family labour	9.2140***	(3.0350)
Farm size	-60.9400***	(22.0700)
Fertiliser applied per hectare	42.9400***	(11.3100)
Burning of residue	121.0000**	(57.2200)
Cost of improve seeds	-0.6810	(1.6150)
Perception of erosion	-99.2800	(76.1500)
Perception of soil fertility	-163.0000*	(92.7000)
Perception of rainfall	-72.0800	(118.7000)
Pest control	95.9800*	(55.3400)
TLU	29.0700***	(7.0760)
WealthIndex	73.9200***	(27.8300)
Extension contacts	-8.8820**	(4.1240)
MeanSocLearn	16.0600*	(9.6220)
NumISFM	434.7000***	(105.4000)
Tolon	-498.900***	(120.8000)
Savelugu	-310.000***	(108.0000)
Constant	524.9000	(327.9000)
Equation 3		
Food security		
Age	0.0104**	(0.0046)
HHS	0.00821*	(0.0047)
Edtnlev (1-4 years)	-0.0515	(0.0809)
Edtnlev (5-8 years)	0.8870**	(0.4210)
Edtnlev (9-12 years)	0.2390	(0.6590)
Off-farm Income	6.68e-05	(6.42e-05)
TLU	-0.0011	(0.0106)
Informal credit	0.0004**	(0.0002)
Extension contacts	0.0006	(0.0053)
Farm size	0.0516**	(0.0251)
Perception of rainfall	0.0958	(0.1330)
NumISFM	-0.6670***	(0.1500)
Maize yields	0.0004**	(0.0002)
Remittances	0.0002	(0.0004)
Dependency ratio	0.0380	(0.1720)
Tolon	0.2190	(0.1640)
Savelugu	-0.0612	(0.1310)
Constant	6.9080***	(0.3360)
Parameters atanh ρ and ln σ^a		
$\ln\sigma_1$	-0.2451***	(0.0426)
$\ln\sigma_2$	6.2937***	(0.0931)
$\ln\sigma_3$	-0.3774***	(0.1287)
atanh ρ_{12}	-0.6024***	(0.1675)
atanh ρ_{13}	0.7871***	(0.1782)
atanh ρ_{23}	-0.6432***	(0.1896)
σ_1	0.7827	(0.0333)

σ_2	541.146	(50.3933)
σ_3	0.6856	(0.0882)
ρ_{12}	-0.5387	(0.1189)
ρ_{13}	0.6568	(0.1014)
ρ_{23}	-0.5671	(0.1286)

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. atanh ρ and $\ln\sigma$ are transformations of parameters ρ and σ respectively into unbounded scale, that prevents the possibility that in the course of its search, the Maximum Likelihood will generate impossible trial estimates for the parameters, such as negative value for a σ (Roodman, 2011).

Source: Author's computations from survey data, 2018.

4.5.4 Effects of intensity of adoption of ISFM practices on maize yields

The second stage equation of the CMP model estimates the effect of intensity of adoption of ISFM on maize yields. Study results in Table 4.8 above indicate that out of the 20 regressors under equation 2, 14 of them were found statistically significant in influencing maize yields whiles 6 factors comprising household size, main occupation, ill-health, cost of improved seeds, perception of farm erosion and rainfall were insignificant.

Age: From the estimates in Table 4.8 above, age was revealed to be negative and statistically significant at 1%. In other words, increasing age of the maize farmer decreases maize yield by 20.2400 kg/acre, other determinants being constant. This indicates that as maize farmers get older they are less willing to undertake risk of trying out new agricultural technologies and hence are exposed to the tendency of recording lower maize yields. Consistent with this, Ntabakirabose (2017) found that farmer's age has a statistically significant but negative effect on the efficiency of maize production.

Experience in maize farming: Experience in maize yields in the study provides an interesting result. Contrary to the expectation that age and experience could be perceived as substitute variables, the empirical verification here demonstrates opposing directions of influence of the two variables. Experience in maize farming though was statistically significant at 1% but it was positive. The result shows that farmers with increasing experience in maize production report 14.3600 kg/acre increase in maize yields, others determinants being constant. This implies that though older farmers may have reduced incentive to adopt new agricultural technologies, their long experience in maize production still has a significant effect on maize yields as farmer are much experienced in their adoption of existing agricultural technologies. This result is confirmative of that of Ntabakirabose (2017) who revealed that experience of farmers' in maize production influences farmers' technical efficiency in maize production.

Family labour (in man-days): One of the major elements of agricultural production is whether family labour is available as it enhances the tendency of the farmer to adopt agricultural practices and provides ready labour to support household farm production. From the empirical results, family labour was revealed to be positive and statistically significant at 1%. That is, for any increase in available family labour results in 9.2140 kg/acre increment in maize yields (Table 4.8 above). The economic intuition is that migration of youth from the study area to major cities in the country reduces availability of family labour for agricultural activities, maize yields and overall economic wellbeing of farm households. Banerjee *et al*. (2014) confirmed that lower yields of farmers are mainly associated with availability of family labour.

Farm size (Maize): Results in Table 4.8 above reveal that the influence of maize farm size on maize yield was negative but statistically significant at 1%. In other words, for every hectare, an increase in maize farm size leads to a 60.9400 kg/acre decrease in maize yields. This implies that when maize farmers increase their maize farm sizes, the effectiveness to intensify adoption of ISFM practices reduces as there are cost implications that come along with expanding farming sizes. Again, Ntabakirabose (2017) buttressed when he found land size to have a positive and significant influence on the technical efficiency in maize production.

Fertiliser Application: It is reckoned that smallholder farmers in Africa are the least users of fertiliser inputs per unit area under agriculture and that applying mineral fertiliser is required for agricultural transformation and averting of low yields (Nhamo *et al.*, 2018). The implementation of fertiliser is unavoidable particularly on soils characterised by obviously poor fertility and those whose nutrients have been depleted through inappropriate farming techniques (Bationo *et al.*, 2007). Empirical evidence provided by the present study showed that fertiliser application positively and statistically significantly influenced maize yield at 1% statistical significance. From the results, an increment in the quantity of fertiliser applied per hectare leads to a 42.9400 yield in maize. Therefore, despite its limited adoption by smallholder producers, lack of adequate initial capital outlay and restricted availability (Bationo *et al.*, 2007; Diouf and Sheeran, 2010; Nakano and Kajisa, 2013), fertiliser use still enhances maize yield compared to non-fertilised plots (Braimoh and Vlek, 2006 and Toenniessen *et al.*, 2008). The implication therefore is that without fertiliser, CA will not provide any positive benefits.

> *"Maize plots treated to organic matter suffered less drought stress than plots without organic matter, but plots with recommended rate of inorganic fertilisers performed best under optimum moisture conditions." CSIR-SARI Report, 2009.*

Burning of crop residue: The practice of regular burning of left-over crop residue after harvesting is discouraged in acceptable farming practices that crop residues can be seen as a vehicle of putting nutrients back to proper agricultural soils as far as the process supports soil carbon storage (Nhamo *et al*., 2018). It will be hypothesised then that farmers whose farmlands are regularly burnt by either themselves or hunters will be motivated to adopt ISFM practices which consequently lead to improved maize yields. Contrary to this, burning of crop residue had a positive but statistically significant effect at 5% on maize yields. The estimated effect indicates that farmers who burn crop residue after harvest have 121.0000 kg/acre maize yields more compared to those who do not. The deduction is that burning and removal of crop residues in post-harvest season are common practices among farmers with the purpose to clear their farmlands for easy movement of farm implements and to control weeds. Therefore, one can deduce that it is not the burning of the crop residue that should warrant encouragement but the controlling of weeds demands special attention as maize farms pervaded by weeds have the potential to experience low maize yields. Study results by Okeyo *et al*. (2014) confirm this as they indicated that maize yields were positively influenced by mulching.

Pest control: Pest control had a positive and significant effect on maize yield suggesting that farmers who sprayed their farms with pesticides are more likely to have higher yields than other who did not. The estimated coefficient of pest control (Table 4.8 above) shows that farmers who sprayed their farms with pesticides had 29.0700 kg/acre maize yields more than those who did not at 1% level of significance.

Intuitively, it implies that pest and diseases are a major influence on maize yield and hence a major cost component of farmers' production expenditure. This result coincides with that of Kirkegaard *et al*. (2008) that crop rotation reduces the tendency of pest and disease incidence and that of Farooq *et al*. (2011) that intensity of adoption of soil fertility practices facilitate weed control and improves crop yields.

Perception of farmlands fertility: Consistent with expectation, perception of fertility of the maize plot had a negative but statistically significant effect at 10% level of significance. The coefficient that suggests that those who perceive their maize plots to be fertile record maize yields of 163.0000 kg/acre lower than others who are pessimistic about the fertility of their maize farmlands. The deduction is that farmers are optimistic about the fertility of their farmlands tend to have low motivation for improving the intensity of their use of the ISFM techniques and hence record low maize yields given that intensity of adoption of ISFM practices has a positively significant effect on maize yields.

Tropical Livestock holding: The availability of livestock to the farm household is hypothesised to increase the probability of ISFM techniques adoption in two ways: sale of livestock for income to acquire and adopt and relying on integrated crop-livestock system to promote the use of ISFM technologies. Study result revealed that access to livestock holding (measured in Tropical Livestock Units) positively and statistically significantly (at 1%) influence the intensity of adoption of ISFM practices. Put in another way, for every additional unit increase in Tropical Livestock Units, maize yields increase by 29.0700 kg/acre.

Wealth index: Adopting ISFM practices such as fertiliser application and composting and organic manure involves not only the purchases of fertiliser but also the cost of acquiring, gathering, transporting and spreading compost and animal droppings on maize plots.

The households' ability to pursue all these production activities is greatly influenced by their level of wealth measured by their wealth index. The study found wealth index to be a highly significant and positive determinant of maize yields at 1%. That is, for every unit increase in farm household wealth index, maize yields increase by 73.9200 kg/acre.

Extension contacts: Unlike in the intensity of adoption equation where extension contacts do not significantly influence the number of ISFM practices adopted, it is revealed to be statistically significant with a negative influence on maize yields in the maize yield equation. This implies that the tendency that maize farmers in the study area are becoming more experience in maize production than some extension agents and hence have better maize yields with less contact with the extension officers or that the information provided does not meet specific needs for improving maize yields. Put differently, farmers who benefit from extension contact do not get adequate and probably appropriate knowledge on the adoption of ISFM practices and as such, any additional contact with extension agents, yield drops by 8.8820 kg/acre. Once the relationship between social networks and maize yields is significantly positive, and given that social networks and extension are substitutes, the negative result between extension contacts and maize yields could then also imply that more extension contacts means less contact with social networks and hence low maize yields. The results contradict that of Moges and Taye (2017) that extension contact positively and significantly influenced farmers' perception of ISFM practices and consequently their yield at 5% level of significance and that of Urassa (2015) that education is a major factor in increasing yields.

Mean Social Network: Overall social networks (Mean Social Network) demonstrated to be statistically significant and positively correlated with maize yields at 10%. For every additional network that a farmer discovers, maize yields improve by 16.0600 kg/acre.

The implied finding is that the existence of social cohesion within the study area supplements, through the provision of communal labour, the labour requirements of the farm household agricultural production. The result is consistent with Mekonnen *et al*. (2018) who also provided evidence of a statistically significant and positive link of networks with the adoption of row planting together with yields for both male and female networks. Their results further suggest that extension services and other programmes that propagate agricultural technologies and requires yield enhancement can gain from social networks but that their success hinges on spotting the ‘‘right” networks, including those of female household members with regards to row-planting.

Number of ISFM practices adopted: The estimated effect of the number of ISFM techniques used on maize yields was 434.7000 kg/acre (Table 4.8 above). The effect is demonstrated to be positive and statistically significant at 1% level of significance. The coefficient implies that, for any addition of ISFM practices to a farmers' ISFM practices adoption intensity will raise maize yields by 434.7000 kg/acre. The implied result is that farm households that adopt many ISFM practices have highly productive maize plots and this is suggestive of the strong combined effect of the intensity of ISFM technology adoption. This finding is corroborated by the field results of Pedzisa *et al*. (2015) that farmers adopting all the CA practices are the most productive, with an estimated maize yield of 2.5000 tons/ha, relative to a yield of less than 1 tons/ha for other farmers applying three techniques or less. Their study furthered that more CA practices implemented in the previous cropping season have a positive impact on current season intensity of adoption, suggesting that CA technologies propagation do have a persistent effect.

District Dummies: District specific geographical characteristics were also hypothesised to have potential effects on maize yields. Results from Table 4.8 above indicate that district specific characteristics statistically significant but negative effect on the maize yields at 1% level of significance. Overall, the findings have established that maize farmers located in the Tolon and Savelugu districts have the tendency to have maize yields of 498.9000 kg/acre and 310.0000 kg/acre lower than their colleagues in the Karaga district. As earlier observed, over the years Tolon and Savelugu districts have witnessed an extensive adoption of ISFM practices particularly fertiliser application relative to the Karaga districts which could imply that previously fertile farmlands are beginning to experience marginal diminishing returns to scale.

4.5.5 Mean Household Dietary Diversity Score by intensity of ISFM practices adoption

One of the key welfare issues in the study area is food security. As regards whether the household in a normal year reduces its quantity of food serve as a result of insufficient money, about 97% of the farmers reported food shortages sometimes within the year irrespective of the number of ISFM practices adopted. For details on the households' food consumption behaviour over a month and frequency distribution of household consumption of food groups, see Appendices IV and V respectively.

Following Swindale and Bilinsky (2006), a generally diversified diet is one with better birth weight, child anthropometric status, improved haemoglobin density, caloric and protein (especially from animal sources) and household income outcomes. Their Household Dietary Diversity Score (HDDS) measurement guideline was then employed to measure HDDS and the HDDS used as a proxy for food security. Results from Figure 4.6 show that there are marginal variations in the food security (HDDS) across different intensities of ISFM adoption.

The Figure 4.6 below suggests a downward trend such that those who adopted only one practice are highly food secured (mean HDDS = 6.25), followed by those who adopted only two practices (mean HDDS = 6.23) and so on till those who adopted five practices (mean HDDS =5.55). The only slight variation was observed for those who adopted all the six practices with a mean HDDS = 5.82 which is marginally above those who applied the five practices. This comparative analysis is quite interesting as it seems contrary to the expectation that the more intense the adoption rates the more food secured the household is (see Figure 4.6). For details on mean Household Dietary Diversity Score by intensity of ISFM practices adoption and distribution of Household Dietary Diversity Score, refer to Appendices III and VI respectively.

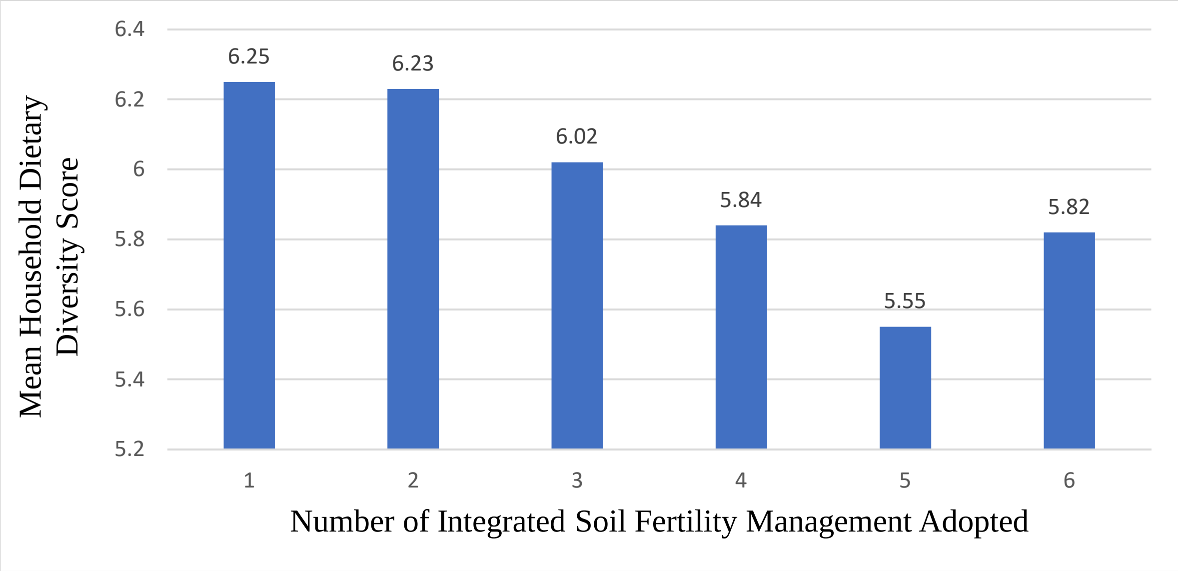

Figure 4. 6: Number of ISFM practices adopted by mean Household Dietary Diversity Score
Source: Author's computations from survey data, 2018.

4.5.6 Effects of intensity of adoption of ISFM practices and maize yields on farm household food security (Dietary Diversity Score)

The third stage equation of the CMP model estimates the effect of intensity of adoption of ISFM practices (measured by the number of ISFM practices adopted) and maize yields on the household food security. The dependent variable (Dietary Diversity Score) is a continuous variable. Study results in Table 4.8 above indicate that of the 14 regressors under equation 3, 7 of them were found statistically significant in influencing household food security whiles 7 factors including surprisingly off-farm income, tropical livestock holding, extension contacts, perception of rainfall, remittances, dependency ratio and district dummies are surprisingly found insignificant factors influencing household food security.

Age: From Table 4.8 above, results show that with the age of the farmer, it was significant at 5% level of significance and it reflects a positive influence on household food security. The finding argues that, *ceteris paribus*, when the farmer's age increases by a year the farm household food security (Dietary Diversity Score) increases by 0.0104. Intuitively, it means that households are managed by adult farm households who have built wealth for years now and are current engaged in various income generating and overall productive activities to promote the household's food security. This result is supported by that of Abafita and Kim (2014) who found age of the house head to be strongly and positively related to household food security.

Household size: Other factors held constant, it is expected that the higher the total household membership the more food insecure the household as there potentially maybe difficulty in food provisioning. Contrary to this expectation, household size is shown to have a positive and statistically significant effect at 10%.

Holding other determinants fixed, when household size increases by one more individual the food security status of the household also increases by 0.0082. This is evidenced by the relatively low dependency ratio of 0.46. However, Beyene and Muche (2010) and Shiferaw *et al*. (2003) reckoned that the number of household members negatively influence household food security. The inconsistency in the results suggests that the distribution of the composition of household population is that there are more adults who are engaged in productive activities than dependants.

Edtnlev13: Tefera and Tefera (2014) have earlier found that level of education, household size positively and significantly influences household food security. From the empirical results in Table 4.8 above, farmers' level of education was positive and statistically significant at 5% level of significance. Hence holding other determinants fixed, farmers with relatively high education (5 – 8 years) have food security of 0.8870 more relative to those who have no formal education. Seminal works by Olabiyi and McIntyre (2014) also indicated that food insecurity is increased where educational attainment is lower.

Informal Credit: Accessibility to credit likely improves food security and permits farm households to attain higher dietary diversity (Bidisha *et al.*, 2017). Results presented on Table 4.8 above showed that indeed there was a positive and statistically significant (at 5%) causal link between informal credit and that of farm households food security. In an interpretative sense, the results demonstrated that for every GH¢ rise in the quantum of accessed informal credit, household food security improves by a factor of 0.0004, other determinants of food security held constant. The implied reasoning here is that in times of poor crop harvest or major crop failure households rely on social networks to access credit to fulfil their food consumption needs. This result is however inconsistent with that Abafita and Kim (2014) who found access to credit as well as remittances to have a negative influence on food security.

Farm size: All other determinants of food security held constant, farm size had a positive and statistically significant (at 5% level of significance) effect on food security. Increasing farm size is calculated to result in 0.0516 increment in food security. This indicates that access to additional farmlands provides the farm household an opportunity for maize production and income generation from sale of maize and so in effect farm size has a transmission or indirect effect on food security. Previous studies (see: Tefera and Tefera, 2014) support this theory of positive link between size of cultivated land and food security.

Number of ISFM practices adopted: It is hypothesised that farmers who intensify the adoption of ISFM practices is correlated with high maize yields. However, from the results, the intensity of ISFM practices adoption was negative and statistically significant at 1%. The result shows that for every additional increase in the intensity of ISFM practices adoption reduces household food security value by 0.6670. The implication could therefore signify that appropriateness of intensified adoption of ISFM technologies is what has a higher potential for improved maize yields for enhanced food security. It could also imply that investment in adoption of ISFM practices is competing with households' direct food purchases decisions with limited income. Furthermore, this result could be limited by the seasonality of household food security which affected the timing of the study. A quite significant implication, however, is that the promotion of ISFM technologies targeted at only maize production is very likely to overlook other important aspects (crops) of farmers' food security situation. The use of the HDD score therefore exposes this observation or challenge. Similar studies by Abafita and Kim (2014) and Beyene and Muche (2010) in Ethiopia found soil conservation practices to be strongly and positively related to household food security.

Maize yields: It is hypothesised that farm households with improved maize yields will have better household food consumption pattern. Against this theory however, empirical findings indeed showed a positive and statistically significant (at 5%) effect of maize yields on food security such that continual increase in maize yields cause a 0.0004 margin of increment in food security.

The result signifies that though dietary diversity score was used as a proxy for food security improvement in maize still has a significantly positive effect on food security since a collection of the sampled maize farmers produce other crops and as well market their agricultural surplus for income to satisfy their food needs.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Introduction

This section of the report presents the summary of the findings, conclusions as well as some useful policy recommendations.

5.2 Summary

This study has examined agricultural information sources and adoption of ISFM practices: Impacts on maize yields and food security. The study specifically examined the factors influencing farmers' choice of agricultural sources. It also, explored the effect of social network and other drivers on the intensity of adoption of ISFM practices. Again, it examined the effect of the intensity of adoption of ISFM technologies on maize yields. Finally, it explored the combined effect of intensity of adoption and maize yields on food security of farm household.

Some major findings indicate the existence of district distribution of ISFM techniques adoption with the Tolon district leading and has an average adoption of 3.35 of ISFM practices relative to Savelugu (3.16) and Karaga (2.59) districts. Majority of the farmers (42.33%) adopt three ISFM practices followed by those adopt four practices (24.67%) and those who adopt two practices (22.67%). The poorly adopted ISFM practices are mulching and composting with only 22 and 19 farmers respectively adopting it out of the 300 sampled farmers. This raises concerns about farmers' awareness of the efficacy of these two practices and the challenges of their adoption.

The findings indicate that farmers do not rely on only one source for agricultural information needs. No farmer depends on only 'Modern ICT' (use of mobile phones only) and majority of them (14%) still rely on 'Social network' and 'Formal Extension' for information. Social network and traditional media are negatively correlated and so the two sources are found as substitutes with a correlation coefficient of 20.37%. For formal extension and modern ICT information sources, the association between them is the highest (21.37%) with a positive sign suggesting that the two sources are complementary. Among the expected factor influencing farmers' choices of sources of agricultural information, age, educational status, farm size, access to radio and mobile phones are evidenced to have significant influence.

Also, age of the farmer, level of education, innovativeness, moist land, perception of erosion of farmland, cost of production, access to research institutions, training on ISFM practices and social networks are the significant determinants of intensity of adoption of ISFM practices. An interesting pattern observed in the social network variable revealed that kinship as one of the indicators of social network is the only significant influencing factor of intensity of adoption compared to the other indicators of social networks such as FBO membership. This suggests that much of the agricultural technology diffusion is carried out from farmer to farmer through informal interactions. This should attract policy attention especially given the surprising finding that access to extension was not identified as a significant influencing factor of intensity of adoption of ISFM practices.

In the context of the determinants of maize yields, age of the farmers, farmers' experience in maize production, availability of family labour, farm size, quantity of fertiliser applied per hectare, burning of crop residue after harvest, pest control, perception of soil fertility, Tropical Livestock holding, wealth, access to extension service, social networks and intensity of ISFM adoption were demonstrated to have significant influence.

With regards the factors influencing farm household food security, the results found age, household size, level of education, informal credit, farm size, intensity of ISFM practices adoption and maize yields to be statistically significant.

5.3 Conclusions

Heavy reliance on social networks and extension services coupled with low dependence on modern ICT (use of mobile phones) as sources of agricultural information implies that the farmers lack the necessary education and access to mobile phones to examine and exploit the tremendous impact of modern ICT on farm production.

Age, educational status, innovativeness, ease of adopting ISFM practices, access to research institutions and social network have positive effect on intensity of ISFM practices adoption whiles access to moist land, access to off-farm income and cost of production negatively affect intensity of adoption.

These results imply that more work still awaits the research institutions and MoFA in turning social networks, farmers' innovative potentials and access to off-farm income into channels for high and appropriate adoption of ISFM practices.

Also, experience, family labour availability, quantity of fertiliser applied per hectare, pest control, burning of crop residue, Tropical Livestock holding, wealth, social networks and intensity of adoption of ISFM practices have significantly positive effect on maize yields whiles age, farm size, perception of soil fertility and access to extension are negatively related to maize yields.

Though age, household size and farm size are significant and positively affect food security, they are not adequate enough to enhance adequate food security for the household. The major policy variables to inform policy are the educational status, informal credit and maize yields which are positively related to food security. The declining trend of mean household dietary diversity score over increasing intensity of ISFM practices adoption is also an indication that the propagation of ISFM techniques targeting at only maize production will not enhance household food security (dietary diversity).

5.4 Recommendations

Based on the study results and the subsequent conclusions made, some important policy recommendations emerge for MoFA and other research institutions in the context of the diffusion of agricultural technology.

Since educational status of farmers, innovativeness, training on ISFM practices adoption and access to research institutions are significant, then there is the need for more educational campaign and sensitisation on ISFM practices to enable farmers become fully aware and appropriately adopt these practices to promote their maize yields and food security. Trainings on the use of ISFM technologies also needs support and should be encouraged because it affords farmers the opportunity to learn simple but new techniques and also allows them to decide which of the practices are good for their situation. Government can support this by paying special focus on the recruitment of extension agents and hence increasing contacts with farmers.

Again, social network was presented to be instrumental in agricultural technology diffusion. Therefore, MoFA and other research institutions should adopt the mass communication and training sessions through the engagement of mini vans and tricycles like that of the International Fertiliser Development Centre (IFDC) that will not only disseminate knowledge on ISFM practices through audio-visual but will bring improved seeds and fertiliser to the doorstep of the rural farmer. The ISFM practices tool kit that contains smaller amounts of improved seeds, fertiliser and other components of ISFM practices should also be promoted. Under this circumstance again, the cost of production was found significant influencing factor of intensity of adoption and therefore for a broader impact of the practices, poor farmers should be incorporated in decisions on the cost of fertiliser so government input subsidy programme should be made sustainable and the labour requirement for them to have an opportunity to adopt the technologies.

Simple tool kits could be considered and developed for soil testing. Most farmers invest in fertiliser application without knowing the nutrients lacking in their soil. The adoption of fertiliser in that case may not only result in improper use by farmers but also poor maize yields. Therefore, Government of Ghana's Planting for Food and Jobs Programme should precondition the allocation of fertiliser to farmers on soil testing. At the policy level, the Government should work with input (fertiliser) suppliers to produce fertiliser to the specific needs of farmers' farmland.

Finally, MoFA and other development partners should promote integrated crop-livestock production systems (diversification of farm enterprises) to enhance food security since Tropical Livestock holding was identified to increase maize yield and maize yields also increase food security.

5.5 Major Contributions of the study

This study is a pioneering study in agricultural economics research methodology by using the Conditional Mixed Process estimation to assess the determinants of adoption, effect of intensity of adoption of ISFM practices on maize yields and food security which is a unique and comprehensive analytical method in this area of research. It provides reliable results and could be used in future research.

5.6 Recommendations for Further Research

Evidence from literature and the empirical analysis in this study still revealed large knowledge gaps in literature. Therefore, future research should focus on the impact of soil and water conservation practices on farmers' wellbeing by using more than one crop to ascertain whether adoption of the technologies has any impact on overall wellbeing instead of only maize yields and food security. Another area that future research should also look at has to do with an experimental study on soil testing and fertiliser application and its implications on maize yields to clarify that farmers are appropriately applying the required type of fertiliser or not. Other future studies could also intensively explore not just the effect of government's fertiliser subsidy programme on uptake of fertiliser application but the appropriate adoption (utilisation) of the input.

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APPENDICES

Appendix I: Results of model choice between zero-truncated Poisson and negative binomial regression models for intensity of ISFM practices adoption

Variables	*Model (1) Zero-truncated Poisson*	*Std. error*	*Model (2) Zero-truncated Negative Binomial*	*Std. error*
Age	0.0040**	(0.0017)	0.0042**	(0.0017)
Household size	0.0018	(0.0022)	0.0018	(0.0022)
Level of Education (1 – 4 years)	0.0172	(0.0478)	0.0191	(0.0478)
Level of Education (5 – 8 years)	0.2630***	(0.0643)	0.2630***	(0.0643)
Level of Education (9 – 12 years)	-0.1150	(0.1570)	-0.1150	(0.1570)
Innovativeness	0.0129**	(0.0060)	0.0129**	(0.0060)
Family labour (in man-days)	-0.0028	(0.0019)	-0.0028	(0.0019)
Moist land	-0.1060*	(0.0618)	-0.1060*	(0.0618)
Ease of adopting ISFM	0.1310***	(0.0415)	0.1310***	(0.0415)
Perception of erosion of farmland	0.0419	(0.0518)	0.0419	(0.0518)
Access to off-farm income (1 = yes: 0 = Otherwise)	-0.1760**	(0.0689)	-0.1760**	(0.0689)
Off-Farm Income	9.71e-05***	(2.98e-05)	9.71e-05***	(2.98e-05)
Tropical Livestock holding	0.0053	(0.0044)	0.0053	(0.0044)
Cost of production	-7.90e-05***	(2.63e-05)	-7.90e-05***	(2.63e-05)
Access to research institution	0.1290***	(0.0448)	0.1290***	(0.0448)
Training on ISFM	0.2340***	(0.0745)	0.2340***	(0.0745)
Informal Credit	2.27e-05	(8.55e-05)	2.27e-05	(8.55e-05)
Extension contacts	0.0014	(0.0023)	0.0014	(0.0023)
Mean Social Learning	0.0200***	(0.0042)	0.0200***	(0.0042)
Tolon (1 = Tolon: 0 = Otherwise)	0.1880***	(0.0589)	0.1880***	(0.0589)
Savelugu (1 = Savelugu: 0 = Otherwise)	0.1720***	(0.0542)	0.1720***	(0.0542)
Constant	0.4180***	(0.1120)	0.4180***	(0.1120)
Observations	300		300	
Alpha[a]			2.93e-08	
Pseudo R^2	0.0423		0.0423	
Log Likelihood	-454.04		-454.04	
Wald Chi squared	167.93***		167.93***	
AIC	950.031		954.037	
BIC	1027.810		1039.26	

****, ** and * represents values that are statistically significant at 0.01, 0.05 and 0.1 respectively. Figures in parenthesis stand for standard errors. [a] is the dispersion parameter for the Negative Binomial count data model. Source: Author's computations from survey data, 2018*

Appendix II: Marginal effects of determinants of intensity of adoption of ISFM practices

Variables	*Model 1 zero-truncated Poisson (Intensity)*	*Model 1 Marginal Effects*	*Model 2 OLS (Maize yields)*	*Model 3 OLS (Food security)*
Age	0.0040**	0.0114**	-16.6719***	0.0003
	(0.0017)	(0.0048)	(4.1533)	(0.0031)
Household size	0.0018	0.0052	-1.9817	0.0066*
	(0.0022)	(0.0062)	(3.4807)	(0.0037)
Level of Education (1 – 4 years)	0.0172	0.0488		-0.0425
	(0.0478)	(0.1360)		(0.0752)
Level of Education (5 – 8 years)	0.2630***	0.7480***		0.0630
	(0.0643)	(0.1800)		(0.3277)
Level of Education (9 – 12 years)	-0.1150	-0.3260		0.4942
	(0.1570)	(0.4480)		(0.6091)
Dependency ratio				0.0499
				(0.1853)
Innovativeness	0.0129**	0.0368**		
	(0.0060)	(0.0170)		
Family labour in man-days	-0.0028	-0.0080	5.7836*	
	(0.0019)	(0.0055)	(3.1699)	
Moist land	-0.1060*	-0.3020*		
	(0.0618)	(0.1750)		
Ease of adopting ISFM	0.1310***	0.3710***		
	(0.0415)	(0.1190)		
Perception of erosion of farmland	0.0419	0.1190	-8.3714	
	(0.0518)	(0.1470)	(78.8077)	
Access to off-farm income	-0.1760**	-0.5000**		
	(0.0689)	(0.1950)		
Off-farm income	-9.71e-05***	-0.0003***		0.0001
	(2.98e-05)	(8.41e-05)		(.0001)
Tropical Livestock Holding	0.0053	0.0150	31.3251***	0.0113
	(0.0044)	(0.0125)	(6.3814)	(0.0071)
Cost of production	-7.90e-05***	-0.0002***		
	(2.63e-05)	(7.46e-05)		
Access to research institutions	0.1290***	0.3660***		
	(0.0448)	(0.1270)		
Training on ISFM (1= yes: 0 = otherwise)	0.2340***	0.6650***		
	(0.0745)	(0.2080)		
Remittances				0.0001
				(0.0004)
Informal Credit	2.27e-05	6.44e-05		0.0004***
	(8.55e-05)	(0.0002)		(0.0001)
Extension Contacts	0.0014	0.0040	-5.8795	-0.0068*
	(0.0023)	(0.0066)	(3.5946)	(0.0038)
Mean Social Learning	0.0200***	0.0568***	33.6398***	

	(0.0042)	(0.0119)	(8.6648)	
Wealth index			47.4087	
			(30.5012)	
Farm size			-67.0533***	0.0153
			(22.9266)	(0.0184)
Fertiliser applied per hectare			42.4197***	
			(11.6159)	
Cost of seeds			-1.3102	
			(1.7669)	
Burning of residue			139.3974**	
			(63.4285)	
Main occupation			-385.0001*	
			(205.2116)	
Experience in maize farming			14.8389***	
			(4.4568)	
Perception of fertility of farmland			-64.25723	
			(98.0973)	
Perception of rainfall			-28.7304	0.1013
			(124.6924)	(0.1355)
Ill-health			146.9808*	
			(77.7208)	
Pest control			124.0753**	
			(59.9866)	
NumISFM			108.3312***	-0.1366***
			(34.0877)	(0.0367)
Maize yields				0.0000
				(0.0001)
Tolon (1= Tolon: 0= Otherwise)	0.1880***	0.5340***	-249.0246***	-0.2237***
	(0.0589)	(0.1680)	(83.8074)	(0.0888)
Savelugu (1= Savelugu: 0= Otherwise)	0.1720***	0.4890***	-91.9714	-0.3270***
	(0.0542)	(0.1540)	(81.8929)	(0.0839)
Constant	0.4180***		1015.7780***	6.3738***
	(0.1120)		(303.9981)	(0.2025)
Observations	300	300	300	300
Log pseudo-Likelihood	-454.067		8.10	4.98
Wald Chi squared	162.98***			
Pseudo R^2	0.0450		0.3796	0.2307
Prob>chi2	0.0000		0.0000	0.0000

***, ** and * represents values that are statistically significant at 0.01, 0.05 and 0.1 respectively. Figures in parenthesis stand for standard errors. Source: Author's computations from survey data, 2018.

Appendix III: Percentage of households who ate fewer meals a day over the last month

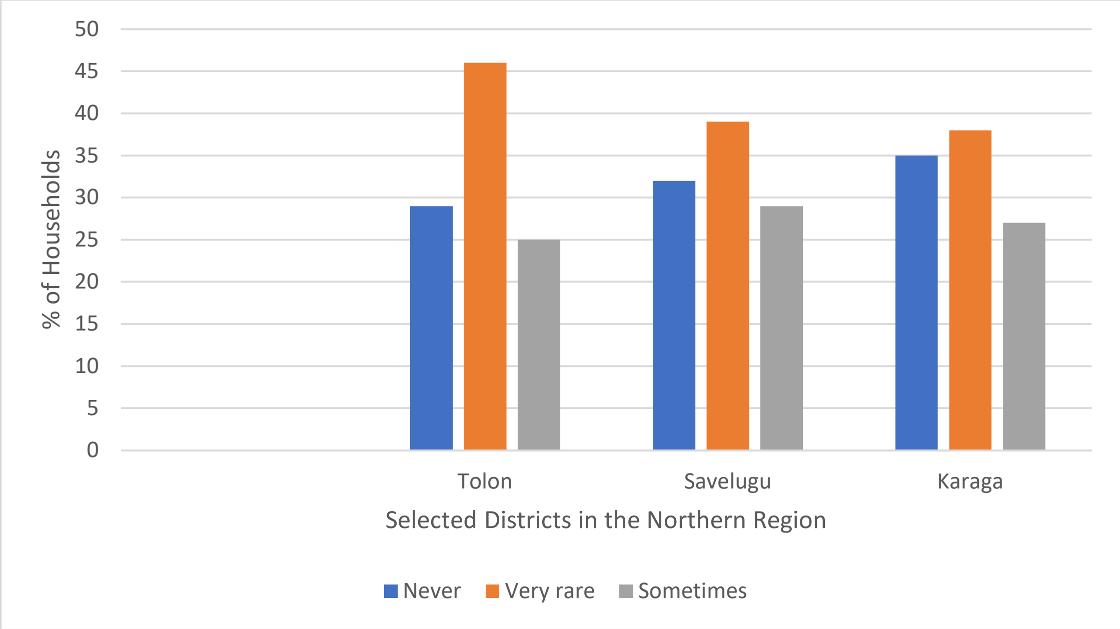

Figure 4. 7: Percentage of households who ate fewer meals a day over the last month
Source: Field survey, 2018.

Appendix IV: Households' Food Consumption Behaviour over a month

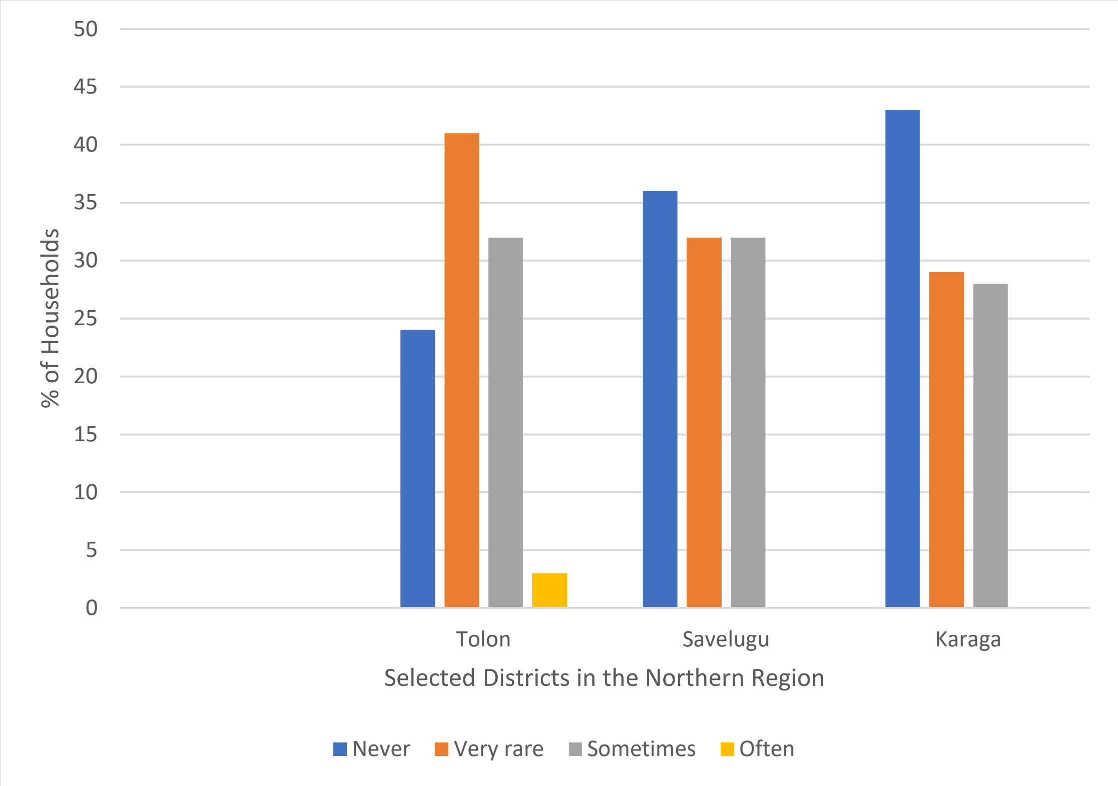

Figure 4. 8:Percentage of households who consume limited food over the last month
Source: Field survey, 2018.

Appendix V: Frequency Distribution of Household Consumption of Food Groups

Sub-food groups	***Frequency***	***Percent***
Cereals	641	100.00
Root and tubers	565	88.14
Pulses/legumes/nuts Oil/fats	620	96.72
Fish and seafood	214	33.39
Meat, poultry, offal	186	29.02
Oil/fats	619	96.57
Eggs	207	32.29
Milk and milk products	228	35.57
Vegetables	641	100
Sugar/honey	230	35.88
Fruits	593	92.51
Miscellaneous	532	83.00

Source: Field survey, 2018.

Fruits; and Miscellaneous

Appendix VI: Distribution of Household Dietary Diversity Score

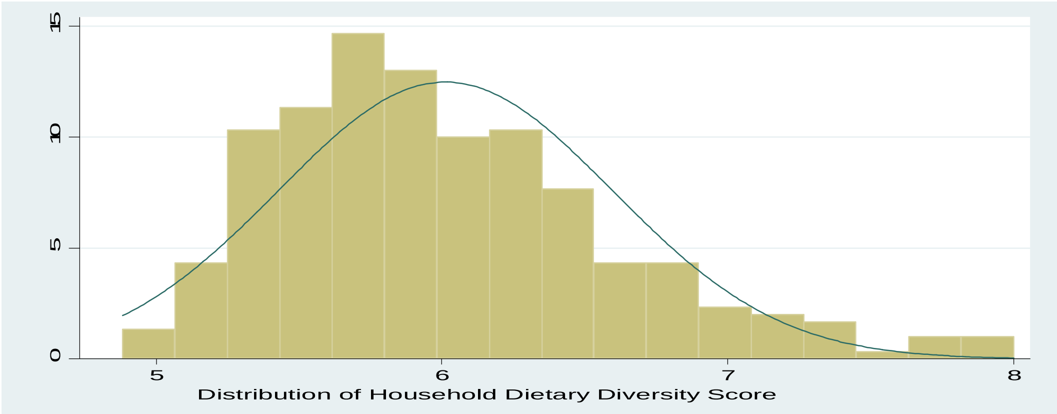

Figure 4. 9: Distribution of Household Dietary Diversity Score

Appendix VII: Smallholder Farmers' Questionnaire

UNIVERSITY FOR DEVELOPMENT STUDIES
FACULTY OF AGRIBUSINESS AND COMMUNICATION SCIENCES
DEPARTMENT OF AGRICULTURAL AND RESOURCE ECONOMICS

SOCIAL NETWORKS AND SOIL FERTILITY MANAGEMENT ADOPTION: IMPACTS ON MAIZE YIELDS AND FOOD SECURITY OF FARMERS IN NORTHERN REGION.

SMALLHOLDER FARMERS' QUESTIONNAIRE

This questionnaire is to solicit information on **SOCIAL LEARNING AND SOIL FERTILITY MANAGEMENT ADOPTION: IMPACTS ON MAIZE YIELDS AND FOOD SECURITY OF FARMERS IN NORTHERN REGION.**

All information obtained will be treated as confidential and will be used solely for the purpose of the study. If you have questions about the survey, you may please contact me at 0509265352. Thank you very much for your time and support.

Name of respondent …………..…………………………… Date of interview____/____/2018 District……………………….....

Community………………………….. Questionnaire Number

Section A: Socio-Demographic Characteristics

A1	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**	**A8**	**A9**	**A10**	**A11**	**A12**
What is the farmer's relationship with the household head? **Codes A**	Sex of farmer? 0=F 1=M	How old is the farmer?	What is farmer's educational level? **Codes B**	What is farmer's religion? **Codes C**	What is farmer's marital status? **Codes D**	What is farmer's main occupation? **Codes E**	Number of years farmer is living in the village?	Farmer's experience (years) in own farming activities	Farmer's experience (years) in cultivating maize on his own?	Does the household head hold any of the following authorities at the community level? **Codes F**	Household size (number of persons who share cooking arrangement/ under your care)

A13. Sex of household head.   0 Male [   ]   1 Female [   ]

A14. What is the type of marriage practised by the household head? 1 Polygamous [   ]   2 Monogamous [   ]   3 Other (specify) ……………

Codes A	**Codes B**	**Codes C**	**Codes D**	**Codes E**	**Codes F**
1 Head 2 Spouse 3 Child 4 Grandchild 5 Parent/Parent-in-law 6 Son/Daughter-in-law 7 Other relative	0 No education 1 Primary 2. JHS 3. SHS 4. Tertiary 5. Non-formal education	0 No religion 1 Muslim 2 Christian 3 Traditional 4 Other (specify) ………….	0 Never Married 1 Married 2 Separated 3 Divorced 4 Widowed	1 Farming (crop and/or livestock) 2 Housekeeping 3 Casual labour on another farm 4 Non-farm business (shops, trade etc) 5. Formal work 6. Others, specify	0 None 1 Chief/community leader 2 Chief council member 3 Assembly/unit committee member 4 Religious leader 5 Youth leader 6 Women leader 7 Political party leader

Please complete the table below on the age composition and non-farm work of the household members

A15	**A16**	**A17**	**A18**	**A19**	**A20**	**A21**	**A22**	**A23**	**A24**
(less than 16 years		(16 – 30 years)		(31 – 60 years)		(above 60 years)		Family non-farm workers	
Male	Female	Male	Female	Male	Female	Male	Female	Male	Female

A25. Has any of the household members migrated from the community for more than 6 months in the last 12 months? 0 No [ ] >> A27 1 Yes [ ]

A26. If yes, how many people? …………………………………………………………………..

A27. Has any of the household members been sick of a chronic illness for more than 6 months in the last 12 months? 0 No [   ] Yes [   ]

A28. What is your main source of income? 1 Agriculture [   ]   2 Others [   ]

Section B: Objective One: Determinants of farmers' choice of sources of agricultural information

Section BI: Farmers networks of family and friends/acquaintances

Network members	**BI1**	**BI2**	**BI3**
	How many people (both within and outside the community) do you consider relevant for exchanging information about agronomic issues with?	How many of them cultivate maize?	In general, how many cultivators of maize do you know in the community?
Family			
Friends/acquaintances			

Family & Friends			

BI4. Which of the following the major source learning or of useful information for your farming operations? …(1) TV (2) Radio (3) relatives (4) extension agents (5) fellow farmers (6) Farmers' organisation (7) agro-input dealers (8) others; please specify ………………………………
(Multiple responses allowed)

Source of information	**BI5**	**BI6**	**BI7**	**BI8**	**BI9**	**BI10**	**BI11**	**BI12**	**BI13**	**BI14**
	Do you know any external officer from the following? 0=No 1=Yes	How long (in years have you known officer)?	Have you ever sought or received maize information from any of the following in the past? 0=No 1=Yes	If yes to **BIII6**,						
				How many of them do you discuss with?	In a normal month, how many times do you discuss crop rotation?	In a normal month, how many times do you discuss maize varieties with?	In a normal month, how many times do you discuss mulching with?	In a normal month, how many times do you discuss fertiliser application with?	In a normal month, how many times do you discuss organic manure with?	In a normal month, how many times do you discuss composting with?
Neighbours										
Family										
Friends/acquaintances										
External officer										
Agric Ext Officer (MOFA)										
Research organisation										
NGOs										
Other farmer organisations										

BI15: Do you have confidence in the skills delivered by the extension officers? 0 No [ ] 1 Yes [ ]
BI16. How far is the nearest Agricultural Extension Office from your Village? …………………………….. Km

Section C: Some drivers of adoption of Integrated Soil Fertility Management practices
Section CI: Some institutional factors
CI1. Do you belong to an agricultural association? 0 No [ ] 1 Yes [ ]
CI2. If yes, how many agricultural associations do you belong to? ……………………………………………………………………
CI3. Do you attend association meetings? 0 No [ ] 1 Yes [ ]

CI4. How many times did you attend meetings during the 2016/2017 season? ………………………………………………………….
CI5. What activities is the association engaged in? 1 Discussions on maize varieties [ ] 2 Fertiliser application [ ] 3. Weedicides and pesticides application [ ] 4 Storage practices [ ] 5. Others, please specify ………………………………..
CI6. During the 2016/2017 cropping season, did you have liquidity constraints in financing production (inputs)? 0 No [ ] 1 Yes [ ]
CI7. If yes, did you apply/ask for any loan to finance production? 0 No [ ] 1 Yes [ ]
CI8. If yes, were you granted? 0 No [ ] 1 Yes [ ]
CI9. If yes, how much were you granted? Formal Credit GHc ……………………….. and Informal credit GHc …………………………….
CI10. What is the distance to a bank or a formal credit institution? ……………………………………………..

Section CII: Farmland holding, tenancy and characteristics
CII1. What is your perception of the annual rainfall pattern in your farm locality? 0 Low [ ] 1 Medium [ ] 2 High [ ]
CII2. What is your total available arable land for all crops? ……………………………………………………………..acres
CII3. What is your total arable land under current cultivation? …………………………………………………………… acres
CII4. Does water log on your maize plot? 0 No [ ] 1 Yes [ ]
CII5. Did you benefit from any input assistance for fertiliser access in 2016/17 season? 0 No [ ] 1 Yes [ ]
CII6. What was the actual land under maize (irrespective of the variety) cultivation during 2016/17 season? ………………………………. acres
CII7. How far is the distance of your maize plot from the house (Km)? ……………………………………………………………………………
CII8. How long have you been farming this land (maize plot)? ………………………………………………………………………………….
CII9. How do you describe the organic matter content of the maize plot? (1=good 2=medium, 3= poor)

CII10. Rank the level of erosion of the maize plot (1=no erosion, 2=minimal erosion, 3=moderate erosion, 4=eroded 5=severe erosion)

Crop	**CII11**	**CII12**	**CII13**	**CII14**	**CII15**	**CII16**	**CII17**	**CII18**	**CII19**	**CII20**
	How fertile is the soil on this farm? **Codes A**	What is the dominant texture of soils on this farm? **Codes B**	How wet is this land compared to other lands in your community? 1…. Less wet 2…. Same 3…More wet	Slope of this land 1=Plain 2=Gentle 3=Hilly	Is the land watered from a source other than the rain? 0=No 1=Yes	If yes, what is your primary source of watering? **Codes C**	How did you obtain this plot, or gain the right to farm this plot? **Codes D**	If tenant, what type of tenancy arrangement do you operate? **Codes E**	If fixed rent, what is the duration of tenure?	If fixed rent, what is the amount of the rent? GHc
Maize										

Codes A	**Codes B**	**Codes C**	**Codes D**	**Codes E**

1 Fertile 2. Moderately fertile 3. Infertile	1 Sandy 2 Rocky/gravely 3 Clay-filled 4. Loamy	1 Well 2 Borehole 3 Pond 4 Stream	1 Owner 2 Purchase 3 Inherited from deceased family member 4 Tenant rented (cash/kind) 5 Allocated free of charge 6 Begged	1 Fixed rent 2 Sharecropped

Section CIII: Awareness of ISFM

CIII1. Have you heard of ISFM technologies? 0 No [ ] >>**CI4** 1 Yes [ ]

CIII2. If yes to **CIII1**, where did you get to know about it? 1 MOFA extension agent [ ] 2 NGOs [ ] 3 Fellow farmer [ ] 4 Research institutions (eg. SARI) [ ] 5 Others, please specify ………………………………………………

CIII3. When (year) did you hear about it? ………………………………………………..

CIII4. When did you actually start practising ISFM (if practising)? ………………………………………………..

CIII5. How many ISFM did you actually practise in the last two farming seasons before the immediate last season? ……………………………..

Maize Varieties

CIII5. Which improved maize varieties do you know (if applicable)? ……………………………………………………………………………….

CIII6. When (year) did you first hear about the variety? ………………………………………………………………………………

CIII7. From whom did you first hear about it? 1 Friends/relatives [ ] 2 Extension officer [ ] 3. Demonstrations/Field days [ ] 4. NGOs [ ] 5 Agro-input dealer [ ] 6. Radio/TV [ ] 7. Traders [ ] 8. SARI [ ] 9. Others, specify ………………...

Please, fill in the following table by indicating the size of your maize farmland under cultivation of the following ISFM practices. Indicate all if applied.

No.	**ISFM technology**	**Improved maize variety**	**Crop rotation**	**Mulching (at least 30% soil cover)**	**Composting**	**Organic manure**	**Fertilisers (Bags/acre)**
CIII8	Indicate the technology you practise.						
CIII9	When did you start practising it?						
CIII10	Land under cultivation (acres)						
CIII11	Why do you practice it? (multiple response is allowed) (1) good for root growth (2) reduces yield failure in seasons of poor rains (3) less expensive (4) for good drainage (5) yield enhancing (6) improves soil fertility (7) reduces quantity of fertiliser use (8) reduces total yield loss (9) reduces incidence of pest and diseases (10) other(s) specify						
CIII12	Indicate which practice you have stopped practicing						
CIII13	If you have stopped practicing it before in which year?						
CIII14	If you stopped practicing it why (multiple response is allowed)						

	(1) labour intensive (2) inadequate labour (3) time consuming (4) animal grazing (5) inadequate quality seeds (6) expensive seeds (7) cannot get seed at all (8) lack of cash to buy seed (9) low yielding variety (10) poor prices (11) don't know how to use it (12) requires more rainfall (13) susceptible to pest/diseases						

CIII15. Do you leave crop residue on the maize farm after harvest? 0 No [ ] 1 Yes [ ]
CIII16. Has your crop residue been always grazed by neighbouring livestock? 0 No [ ] 1 Yes [ ]
CIII17. Is the crop residue being set on fire annually? 0 No [ ] 1 Yes [ ]
CIII18. If yes by who? (1=self, 2=hunters, 3=neighbours 4=I don't know, 5=others (specify)
CIII19. Have you ever been prevented by the landlord from practicing ISFM on the maize plot (if farmland is begged or rented)? 0 No []1Yes [ ]
CIII20. If no to CIII19, do you practise ISFM practices such as fertiliser application etc on the maize plot (if farmland is begged or rented)?
0 No [ ] 1 Yes [ ]
CIII21. Before adopting any of the technologies, did you see the technology being practised in the field? 0 No [ ] 1 Yes [ ]
If No >> **CIII21** but if yes, where was this plot located? 1 Next to my plot, 2 on the way to my plot 3 Different locality area in the community 4 Outside the community
CIII22. If you practise crop rotation, which crop (s) do you rotate with maize? ……………………………………………………………………
CIII23. What is the nearest distance to market for purchasing fertiliser input (km)? …………………………………………………………..

CIII24. Do you have a mobile phone available to the household? 0 No [ ] 1 Yes [ ]
CIII25. Do you have a radio available to the household? 0 No [ ] 1 Yes [ ]
CIII26. Did you use the phone in the last farming season to contact an extension officer or friend on ISFM or listen to radio about ISFM?
0 No [ ] 1 Yes [ ]
CIII27. If yes, how many times? ………..
CIII28. Which other agricultural information have you been accessing with your mobile phone or radio? 1 Price data [ ] 2 Rainfall [ ]
3 Others, please specify ……………………………………………………………………………..
CIII29. Have you ever received training on any of the Integrated Soil Fertility Management components from an organisation within or outside of the community? 0 No [ ] 1 Yes [ ]
CIII30. If yes, which organisation? ………
CIII31. Do you perceive ISFM to be easy to adopt? 0 No [ ] 1 Yes [ ]

Section D: Objective Three: Impact of Adoption of Integrated Soil Fertility Management Technologies on Farm Yield of Smallholder Famers

Section DI: Variable Input Cost:

Crop	DI1	DI2	DI3	DI4	DI5	DI6	DI7	DI8

	What quantity of crop seeds did you use on farm?	What type or variety of the seed did you plant on farm?	If any seeds were purchase, what quantity was purchased? (k)	How much did you pay for the purchased seeds used on farm? (GH)	Did you apply fertiliser? 0=No 1=Yes	Which type did you apply? **Codes** 1 Fertiliser NPK (15-15-15) 2 Fertiliser Amonia 3 Fertiliser 23-10-5 (Actyva) 4 Commercial organic fertiliser (including fertisoil etc)	What quantity was applied? (Kg)	What was the unit price? (GHc)
Maize								
Others								

Crops	**DI9**			**DI13**		
	Did you apply pesticides? 0=No 1=Yes			Did you apply weedicides? 0=No 1=Yes		
	DI10 Quantity applied on farm (litres/kg)	**DI11** Unit Price (GH₵)	**DI12** Total expenditure on pesticides GH₵	**DI14** Quantity applied on farm (litres/kg)	**DI15** Unit Price (GH₵)	**DI16** Total expenditure on weedicides GH₵
Maize						
Others:						

DI17. What is the distance to input (fertiliser, pesticides, weedicides, improved seeds) market? …………………………………… Km.
DI18. What is the means of transport to the market? 1 = Walking 0= Otherwise
DI19. What is the nature of the road infrastructure from the community to the market? (1=good 2=medium, 3= poor)
DI20. Do you think you apply enough fertiliser for your farm? 0 No [ ] 1 Yes [ ]
DI21. If No, how much more do you need? Type …………………………………………….. Qty …………………………………………
DI22. Do you have problem in buying your fertiliser? 0 No [ ] 1 Yes [ ]
DI23. If yes, what are those problems, please specify ………………………………………………………………………………………
DI24. Do you think you are applying enough pesticides for your farm? 0 No [ ] 1 Yes [ ]
DI25. If No, how much more would you like to use? Type …………………………………..………...Qty. ……………………………
DI26. Do you have any problem in buying pesticides? 0 No [ ] 1 Yes [ ]
DI27. If Yes, please explain …………………………………………………...
DII: Labour Input cost

Crop	**DII1 Family**						**DII2 Hired** Did you use hired labour? 0=No 1=Yes						**DII3 Communal** Did you see communal labour? 0=No 1=Yes			
	Males		Females		Children		Males			Females			Males		Females	
	Num.	Days	Num.	Days	Num.	Days	Num.	Days	Rate (GHc)	Num.	Days		Num.	Days	Num.	Days
Maize																
Others																

(***Please note, the labour activities include land preparation, bed preparation, sowing/planting, fertiliser and chemical application, weeding, harvesting and other costs***)

DII4. Which operation do you use the labour for? (1=all farm operations, 2=land preparation, 3=planting, 4= weeding, 5=fertiliser application, 6=spraying, 7= harvesting, 8=others (specify) ………………………… **(Multiple response allowed)**

Section DII: Harvest, Storage and marketing

Crop	**DII1** What quantity of crop was harvested from plot over the 2016/17 farming season?	**DII2** Was any crop lost during harvesting on field? 0=No 1=Yes	**DII3** How much of crop did you lose in total? (%)	**DII4** Do you treat harvest under storage with chemicals? 0=No 1=Yes
Maize				
Others:				

Crop	**DII5** Did you sell crop? 0=No 1=Yes	**DII6** Quantity sold during and since harvest in 2016/17	**DII7** What unit price did you sell most of crop?	**DII8** Where did you sell most of crop? **Codes A**	**DII9** Distance to market for crops transported to the market for sale? (Km)	**DII10** What was the transport cost to the market? GHc	**DII11** What other marketing cost did you incur? **Codes B**	**DII12** Do you have a particular buyer for your maize? 0=No 1=Yes	**DII13** Did buyer provide you with any services? 0=No 1=Yes	**DII14** If yes, which services were you provided? **Codes C**
Maize										

Others										

Crop	DII15	DII16	DII17	DII18				
	When did you sell most of the harvest? **Codes D**	What was the principal reason for these sales? **Codes E**	Is the crop considered primarily as a cash or staple food crop? **Codes F**	Did you buy any crop for household consumption? 0=No >>next crop 1=Yes				
				DII19 If yes, quantity of crop purchased in 2016/17?	**DII20** What unit price did you buy most of the crop?	**DII21** Where did you buy most of these? **Codes A**	**DII22** If in the market, distance to purchase point? (Km)	**DII23** Transport cost from the market? GHc
Maize								

Codes A	**Codes B**	**Codes C**	**Codes D**	**Codes E**	**Codes F**
1 On the farm 2 Market within the community 3. Market outside the community	1 Market toll 2 Loading/off-loading 3 Others, specify …………	1 Tractor/plough 2 Seeds 3. Weedicides 4 Fertiliser 5. Extension 6. Others, specify ……………	1 Immediately after harvest/before cultivation 2 when household is cash constraint 3 when I had enough food for consumption 4 when output prices increased	1 Meeting household needs 2 Had some surplus left 3 Profit	0 = Staple food crop 1= Cash crop

S/N	Source of income	Amount (GHc)
DII24	Annual income from sale of farm produce/crops	
DII25	Annual income from sale of livestock	
DII26	Annual income from non-farm activities, eg. Hired labour, etc.	
DII27	Annual income from non-agricultural activities, eg. Teaching, carpentry, etc.	
DII28	Gifts and remittances	
DII29	Aid (from NGO/Gov't)	
DII30	Others, specify	

Section DIII: Livestock and other assets: Please, I will like to ask about your livestock and other assets of the household.

DIII1	Do you own any of these animals in the household?	**Cattle**	**Sheep**	**Goat**	**Pigs**	**Poultry**	**Others**
		0=No 1=Yes	0=No 1=Yes	0=No 1=Yes	0=No 1=Yes	0=No 1=Yes	0=No 1=Yes

DIII2	If yes, how many does the household own?						
DIII3	How many did you sell in 2016/17 season?						
DIII4	At what price did you sell most of this? GHc						
DIII5	How many did you buy in the 2016/17 season? GHc						
DIII6	Do you seek for vetenary services for them? 0=No 1=Yes						
DIII7	If yes, how much did it cost you to vaccinate them in the last 12 months? GHc						

Capital/Fixed Cost Estimation:

S/N	**Asset/Item**	**Do you have item?** **0=No 1=Yes**	**If yes, how many?**	**How much did you purchase the most recent one? GHc**	**Price if you were to sell it now? GHc**
DIII8	Cutlass				
DIII9	Hoe				
DIII10	Knapsack				
DIII11	Irrigation pump				
DIII12	Radio				
DIII13	Television				
DIII14	Bicycle				
DIII15	Motorcycle				
DIII16	Car/Moto-King				
DIII17	Bullock/Donkey				
DIII18	Thresher				
DIII19	Tractor				
DIII20	House				
DIII21	Others, (specify)				

Section E: Objective 4: Adoption of Integrated Soil Fertility Management Technology on Food Security of Smallholder Farmers
Household Food and Nutritional Status

Please answer the following questions in your capacity as the person responsible for food provision/preparation in the household in the past one week. Could you please tell me how many days in the last 7 days your household has eaten the following foods?

	Food item	Days eaten in the last week (0-7 days)		
E1	Cereals (eg. Maize, millet/Sorghum, rice, etc)			
E2	Tubers (yam, cassava, plantain, others)			

E3	Pulses/legumes/nuts (beans, other nuts)			
E4	Fish and seafood (eg. Fish powder, small fish - used for flavour only, etc)			
E5	Meat, poultry, offal (sheep/goat/beef/etc)			
E6	Oil/fats (Vegetable oil, butter, shea butter,)			
E7	Eggs			
E8	Milk and milk products			
E9	Vegetables (including green leaves)			
E10	Fruits			
E11	Sweets, sugar, honey			
12	Miscellaneous			

E13. In the last 7 days, how many hot meals did you have on average per day? …………………………………………. (number of meals)
E14. In the last 3 months, was there an instance where the household took less preferred food? 0=No 1=Yes
I will like to ask about your household food situation for the last 12 months

S/N	Statement	Never	Very rare	Sometimes	Often	Number of months
E15	In the last 12 months, since (current month) of last year, we ever reduced the quantity or quality of (entire household) meals because there wasn't enough money for food.					
E16	In the last 12 months, since (current month) of last year, we ever reduced the quantity or quality of (our child's /any of the children's) meals because there wasn't enough money for food.					
E17	In the last 12 months, there was no food to eat of any kind in the household because of lack of resources to get food.					
E18	In the past 12 months, a household member went to sleep at night hungry because there was not enough food.					
E19	The household consumed a limited variety of food in the last month					
E20	The household ate fewer meals a day in the last month					

E21. How much do you spend on food in a regular month? GHc ………………………………………….
E22. How much do you spend on non-food items (eg. Health, education etc) in a regular month? GHc ………………………………………….
E23. Other expenditures (eg. Funerals, remittances, weddings, gifts etc) over the past year? GHc ………………………………………….

THANK YOU