ECONOMIC ASSESSMENT OF THE TRIALS AND ADOPTION OF SELECTED SOIL FERTILITY MANAGEMENT (SFM) TECHNOLOGIES

AMONG GRAIN LEGUME FARMERS IN THE NORTHERN AND UPPER WEST REGIONS OF GHANA.

BY MARGARET BANKA NOVEMBER, 2016

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BY:

MARGARET BANKA (BSc. AGRICULTURE)

THIS THESIS IS SUBMITTED TO THE DEPARTMENT OF AGRICULTURAL ECONOMICS, AGRIBUSINESS AND EXTENSION KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR MASTERS OF PHILOSOPHY DEGREE IN AGRICULTURAL ECONOMICS

NOVEMBER 2016.

DECLARATION

I, Margaret Banka, author of this Thesis, "**ECONOMIC ASSESSMENT OF THE TRIALS AND ADOPTION OF SELECTED SOIL FERTILITY MANAGEMENT (SFM) TECHNOLOGIES AMONG GRAIN LEGUME FARMERS IN THE NORTHERN AND UPPER WEST REGIONS OF GHANA",** do hereby declare that this thesis was done by me towards the achievement of a Masters of Philosophy degree in Agricultural Economics. With the exception of materials used, which were appropriately acknowledged via references cited, this work contains no materials previously published in part or in whole for the award of any other degree in this University or elsewhere.

Margaret Banka	……………………….	………………………
(Student)	(Signature)	(Date)

Certified and approved by:

Dr. Robert Aidoo	………………………….	……………………
(Supervisor)	(Signature)	(Date)
Prof. Simon Fialor	..………………………….	……………………
(Co-Supervisor)	(Signature)	(Date)
Dr. Fred Nimoh	……………...…………	..…………………..
(Head of Department)	(Signature)	(Date)

DEDICATION

To thou who inspired it but will not read it: NAA. DR. FRANCIS XAVIER BANKA of blessed memory. You identified a hidden potential in me and mentored it into its being. Your encouragement, support and love thought me to be candid and focused.

You gave me the greatest gift anyone could give another person; you believed in me. Thank you dad, I love you.

ACKNOWLEDGEMENT

The journey towards the fulfillment of this thesis comprised the combined effort of a group of benevolent individuals. Through their guidance, support and advice both psychologically and practically, I successfully completed my thesis.

Primary gratitude goes to my Heavenly Father, who has always blessed me with unmerited favors and elevated me from my lowest points to accomplish tasks I never knew I could. I am indeed a living testimony of the aura of God because I have been blessed and anointed beyond measure. Thank you Father.

Exceptional gratitude goes to my main supervisor; Dr. Robert Aidoo, for believing in me and giving me an opportunity I will forever be grateful for. Thank you Dr. for your patience, guidance, and support and for being one of my greatest mentors. To my cosupervisor; Prof. Simon Fialor, I am grateful for his instrumental contribution to this study. I am also forever indebted to all lecturers of the Department of Agricultural Economics, Agribusiness and Extension for their diverse roles in helping me accomplish this study especially Dr Gyiele Nurah, Dr James Osei Mensah, Dr. Fred Nimoh, among others.

I am particularly thankful to my project coordinators; most especially Prof. Robert Clement Abaidoo, words are not enough to express my appreciation for this opportunity you gave me, God bless you. To Dr. Masso Cargele and all my supervisors of the IITA COMPRO II project, as a proud recipient of the IITA scholarship on the project, "Institutionalization of quality assurance mechanisms and dissemination of top quality commercial products to increase yields and improve food security of smallholder farmers in sub-Saharan Africa – COMPRO-II", my gratitude knows no bounds and all I can say is God richly bless you all for I could not have come this far without your financial support and resources provided towards the execution of this project.

To my colleague on the COMPRO II project, Jacob Ulzen, for your assistance in providing me with the necessary experimental field data needed for part of my analysis and for your overall support, I am grateful. To all who assisted me with my socioeconomic data collection, data entry, and data analysis and the overall build up of my thesis especially Alhaji Antika, Basit, farmers interviewed, enumerators who aided in data collection and Williams Ali.

Last but not least, I thank my beloved family and friends; most especially my mum Mrs. Catherine Banka, Dr. Charles Banka, Francisca Banka, Tony and Evelyn Basingnaa.

You are such an amazing family and I am blessed to have had you all supporting me each step of the way. To Callistus Nakpih, for your support both spiritually and emotionally. To Diyaudeen Khalid, you have been a true friend all these years and have genuinely looked out for my wellbeing, God richly bless you. To all my friends; Leslie Offei, Solomon Amissah, Rechiatu Asei, Paschal Chakirwa, Caleb Melenya and most

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importantly Kweku Adu my most cherished course mate. You all made my stay through out my course a pleasurable and happy one. I can never forget you, thank you and God richly bless you all.

In the face of high prices of existing mineral fertilizers, farmers in Ghana need costeffective Soil Fertility Management (SFM) technologies to address the problem of low crop yields, which are particularly pronounced in grain legumes. This study assessed the financial returns associated with different SFM trials conducted on grain legumes (soybean, cowpea and groundnuts) in northern Ghana in order to examine farmers' adoption decision *ex-ante* and willingness to pay for the most financially rewarding technologies. Benefit-cost ratio analysis based on experimental data identified bio-fertilizer technologies (*Biofix*, *BR3267* and *Legumefix*) as the most financially viable SFM technologies for grain legumes (soybean, cowpea and groundnut respectively) production. The study elicited primary data from 400 grain legume farmers randomly selected from Northern (200) and Upper West (200) Regions to evaluate adoption decisions and willingness to pay for the three selected SFM technologies. Evidence from the study shows that a significant proportion of farmers (>50%) were willing to adopt each of the three selected biofertilizer packages when they are made available on the market. A multivariate probit model identified farming experience, membership of Farmer Based Organizations (FBOs), farm income, amount of credit used and distance to extension office as critical variables influencing farmers' adoption decision. Generally, legume farmers in Northern Region were willing to pay higher for the three biofertilizer packages as compared to their counterparts in Upper West Region. For 0.2 kg each of *Biofix*, *BR3267* and *Legumefix*, farmers in Northern Region were willing to pay approximately GHC 17.00, GHC 12.00 and GHC 23.00 respectively whereas those in Upper West Region were willing to pay GHC 14.00, GHC 9.00 and GHC 11.00 for the same quantity of each SFM technology respectively. The study has revealed that farming experience,
FBO membership, awareness and use of biofertilizers are the significant determinants of farmers' willingness to pay for biofertilizers. The most critical constraints hindering adoption of SFM technologies among grain legume farmers were identified to be high cost of technologies, unavailability and inadequacy of information on potentials of SFM technologies. Even though, biofertilizer technologies present key opportunity in resolving soil fertility deficiencies, they are quite new and most farmers are unaware of their use in grain legume production. The study therefore recommended sustained awareness creation through periodic education and sensitization by using FBOs as leverage points. This and other recommendations from the study are expected to

improve the future adoption of biofertilizers to improve the productivity and profitability of grain legume production in northern Ghana.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

"Soil" has been identified as farmer's greatest asset (Fairhurst, 2012). This notwithstanding, soil fertility status continues to be an issue of great concern in subSaharan Africa (SSA) where an estimated amount of 75% of farmlands are recorded to be severely depleted of essential soil nutrients (especially nitrogen and phosphorus). Ghana has been identified as one of the countries in sub-Saharan Africa with the highest rate of soil nutrient depletion (World Bank, 2007).

Ghana has a total landmass of about 155,000 km^2 (23,853,900 ha) of which about 57% is considered arable; a significant portion of this landmass is however inherently deficient in terms of fertility (Guo *et al,.* 2013; Jayne, 2015; USAID, 2015). Of the total agrarian land cultivated in Ghana, smallholder farms dominate with about 90% being less than two hectares, typically rain-fed and with the use of rudimentary agricultural technologies accounting for about 80% of total agricultural production.

There is need for substantial investment in soil health and fertility as continuous degeneration in soil fertility status stands out as the key-contributing factor to low per capita food production leading to food insecurity and poverty among smallholder farmers in Sub-Saharan Africa (Sanchez *et al,.* 1997).

A substantial segment of people in SSA live in extreme poverty most of who are smallholder food crop farmers with the main cereal and legume crops being their priority crops of cultivation. The yields of these crops are however far below the actual attainable levels and this has been attributed to no or low-level of fertilizer use. Yields of the main grain cereals have been reported to be less than 1.5 tons/ha as against the actual attainable yield of about 5 tons /ha and that for legume has been estimated at about 0.7 ton/ha as against the attainable yield of about 3 tons/ha (Smale and Heisey, 1993; Jager *et al,.* 2001; Mutegi and Zingore, 2001).
In Ghana, poverty is noted to be mostly concentrated among smallholder farmers in Northern Ghana (Upper West, Upper East and Northern Regions) who are mostly food crop farmers

with family oriented farms practicing traditional production technologies (GSS, 2007). Their traditional practices of nutrient management have however become obsolete due to increased concerns about environmental stewardship in agriculture and cost related factors. Hence, to practice sustainable agriculture, farmers are being advised to reduce the use of expensive chemical inputs and intensify the use of natural or biological inputs. Conventional fertilizer use and intensity in Sub-Saharan Africa remains the lowest in the world due to several factors including cost. The use of bio inputs is gaining attention as a potential solution to the improvement of soil fertility and agricultural productivity in SSA owing to their costeffectiveness and environmentally-friendly nature (Stella *et al*,. 2013; Chapoto *et al*,.
2015).

A study by N2 Africa (2013) in Ghana recognized legumes (soybean, cowpea and groundnuts) as very important contributors to household income and food security. They are referred to as meat for the poor due to their protein content (Mushi, 1997), with production concentrated mainly in the three northern regions of Ghana (Northern Region, Upper West and Upper East).

The two most prevalent challenges facing legume farmers in Ghana are erratic rainfall pattern together with inaccessibility and exorbitant prices of fertilizers including grain legume specific fertilizers (Single Super Phosphate, Urea and Triple Super Phosphate among others). Since little can be done about the climatic conditions affecting legume production, to a large extent, if appropriate and affordable fertilizer technologies are established, the existing yield gaps in grain legume production in Ghana can be bridged.

Consequently, there are calls for increased use of less costly and more environmentally friendly soil fertility management technologies. And these include the use of biological sources (organic fertilizers and biofertilizers) and/or integrated soil fertility management (ISFM) practices (i.e. integrated use of the different fertilizer sources). Some of the aforementioned technologies have been proven agronomically to increase yields of legumes and also increase the reserves of the most limiting plant nutrients (especially nitrogen and phosphorus) for the benefit of other non-leguminous crops planted in rotation. However, the financial/economic assessment of the technologies and the future adoption behavior of grain legume farmers are still in the realm of speculation. This study was intended to shed light on these important issues in order to bridge the knowledge gap that currently exists.

1.2 Problem Statement

A sector that once served as the backbone of the Ghanaian economy, agriculture now forms only a fifth of Ghana's GDP, employing more than 40% of the economically active population with an approximated 2.74 million households engaged in farming. Also noted as the country's major foreign exchange earner, a total of 80% of agricultural output is supplied by smallholder farmers (GNC, 2010; ISSER, 2010; FAOSTAT, 2014).

Despite the sector's immense contribution to livelihoods, the incidence of low crop productivity is a general problem facing most farming systems in sub-Saharan Africa (SSA), with deteriorating soil fertility status standing out as a major constraint. Soils in SSA are usually low in nitrogen and phosphorous (the most limiting plant nutrients) and this gives rise to low yields.

These low yields are particularly pronounced in grain legumes as a result of low or no use of fertilizer sources by farmers. This behavior of legume farmers is attributed to lack of awareness of the possible economic returns from fertilization and/or the high cost of fertilizers (mineral fertilizer) which majority of African smallholder farmers are unable to afford.

Low cost and sustainable solutions compatible with the socioeconomic conditions of smallholder farmers are therefore needed to solve these soil fertility problems. A recognized approach by soil scientists and agronomists to dealing with soil health and fertility problems of smallholder farmers has been the introduction of cost effective and yield rewarding soil fertility management technologies or packages (biofertilizers, organic fertilizers and ISFM). The adoption of such modern improved agricultural technologies has however been low in Ghana and this has been acknowledged as a key factor to low productivity of agriculture in the country (Abunga, *et al*,. 2012).

The IITA project on “Institutionalization of quality assurance mechanisms and dissemination of top quality commercial products to increase yields and improve food security of smallholder farmers in sub-Saharan Africa (COMPRO-II) has supported trials of different soil fertility management technologies in a number of African countries including Ghana. The trials are aimed at identifying various technologies that enhance soil fertility and agronomic performance of crops in order to recommend such soil fertility management technologies to farmers for adoption.

Even though positive agronomic responses have been observed in a wide range of field trials, there is remarkable inconsistency in responses across crops, regions and agroecologies.

Without downplaying the importance of the soil and agronomic outcomes (i.e. biological parameters) of these trails, a major and equally important aspect is the financial profitability/viability of the different treatments or combinations of soil fertility management technologies or packages since it is very critical for policy, dissemination and adoption purposes. Such an assessment of the different technologies will provide a holistic view to guide the selection of the most promising options for dissemination to farmers.

Upon selection of the ‘best/viable’ SFM technologies, farmers’ perceptions about them and their willingness to adopt and pay for such packages needed to be examined to boost the success of future dissemination and adoption efforts.

1.3 Research Questions

The study sought to answer the following questions:

1. What are the quantities and costs of inputs employed under different SFM treatments/trials/technologies in northern Ghana?

2. What are the crop outputs and market values of produce obtained from employing different SFM treatments/packages/technologies?

3. Are the current SFM treatments/packages/trials in northern Ghana financially profitable? And which package promises the highest returns on investment?

package?

5. Are farmers in northern Ghana willing to pay for the best SFM package or technology?

6. What are the key determinants of the willingness to pay for the 'best' SFM technology by farmers in northern Ghana?

1.4 Objectives of Study

1.4.1 Main Objective

The main objective of the study was to conduct a financial/economic assessment of trials and adoption of selected Soil Fertility Management (SFM) technologies among grain legume farmers in northern Ghana.

1.4.2 Specific Objectives:

The specific objectives of the study were to:

1. Estimate the costs and benefits associated with different packages/technologies/trials in Northern Ghana.

2. Determine the *ex-ante* adoption rate for the 'best'
4. What is the *ex-ante* adoption rate for the 'best' (financially rewarding) package in northern Ghana and what factors are most critical in the future adoption of such

SFM

SFM

package/treatment/technology in northern Ghana and factors that are most critical in the future adoption of the 'best' package.

3. Evaluate farmers' willingness to pay for the best SFM package/technology in Northern Ghana and factors that explain the willingness to pay by farmers.

4. Identify constraints associated with the use of different SFM packages/technologies.

1.5 Justification of Study

Though substantial amount of time and effort have been invested in the development of soil fertility management technologies by agronomist and soil scientist as a means to solving soil fertility problems in SSA (including Ghana), economic evaluations of these technologies to ascertain their returns to investment have been neglected in the past and this has contributed partly to the low adoption rates by farmers. This study will provide empirical information on the returns associated with each SFM technology/trial to enable farmers and extension agents opt for better alternatives for the cultivation of grain legumes for increased productivity and profitability.

Research on technology adoption in agriculture is still developing and farmers' understanding of the decision making process in relation to adoption is still low. The outcome of this research is to therefore provide useful empirical information to inform the investment decisions of farmers, agro-input dealers and other stakeholders involved in the grain legume value chain. This study also sought to provide useful insights for extension agents and NGOs when packaging dissemination messages and fashioning out approaches to improve the rate of SFM uptake in Ghana.

Farmers need to be familiar with information in relation to the implications of the use of SFM technologies on their resource allocation, skills and time so as to make informed decisions. This study identifies the most cost-effective SFM technologies for dissemination to farmers; it assesses key factors that influence farmers' adoption decisions and a WTP component, which serves as a guide during the pricing of financially rewarding SFM technologies/packages.

In sum, a comprehensive financial analysis of the costs and benefits associated with different SFM technologies have been evaluated to be made available to farmers to inform their choice of the best technology for dissemination and an evaluation of farmers' willingness to adopt and pay for the "best" package *ex-ante*. The study also highlights and ranks the major constraints hindering the adoption of SFM technologies in Ghana in order for stakeholders to find solutions to the most pressing issues.

1.6 Organisation of Study

The study has been organised into five chapters. Chapter one presents a brief background to the study, a narrative of the research problem at hand and its accompanying research questions. Objectives of the study are then coined from the research questions and a final justification of the need of the study is elaborated.

Chapter two reviews relevant literature on topics pertaining to the study. Chapter three which is the methodology firsts starts with a description of the study areas, followed by data collection and data collection procedures used and the analytical framework incorporated in analysing the data. Chapter four presents the results and discussion from the analysis carried out. Chapter five specifies the summary of key findings, conclusions and recommendations based on the key findings.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Soil Fertility Status and Crop Production in SSA

"Soil" is said to be a farmer's most beneficial asset (Fairhurst, 2012). An unwavering issue in SSA has however been the rapid decline in soil fertility status (Sanchez *et. al,*. 1997; Bationo *et al,*. 2004; Sanginga and Woomer, 2009; Vanlauwe *et. al,*. 2010) with an estimated 75% of farmlands severely depleted of essential soil nutrients (World Bank, 2007).

Soils in Africa have been characterized among the most degraded in the world; fundamentally poor in fertility and consequently resulting in extremely low crop yields. Soil fertility decline stands out as a key underlining factor to the low per capita food production of smallholder farmers in sub-Saharan Africa with a projected annual rise of more than 30 million metric tons in cereal imports by 2020 as against a rapidly increasing population growth of an estimated 3% per annum (AGRA and IIRR. 2014; Jayne *et. al,*. 2013).

Sanchez *et al,*. (1997) classified soil fertility depletion on smallholder farms as the, "fundamental biophysical root cause of declining per capita food production in Africa". RELC (2010) endorsed this trend in northern Ghana when it was disclosed that for the past decade, low soil fertility status has been ranked the leading constraint in agricultural production in the region.

Fairhurst (2012) of the Africa Soil Health Consortium established that; the African continent in comparison to others in the world continues to contend with several incidence of hunger and low crop productivity in line with its ever-growing population and this has resulted in farmers (especially smallholders) having to foster the habit of continually producing crops on the same land each season. He goes on to further prove that this practice of continuous land use has resulted in tremendous soil fertility deterioration. It is in this regard that the adoption of soil fertility management technologies among smallholder farmers is regarded as a critical mechanism in dealing with the problem of food insecurity and poverty particularly in sub-Saharan African countries. In SSA, majority of the populations earn their livelihoods as smallholder farmers; and they are incapable of affording improved seeds and recommended fertilizer dosages to increase their productivity. It is also important to note that adoption of improved soil fertility management technologies does not only impact yields during the season of application, but also has meaningful effect on future yields (Donovan and Casey, 1998; Freeman and Omiti, 2003; Wopereis *et. al*,.
2008 AGRA and IIRR. 2014).

2.2 Soil Fertility Management (SFM) Technologies in SSA

2.2.1 Definition of Concept

Soil fertility management technologies/practices have been identified as a primary gateway to improving agricultural productivity among smallholder farmers in Africa, without which all other crop productivity technologies will not yield any substantial results (AGRA and IIRR. 2014). In maintaining soil fertility, two main technological practices have been identified as key; organic technological practices (biofertilizers and organic fertilizers) and chemical technological practices (Laura and Rienke, 2004). As a means of ensuring sustainable agriculture, farmers are advised to adopt improved and financially rewarding SFM technologies that rely to a greater extent on local or renewable resources (organic fertilizers or biofertilizers) rather than agrochemical based inputs, which present a lot of challenges both financially and ecologically (Sarker *et al*,. 2005).

2.2.2 Paradigm Shifts in SFM in SSA

The past three decades have seen research and development agenda on soil fertility management technologies in agriculture as a result of low adoption of improved soil fertility management practices by farmers (Vanlauwe and Bationo, 2003). The paradigm transitions of the various fertility management practices in Africa over time have been summarized in Table 2.1.

The 1960s and 1970s presented a period of external input use as the focus of research and development with a lot of attention directed towards the use of mineral fertilizer as a process to improving yields of crop production (Sanchez *et. al,*. 1997). As a result of this, a fertilizer subsidy program was introduced in SSA (Smaling 1994). In the 1980s, the focus on chemical fertilizer shifted towards organic resources. This change was attributed to difficulties in accessing fertilizer in SSA. During this period, fertilizer subsidy was abolished due to the structural adjustment program. This period was referred to as, “Lowinput Sustainable Agriculture” (LISA) Program by Jeannin (2013) and Fairhurst (2012). The drift from mineral fertilizers to organic fertilizers was however short lived despite its essential role in enhancing soil fertility and this was due to some inherent deficiencies existent in organic resources (Jeannin, 2013). After the inception of organic fertilizer, then came the era of ISFM during the 1990s and 2000s (Sanchez, 1994). ISFM presented the combined use of mineral fertilizers and/or organic resources and/or biological sources with emphasis on their adaptation to local conditions in order to achieve adequate yields and efficient fertilizer use. Vanlauwe *et al,*. (2001) reported on the positive interaction between organic and mineral fertilizers. The two sources of fertilizers were also found to be complimentary in nature in that, while organic fertilizers aimed at enhancing soil organic matter; mineral fertilizers were intended to limit the losses of targeted nutrients (Vanlauwe *et. al,*. 2010; Buresh *et al,*.1997).

Table 2.1: Changes in Tropical Soil Fertility Management Paradigms over the Past Five Decades

Period	Intervention	Role of Fertilizer	Role of Organic Inputs	Remarks
1960s-1970s	External input use	Mineral fertilizer alone was presumed to be a sufficient means of improving crop yields	Organic resources played a minimal role	Limited accomplishment due to shortfalls in policy and farming systems

1980s	Organic Input Use	Fertilizer played a trifling role	Organic resources were the main plant nutrient sources	The adoption of organic inputs was limited since it required livestock ownership.
1990s	Combined mineral fertilizer and organic residue use	Mineral fertilizer use was vital in alleviating essential nutrient constraints	Organic resources served as the major 'entry point' to soil fertility improvement	Focused adoption around specific crops
2000s	Integrated Soil Fertility Management	Fertilizer was a major entry point to increasing yields	The efficiency of mineral fertilizers was increased by organic resources	Goal of large-scope adoption

Source: Fairhurst (2012).

2.2.3 Components of SFM Technologies in SSA

Chen (2006) and Mishra & Dash (2014) refered to fertilizers as catalysts responsible for the provision of plant nutrients for optimum growth and yield. They categorised them into three types; chemical, organic and biofertilizer and also implicitly indicated that for optimum performance, these three sources of nutrient supply must be used in an integrated fashion since they all have their deficiencies when used exclusively. These different components are discussed below.

2.2.3.1 Biofertilizer as a Component of SFM

As a form of organic/biological product, biofertilizers are said to be comprised of specific microorganisms in concentrated forms which, when applied to seed or soil, colonize plant roots thus promoting growth through increase in supply of primary nutrients to the host plant (Chen, 2006; Gaur, 2010; Gupta and Sen, 2013). They have been recognized as microbial inoculants artificially multiplied to improve soil fertility and crop productivity and have been internationally accepted as efficient and economical alternatives to mineral-N fertilizer due to the need for less capital input associated with their use (Hafeez *et al*,. 2002; Howladar & Rady, 2013 ; Mazid & Khan 2014).

By definition, biofertilizers are described as substances containing living microorganisms which colonize the rhizosphere, promoting plant growth through increase in supply of essential nutrients to targeted crops when applied to seeds or medium of growth (Muraleedharan *et al*,. 2010). Biofertilizers contain different types of microorganisms, which have the ability to convert nutritionally vital elements from unavailable to available forms through biological processes (Hedge *et al*,. 1999; Vessey, 2003). Biofertilzers have been described as low cost, non-bulky, environmentally friendly agricultural inputs, which act as supplementary to chemical fertilizers (Sahai, 2004). As low cost, renewable sources of plant nutrients, biofertilizers are said to be the answer to the inherently nutrient-deficient sub-Saharan agrarian soils that are mostly Nitrogen and Phosphorus deficient; and this boils down to their ability to generate these essential nutrients through their biological activity in the rhizosphere (Schachtman *et al*,. 1998; Muraleedharan *et al*,. 2010).

While some studies view biofertilizers as potential supplements/complements to chemical fertilizers, meaning they cannot act as standalone in plant nutrient management (Rai, 2006; Raghuwanshi, 2012), other studies identify them as safe alternatives or substitutes to mineral fertilizers (Deepali and Gangwar, 2010; Prasanna *et al*,. 2011; Aziz *et al*,. 2012; Youssef & Eissa, 2014).

Several types of biofertilizers exist and they are broadly categorized as nitrogen fixers, phosphorus solubilizers and zinc solubilizers (Ghosh, 2002; Rai, 2006; Vaishno, 2008; Mishra & Dash, 2014). Among the nitrogen fixers, the common biofertilizers are rhizobia, azospirillum, blue green algae and azolla. Rhizobia belongs to the family *Rhizobiceae;* this bacterium is the most well-known and exploited nitrogen fixing bacteria mostly compatible with only leguminous crops (chickpea, soybean, groundnut and forage legumes) fixing atmospheric nitrogen in symbiotic association with legumes through their root nodules. They have the ability to fix 50100 kg/ha of nitrogen. As inoculants, rhizobial inoculum are either in powder, liquid or granular formulations. Azospirillum is a member of the family *Spirilacea.* This bacterium in addition to its nitrogen fixing capabilities, also promotes growthregulating substances. It is mainly recommended for cereal crops fixing 20-40 kg of nitrogen per hectare and increasing yields by 10-15%. Blue Green Algae

(Cyanobacteria) and Azolla commonly referred to as, “paddy organisms”, are mostly common among paddies fixing about 20-30 kg/N/ha with an associated 10-15% increase in yields. Phosphorous solubilizers act as biofertilizers capable of increasing yields by 10-20% and also produce plant growth hormones, which act as phosphate solubilizing agents in the soil. In contrast to nitrogen fixers and phosphorus solubilizing bacteria, zinc solubilizers supply micronutrients like zinc and copper, among others.

The need for less costly, more eco-friendly soil fertility management practices has led to the promotion of biological nitrogen fixation (BNF) sources as a solution to limited nitrogen in soils of SSA (Ghosh, 2003; Choudhury and Kennedy, 2004; Kennedy *et al*,. 2004).

Owing to the positive attributes of bioinputs or bioinoculants (N-fixers and Psolubilizers) which include; being economical, eco-friendly and a sustainable potential source of nitrogen (Herridge *et al*,. 2008), they have emerged as an essential and integral component of the integrated plant nutrient supply system for crop production (Susheela *et al*,. 2007;Mishra & Dash, 2014). As an expedient intervention for smallholder farmers, BNF (biofertilizers) presents a vital source of N and an economical fertilizer management technology for those who use little or no mineral fertilizers or farmyard manure for legume production (Smaling *et al*,. 2008; Maputo 2011).

Reports from previous studies (e.g. Waddington *et al*,. 2004; Mapfumo, 2011) revealed that, using the biofertilizer technology (for grain legumes) to induce BNF does not only benefit legume production, but it also benefits subsequent cereal crops planted in rotation on the same fields. Biofertilizers can therefore be said to have a long-term effect on maintaining soil fertility as well as ensuring sustainable agriculture through the buildup of soil nitrogen and other essential microbial organisms for use by other nonleguminous crops.

Notwithstanding their role as a financially efficient approach in addressing soil fertility concerns, demand for biofertilizers (inoculants) in SSA has been rather minimal (Kannaiyan, 1993). The reasons for this according to Kannaiyan (1993), Odame (1997) and Mazid & Khan (2014) include; resource constraints, (i.e. suitable carriers and resources for production leading to quality assurance issues), market level constraints coupled with farmers lack of awareness, soil and climatic factors, inadequate extension services and native antagonistic microbial populations and defective inoculation procedures.

2.2.3.2 Mineral Fertilizer as a Component of SFM

The important role of chemical fertilizers in crop production cannot be downplayed. This notwithstanding, it remains an undisputed fact that mineral fertilizer cost is continually on the rise and its intensive use leads to a number of anti eco-friendly concerns such as water pollution, soil contamination, destruction of beneficial soil micro-organisms and insects known for their role as catalyst in soil organic matter decomposition and their ability to make available essential plant nutrients such as N, P and S (Shumway, 1990; Rajendra *et al*,. 1998; Tanga *et al*,. 2003; Maihdi *et al*,. 2010). Mineral fertilizers, irrespective of their inadequacies however if applied appropriately will continue to be of central importance in meeting future crop productivity demands (Havlin *et al*,. 2005; Shand, 2007; Al-Khalil and Ali, 2009). This results from the fact that chemical fertilizers have the tendency of rapidly restoring soil fertility since nutrients from chemical sources are readily made available to plants as soon as they are applied and dissolve in soils, unlike organic sources, which take much longer time for nutrients to be discharged (Laura and Rienke, 2004).

2.2.3.3 Organic Fertilizers as a Component of SFM

Organic farming has emerged as an important priority area globally in relation to the growing demand for safe and healthy foods, long term sustainability and most importantly, increasing concerns on environmental pollution associated with indiscriminate use of agrochemicals (Venkatashwarlu, 2008).

Despite the cheap production cost of organic fertilizers, information on organic fertilizers is quite scarce and they face the incident of increasing opportunity cost in terms of labour use as well limited availability (Omiti *et al*,. 1999; Williams, 1999; Place *et al*,. 2003). Agegnehu *et al*,. (2014) noted that exclusive application of organic fertilizer sources is constrained by inadequacy, high demand for labor in terms of preparation and transportation as well as low nutrient content. Owing to their inherent deficiencies, biological sources (organic) cannot be regarded as fully reliable, based on which instead of substitutes, they rather act as effective supplements to the chemical sources in plant nutrient management (Sundaravardarajan *et.al*,. 2006).

2.2.3.4 The Use of Different Fertilizers in Combination (ISFM)

There has been an advocacy for a balanced and sustainable nutrient supply system as well as high crop productivity and optimization of benefits from the different sources of plant nutrient supplies in an integrated fashion, thus a mineral-organic-bio fertilization rather than their sole application as stand-alone (Chen, 2006).

With the increasing environmental and economic concerns associated with the use of mineral fertilizers, which is the most common source of plant nutrient supply for farmers especially in SSA, there has been the call for other alternative sources of plant nutrient management technologies aimed at reducing its use. Though biological sources of the plant nutrient supply system present us with a much better alternative environmentally and economically, due to their inherent deficiencies they more or less act as effective supplements to chemical fertilizer sources. Hence the need for a prudent combination of these different fertilizer sources (mineral fertilizers with organic and biological source) with the anticipated end result of higher crop productivity coupled with a much safer environment (Shand, 2007; Ali and Aljuthery, 2015).

2.2.4 Legume Production in Ghana

The important role of grain legumes to the livelihoods of the poor (especially) in developing countries as sources of food and income cannot be overemphasized. Four key roles identified by CGIAR in relation to grain legumes include; their ability to reduce poverty, improve food security, improve nutrition and health and last but not least their ability to sustain the natural resource base. Acknowledged worldwide as an essential component of the agricultural and food systems, grain legumes have been identified as key in the regeneration of nutrient deficient soils as well as important sources of protein, vitamins and minerals to both humans and livestock (Beebe, 2006; Bejosano, 2012).

Grain legumes are mostly referred to as, "women's crop" owing to the fact that women traditionally play a larger role in their cultivation, while their male counterparts play a greater role in the cultivation of staple food crops such as cereals, roots and tubers among others especially in Africa (CGIAR, 2016). This notwithstanding, women are constrained when it comes to resources such as labour, land, modern seed varieties, fertilizers and credit thereby limiting their production capabilities (CGIAR, 2013).

Nutritionally, legumes serve as the cheapest option for improving the diet of the 'poor' especially who cannot afford protein in the form of meat, diary and/or fish.
They are mostly referred to as "meat for the poor" due to their inability to afford protein in the form of meat. Rich in protein, oil and micronutrients, they complement cereals by increasing the nutritional effectiveness of cereal-dominated diets of the 'poor'. Some essential nutrient sources and diets from grain legumes like Omega-3 fatty acids from soybean oil; "plumpy nut" from groundnut and chickpea are mostly distributed to famine areas for emergency feeding of severely malnourished children (Duranti, 2006; Chianu *et al,*. 2011; Bejosano, 2012).
Agronomically, they play vital roles as rotational crops with cereals where impacts are made on harvest as well as improvement and sustainability of soil fertility. They have the ability of minimizing the detrimental effects of soil pathogens and most importantly, serve as a source of nitrogen to cereal crops (Beebe, 2006; Jones, *et al,*. 2007).
In terms of rural poverty reduction, grain legumes serve as food for consumption as well as grain for sale by rural households in bid to introduce some flexibility in the optimization of their livelihood strategies in terms of household food needs and market conditions (Shiferaw *et al,*. 2007; Lowenberg-DeBoer and Ibro 2008). As grain, they have the potential of producing high quality grains, oil, and pods, among others that are of high demand on the market. When processed, they generate incomeearning opportunities, especially for women (Bejosano, 2012). Economically, they have been identified as highly profitable in some areas due to their ability to capture attractive market prices (Beebe, 2006) and generation of significant benefits to the well being of smallholder families where harvests are either consumed and/or sold to generate household income.

Cultivation of the main grain legumes (groundnut, cowpea and soybean) predominantly takes place in the northern part of Ghana (Upper East Region, Upper West Region and Northern Region). In Ghana, groundnuts have been identified as both a cash and food crop and have been known to be intensely cultivated in the Northern region (Angelucci and Bazzucchi, 2013; Debrah and Waliyer, 1996). Cowpea has been identified as the leading food grain legume with good soil fertility enrichment capabilities in SSA (Makoi *et al,*. 2009; Peoples *et al,*. 2009). It ranks second to groundnuts in Ghana (Gates, 2011) and mostly cultivated as an intercrop. Branded as a beneficial contributor of N (201 kg N/ha), it is well known as a leading legume for rotational farming practice (Belena and Dakora, 2009). Recognized as a crop cultivated by women in Ghana, it is mostly cultivated in the Northern belt contributing about GHC 15 to GHC 16 million to household income of which not less than 40% goes to women farmers. Comparatively a new crop in Ghana relative to the other legumes, the potential of soybean surpasses other grain legumes (groundnut and cowpea) in terms of its reduced susceptibility to pest and disease, storage quality and longer shelf life and most importantly, its potential to impact positively on soil fertility status as a result of its large leaf biomass (Ugwu and Ugwu 2010; Akramov & Malek, 2012).

Yields of grain legumes have been reported to be below the achievable rate (0.7 ton/ha as against 3 tons/ha) thereby presenting a wide yield gap, which needs to be bridged in order to curb food insecurity, and poverty related issues in SSA (Ghana) (Mutegi and Zingore, 2014). A study reporting on the average yields of grain legumes by Mushi (1997) noted that yields remain relatively low under farmers' field conditions. These low yields have been attributed to the rapid decline in soil fertility caused by endless use of parcels of farmlands without any form of replenishment strategies coupled with insufficient availability of N in soils (Dakora and Keya, 1997).

To address this issue, SFM technologies specific to legume production have to be put in place. Mineral fertilizers offer great potential of resolving the low yields of grain legumes. Farmers in developing countries have generally been known to rather fertilize their cash crops (cocoa) and cereal crops (especially maize) and this has been largely attributed to the high cost of mineral fertilizers and/or lack of awareness of the possible economic returns associated with fertilization of legumes (Ndakidemi *et al,*. 2006).

A number of field experiments carried out disclosed that legume productivity more than doubled through the application of plant nutrients. This also resulted in an increase in nitrogen fixing abilities of legumes in treated fields as compared to their controls (De' Silva *et al,*. 1993; Ndakidemi *et al,*. 2006).

Improvement of biological nitrogen fixation has been credited to rhizobium inoculation of legumes, an agricultural practice in existence for over a century (Qureshi *et al*,. 2009; Masso *et al*,. 2015) and identified as a viable source of N in legume production, fixing about 100-175 million metric tons of nitrogen a year as against 40 million fixed by mineral fertilizers (Ishizuka, 1992; Chianu *et al*,. 2011). Through the alteration of legume nodules and biological nitrogen fixation by plant growth promoting rhizobia (PGPR), inoculation of legumes with rhizobia presents an efficient means of enhancing nodulation leading to increased legume productivity (Garcia *et al*,. 2004).

As explored by literature, yield response from the use of biofertilizers on legumes such as soybeans has been commendable. In Zimbabwe, the use of biofertilizers has led to the achievement of about 2,000 kg/ha of soya and even higher yields of about 4,0006,000 kg/ha in Brazil and Argentina. Rhizobium inoculation of groundnuts in a field trial by Mohamed & Abdalla (2013) resulted in approximately 18% and 11% increase in yields over the control plots in two respective seasons, and an even higher yield (38%) from a combination treatment of P-fertilizers and the inoculant. The evaluation BNF capabilities in legumes have been mostly concentrated around groundnuts, soya and cowpea as compared to the other leguminous crops in Africa (Belane and Dakora 2009; Pule-Meulenberg and Dakora 2009).

2.2.5 Advantages and Disadvantages Associated with the Different SFM Components

For the different components of soil fertility management practices, there occur a number of benefits associated with their use as well as some insufficiencies. Outlined below are some advantages and disadvantages associated with the different components of SFM.

Biofertilizers

Economically, biofertilizers have been generally recognized as eco-friendly, economical substitutes/supplements to chemical fertilizers. They offer a relatively cheaper source of plant nutrient sourse as compared to mineral fertilizers. Biologically, they ensure the existence of healthy plants through the provision of a balanced nutrient supply system by stimulating growth of beneficial soil microorganisms. Thereby guaranteeing nutrient mobilization from organic and mineral sources and decomposition of toxic elements reducing soil-borne plant diseases and parasites. Phosphorus and nitrogen (the most limiting plant nutrients) supply is also slowly enhanced through the improvement of mycorrhizae colonization thus ensuring phosphorus fixation and limiting nitrogen losses through leaching (Rao, 1982; Venkataraman and Shanmugasundaram, 1992; Chen, 2006; Chen, 2010; Mishra & Dash, 2014; Youssef & Eissa, 2014) .

Despite these advantages, a major challenge to biofertilizers is viability, as some beneficial microorganisms are more effective *in vitro* as against harsh field conditions. They are relatively low in nutrient content coupled with a slow rate of release resulting in insufficient and untimely supply of nutrients. Short shelf life, lack of suitable carrier materials, susceptibility to high temperatures are among some of the bottlenecks associated with biofertilizers that have to be addressed before effective inoculation can take place. (Chen, 2006; Mishra & Dash, 2014; Kholkute, 2014).

Mineral Fertilizers

Of all the SFM technology components, mineral fertilizers have been identified as offering the quickest and most direct means of supply of soluble nutrients easily accessible to plants. They are relatively high in nutrient content and are required in small quantities for optimum plant growth (Chen, 2006; Mishra & Dash, 2014). Nothwithstanding its agronomic advantages, the exorbitant prices of mineral on the market makes it particularly difficut for farmers (small-scale farmers) to afford. The extreme use of mineral fertilizers have also been known to lead to adverse environmental effects such as; water pollution, leaching, destruction of soil microorganisms and beneficial insects with the end results of reduced fertilizer efficiciency (Chen, 2006; Mtambanengwe *et al*,. 2007; Mishra and Dash, 2014)

Organic Fertilizers

Comparatively less costly than mineral fertilizers, organic fertilizers improve soil structure as well as its water and nutrient holding capacity. They increase the availabilty of soil microorganisms through the provision of soil organic matter and micronutrients and also improve biodiversity and long term soil productivity (Gupta & Hussain, 2014).

Nevertheless, relatively large amounts are required for effective performance. Nutrient contents are variable and may not be released at an appropriate stage of plant growth. They are also bulky in nature and therefore difficult to transport and manage in large quantities (Mtambanengwe *et al*,. 2007; Gupta & Hussain, 2014).

2.3 Cost and Benefits Associated with Improved SFM Technologies

A farmer's decision to either participate in the use of an agricultural innovation or technology is mostly considered under the broad context of profit or utility maximization under the basic assumption that the alleged net benefit from using the technology will be significantly greater than the before situation (no technology) (Pryanishnikov and Katarina, 2003).

As an economic assessment tool for appraising investment projects, benefit-cost analysis (BCA) has been used to estimate in terms of benefits and cost, the socioeconomic impacts of projects with the ultimate goal of identifying and quantifying profits and expenses of projects by comparing the before scenario (before intervention) to an after scenario (after intervention) before making a final implementation decision (Bumbescu & Voiculesu, 2014). BCA therefore helps in implementing projects that have the capacity of maximizing benefits. Below in Table 2.2 are some economic indicators used in evaluating projects.

	Indicator	Description	Formula
1	Financial Net Present Value (FNPV)	Sum of results after expected financial cost of an investment are deducted from discounted value of expected revenues	$FNPV = \sum_{t=0}^{n} a_t S_t = \frac{S_0}{(1+i)^0} + \frac{S_1}{(1+i)^1} + \dots + \frac{S_n}{(1+i)^n}$
2	Financial Rate of Return on Investment	Discount rata that zeros out FNPV	$\sum \frac{S_t}{(1+FRRC)^t} = 0$
3	Financial rate of Return on Capital	Return for national beneficiaries (private and public combined)	$\sum \frac{S_t}{(1+FRRK)^t} = 0$

4	Economic Net Present value	Difference between discounted total social benefits and cost	$ENPV = \sum_{t=0}^{n} a_t S_t = \frac{S_0}{(1+i)^0} + \frac{S_1}{(1+i)^1} + \dots + \frac{S_n}{(1+i)^n}$
5	Economic rate of return	Discount rate that zeros out the ENPV	$\sum \frac{S_t}{(1+ERR)^t} = 0$
6	Benefit-Cost Ratio	Ratio of present value of social benefits to present value of social cost over time If B/C >1 the project is suitable because the benefits, measured by the Present Value of the total inflows, are greater than the costs, measured by the Present Value of the total outflows.	$\frac{B}{C} = \frac{PV(B)}{PV(C)}$

Table 2.2 Performance Indicators used for Evaluating Project Worthiness have been summarized below

Source: Guide to CBA of investment projects, 2008.

The cost of inorganic fertilizers (nitrogen fertilizers), which is the commonest SFM technology practiced by farmers in sub-Saharan Africa has been estimated to be between two to six times higher as compared to some other parts of the world (North America or Europe) as noted by Sanchez (2002) and Donavan (1996). A number of studies have been conducted in literature by assessing the costs and benefits associated with some improved agricultural technologies using some of the performance indicators specified above to evaluate the profitability levels of these technologies.

A study in Zambia identified that the price of a SFM technology (nitrogen fertilizer) and maize (major crop) increased about fourfold after the removal of the subsidy program in the region and as a result caused a 70% decline in fertilizer use by farmers. (Howard and Mungoma, 1996).

A study by Africa Rising (2016) in Northern Ghana evaluated the profitability of some improved agricultural technologies (pest management, soil fertility management and crop diversification) from farmer's point of view using three main economic indicators (gross margin. benefit-cost-ratio and returns to labour). Results from this study revealed that most of the technologies yielded positive benefits. Crop diversification brought in significant higher returns while average benefits from SFM and IPM did not statistically differ from each other.

Another study by Macharia, *et al,. (*2006) in Kenya, economically assessing organic and inorganic resources for recapitalizing soil fertility in smallholder maize-based cropping systems using the Net Present value approach to evaluate some on-farm trials of different SFM technology treatments revealed that sole application inorganic sources (N fertilizers) was not financially viable but rather, the combined use of organic sources and inorganic sources (mineral fertilizers) presented a more financially rewarding approach in terms of profitability.

Improving soil fertility in African farming systems has therefore been identified as a major area of concern. Hence the need for cost-effective SFM approaches in line with the socio-economic conditions of smallholder farmers who form a greater percentage of farmers in Africa (NEPAD, 2003).

2.4 Adoption of Improved SFM Technologies

The words technology and innovation have been described as synonymous to each other by Rogers (2003), based on which he defined "technology" as a design set out to influence actions that tend to reduce the risk involved in attaining a desired goal. And an "innovation" as an idea or practice perceived as novel by an individual (unit of adoption).

Technological change has been identified as a major turning point in agriculture for the past 100 years (Schultz 1964; Cochrane, 1979). Studies on agricultural technology adoption in Sub-Saharan Africa (SSA) have however been scarce and the decisionmaking process of farmers with respect to the adoption of improved technologies poorly understood (Doss, 2006; Lambrecht *et. al*,. 2014).

This notwithstanding, adoption of improved technologies/innovation in agriculture is considered a major yardstick for determining the success level of resource poor smallholder farmers in SSA and a gateway to increasing their agricultural productivity and farm-income (Feder *et al*,. 1985; Oladele, 2005; Pannell *et al*,. 2006). Hence the need for further exploitation.

2.4.1 Concept of Adoption and Adoption Theory

A number of recognized definitions for "adoption" by various authors/literature exist. Parminter (2011) described adoption as a conscious decision by a subject of interest to implement an innovation or novel practice on a consistent basis. Ovwigho (2011) distinguished adoption as mental concept correlated with an individual's socioeconomic standing. Rogers (1962) defined adoption as, "a mental process an individual passes from initially hearing about an innovation to finally adopting its use".

All the above definitions describe adoption as a single component making it quite complicated. Feder *et al*,. (1985) however felt it more practical to disintegrate the above definitions to spell out the different levels of adoption (individual level adoption and aggregate adoption) with the latter being the measure of diffusion of the technology or innovation within a specified geographical location and the former being the degree of use of a technology at the farm level by the individual farmer after it has passed through the awareness stage. The ultimate result of any new agricultural innovation is farmers adoption of the technology, its practice and its diffusion (Chi & Yamada, 2002).

Works by Rogers have been branded as the generally accepted theoretical framework used in the area of technology diffusion and adoption (Dooley, 1999 and Stuart, 2000).

Rogers (2003) outlined a sequence of processes an innovation passes through prior to its adoption starting from;

1. An initial knowledge/awareness stage of the innovation where the unit of adoption learns about the existence of the innovation as well as information pertaining its use. It embodies these 3 essential questions ("what?", "how?" and "why?").
2. Development of interest, where the individual develops an attitude either (positive or negative) towards the innovation.
3. A decision or evaluation stage as a form of assessment of the innovation where a choice between adoption or rejection of the innovation is made
4. A trial/implementation stage, where the innovation is put into practice
5. A final confirmation phase to buttress the adoption decision

Feder *et al,*. (1985) postulated that it is only in rare cases agricultural technologies are deployed singly rather than in packages and as a result most constituents of an agricultural technology package complement each other while a few others are also adopted independent of each other.

2.4.2 Measurement of Adoption

Any procedure for measuring adoption must be dependent on the specific setting being considered (Doss, 2003). The appropriate measuring technique used in the evaluation of adoption of agricultural innovations is imperative in establishing the ultimate goal of technology transfer. A number of measuring techniques subsist, from the pervasive dichotomous approach (yes or no responses) by Imbur *et al,*. (2008) and Hill & Linehan (2011). This approach though necessary is conversely viewed as insufficient since it is perceived to only reveal the level of awareness of the innovation and not so much of actual adoption (Jain *et al,*. 2009). Other methods such as the Sigma scoring method, percentage estimation of adopters, Likert scale, mean score among other measurement procedures have also been outlined in literature (Agbamu, 2006).

2.4.3 Determinants of Adoption

Economists have dedicated extensive attention to the technology adoption process at both individual farmer level where focus has been drawn on the individual farmers biophysical, human-capital endowment coupled with economic determinants of adoption of modern agricultural innovations such as high yielding varieties, fertilizers, pesticides among others and on aggregate levels (Feder *et al,*. 1982; Arellanes and Lee, 2003).

An in-depth understanding of factors influencing the adoption decision of an individual pertaining an innovation after examining the benefits and cost associated with its use has been identified as fundamental by economist in terms of technology evaluations and to producers and disseminators of the innovation (Hall and Khan, 2002). It is prudent to acknowledge the fact that, adoption of an innovation does not just happen in a vacuum but influenced by a number of factors ranging from attributes of the technology, to the individual adopters' characteristics as well as the socioeconomic, biological and physical environment context of the innovation (Cruz, 1987).

Household-specific factors

Gender, farmers education level, age, income, family size categorized as farmers "human capital" (Mwangi & Kariuki, 2015) have been identified as an appropriate means of evaluating a farmers level of human capital endowment (Fernandez-Cornejo *et al,*. 2007; Mignouna *et al,*. 2011; Keelan *et al,*. 2014)

Gender

Literature including Dey (1981) is of the argument that, in terms of resource and information accessibility, women are largely found to be victimized against. Most literature is of the view that the head of the household who is mostly the male is the primary decision maker and is most often in control over vital production resources and information (Mesfin, 2005; Omonona *et al,*. 2006; Mignouna *et al,*. 2011). This therefore mostly leads to men being hypothesized to adopt improved agricultural technologies than women. To buttress this proposal, studies by Lavison (2013) and

Obisesan (2014) reported a positive and significant correlation between gender and adoption of organic fertilizer and improved cassava production respectively.

Age

Following the adage that with age comes wisdom, it is alleged that farmers as they advance in age mostly accrue a lot of "wealth" in terms of personal-capital. Older farmers are believed to gain considerable farming knowledge and experience over time and as such are better at evaluating technology information than their younger counterparts (Nkamleu *et al*,. 1998, Mignouna *et al*,. 2011). This notion therefore proposes a positive influence of age on adoption. This analogy is however not conclusive since it is also believed that younger generations are likely to be less riskaverse due to the availability of information at their disposal and as such will exhibit more flexibility towards the adoption of a new technology, thereby suggesting a negative correlation between age and adoption (Mauceri *et al*,. 2005; Alexander and Van Mellor,2005).

A study on the control of rice sting bug by chemical methods in Texas showed a positive correlation between age and the control technology (Harper *et al*,. 1990) so was for the adoption of IPM on peanut in Georgia and sorghum in Burkina Faso by McNamara *et al*,. (1991) and Adesiina & Baidu-Forson (1995) respectively. While studies on the adoption of Hybrid cocoa in Ghana (Boahene *et al*,. 1999), IPM sweep nets in Texas (Harper *et al*,. 1990) and Fertilizer use in Malawi (Green and Ng'ong'ola, 1993) illustrated a rather negative influence of age on adoption.

Education level

Education level of a farmer is postulated to have a positive and statistically significant correlation with the adoption of an innovation. This is based on the belief that educated individuals are more likely to be skilled with the ability of obtaining, processing and optimizing information relevant to technology adoption. Educated farmers are also believed to search for appropriate technologies to help alleviate their production constraints (Uaiene, R.N. *et al*,. 2009; Mignouna *et al*,. 2011; Namara *et al*,. 2013). A study by Ajewole (2010) on adoption of organic fertilizers identified farmer's level of education to positively and significantly influences adoption.

Farming Experience

Number of years of experience in farming has been postulated as positively correlated with the adoption of improved agricultural technologies. This assertion is in conformity with studies by Edemeades *et al*,. (2008) who found relative farming experience to increase the prospects of adoption of different varieties of banana in Uganda and Onumadu and Osahon (2014) who reported a significantly positive correlation between number of years of experience and the adoption of improved rice technologies by farmers in Ayamelum local government area, Nigeria. Both studies concluded that farmers with more years in farming are more positively inclined to adopting technologies they assume to increase their crop productivity.

Household-size

Household size is seen as a direct proxy to labour availability in rural households among small-scale farmers. It is mostly the primary source of labour for farming activities and as such soothes out the possible labor issues associated with a new technology (Mignouna *et al*,. 2011). Thus, in terms of intensive SFM practices, household size correlates positively with adoption.

Economic Factors

Farm-specific characteristics

This is argued as one of the first and most important factors influencing the adoption decisions of farmers in relation to an innovation and has quite a number of assorted literature backing it (Harper *et al.*, 1990; Daku, 2002; Kassie *et al*,. 2009; Waithaka *et al*,. 2007). Existing literature on farm size has postulated its effect on adoption to be negative, positive or neutral (Gou *et al*,. 2013).

Studies proposing a positive relation between farm size and adoption of improved technologies include (Feder *et al*,. 1985; Fernandez-Cornejo 1996; Kasenge 1998; Ahmed, 2004; Uaiene *et al*,. 2009; Mignouna *et al*,. 2011).

Other studies suggest a negative correlation especially in cases were the said agricultural technology being introduced is considered input intensive in terms of land or labor (Harper *et al*,. 1990; Yaron *et al*,. 1992).

Yet still, other schools of thought envisage a rather neutral and insignificant correlation between farm size and adoption and this was obvious in studies concerning adoption of integrated Pest Management technologies by MugisaMutetikka *et al,.* (2000) and Samiee *et al,.* (2009).

It has however been suggested that in evaluating the impact of farm size on technology adoption, instead of considering the total farm holding of the household, adoption should rather be measured based on the portion of land area suitable to the technology being introduced (Lowenberg-DeBoer, 2000; Bonabana- Wabbi, 2002).

Cost of technology

In general, an adoption decision is always more of an investment evaluation involving assessing cost and benefit parameters associated with the said technology (Guo *et al,.* 2013). Based on this backdrop, more capital-intensive technologies are less likely to be adopted by resource poor farmers, hence a negative correlation (El-Osta and Morehart, 1999).

Off-farm activities

Off-farm activities has been identified as an efficient alternative to borrowed capital since most farmers are mostly credit constraint especially in developing countries (Reardon *et al,.* 2007; Ellis and Freeman, 2004). (Guo *et al,.* 2013) noted time as an essential element affecting technology adoption either positively or negatively. Offfarm activities that rely heavily on farmer's time and labour may obstruct adoption of a technology related to on-farm activities and therefore lead to a negative correlation (Goodwin and Mishra, 2004).

However other instances were off-farm activities are lucrative enough to financially resource the new technology hence leading to its adoption is possible (Diiro, 2013). And this was evident in her study on the impact of off-farm earnings on the intensity of adoption of improved maize varieties and the productivity of maize farming in Uganda where she reported a significantly positive correlation among farmers with off-farm income as against their colleagues who did not indulge in any off-farm activities.

A study by SADA (Savannah Accelerated Development Authority) on factors to consider in modernizing agriculture in modern Ghana, evaluated the influence of this variable (off-farm income) on adoption by assigning a dummy variable of zero (0) to farmers who had no off-farm activities and 1 to those who had off-farm income generating activities (Guo *et al,.* 2013).

Institutional factors

Membership to an agricultural association

Social networks often influence individual decisions. This is evident from the fact that in a particular setting of agricultural technology adoption, farmers in an association will usually indulge in information sharing to gain more insight about the technology. Hence a positive relationship between membership of a famer based organization (FBO) and adoption (Foster and Rosenzweig 1995; Conley and Udry 2000). A study by Katungi and Akankwasa (2010) to assess the effect of community based organization in adoption of corm-paired banana technology in Uganda reported a positive correlation between FBO membership and adoption.

Access to extension services

Since extension services serve as the primary entry points of agricultural innovations and technologies to farmers, by exposing farmers to the availability of these technologies and practices. Access to extension is therefore likely to stimulate the whole adoption process after increasing awareness of the technology (Polson and Spencer, 1991; Kebede *et al*,. 1990 Mignouna, *et al*,. 2011). Studies buttressing this positive influence of access to extension services with adoption include; a study on the adoption of modern agricultural technologies in Ghana (Akudugu *et al*,. 2012).

Access to Credit

Credit availability is considered a key factor enhancing agricultural growth in developing countries (Kiplimo, 2015) and have been envisaged to increase the adoption of improved technologies (Paudel & Thapa, 2004; Tiwari *et al*,. 2008a).. Extensive amount of literature assessing factors of adoption all noted a positive impact of credit on technology adoption (Feder and Umali 1993; Cornejo and McBrid 2002; Hazarika & Alwang, 2003) A study by Andre and Mulat (1996) on the determinants of adoption and levels of demand for fertilizer for cereal growing farmers in Ethiopia revealed that, credit availability to farmers influenced adoption and level of fertilizer use.

Technological factors

Access to information about a technology tends to reduce performance uncertainties

(Caswell *et al*,. 2001; Bonabana- Wabbi 2002). It is therefore prudent to promote technology awareness in terms of its use and associated benefits in order for effective adoption to take place. Other sources of literature however perceive the influence of access to information differently, thereby suggesting a rather negative relationship especially in instances where the information provided is limited (Uaiene *et al*,. 2009). A trial stage before complete adoption of a technology is therefore perceived as a major determinant of adoption (Doss, 2003). Rogers and Shoemaker (1971) classified the perceived characteristics of a technology as a determinant of adoption. Literature by Mignouna *et al*,. (2011) and Adesina & Zinnah (1993) both recorded a positive influence of farmers' perception of technology characteristics to influence their adoption of Imazapyr-Resistant maize technology and modern rice variety respectively.

2.4.4 Constraints to Adoption of SFM Technologies

Risk and uncertainty are two vital standing blocks to technology adoption and have been linked to the possible changes likely to occur as a result of the decision to either adopt or reject an innovation (Rogers, 2003 and Sahin,2006).

The adoption of improved soil fertility management technologies/practices presents the uttermost solution to the poor soil fertility status of soils in SSA. Notwithstanding this discovery, a number of limitations prevent farmers from adopting these improved soil fertility management technologies. A major constraint by (Buah and Karbo, 2012) has been costly nature of these technologies especially with fertilizers (inorganic/chemical), presenting smallholder farmers with affordability and accessibility issues. Improving access to fertilizers and educating farmers on the best means of deriving optimum benefits (yields)) from their application is therefore an important step in enhancing the adoption of improved SFM technologies (Sanginga and Woomer, 2009).

Feder *et al*,. (1985) summarized some vast amount of empirical literature on adoption based on which he suggested that constraints to adoption of a new technology may arise from many sources, such as cost, lack of credit, inadequate farm size, unstable supply of complementary inputs, limited access to information, uncertainty, among other factors. Some of the above factors were reinforced by Cary and Wilkinson (1997), when they noted dearth of profitability and credit constraints as two major issues hindering adoption of sustainable agricultural technologies as suggested by some economic works. Schultz (1995) suggested many testable hypotheses to the effect of how farmers weigh the possible risks associated in the adoption of a new innovation before a final decision is made. One of which was the fact that the probability of adoption of a new technology will to a great extent depend on the difference in profitability between the new technology and old technology they are already practicing, and the ability of the farmer to perceive the advantages of the new technology and efficiently utilize it

2.4.5 *Ex-ante* Evaluation

The whole concept of “adoption” of an innovation goes beyond the scope of a benefitcost analysis (BCA) to a much broader picture of biophysical and socioeconomic characteristics likely to influence adoption (Imogen, 2013).

Ex-ante cost benefit analysis have been termed as, “forward looking assessments” (Maredia *et al*,. 2014). In agricultural research, it has evolved as an important area forming baselines for decision makers in assessing potential impacts of research investments, (ex-post evaluations), aid in setting up priorities and making inferences about other populations and backgrounds among others (Rusike, 2010; Maredia *et al*,. 2014). An *ex-ante* impact assessment by USAID of their Feed the Future project used the benefit-cost analysis (BCA) approach where after assessing several investments, the investment offering the best prospects of generating the highest possible returns in terms of higher incomes is selected amidst alternative investments (Andoseh *et al*,. 2014).

An in-depth understanding of factors of possible influence on farmers’ adoption decision of a particular technology can go a long way in improving the design of the technology, more competent dissemination strategies and in the long run higher adoption rates (Lambrecht *et. al*., 2015). And an *ex-ante* assessment provides this indepth-understanding. (Pindyck *et. al*,. 1997 and Green, 2000) identified probit and logit models as the main econometric models used in *ex-ante* adoption analysis. In the case of choice between two options, a binary probit/logit model is used and with the case of more than two alternatives; the use of multivariate probit/logit model is employed.

2.5 Farmers' Willingness to Pay (WTP) for Improved SFM Technologies

2.5.1 Concept of WTP

Having it roots embedded in economics, WTP has been identified as one of the primary approaches to assessing consumer reactions to price (Gall-ely, 2010; Lankoski, 2010). A number of conceptual definitions of WTP exist in literature. (Kohli and Mahajan, 1991; Wertenbroch and Skiera, 2002; Freeman 2003) define this concept as the maximum price a buyer associates with or is willing to sacrifice for a good or services of interest. WTP has been defined as an operational tool for evaluating the capacity of a target group of people to pay for a good or service in an attempt to establish hypothetically the monetary value placed on these goods. It has been known to apply a great deal in benefit-cost and econometric models with the goal of aiding in a decisionmaking processes (Escudero, 2009). In general, a consumers WTP for a product is acknowledged as key in ensuring sustainability since it comprises combined teamwork by management (producers) and consumers, in the determination of price instead of management determining prices alone in a vacuum without consumers knowledge or input (Lankoski, 2010).

2.5.2 Measuring WTP

A number of methods for assessing WTP (in terms of preference and calculating WTP estimates) are found in literature and these include Contingent valuation methods (CVM) which is a hypothetical valuation method, Conjoint analysis (CA) which complements CVM by presenting different attributes of the commodity and experimental auction which is a much old-fashioned method where the researcher interacts with his respondents to determine price of products (Sanchez *et al*,. 2001; Umberger *et al*,. 2002; Nakaweesa, 2006; Cerda *et al*,. 2012).

The most economically accepted is the contingent evaluation method instigated by Davis (1963), which entails the estimation of the worth an individual associates with a good, or service not already sold in the market (non-market goods) Donfouet and Makaudze (2011). This evaluation method involves asking a sampled population of interest their willingness to pay for a given good or services not yet on the market by presenting to them a hypothetical scenario based on which prices are elicited (Portney, 1994; López-feldman, 2013).

Evaluating WTP using contingent valuation can be done using three approaches

1. Open-ended questions: were an individual is asked how much he/she is willing to pay for a good or service
2. Payment cards: were a number of possible amounts are presented and the individual makes a choice based on their personal valuation
3. Dichotomous choice questions (close-ended format): which involves a yes or no response to the willingness to pay question

Of the three methods outlined above, the dichotomous choice format which was introduced by Bishop and Heberlein (1979) is the most accepted and adequate technique for accessing WTP (Calia & Strazzera, 2000; Cooper *et al*,. 2002). Within the dichotomous choice format, two main approaches for soliciting WTP responses exist;

1. The Single Bound Dichotomous Choice (SBDC): with this approach, the individual is asked if he/she will be willing to pay a set amount for a given good or service (Hanemann *et al.*,1991).
2. The Double Bound Dichotomous Choice (DBDC) approach was developed later by (Carson *et al*,. 1986) after it was realized that the SBDC provided less information about respondents WTP. This approach involves a presentation of two bids to a respondent with the level of the second bid always influenced by response to the first bid. Respondents are asked if they would accept or reject the first bid (B_i) and based on their answer, a second bid which may be higher (B_i^u if yes to first bid) or lower (B_i^d if no) is presented. This format as proposed by (Hanemann, *et al*,. 1991) therefore has four possible outcomes:

   "yes:yes, yes:no, no:yes, no:no".

A considerable number of literature after assessing the two approaches above concluded that the DCDC format provided more efficient and less biased estimates as compared to the SBDC (Hanemann, *et al*,. 1991; Leòn 1995; Donfouet and Makaudze 2011)

2.5.3 Determinants of WTP

A number of factors have been identified by literature to influence farmers WTP for some agricultural technologies and these include Adesina and Baidu-Forson (1995), Ulimwengu and Sanyal (2011), Chiputwa *et al,.* (2011), Baffoe-Asare *et al,.* (2013). Zakaria *et al,.* (2014). The above researchers suggested factors such as gender, age, education, farm size, access to credit, FBO membership. among others to likely influence farmers' willingness to pay decision. Some empirical evidence on farmers' WTP for selected improved agricultural technologies and some key determinants of WTP include;

A study conducted in Tanzania by Shee, *et al,.* (2016) on "Farmers Attitude Toward Improved Agricultural Technology" through WTP analysis, using the contingent valuation format. WTP for improved seeds and fertilizers was evaluated using a dichotomous choice approach. The outcome of this study showed the mean WTP for hybrid maize (improved seed) as more than 50% higher and less than 50% for improved fertilizer as against their average on-going market prices.

A study by Kasaye (2015), assessing farmers WTP for improved soil conservation practices in Ethiopia using both single and double-bounded dichotomous choice format of CVM in seeking responses and data analyzed using a Probit model revealed that most farmers were willing to pay for conservation practices. The study also identified some statistically significant determinants of WTP as gender, education level, income and livestock ownership of household head.

A case study of Bontanga irrigation scheme by Zakaria, *et al,.* (2014) in Northern Ghana, assessing factors influencing farmers WTP for improved irrigation services also used the contingent valuation approach in soliciting responses. Results from the study revealed that farmers were willing to pay for the improved service but at a mean WTP of approximately GHC 23.00, which is far below the proposed price given by management (GHC 50.00). The study identified factors such as age and maintenance of facilities, on-scheme and off-scheme income as statistically significant determinants of farmers WTP.

A joint estimation of farmers WTP for agricultural services by (Ulimwengu, 2011) in Uganda using a multivariate probit model to assess the provision of different agricultural information services on (soil fertility management, crop protection, farm

CHAPTER THREE

3.0 STUDY AREA AND METHODOLOGY

3.1 Study Area

management, improved produce quality, on-farm storage, improved individual and group marketing, and disease control) classified farmers with access to information and extension services as less likely to be WTP for the information service. Distance was also found to impede farmers WTP while agricultural income and land ownership significantly influenced farmers WTP.

The study was conducted in the Upper West and Northern Regions of Ghana. These regions where selected mainly because they are the COMPRO II trial sites/regions in Ghana and are also well known as the 'breadbasket' regions of the selected grain leguminous crops (soybean, cowpea and groundnut).

3.1.1 Northern Region

Occupying a landmass of about 70,384 square meters, the Northern region of Ghana is considered the largest region in the country. Boundary wise, it shares borderlines with Upper West and Upper East to the north, Brong Ahafo and Volta regions to the south, Togo to the east and lastly Cote d'Ivoire to the west.

Climatically, it is a moderately dry region with a single rainy season starting from May to October. The total amount of rainfall recorded in the region annually varies between the range of 750 millimeters and 1,050 millimeters. The second season that is the dry season usually starts in November and ends between March and April.
Humidity is relatively very low (GSS, 2013).

The main economic activity for majority of the inhabitants in the region is agriculture. The crops they mainly produce include maize, guinea corn, yam, rice millet, groundnuts, soybean and cowpea. Economic activities in the region are adversely affected by the rather harsh climatic and poor soil fertility conditions (GSS, 2013).

3.1.2 Upper West Region

Located in the Guinea Savannah belt, the Upper West Region of Ghana occupies a geographical area of about 18,476 square kilometers. It shares boundaries with Burkina Faso to the north, Northern region to the South, Upper East to the East and Cote d'Ivoire to the west. The general climatic pattern of the region is similar to that of the other two northern regions (Upper East and Northern regions) with an annual rainfall pattern of approximately 115 rainfall millimeters. It has two major seasons, a single rainy season from April to September and a single dry season from November to March (GSS, 2013).
A vast majority of the inhabitants are agriculture inclined, with most being peasant farmers mostly farming on both subsistence and commercial basis. Crops mainly produced include cereals, legumes and tuber crops (GSS, 2013).

Table 3.1 provides production statistics of the major grain legumes produced in Northern and Upper West regions.

Table 3.1 Production of Major Grain Legumes in NR and UWR

Legumes	**NR**		**UWR**	
	Area (Ha)	Production (Mt)	Area (Ha)	Production (Mt)
Soybean	60,431	126,656	15,630	17,736
Groundnut	130,352	224,476	132,605	162,265
Cowpea	62,544	124,720	75,956	84,996

Source: Statistics, Research and Info. Directorate (SRID), MoFA, (2012).

Due to their importance in grain legume production, IITA's COMPRO II trial sites were located in the Northern and Upper West Regions.

3.2 Data Types and sources

The study relied heavily on experimental and socio-economic data. Experimental data was obtained from field trials conducted by soil scientists and agronomists under the COMPRO II project. Table 3.2 provides a summary of the treatments at the different experimental sites in the two regions. Northern region had two different experimental trials set up for Soybean under selected SFM (fertilizer) technologies. For experiment one, in addition to the control plot (farmer practice) where no form of fertilizer treatment was carried out, the main treatments included the use of a biofertilizer (Legumefix), the integrated use of a biofertilizer and chemical fertilizer (Legumefix and Triple Super Phosphate-TSP) and the use of chemical fertilizer alone (TSP). The second experiment in NR comprised of control plot, two biofertilizer treatments (Biofix and Nodumax) and chemical fertilizer treatment (Urea) only. Only one experimental trial field was established in Upper West Region for soybean under the different SFM technologies. The following trials were carried out; the control plot representing the farmers practice, biofertilizer treatment (Legumefix), combined use of biofertilizer and a chemical fertilizer (Legumefix and TSP) and chemical fertilizer treatment only.

For cowpea production under the selected SFM treatments in both NR and UWR, there was only one experiment carried out in each region. The treatments included; two separate biofertilizer treatments (BR3262 and BR3267), chemical fertilizer treatment (Urea) only and the control plot (farmer practice).

SFM trials for groundnut production were established only in NR and these included; the control plot, biofertilizer treatment (Legumefix), integrated fertilizer use (biofertilizer and TSP) and chemical fertilizer treatment (TSP) only.

The trials were established on a 10m x 10m area of land at each site. The experiments were carried out in a participatory manner with the active involvement of selected farmers and agricultural extension agents.

Table 3.2 Summary of Treatments carried out at Experimental Sites

	TREATMENTS	
	Northern Region (NR)	**Upper West Region (UWR)**
Soybean Experiment 1	1.Control (Farmer practice)	1.Control (Farmer practice)
	2.Biofertilizer (Legumefix)	2.Biofertilizer (Legumefix)
	3.Biofertilizer (Legumefix) + chemical (TSP)	3.Biofertilizer (Legumefix) + chemical (TSP)
	4.Chemical fertilizer (TSP)	4.Chemical fertilizer (TSP)
Experiment 2	1.Control (farmer practice) 2.Biofertilizer (Biofix) 3.Biofertilizer (Nodumax) 4.Chemical fertilizer (Urea)	
Cowpea Experiment 1	1.Control (Farmer practice)	1.Control (Farmer practice)
	2.Biofertilizer (BR3262)	2.Biofertilizer (BR3262)
	3.Biofertilizer (BR3267)	3.Biofertilizer (BR3267)
	4.Chemical fertilizer (Urea).	4.Chemical fertilizer (Urea).
Groundnut Experiment 1	1.Control (Farmer practice)	
	2.Biofertilizer (Legumefix) 3.Biofertilizer (Legumefix + chemical (TSP) 4.Chemical fertilizer (TSP)	

Source: Authors Compilation, 2016.

A checklist was designed for scientists to keep at their experimental and demonstration sites where quantities of inputs used and output values where recorded periodically throughout the lifespan of these experimental trials. All scientists involved in the trials where trained on the type of data to be captured and how such data should be measured or recorded. The researcher also monitored scientists on the field to ensure that data had been correctly captured.

Since the key objective of establishing these trials was to conduct a benefit cost analysis on them and the outcome of the analysis presented to farmers, though the experimental fields were originally established on a 10mx10m (100m^2) area of land, original input and output figures were extrapolated to per acre basis for easy comprehension and understanding of values by farmers who are mostly known to produce on per acre basis.

Socio-economic data for the study was obtained through a socio-economic survey of grain legume farmers in the target regions. Data on general characteristics of the households, grain legume production, input usage and technology adoption decisions as well as constraints to technology adoption were elicited from farmers.

3.3 Sampling Procedure

Purposive and simple random sampling methods where employed for drawing samples at various levels.

Twenty (20) demonstration (demo) sites for each of the experimental trials under the targeted legume crops were selected in the regions (Upper West and Northern) for the experimental data collection. Two districts (Karaga and Savelugu) were purposively selected in the Northern Region since they were the only two project districts in the region. Ten (10) demo sites were then randomly selected from each of the two districts under each experiment (expt), totaling 20 demos under each experiment and legume crop type. In UWR however, the project took place in six (6) districts out of which 4 (Sissala East, Wa West, Wa Municipal and Nadowli) were randomly selected for the experimental data collection. Five (5) demo sites were randomly selected from each of the four (4) districts totaling 20 demo sites under each experiment and legume crop. Table 3.2 provides a summary of the districts and the number of demo sites selected under each district, legume and experiment.

Table 3.3 Districts and Demonstration Sites Selected for Experimental Data Collection

Legumes	NR Districts	NR No.of Demos	UWR Districts	UWR No.of Demos
Soybean **Expt 1**	1. Savelugu	10	1. Sissala East	5
	2. Karaga	10	2. Wa West	5
			3. Wa Municipal	5
			4. Nadowli	5
Expt 2	1. Savelugu	10		
	2. Karaga	10		

Groundnut 1. Savelugu 10 **Expt 1** 2. Karaga 10	
Cowpea 1. Savelugu 10 **Expt 1** 2. Karaga 10	1. Sissala East 5 2. Wa West 5 3. Wa Municipal 5 4. Nadowli 5

Source: Authors Compilation, 2016.

For the socio-economic survey, all two-project districts in the Northern region were selected purposively (Karaga and Savelugu) while two out of the six districts in the Upper West Region were selected through a simple random approach (Wa West and Nadowli). Five (5) communities were randomly selected from each district and 20 legume farmers randomly selected from each of the 5 communities. Hence, a total sample size of 400 grain legume farmers were selected for the socio-economic survey.

3.4 Data collection

The data collection procedure used in this study included; the use of data sheets for the collection of experimental data at the demonstration sites and structured questionnaires designed to conduct personal interviews during the socio-economic field survey.

For assessing farmers' willingness to pay, a choice card consisting of relevant information on the treatment results of the various soil fertility management technologies on crop basis was designed and presented to farmers to determine their willingness to pay for the best SFM package identified from the experimental data analysis.

The experimental data was compiled from May to November 2014 and the socioeconomic data collected in April of 2016.

Enumerators used in the data collection process were trained on the objective of the study, parameters to be measured and how measurements were to be done. The appropriate approach needed in eliciting responses from farmers, how to probe further on responses as a form of verification and other important details of the questionnaire used. This in-depth training was done in order to obtain quality data after which a pretesting was done to assess their understanding of the questionnaire.

The respective native languages in each of the regions were used in interviewing the farmers. Dagaare and Waale in UWR and Dagbani in the NR. This approach was used to help farmers better comprehend the concept being presented to them.

3.5 Analytical Framework

This study was aimed at evaluating the adoption decision of smallholder grain legume farmers and their willingness to pay for selected SFM technologies in Northern and Upper West Regions of Ghana by presenting to them recommended SFM technology packages based on an initial Benefit-Cost analysis of experimental data.

3.5.1 Cost-Benefit-Analysis

Cost-Benefit analysis has been reported in literature as the fundamental tool for *exante* evaluation of projects (Boardman *et al.*, 2006). Using the Benefit-Cost Ratio approach, data from the various experimental fields set out with regard to this study was evaluated to find the "best" fertilizer technology to recommend to farmers for specific legume production (soya, cowpea and groundnuts). One of the major goals of this study was to therefore identify the most financially rewarding SFM technology for each of the leguminous crops under study by generating their BCR values. The general form of the equation used is presented as;

$$BCR = \frac{GrossIncome}{Total\mathrm{Cost}}$$

Where;

- **Gross income** = [quantity of main product (soya or cowpea or groundnuts) * unit price of main product]
- **Total Cost** = expenses incurred for agronomic operations in terms of labour and other input cost

  Labour cost, which consisted of costs, associated with ploughing of fields, planting, weeding, harvesting, gathering and threshing.

Other input cost components covered were costs of seeds, fertilizers and insecticides.

Data on the above input and output parameters were collected per treatment/technological package ($10_m x 10_m$ area of land) and were extrapolated to per acre basis for easier comprehension by farmers who mostly plough on per acre basis.

The SFM technology or package with the highest BCR for each of the crops was selected as the most financially viable technology/package and presented to farmers.

3.5.2 Factors Influencing Adoption of Selected SFM Technologies *Ex-ante*

The Benefit-Cost analysis of the different fertilizer treatments resulted in the selection of three main fertilizer technology packages; one for each of the three main leguminous crops (soya, cowpea and groundnuts). The selected packages were then presented to farmers to ascertain their adoption decision.

Regression models are widely used in adoption studies (Chianu and Tsuji, 2004; Polson and Spencer, 1991) and were accordingly incorporated in this study. Literature on adoption studies has it that adoption decision of farmers pertaining technologies that are either substitutes or compliments results in some level of interdependence and as such decisions on such technologies are most often than not interrelated (Ndiritu *et al*,. 2012). Since in the case of this study, we are dealing with fertilizer technology packages for mainly legume crops (soya, cowpea and groundnuts), which are from the same family and are most likely to be related in terms of farmers decision to cultivate legumes, the most appropriate regression model to use was the multivariate probit model. Dorfamn, (1996) and Greene, (2008) noted that, if indeed some level of correlation occurs, estimating the adoption model equation separately for each fertilizer technology under each legume crop would result in the loss of very pertinent economic knowledge, biased and inefficient estimates as well as inappropriate interpretations pertaining to the influence of the determinants of adoption of the technology.

The multivariate probit model consists of a set of binary dependent variables in which the observed outcome for a dependent variable can have only two possible types (for example, "yes" vs. "no").

The general form of the equation is presented as:

$$T_{i^*} = \beta_0 + \beta_i X_i + \varepsilon$$

The empirical model is specified as:

$$T_{i^*} = \beta_o + \beta_1 GEN \pm \beta_2 AGE + \beta_3 YEDU + \beta_4 YEXP - \beta_5 TFL + \beta_6 FBO - \beta_7 DisEXT - \beta_8 DisAgro + \beta_9 AmtC + \beta_{10} FInc - \beta_{11} OffINC + \beta_{12} LSTK + \beta_{13} BIOAW + \varepsilon \text{.............}1$$

$$T_i = \begin{cases} 1 & \text{if } T_i^* > 0 \\ 0 & \text{otherwise} \end{cases} \text{.........................}2$$

Where

- T_i^* = Adoption decision of farmer pertaining SFM technology 'i' (1=Yes; 0 otherwise)
- $\mathbf{X_i}$ = a vector of explanatory variables. Their definitions, measurement and a priori expectations have been summarized in Table
- $\boldsymbol{\beta_0}$ = intercept
- $\boldsymbol{\beta_i}$ = coefficients of the independent variables, and
- $\boldsymbol{\varepsilon}$ = error term

A more detailed specification of the multivariate probit model used was sourced from (Cappellari & Jenkins, 2003) as;

$$T_{im^*} = 1 \text{ if } T^*_{im} > 0 \text{ and } 0 \text{ otherwise}$$

T_{im}^* = Outcomes for M different biofertilizer choices, that is if an individual farmer will adopt each of the m different biofertiliezrs.

$\varepsilon_{im,}$ m=1,…., M are error terms distributed as multivariate normal, each with a mean of zero and variance/covariance matrix V, where V has values of 1 on the leading diagonal and correlations $\rho_{jk} = \rho_{kj}$

Estimating the model with M=3 (adoption of three different SFM for the three legumes) makes the model a trivariate probit model. The log -likelihood function for the sample of N (400) independent observations is specified as;

$$L=\sum_{i=1}^{N} w_i \log\Phi_3(\mu_i;\Omega)$$

Where; w_i is the optional weight for observation i=1,…,N, and $\Phi_3(.)$ is the trivariate standard normal distribution with influences μ_i and Ω .

Table 3.4: Description of the Variables used in *ex-ante* Adoption Analysis

Variable	Description	Measurement	Apriori Expectation	Source
GEN	Gender	1 if male, 0 otherwise	+	Omonona *et al,.* (2006) Mignouna *et al,.* (2011) Lavison, (2013) Obisesan, (2014)
AGE	Age	Age of farmers in years	+/-	McNamara *et al,.* (1991) Adesiina & Baidu-Forson, (1995) Harper *et al,.* (1990) Boahene *et al,.* (1999)
YEDU	Years of Formal Education	Number of years of formal education of famer	+	Nkamleu & Adesina, (1999) Mignouna *et al,.* (2011) Namara *et al,.* (2013) Ajewole, (2010)
YEXP	Years of Experience in	Farmers number of years of experience in farming	+	Edemeades *et al,.* (2008)

	Farming			Onumadu & Osahon, (2014)
TFL	Total Farmland Allocated to the selected legumes	Total farmland allocated for legume production	+/-	Uaiene *et al*,. (2009) Mignouna *et al*,. (2011) Harper *et al*,. (1990) Yaron *et al*,. (1992).
FBO	Farmer Based Organisation	1 if farmer is a member of an FBO, 0 otherwise	+	Foster and Rosenzweig,(1995) Conley and Udry, (2000) Katungi and Akankwasa, (2010) Ehiakpor *et al*,. (2016)

DisEXT	Distance to Agric Extension Office	Distance to the nearest Agric extension office in km	-	Adesina, (1996)
DisAgro	Distance to AgroInput Shop	Distance to the nearest agro input shop in km	-	Adesina, (1996)
AmtC	Amount of Credit	Amount of credit used for legume production in 2015 cropping season	+	Andre and Mulat, (1996) Hazarika &Alwang, (2003) McBrid, (2002) Paudel & Thapa, (2004)
FInc	Farm Income	1 if farm income is a major source of household income, 0 otherwise	+	
OffInc	Off-Farm Income Generating Activities	1 if farmers involved in any form of off farm activities, 0 otherwise	+/-	Goodwin and Mishra (2004). Diiro (2013).
LSTK	Livestock Ownership	1 if farmer owns livestock, o otherwise	+	
BIOAW	Biofertilizer Awareness	1 if farmer is aware of the use of biofertilizer for legumes, 0 otherwise	+/-	Mignouna *et al*,. (2011) Adesina & Zinnah (1993) Diagne and Demont (2007) Diagne (2010)
BIOU	Biofertilizer Use	1 if farmer has ever used biofertilizers for legume production	+/-	Mignouna *et al*,. (2011) Adesina & Zinnah (1993) Diagne and Demont (2007)

Source: Authors Compilation, 2016.

3.5.3 Willingness to Pay for 'best' SFM technology

Farmers' willingness to pay for the best package or technology was evaluated by employing the contingent valuation approach which has been recognized as one of the best means of valuing goods which are not already on the markets (Randall *et al.*, 1974; Donfouet and Makaudze, 2011). The contingent valuation method which stands out as the most economically accepted approach for evaluating WTP was used and it involved asking respondents their willingness to pay for a commodity, in this case the selected

SFM technologies. Farmers were presented with hypothetical scenarios dependent on simulated values.

Among the existing approaches of evaluating WTP using contingent evaluation, the 'Double-Bounded Dichotomous Choice Format' was used. The double bounded dichotomous choice format presents follow-up questions that provide more effective binary responses than the single bounded method. Adding a follow-up bid substantially improves statistical information provided by the data (Hanemann, *et al*,. 1991).

Double-bounded dichotomous choice format, presents respondents with a follow-up bid offer after an initial first bid is introduced. Respondents are then asked if they would accept or reject the first bid (B_i) and based on their answer, a second bid which may be higher (B_i^u if yes to first bid) or lower (B_i^d if no) is presented. This format therefore has four possible outcomes: "yes:yes, yes:no, no:yes and no:no".

Table 3.5 provides a summary on Bids generated for the double-bounded choice format.

Table 3.5 Proposed Bid Prices (GHC) for the Selected Biofertilizers

Biofertilizer	Bid 1	Higher Bid	Lower Bid
Biofix	28.00	56.00	14.00
BR3267	55.00	110.00	28.00
Legumefix	40.00	80.00	20.00

Source: Generated from Experimental Data

The table below presents the different variables that were used in the willingness to pay model.

Table 3.6: Description of variables used in Generating Bids

Variable	Description	Measurement of Values
Bid 1	Initial amount (bid) in GHC	1 if yes and 0 otherwise
Bid h	Higher amount (bid) in GHC	1 if yes and 0 otherwise
Bid l	Lower amount (bid) in GHC	1 if yes and 0 otherwise
Nn	Rejection of initial and lower bid	1 if no,no to WTP question
Ny	Rejection of initial but acceptance of lower bid	1 if no,yes to WTP questions

Yn	Acceptance of initial bid but rejection of a higher bid	1 if yes,no to WTP questions
Yy	Acceptance of both initial and higher bid	1 if yes,yes to WTP questions
DepVar	Dependent variable as (=1 if nn=1, =2 if ny=1, =3 if yn=1 and =4 if yy=1)	
	Response to Bid 1	1 if DepVar = 3 or 4
	Response to Bid 2	1 if DepVar = 2 or 4

Source: Authors Compilation, 2016.

The Log-likelihood function for the responses, following Hanemann *et al*., (1991) is given as;

$$\ln L_D(\theta) = \sum_{i=1}^{N} \left\{ d_i^{yy} \ln \pi^{yy}\left(B_i B_i^u\right) + d_i^{yn} \ln \pi^{yn}\left(B_i B_i^u\right) + d_i^{ny} \ln \pi^{ny}\left(B_i B_i^u\right) + d_i^{nn} \ln \pi^{nn}\left(B_i B_i^u\right) \right\}$$

Where:

- $\mathbf{B_i}$ =1st bid (if response is yes)

u nd

- B_i^d = 2nd bid (if response is yes)
- B_i^d = 2nd bid (if response is no)
- $d_i^{yy}, d_i^{yn}, d_i^{ny}, d_i^{nn}$ denote responses to "yes:yes, yes:no, no:yes and no:no" respectively
- $\pi^{yy}, \pi^{yn}, \pi^{ny}, \pi^{nn}$ represent probability of obtaining a "yes:yes, yes:no, no:yes, and no:no" respectively.

To estimate the double bound model, the following information is necessary; Let t^1 and t^2 represent the 1st and 2nd bids respectively.

1. An individual farmer rejecting both initial and lower bid implies $0<WTP < t^2$.
2. An individual farmer rejecting initial bid but accepting the lower bid, then $t^2 > t^1$ implying $t^2 \leq WTP \leq t^1$
3. An individual farmer accepting the initial bid but rejecting the higher bid, then $t^2 > t^1$ implying $t^1 \leq WTP < t^2$
4. An individual farmers accepting both initial and higher bids implies $t^2 \leq WTP < \infty$

We define Y_i^1 and Y_i^2 as dichotomous variables representing responses to the first and second questions; and under the assumptions that; $WTP_i(z_i, \mu_i) = z_i'\beta + \mu_i$ and $\mu_i \sim N(0, \sigma^2)$

Therefore, the probability of each of the four scenarios above occurring is given as;

1

1

2

μ

1. $Y_i^1=1$ and $Y_i^2=0$

$$\Pr(y,n) = \Pr(t^1 \le WTP < t^2)$$

$$= \Pr(t^1 \le z_i'\beta + \mu_i < t^2)$$

1 −zi¢β μi t2

−zi¢βö æt

=Prçè σ £ σ < σ ÷ø

$$= \Phi\left(\frac{t_2 - z_i'\beta}{\sigma}\right) - \Phi\left(\frac{t_1 - z_i'\beta}{\sigma}\right)$$

Hence using symmetry of the normal distribution, we have

$$\Pr(y,n) = \Phi\left(\frac{z_i'\beta}{\sigma} - \frac{t_1}{\sigma}\right) - \Phi\left(\frac{z_i'\beta}{\sigma} - \frac{t_2}{\sigma}\right)$$

2. $Y_i^1=1$ and $Y_i^2=1$

$$\Pr(s,s) = \Pr(WTP > t^1, WTP \geq t^2)$$

$$= \Pr(z_i'\beta + \mu_i > t^1, z_i'\beta + \mu_i \geq t^2)$$

By symmetry, we have;

$$\Pr(s,s) = \Phi\left(\frac{z_i'\beta}{\sigma} - \frac{t^2}{\sigma}\right)$$

3. $Y_i^1=0$ and $Y_i^2=1$

$$\Pr(n,s) = \Pr(t^2 \leq WTP < t^1)$$

$$= \Pr(t^2 \leq z_i'\beta + \mu_i < t^1)$$

$$= \Pr\left(\frac{t^2 - z_i'\beta}{\sigma} \leq \frac{\mu_i}{\sigma} < \frac{t^1 - z_i'\beta}{\sigma}\right)$$

$$= \Phi\left(\frac{t^1 - z_i'\beta}{\sigma}\right) - \Phi\left(\frac{t^2 - z_i'\beta}{\sigma}\right)$$

$$\Pr(n,s) = \Phi\left(\frac{z_i'\beta}{\sigma} - \frac{t_2}{\sigma}\right) - \Phi\left(\frac{z_i'\beta}{\sigma} - \frac{t_1}{\sigma}\right)$$

4. $Y_i^1 = 0$ and $Y_i^2 = 0$

$$\Pr(n,n) = \Pr(WTP < t^1, WTP < t^2)$$

$$= \Pr(z_i'\beta + \mu_i < t^1, z_i'\beta + \mu_i < t^2)$$

$$= \Pr(z_i'\beta + \mu_i < t^2)$$

$$= \Phi\left(\frac{t^2 - z_i'\beta}{\sigma}\right)$$

$$\Pr(n,n) = 1 - \Phi\left(\frac{z_i'\beta}{\sigma} - \frac{t^2}{\sigma}\right)$$

Farmers' willingness to pay for the selected SFM technologies for their legume production after generating the relevant variables above was hence specified as:

$$WTP_i = \beta_o + B_1 GEN - \beta_2 AGE + \beta_3 YEDU + \beta_4 YEXP - \beta_5 TFL + \beta_6 FBO - \beta_7 DisEXT - \beta_8 DisAgro + \beta_9 AmtC + \beta_{10} FInc - \beta_{11} OffINC + \beta_{12} awBIO + \beta_{13} useBIO + \varepsilon$$

Where;

- WTP_i represents farmers willingness to pay for the selected i th SFM technology (i.e. either Biofix, Legumefix or BR3267)
- ε denotes the error term.

Table 3.7 provides a description of the variables used in the WTP model.

Table 3.7: Description of variables used in WTP Analysis

Variable	Description	Values	Apriori Expectations
Individual Characteristics			
GEN	Categorical variable representing the gender of respondent	1 if male and 0 otherwise	+
AGE	Age of respondent in years	Continuous variable (count)	+/-
YEDU	Number of years of formal education of respondent	Continuous variable (count)	+
YEXP	Number of years of farming experience	Continuous variable (count)	+
Farm Level Characteristics			
TFL	Total farmland in acres allocated to legume crops	Continuous variable (count	+/-
Institution al Characteristics			
FBO	Membership of a farmer based organization	1 if yes and 0 otherwise	+
AmtC	Amount of credit used during the 2015 cropping season	Continuous variable (count)	+
FInc	Farm income as a major source of household income	1 if yes and 0 otherwise	
DisExt	Distance to nearest agric extension office in km	Continuous variable (count)	-
Offinc	Farmers participation in off farm income generating activities	1 if yes and 0 otherwise	+/-
DisAgro	Distance to nearest agro input shop in km	Continuous variable (count)	-
Technology Awareness and Use			
awBIO	Awareness of the use of biofertilizers for legume production	1 if yes and 0 otherwise	+
useBIO	The use of biofertilizer for legume production	1 if yes and 0 otherwise	+

Source: Authors Computation, 2016.

3.5.4 Constraints to Adoption of SFM Technology Practices

To examine the constraints to adoption of SFM technologies, Likert scale ranking and Kendall's Co-efficient of Concordance were employed. Identified constraints were presented to farmers to be ranked on a five-point Likert scale (1=Strongly Agree, 2=Agree, 3= Neutral, 4= Disagree and 5= Strongly Disagree). The Kendall's concordance co-efficient (W), which measures the degree of agreement among a set of ranked variables was used. The co-efficient ranges between 0 and 1; and high value of W indicate a high degree of agreement among those ranking. The equation for the

co-efficient (W) is given as: $W = \frac{12S}{k^2(n^3 - n)}$

Where;

- $S = \sum (SR)^2 - n\left(\overline{SR}\right)^2$
- **k** = groups (columns) with n items in each category
- **SR_i** = Sum of ranks in each row
- $\overline{SR} = \frac{(n+1)k}{2}$
- **n**=number of constraints

The observed chi -square is calculated with the formula:

$$\chi^2_{(n-1)} = k(n-1)W$$

Where the definitions for k,n and W are same as above.

CHAPTER FOUR
4.0 RESULTS AND DISCUSSION

This chapter presents results on data analyzed from the experimental sites and socioeconomic survey conducted. Description of individual famers' demographic characteristics, farm level and institutional characteristics has been provided. In addition, farmers' awareness of soil fertility management practices is presented, followed by results and discussions on the benefit-cost analysis of the selected soil fertility management technologies or packages for legume production. The empirical results on determinants of farmers' decision to adopt SFM *ex-ante* and their willingness to pay for selected biofertilizers follow. Finally results on ranking of constraints using Kendall's W are presented.

4.1 Descriptive Results

4.1.1 Demographic Characteristics of Respondents

Grain legume farmers interviewed during the field survey had different characteristics (Table 4.1). Females made up 27% and 45% of the sampled farmers in Northern and Upper West Regions respectively. While the mean age of a typical grain legume farmer was 40 years in the Northern region, in the Upper West region a typical farmer was 44 years. A greater percentage of the farmers were married with about 95% in Northern Region and 88% in Upper West Regions. As was expected, nearly nine out of every ten farmers interviewed indicated that farming was their main occupation. A typical household consisted of about 11 inhabitants, with less marked difference across the different regions. About 72% of the farmers between the study regions reported having no formal education. There was however marked difference across the two regions; with about 78% and 67% in Northern and Upper West regions respectively. A few were educated up to the tertiary level.

Table 4.1: Demographic Characteristics of Respondents

Variable	Category	Northern		Upper West		Pooled	
		Freq	**%**	**Freq**	**%**	**Freq**	**%**
Gender	Male	147	73.5	110	55.0	257	64.2
	Female	53	26.5	90	45.0	143	35.8

Age (years)	<20	1	0.5	2	1.0	3	.8
	20-40	199	59.5			210	52.5
	41-60	67	33.5			144	36.0
	>60	13	6.5			43	10.7
Marital status	Single	9	4.5	20	10	29	7.2
	Married	189	94.5	175	87.5	364	91.0
	Divorced/Widowed/Separated	2	1.0	5	2.5	7	1.8
Main occupation	Farming	186	93.0	184	92.0	370	92.5
	Public service	1	0.5 6.0	3	1.5	4	1.0
	Trading	12	0.5	9	4.5	21	5.2
	Others (Student)	1		4	2.0	5	1.3
Mean (SD)		**39.8(13.3)**		**43.6(14.3)**		**41.7(13.9)**	
Household size (number of persons)	<5	7	3.5	8	4.0	15	3.8
	5-10	84	42.0	105	52.5	189	47.2
	11-15	62	31.0	63	31.5	125	31.3
	>15	47	23.5	24	12.0	71	17.7
	Mean (SD)	**11.9 (4.8)**		**10.4 (4.5)**		**11.2 (4.7)**	
Level of formal education of household	None	156	78.0	134	67.0	290	72.5
	Basic	30	15.0	43	21.5	73	18.2
	SHS	11	5.5	17	8.5	28	7.0
	Tertiary	3	1.5	6	3.0	9	2.3
Number of educated household members	None	33	16.5	7	3.5	40	10
	<5	136	68.0	140	70.0	276	69
	5-10	30	15.0	49	24.5	79	19.7
	>10	1	0.5	4	2.0	5	1.3
	Mean (SD)	**2.4 (2.0)**		**3.7 (2.4)**		**3.1(2.3)**	

Source: Field Data, 2016.

91 45.5
77 38.5
30 15.0

4.1.2 Information on Farming and Institutional Variables

Average land owned across the study regions was not significantly different (Table 4.2). The mean land owned was 25 acres for farmers in Northern Region (NR) and 22 acres for those in Upper West Region (UWR). On the average farmers in NR cultivated 12 acres during the last cropping season; in UWR a relatively smaller area of 8 acres was cultivated. A considerable number of grain legume farmers interviewed had more than 10 years of farming experience. About 41% and 40% of farmers in Northern and Upper West region respectively, had farming experience ranging from 10 to 20 years with respective mean values of 18 and 22 years. Farmers in NR on the average trekked about 2.7 km to their farms, whiles in the UWR, the distance between their farms and their house was only 1.7 km.

Table: 4.2: General Farm Level Information

Variable	Categories	Northern Freq	Northern %	Upper West Freq	Upper West %	Pooled Freq	Pooled %
Farming Experience (years)	**<10**	52	26.0	31	15.5	83	20.8
	10-20	81	40.5	80	40.0	161	40.2
	21-30	44	22.0	44	22.0	88	22
	>30	23	11.5	45	22.5	68	17
	Mean (SD)	**17.8 (11.8)**		**22.2 (13.0)**		**20.0(12.6)**	
Total land owned (acres)	**<20**	90	45.0	101	50.5	191	47.7
	20-40	79	39.5	80	40.0	159	39.7
	41-60	23	11.5	14	7.0	37	9.3
	>60	8	4	5	2.5	13	3.3
	Mean (SD)	**25.0 (17.3)**		**21.8 (15.9)**		**23.4 (16.7)**	
Total land under cultivation (acres)	**<10**	102	51.0	147	73.5	249	62.3
	10-20	75	37.5	48	24.0	123	30.7
	21-30	15	7.5	4	2	19	4.8
	>30	8	4	1	0.5	9	2.2
	Mean (SD)	**11.5 (9.9)**		**7.5 (4.9)**		**9.5 (8.1)**	
Portion of land for legume production (acres)	**<5**	129	64.5	165	82.5	294	73.5
	5-10	63	31.5	33	16.5	96	24.0
	>10	8	4.0	2	1.0	10	2.5
	Mean (SD)	**4.8(4.0)**		**2.8(2.3)**		**3.8(3.4)**	
Distance to	**<5**		99.5		98.5		99.0
						10	2.5
Distance to	**<5**	182	91.0	194	97.0	376	94.0
		199		197		376 **1.7 (1.2)**	
nearest Legume farm (km)	**5-10**	0.5		1.5		0.7	
	>10	0.0		0.0		0.3	
	Mean (SD)	**(1.4)**		**(1.1)**			

farthest Legume farm (km)	**5-10 >10**	17 1	8.5 0.5	6 0	3.0 0.0	23 3	5.7 0.3
	Mean (SD)	**2.7(2.1)**		**1.7(1.2)**		**2.3(1.8)**	

Source: Field Data, 2016.

Summary statistics of key institutional factors that affect the behaviour of farmers have been presented in Table 4.3. Membership of Farmer Based Organizations (FBOs) has been recognized as one of the essential means through which new technologies are disseminated to farmers. More than 75% of legume farmers interviewed in NR and UWR were members of FBOs. A significant number of these farmers did not use any form of credit source but largely self-financed their legume production. While approximately 59% of farmers in NR indicated they did not use credit, a relatively larger percentage (80%) did not use credit in the UWR. Of the minority who reported some level of credit use, most of them sourced their credit from friends and relatives.

Table: 4.3: Summary Statistics on Institutional Factors/Variables

Variable	**Category**	**Northern**		**Upper West**		**Pooled**	
		Freq	**%**	**Freq**	**%**	**Freq**	**%**
83.0	**Yes** **FBO** 154	77.0	178	89.0 332 **membership**			**No**
Credit Use	**Yes**		46	23.0	22	11.0	6817
	No		83	41.5	41	20.5	12431.0
		117	58.5	159	79.5	276	69.0
Amount of	**None**	117	58.5	159	79.5	276	69
Credit used last **<100** 23 11.5 5 2.5 28 7.1 **cropping** **100-500** 57 28.5 35 17.5 92 23.5 **season** **>500** 3 1.5 1 0.5 4 0.4							
	Mean (SD)	**72.95(125.05)**		**38.65(94.76)**		**55.8(112.13)**	
Source of Credit	**Own financing**	117	58.5	159	79.5	276	69
	Credit union	0	0	8	4.0	8	2.0
	Susu	2	1.0	18	9.0	20	5.0
	Friends/Relatives 76 38.0 15 7.5 91 22.7 **Other Sources (tractor** 5 2.5 0 0 5 1.3 **service)**						
Major Source of Production information	**AEA**	68	34.5	51	25.5	120	29.9
	Media	76	38.0	63	31.5	139	34.8
	Other farmers	54	27.0	81	40.5	135	33.8
	Market square	1	0.5	5	2.5	6	1.5

Number of Extension contacts	None	50	25.0	120	60.0	170	42.5
	1-5	137	68.5	66	33.0	179	44.7
	6-10	13	6.5	14	7.0	51	12.6
	Mean (SD)	2.5 (2.0)		1.4 (2.3)		2.0(2.2)	
Access to Extension Agents	Yes	153	76.5	178	89.0	331	82.2
	No	47	23.5	22	11.0	69	17.8
Distance to extension office (km)	<5	99	49.5	22	11.0	121	30.3
	5-10	4	2.0	22	11.0	26	6.5
	>10	97	48.5	156	78.0	253	63.2
	Mean (SD)	12.1 (8.3)		15.4 (6.2)		13.8(7.5)	
Distance to agro-input market (km)	<5	138	69.0	87	43.5	225	56.3
	5-10	3	1.5	44	22.0	47	11.7
	>10	59	29.5	69	34.5	128	32.0
	Mean (SD)	8.6 (6.9)		8.8 (7.2)		8.6 (7.1)	
Distance to nearest output market (km)	<5	143	71.5	106	53.0	249	62.3
	5-10	4	2.0	37	18.5	41	10.2
	>10	53	26.5	57	28.5	110	27.5
	Mean (SD)	8.0 (6.7)		7.7(6.5)		7.9 (6.6)	

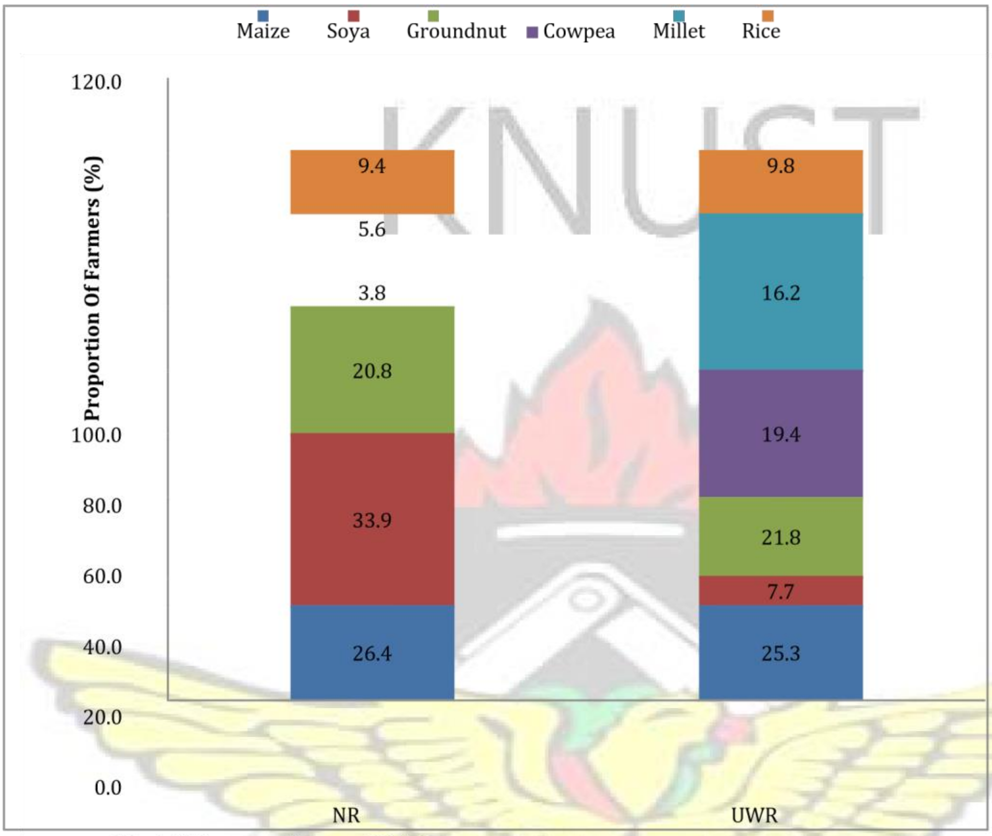
Source: Field Survey, 2016

Farmers' generally had contacts with extension agents. More than 75% of farmers in the two study regions reported contact with AEAs during the 2015-cropping season in NR and UWR. The distance of the various accessible extension offices was also assessed. The result reveals that farmers and extension agents had to travel an approximated 14 km to access production information and offer production information respectively if the need arose. Distance to nearest agro input shops was on the average 9 km in both regions. Farmers were also situated far from their nearest output markets and had to travel about 8 km. The implications are that farmers with limited resources to make the journey to input and output markets are likely to have limited access to critical inputs for production and may also be compelled to market their harvested produce at cheaper prices at the farm gate.

4.1.3 Crop Production

Farmers interviewed cultivate grain legumes (soya, groundnuts, cowpea) together with other crops. The predominantly cultivated crop was soybean in NR and maize in the UWR (Figure 4.1). The dominance of maize as the most cultivated crop in UWR and the second most cultivated in NR can be attributed to its dual roles of food security and income generation. Cowpea and soybean were the least cultivated crops in NR and UWR respectively.

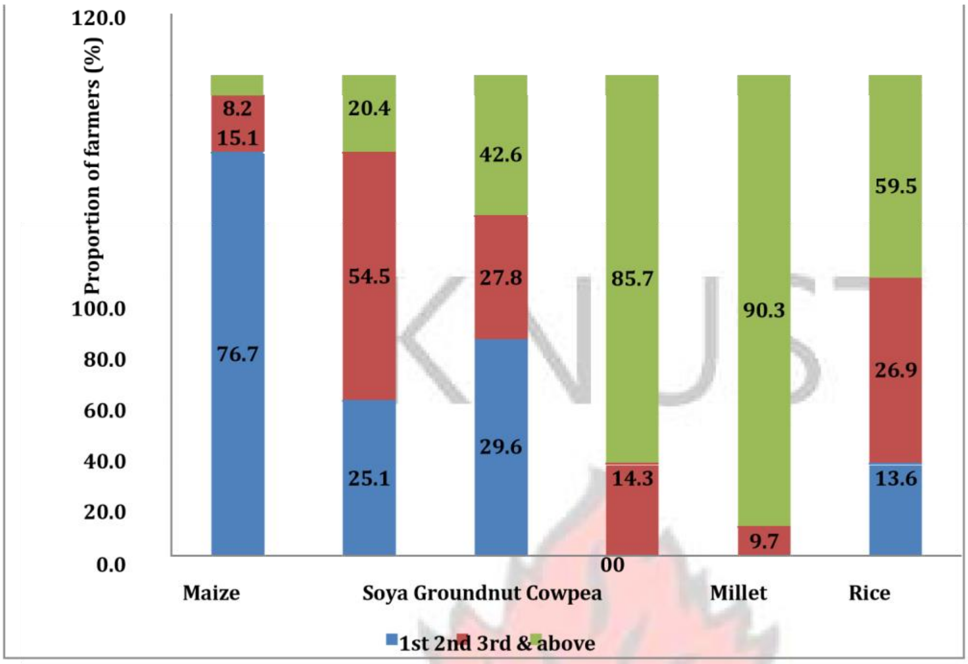
Figure 4.1:Major Crops Cultivated by Households during 2015 Cropping Season



Source: Field Survey Data, 2016.

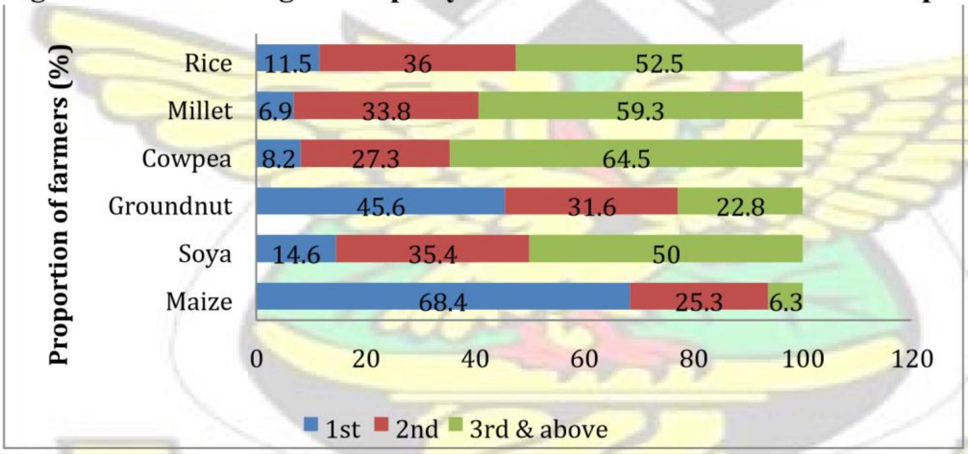
Farmers in these two study regions were made to rank the major crops they cultivated based on their level of importance to the household and the results are summarized in Figure 4.2a and 4.2b. Maize was ranked by majority of these farmers in both regions as the most important crop (77% and 68% in NR and UWR respectively) to the household since it is the major staple food crop-sustaining households in terms of food security and income generating roles. Groundnut was ranked second to maize as the most important crop by 30% of farmers in NR and 46% in UWR. The reason given was that it is a cash crop with high market value and in times of food scarcity it is usually sold to buy other staple foods as well as take care of other household cash needs. Soya was ranked third to maize and groundnut as the most important crop by 15% of farmers in NR and 25% in UWR for almost the same reason given for groundnuts.

Figure 4.2a: Ranking of Crops by Farmers in NR in Terms of Importance



Source: Field Survey Data, 2016.

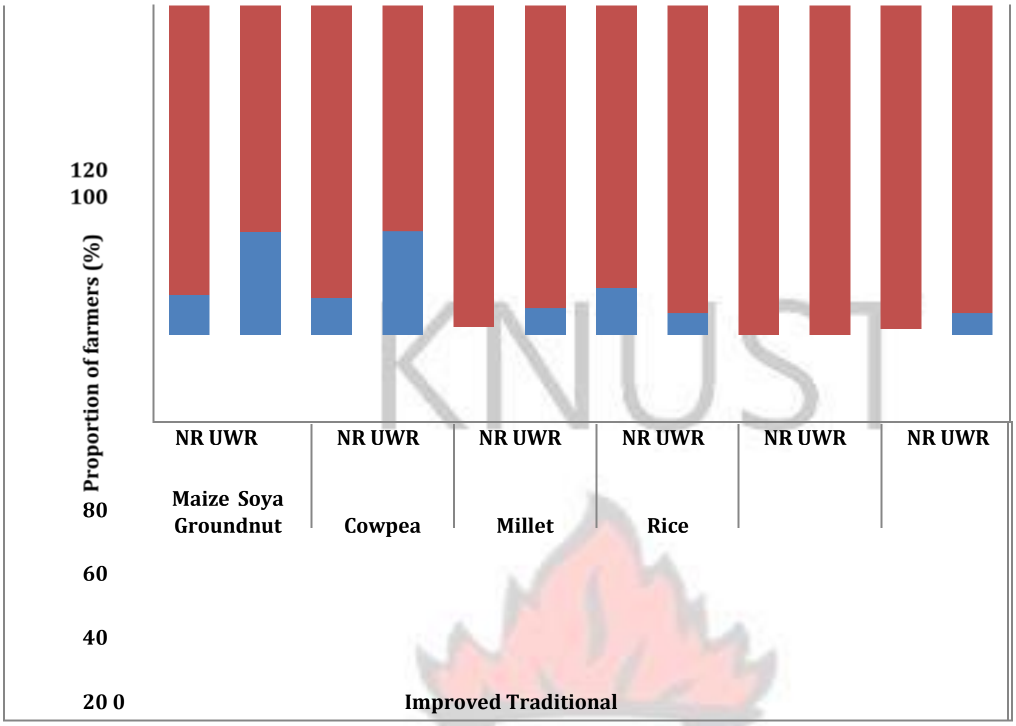
Figure 4.2b: Ranking of Crops by Farmers in UWR in Terms of Importance



Source: Field Survey Data, 2016.

A prerequisite to increasing yields of crops is the use of improved certified seeds/varieties for cultivation. Despite the large membership to FBOs and contact with extension agents, farmers' use of improved seeds was generally low (Figure 4.3). Among those who reported using improved seeds, maize and soybean were dominant in both regions recording between 10% to 30% of farmers using improved varieties. More than 50% of farmers in both study areas however used traditional seed varieties for cultivation of the major crops. The implications for the low productivity and disease susceptibility are quite obvious.

Figure 4.3: Type of Planting Material Used in 2015 Cropping Season



Source: Field Survey Data, 2016.

4.1.4 Crop Production Area and Output of Major Crops Cultivated in 2015 Cropping Season

Table 4.4 provides the acreage allocated to the major crops, average seed quantity used in planting an acre of land and quantity of grains (kg) harvested per acre for the major crops cultivated during the 2015-cropping season. Averagely, farmers allocated a little above 2 acres of their farmlands to the cultivation of maize. Among the legumes, apart from soya where there was some variation in the area cultivated between the regions (NR 3.3 acres and UWR 1.8 acres), groundnut and cowpea recorded the same area allocations in both regions. Rice cultivation in NR recorded the highest acreage (approximately 5 acres). Generally, higher acreages were allocated to the major crops cultivated in NR as compared to the UWR. Area allocations for these major crops are however generally below 2 ha (5acs) which conforms to MoFA's facts and figures where is established that about 90% of farms are less than 2 hectares in size (MoFA, 2012).

Farmers were generally observed to follow recommended seed rates given by MoFA, research institutes and NGOs. The mean seed rate of about 6 kg/ac recorded for maize farmers falls in line with the recommended rate of about 4-10 kg extrapolated from studies by ((IITA, 2014). The seed rate of 14 kg/ac for soya from the study also conforms to literature by (DOASL, 2006; SPG, 2016) which recommends rates ranging from about 10-22 kg. Farmers sowed averagely 17 kg of groundnuts per acre, an observation slightly deviating from that recommended by (TOF, 2015). Cowpea seed rate of about 6.5 kg/ac in UWR falls below the recommended range of about 1116 kg (SARI, 2012) but conformed to this rate in NR where the seed rate recorded was 11.8 kg/ac.

Table 4.4: Land Area, Seed Rate and Output of Major Crops during 2015 Cropping Season

Crop	NR	UWR	NR	UWR	NR	UWR	NATIONAL
	Total Area (ac) Mean (SD)		**Seed Quantity (kg/ac) Mean (SD)**		**Quantity of Grains Harvested (kg/ac) Mean (SD)**		**Achievable Yield kg/ha (kg/ac)**
Maize	3.7 (2.8)	2.2 (1.6)	5.4 (2.5)	6.0 (2.1)	496.6 (231.5)	358.9 (220.3)	6,000 (2,400)
Soya	3.3 (2.9)	1.8 (1.7)	14.1 (5.7)	15.8 (5.4)	308.0 (157.2)	256.3 (180.9)	2,300 (920)
Groundnut	2.4 (1.9)	2.4 (1.6)	15.7 (5.1)	17.9 (6.6)	333.0 (247.7)	362.5 (214.3)	2,500 (1,000)
Cowpea	1.2 (1.0)	1.2 (0.6)	11.8 (3.8)	6.5 (2.6)	195.2 (162.7)	136.4 (70.1)	2,600 (1,040)
Millet	1.7 (1.1)	1.9 (1.1)	1.8 (0.8)	2.9 (1.1)	235.5 (133.0)	195.1 (96.3)	2,000 (800)
Rice (Paddy)	4.8 (4.2)	1.3 (0.8)	38.7 (10.2)	41.6 (11.7)	505.8 (323.2)	401.6 (225.5)	6,500 (2,600)

Note: (SD) denotes Standard Deviation
Source: Field Survey Data, 2016 and MoFA, 2012.

Yields per acre of land cultivated for the major crops are generally below the achievable targets set up by (MoFA, 2012). The highest yield return in both regions was from the cultivation of rice where output was between 400 kg/ac and 510 kg/ac.

This was followed by maize output in NR, which was almost 500 kg/ac and then groundnut in the UWR with an output of more about 363 kg/ac. These output quantities recorded for rice, maize and groundnut where however far below the achievable national targets of 2,600 kg/ac; 2,400 kg/ac and 2,500 kg/ac respectively (MoFA, 2012).

4.1.5 Farm Income and other Household Income Sources

From Table 4.5, farmers in NR on the average sold approximately 1061 kg of their harvested rice, which represents 43.5% of their total harvest. This generated average total revenue of GHC 692.00 to farming household in the region thereby representing the highest farm income contributor to households. The highest income-contributing crop in the UWR was groundnuts with about 50% of harvested produce sold and an associated income generating value of approximately GHC 618.00. The least income generating crops in both regions were cowpea and millet generating GHC 105.00 and GHC102.00 respectively in NR and GHC 46.00 and GHC 31.00 respectively in UWR.

Table 4.5: Farm Income for 2015 Cropping Season

Crop	Quantity Sold (kg)		Percentage of Total Harvest Sold (%)		Total Revenue (GHC)	
	NR Mean (SD)	**UWR Mean (SD)**	**NR Mean**	**UWR Mean**	**NR Mean (SD)**	**UWR Mean (SD)**
Maize	281.1 (668.5)	157.0 (483.0)	14.9	8.8	252.1 (634.6)	171.8 (529.1)
Soya	542.8 (682.8)	268.8 (467.8)	59.3	36	560.4 (706.7)	321.7 (579.8)
Groundnuts	476.5 (667.5)	465.4 (554.1)	57	50	628 (1061.6)	617.5 (734.5)
Cowpea	76.2 (99.5)	26.5 (60.2)	40	12.7	105.2 (149.4)	46.4 (112.0)
Millet	100 (180.7	25.7 (97.6)	18.5	6.2	102.3 (193.1)	31.1 (129.1)
Rice (Paddy)	1061 (1268.2)	132.8 (237.2)	43.5	19.7	692.0 (843.1)	138.1 (247.5)

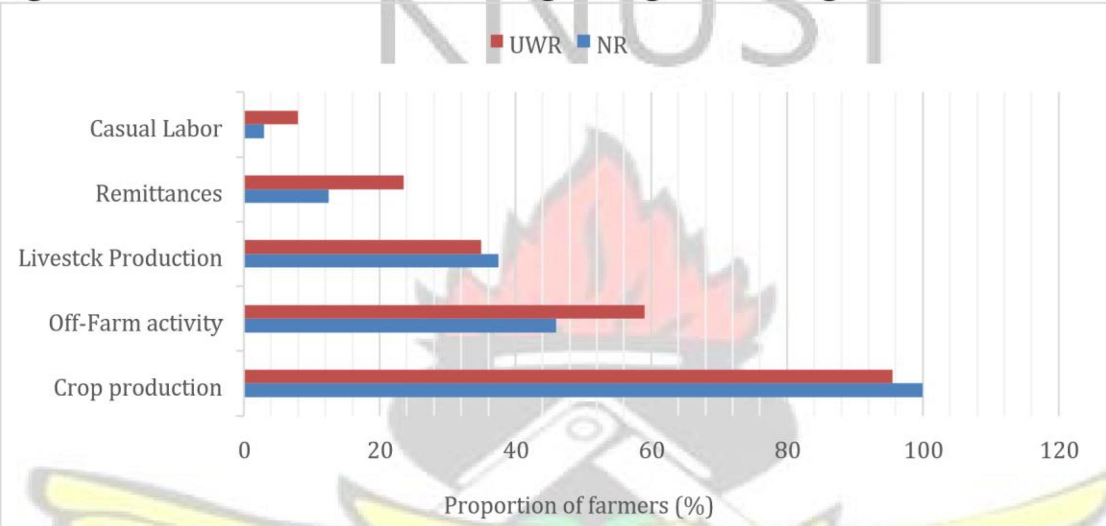
Note: (SD) implies Standard Deviation *Source: Field Survey Data, 2016.*

Considering the percentage of total harvest sold in the NR and UWR, soybeans and groundnuts recorded the highest of approximately 59% and 57% respectively in NR and 36% and 50% in UWR. The crop with the least percentage of its harvested produce sold in NR was maize (15%) and that for UWR was millet (6%). From the results it can be inferred that for farmers in the NR, per the percentage of total harvest of the major crops cultivated, maize and millet are more of food crops than cash crop.

And that for UWR was maize, cowpea and millet.

Farmers were assessed to ascertain their general sources of income and to also determine the contribution of each of these sources to total household income based on a multiple response approach. Figure 4.4 shows that crop production, livestock production and off-farm business activities are the main sources of household income in the two regions.

Figure 4.4: Main Sources of income for grain legume farming Households



Source: Field Survey Data, 2016.

More than 90% of farmers in both regions acknowledged farming as a major source of household income. Off-farm income generating activities was reported by more than 40% of famers as a major source of household income.

From Table 4.6, groundnut was the highest (29%) contributor to household incomes in UWR and soybean (37%) was the highest in NR. Off-farm activities contributed about 13% and 22% to total income in NR and UWR respectively representing the second highest income generator to households in UWR and fourth in NR.

Table 4.6: Percentage Contributions of Different Sources to Household Income

Income Source	Percentage (%)

Farm income	NR	UWR	Pooled Data
Soya	37.4	5.1	21.2
Groundnuts	19.3	28.5	23.5
Cowpea 1.8 **Cereals**	16.7	8.2	4.7
Yam	2.1	20.6	18.7
		1.2	2.4
Sub Total **77.3** **63.6** **70.5** **Off-Farm Income**		13.1 22.1	17.5
Livestock Production 7.2 8 7.6 **Remittances**		2.1 4.2	3.2
Casual Labor 0.3 2.1 1.2 Sub Total **22.7**		**36.4** **29.5**	**Grand**
Total **100** **100** **100**			

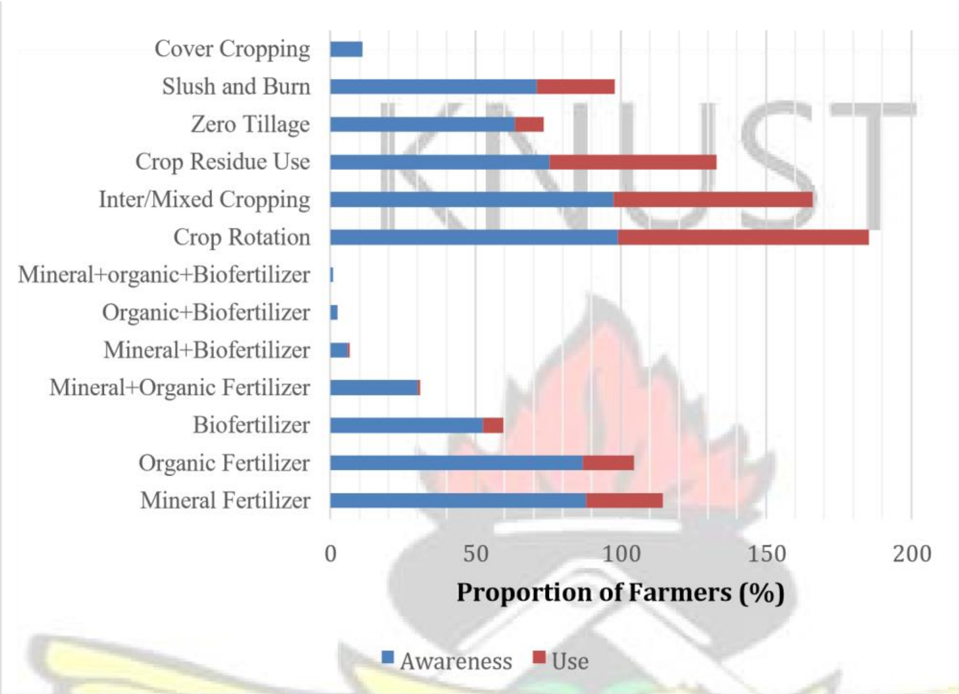
Source: Field Survey Data, 2016.

4.2 Awareness and Use of SFM Technologies

The study evaluated farmers' awareness and use of some available soil fertility management technologies recommended for legume production. From Figure 4.5a, over 80% of legume farmers were aware of the use of mineral fertilizers and organic fertilizers as standalones. However, only about 30% of them were aware that the two types of fertilizers could be combined in the production of grain legumes. For biofertilizers, about 50% of the farmers were aware that they are used to produce grain legumes. However, less than 5% of the farmers in NR knew that it could be combined with mineral fertilizers or organic fertilizer in the production of grain legumes. The trend in UWR regarding awareness about SFM was similar to the observed pattern in NR except that awareness level was generally low for farmers in UWR (Figure 4.5b). In terms of SFM technology use, the levels were generally low in both regions. Even for the well-known mineral fertilizers, only about 20% used them for grain legume production in NR and 12% in UWR.

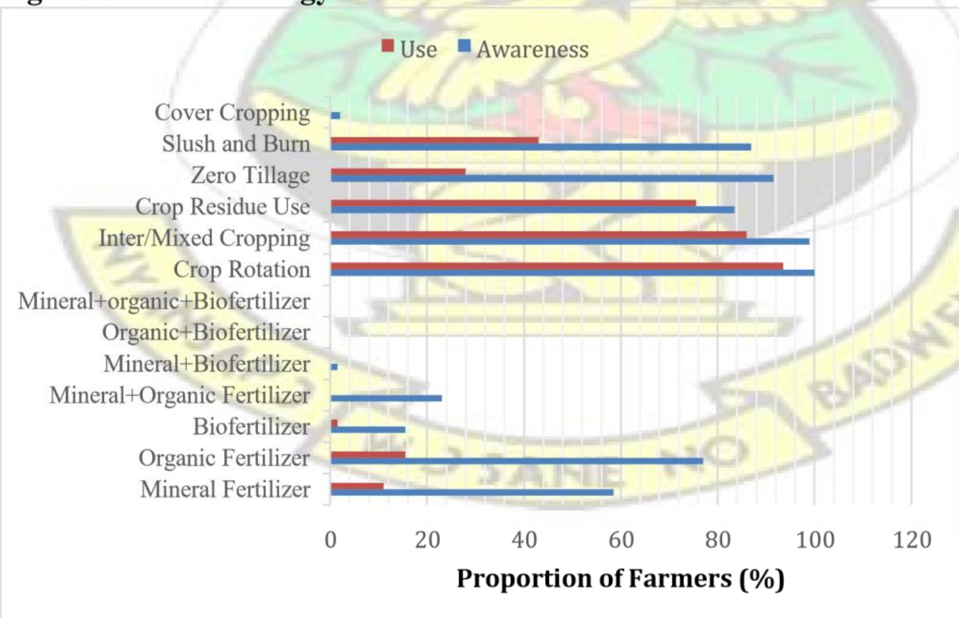
Biofertilzer which is a quite a novel technology had less than 50% of total sampled respondents being aware of it and an even smaller figure of less than 10% ever using in both regions. With the non-fertilizer SFM practices, crop rotation and inter/mixed cropping had more than 90% of farmers being aware of them with more than 70% of respondents practicing them on their legume farms in both regions. This observation indicates that grain legume farmers are more attuned to the use of non-fertilizer technologies to manage the fertility status of their soils. This could be as a result of the general view among farmers that legumes are a source of fertilizer to the soil and farmers do not have to apply fertilizers in their production.

Figure 4.5a: Technology Awareness and Use in NR



Source: Generated from Experimental Field Data, 2016.

Figure 4.5b: Technology Awareness And Use in UWR



Source: Generated from Experimental Field Data, 2016

4.3 Financial Analysis of SFM Trials in Northern and Upper West Regions

4.3.1 Quantities and Costs of Inputs under Different SFM Trials

Table 4.7 below displays the various input items and field activities undertaken for each of the selected SFM treatments or trials under soybean production on per acre basis in the NR. A review of this table shows a constant seed quantity and cost per an acre of land for all the treatments (40 kg for GHC104.00). The most expensive fertilizer treatment was TSP +Legumefix (GHC128.56 per 49.4 kg) in experiment one and Urea (GHC 165.07 per 86.9 kg) in experiment two. The least cost treatments were the biofertilizer treatments (Biofix:GHC 28.00, Nodumax and Legumefix each costing GHC 40.00). Labour cost for the various treatments was constant with the exception of threshing and transportation cost due to the variation in yield parameters for the various treatments. The highest total input cost recorded was for chemical fertilizer treatment (Urea) with the control experiments recording the least total input costs.

Input types, quantities and cost of the selected SFM treatments under soybean production in UWR are displayed in Table 4.8. Seed quantity and cost were constant for all the treatments at 40 kg and GHC 104.00. The least expensive fertilizer treatment was biofertilizer (Legumefix) at GHC 40.00 per 0.2 kg for an acre of land and the most expensive one being the combined treatment of biofertilizer and chemical fertilizer (TSP+Legumefix). Labour cost of the various activities was constant for all the treatments with the exception of cost of threshing and transportation. The variations in labour cost were however not so much between the treatments, ranging between GHC 320.00 and GHC 340.00. The highest total input cost recorded was for TSP+Legumefix treatment and the least being for the control treatments as a result of no cost of fertilizer input.

Labour Cost (GHC)

Table 4.7: Quantities and Cost of Inputs for Different SFM Trials under Soybean Production in NR (Per Acre of Land)

Cost Items	Experiment 1								Experiment 2							
	Control		Legumefix		TSP		TSP+Legumefix		Control		Biofix		Nodumax		Urea	
	Q'ty	Cost	Q'ty	Cost	Q'ty	Cost	Q'ty	Cost	Q'ty	Cost	Q'ty	Cost	Q'ty	Cost	Q'ty	Cost
A.**Seed (kg)**	40	104.0	40	104.00	40	104.00	40	104.00	40	104.00	40	104.00	40		40	104.00
B.**Fertilzer (kg)**	0	0.0	0.2	40.00	49.2	86.90	49.4	128.56	0.0	0.00	0.2	28.00	0.2	40.00	86.9	165.07
C.Sub Total		**104.00**		**144.00**		**192.56**		**232.56**		**104.00**		**132.00**		**144.00**		**269.07**
Land clearing		20.00		20.00		20.00		20.00		20.00		20.00		20.00		20.00
Ploughing		70.00		70.00		70.00		70.00		80.00		80.00		80.00		80.00
Sowing		42.00		42.00		42.00		42.00		42.00		42.00		42.00		42.00
Weeding (1&2)		70.00		70.00		70.00		70.00		70.00		70.00		70.00		70.00
Harvesting		30.00		30.00		30.00		30.00		30.00		30.00		30.00		30.00
Gathering		30.00		30.00		30.00		30.00		30.00		30.00		30.00		30.00
Threshing		37.52		59.06		61.71		68.72		50.25		100.87		65.39		101.82
Transportation		3.13		4.92		5.14		5.73		1.05		2.10		1.36		2.12
D.Sub Total		**302.65**		**325.98**		**328.86**		**336.45**		**323.3**		**374.97**		**338.75**		**375.94**
E.Total Input Cost (C+D)		**406.65**		**469.98**		**521.42**		**569.01**		**427.3**		**506.97**		**482.75**		**645.01**

Source: Generated from Experimental Field Data, 2014

Table 4.8: Quantities and Cost of Inputs for Different SFM Trials under Soybean Production in UWR (Per Acre of Land)

Cost Items	Experiment 1							
	Control		Legumefix		TSP		TSP+Legumefx	
	Q'ty	Cost	Q'ty	Cost	Q'ty	Cost	Q'ty	Cost
A. **Seed (kg)**	40	104.0	40 0.2	104.00	40	104.00	40	104.00
B. **Fertilizer (kg)**	0	0.0		40.00	49.2	86.90	49.4	128.56
C. Sub Total		**104.00**		**144.00**		**192.56**		**232.56**
Labour Cost								
Land clearing		20.00		20.00		20.00		20.00
Ploughing		75.00		75.00		75.00		75.00
Sowing		42.00		42.00		42.00		42.00
Weeding (1&2)		70.00		70.00		70.00		70.00
Harvesting		30.00		30.00		30.00		30.00
Gathering		30.00		30.00		30.00		30.00
Threshing		50.75		58.96		65.39		65.39
Transportation		4.23		4.91		5.45		5.45
D. Sub Total		**321.98**		**330.87**		**337.84**		**337.84**
E.Total Input Cost (C+D)		**425.98**		**474.87**		**530.4**		**570.4**

Source: Generated from Experimental Field Data, 2014.

The input quantities and cost for cowpea production under the selected treatments carried out in NR are displayed in Table 4.9. The chemical fertilizer (urea) treatment was the most expensive at GHC 165.07 for 55 kg of the fertilizer. The least cost treatment was the use of biofertilizers (BR3262 and BR3267) at GHC 55.00 per 0.28 kg. Where as seed quantity and cost were constant for all the treatments, labour cost per acre for the treatments ranged between GHC 325.00 and GHC 360.00.
Considering total input cost, urea treatment recorded the highest value of GHC 615.80 per acre.

Input quantities and cost of the selected SFM treatments for cowpea production in UWR is presented in Table 4.10. Chemical fertilizer (urea) is recorded as the most expensive SFM treatment (GHC 165.07 per 55 kg) for cowpea production with the least expensive treatment being the use of biofertilizer (BR3262 and BR3267) at GHC 55.00 per 0.28 kg. Labour cost per acre for the treatments ranged between GHC 320.00 and GHC 330.00. Considering total input cost, urea treatment again recorded the highest value of GHC 578.08 in the UWR.

Table 4.11 presents input quantities and cost of SFM treatments carried out for groundnut production in the NR. From the table, the least cost effective fertilizer treatment is the combined application of chemical and biofertilizer (TSP+Legumefix) recording a total value of GHC 128.56 per 49.4 kg per acre followed by the chemical fertilizer treatment (TSP) with a value of GHC 86.90 per 49.2 kg per acre. The least cost treatment was the use of biofertilizer (Legumefix) with a value of GHC 40.00 per 02 kg per acre of land. Labour cost varied between GHC 261.00 and GHC 268.00 for

the treatments. Total input cost was highest for the combined treatment (TSP+Legumefix) with a value of 503.11 with the least being the biofertilizer treatment (Legumefix) recording approximately GHC 412.00.

Labour Cost		
Land clearing	20.00	20.00
Ploughing	80.00	80.00
Sowing	42.00	42.00

Table 4.9: Quantities and Cost of Inputs for Different SFM Trials under Cowpea Production in NR (Per Acre of Land)

Cost Items	Experiment 1							
	Control		BR3262		BR3267		Urea	
	Q'ty	Cost	Q'ty	Cost	Q'ty	Cost	Q'ty	Cost
A. Seed (kg)	55	91.85	55	91.85	55	91.85	55	91.85
B. Fertilizer (kg)	0	0.00	0.28	55.00	0.28	55.00	86.88	165.07
C.Sub Total (A+B)		**91.85**		**146.96**		**146.96**		**256.93**
		20.00		20.00				
		80.00		80.00				
		42.00		42.00				
		70.00		70.00				
		30.00		30.00				
		30.00		30.00				
		53.02		58.69				
Weeding (1&2)						70.00		70.00
Transportation		3.31		3.67		4.58		5.11

Harvesting	30.00	30.00
Gathering	30.00	30.00
Threshing	73.20	81.76

	328.34	**334.36**		
E. Total Input Cost (C+D)	**420.19**	**481.32**	**496.74**	**615.8**

Source: Generated from Experimental Field Data, 2014.

Table 4.10: Quantity and Cost of Inputs for Different SFM Trials under Cowpea Production in UWR (Per Acre of Land)

Cost Items	**Experiment 1**							
	Control		**BR3262**		**BR3267**		**Urea**	
	Q'ty	**Cost**	**Q'ty**	**Cost**	**Q'ty**	**Cost**	**Q'ty**	**Cost**
A. Seed (kg)	55	91.85	55	91.85	55	91.85	55	91.85
B. Fertilizer (kg)	0	0.00	0.28	55.00	0.28	55.00	86.88	165.07
C. Sub Total (A+B)		91.85		146.96		146.96		256.93
clearing		20.00		20.00		20.00		20.00
Ploughing		80.00		80.00		80.00		80.00
Sowing		42.00		42.00		42.00		42.00
D. Sub Total						**49.78**		**358.87**

Labour Cost Land

Weeding (1&2)	75.00	75.00	75.00	75.00
Harvesting	30.00	30.00	30.00	30.00
Gathering	30.00	30.00	30.00	30.00
Threshing	40.64	44.48	48.49	41.56
Transportation	2.54	2.78	3.03	2.60
D. Sub Total	**320.18**	**324.26**	**328.52**	**321.15**
E.Total Input Cost (C+D)	**412.03**	**471.22**	**475.49**	**578.08**

Source: Generated from Experimental Field Data, 2014.

Table 4.11: Quantity and Cost (GHC) of Inputs for Different SFM Trials under Groundnut Production in NR (Per Acre of Land)

Cost Items	**Experiment 1**							
	Control		**Legumefix**		**TSP**		**TSP+Legumefx**	
	Q'ty	**Cost**	**Q'ty**	**Cost**	**Q'ty**	**Cost**	**Q'ty**	**Cost**
A. Seed (kg)	40 0	106.80 0.0	40	106.80	40	106.80	40	106.80
B. Fertilizer (kg)			0.2	40.00	49.2	86.90	49.4	128.56
C. Sub Total (A+B)		**106.80** 20.00		**146.80**		**195.36**		**235.36**

Labour Cost				
Land clearing		20.00	20.00	20.00
Ploughing	70.00	70.00	70.00	70.00
Sowing	30.00	30.00	30.00	30.00
Weeding (1&2)	75.00	75.00	75.00	75.00
Harvesting	30.00	30.00	30.00	30.00
Gathering	30.00	30.00	30.00	30.00
Threshing	5.29	8.94	8.97	10.63
Transportation	1.06	1.79	1.79	2.13
D. Sub Total	**261.34**	**265.73**	**265.77**	**267.75**
E.Total Input Cost (C+D)	**368.14**	**412.53**	**461.13**	**503.11**

Source: Generated from Experimental Field Data, 2014.

4.3.2 Output and Market Values Obtained under Different SFM Trials

Average output and market values obtained under the various treatments for soybean in NR and UWR are presented in Table 4.12. Experiment one in NR and UWR had the highest output recorded for the combined SFM treatment; TSP+Legumefix (572.66 kg and 585.89 kg per acre respectively) with the least yields associated with the control treatments (312.71 kg and 422.95 kg per acre respectively). Experiment two established in NR had the highest output under the chemical fertilizer treatment (Urea) with an output value of 848.48 kg per acre followed by the biofertilizer treatment (Biofix) with an output of 840.59 kg per acre.

For both regions TSP+Legumefix and the control treatments recorded the highest and lowest market values respectively, reflecting the output levels since unit price was the same. The highest market value for yields in experiment two in the NR is noted for chemical fertilizer (Urea) and biofertilizer (Biofix) treatments with values of approximately GHC 1357.00 and GHC 1345.00 respectively per acre.

Table 4.12: Quantity of Grains and Market Values of Soybean Trials in NR and UWR (2014 Cropping Season) Per Acre

Trials	NR			UWR		
	Quantity Harvested (kg)	Unit Price (GHC)	Market Value of Output (GHC)	Quantity Harvested (GHC)	Unit Price Output	Market Value of (kg) (GHC)
Experiment 1 **Control**	312.71	1.6	**500.34**	422.95	1.6	**676.72**
Legumefix	492.18	1.6	**787.49**	491.33	1.6	**786.13**
TSP	514.28	1.6	**822.85**	544.95	1.6	**871.92**
TSP+Legumefix	572.66	1.6	**916.26**	585.89	1.6	**937.42**
Experiment 2 **Control**	418.73	1.6	**669.96**	-	-	-
Biofix	840.59	1.6	**1344.95**	-	-	-
Nodumax	544.91	1.6	**871.86**	-	-	-
Urea	848.48	1.6	**1357.57**	-	-	-

Source: Generated from Experimental Field Data, 2014.

Comparing all the yield values of the treatments in the various experiments in the respective regions (NR and UWR), for experiment one, the integrated soil fertility management treatment generated the highest output conforming to the notion that ISFM is the future of SFM hence its advocacy in agriculture.

Table 4.13 below showcases quantity of outputs and their associated market values for various SFM treatments under cowpea production in NR and UWR. The results show the highest output (511.03 kg) with the highest market value of GHC 1022.06 to be linked to chemical fertilizer treatment (urea) in NR. Output and market values in the UWR are generally low as compared to NR. This could be attributed to rainfall fluctuations in the region. The treatment with the highest production output and market value in UWR was the biofertilizer treatment (303.06 kg and GHC 606.12 respectively). Relatively, chemical fertilizer treatment (urea) generated the highest yield as compared to the other treatments in their respective experimental locations (NR and UWR). This conforms to finding from other studies that point to immense impacts of chemical fertilizers on crop yields (Shand, 2007; Al-Khalil and Ali, 2009).

Table 4.13: Quantity of Grains and Market Values of Cowpea Trials in NR and UWR (2014 Cropping Season) Per Acre

Trials	**NR**			**UWR**		
	Quantity Harvested (kg)	Unit Price (GHC)	Market Value of Output (GHC)	Quantity Harvested (kg)	Unit Price (GHC)	Market Value of Output (GHC)
Control	331.39	2.00	**662.78**	254.00	2.00	**508**
BR3262	366.81	2.00	**733.62**	277.97	2.00	**555.94**
BR3267	457.51	2.00	**915.02**	303.06	2.00	**606.12**
Urea	511.03	2.00	**1022.06**	259.72	2.00	**519.44**

Source: Generated from Experimental Field Data, 2014.

The highest output and market value recorded for groundnut production in NR (Table 4.14) was linked to the combined fertilizer treatment of TSP+Legumefix (212.6 kg and GHC 807.77). Comparatively, yield from combined treatment was higher than all the other treatments with TSP and Legumefix having very close outputs when used as standalone.

Table 4.14: Quantity of Grains and Market Values of Groundnut Trials in NR (2014 Cropping Season)

	NR		
Trials	Quantity Harvested (kg)	Unit Price (GHC)	Market Value of Output (GHC)
Control	105.71	3.8	**401.71**
Legumefix	178.86	3.8	**679.66**
TSP	179.43	3.8	**681.83**
TSP+Legumefix	212.57	3.8	**807.77**

Source: Generated from Experimental Field Data, 2014.

4.3.3 Profitability of Grain Legume Trials under Different SFM Technologies

Using a benefit cost ratio approach to ascertain the most financially viable and rewarding SFM treatment. The various benefits and costs are extracted from the initial cost and revenue tables and presented in Table 4.15. From the table, despite the high benefits generated from the chemical fertilizer treatments (TSP and Urea) and the integrated treatments (TSP+Legumefix) as compared to the controls and biofertilizer treatments (Biofix, Nodumax and Legumefix), the associated higher costs of these treatments makes them less financially viable and sustainable treatments to be recommended to farmers. Comparatively, BCR values for the biofertilizer treatments in their respective experiments under the selected legumes are higher than the chemical and integrated treatments. This finding is consistent with (Howladar & Rady, 2013 ; Mazid & Khan 2014) who noted that biofertilizers are cost effective SFM technologies or practices in contrast to chemical fertilizers.

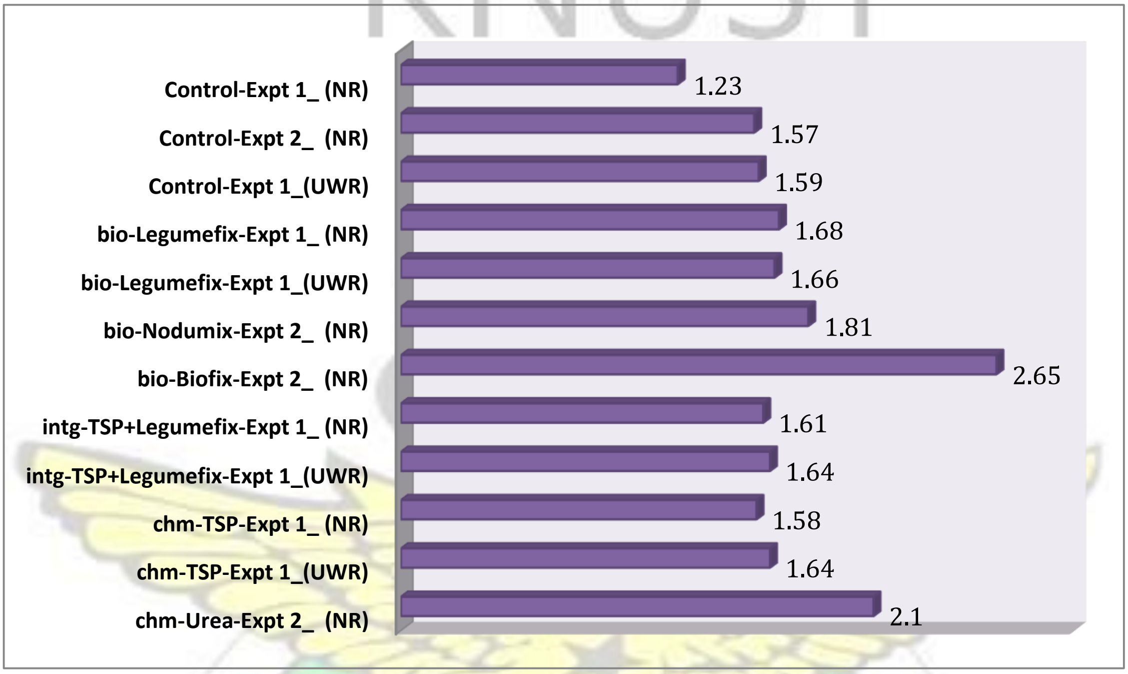
Table 4.15: Summary Table on Benefit Cost Ratios (BCR) for Legume Production under Different SFM Trials

TRIALS	BENEFIT (B)	COST (C)	BCR (B/C)
Experiment 1_Soya (NR)			
Control	500.34	406.65	**1.23**
Legumefix	787.49	469.98	**1.68**
TSP	822.85	521.42	**1.58**
TSP+Legumefix	916.26	569.01	**1.61**
Experiment 2_Soya (NR) Control	669.96	427.3	**1.57**
Biofix	1344.95	506.97	**2.65**
Nodumax	871.86	482.75	**1.81**
Urea	1357.57	645.01	**2.10**
Experiment 1_Soya (UWR) Control	676.72	425.98	**1.59**
Legumefix	786.13	474.87	**1.66**
TSP	871.92	530.4	**1.64**
TSP+Legumefix	937.42	570.4	**1.64**
Experiment 1_Cowpea (NR) Control	662.78	420.19	**1.58**
BR3262	733.62	481.32	**1.52**
BR3267	915.02	496.74	**1.84**
Urea	1022.06	615.8	**1.66**
Experiment 2_Cowpea (UWR) Control	508	412.03	**1.23**
BR3262	555.94	471.22	**1.18**
BR3267	606.12	475.49	**1.27**
Urea	519.44	578.08	**0.90**
Experiment 1_Groundnuts (NR) Control	401.71	368.14	**1.09**
Legumefix	679.66	412.53	**1.65**
TSP	681.83	461.13	**1.48**
TSP+Legumefix	807.77	503.11	**1.61**

Source: Generated from Experimental Field Data, 2014.

Per the BCRs of the different SFM treatments/trials for soybean production in NR and UWR, the most financially rewarding technology for soybean was the biofertilzer technology package; BIOFIX (Figure 4.6). Comparatively it has the highest BCR value (2.65) implying its impact on the output of soya production was relatively higher as against cost of producing soybean thereby making it more financially viable. The mineral fertilizer treatment (urea) had an equally high BCR value (2.10). However, despite its high return on investment, the initial cost of approximately GHC165.00 would present a challenge to smallholder farmers who are most often than not financially constrained. Though profitable, the control plots, which represented the present farmer practice of no fertilizer application, had low BCRs of between 1.20-1.60. This implies that farmers are not making maximum returns on their investment in grain legume production under current soil fertility management practices.

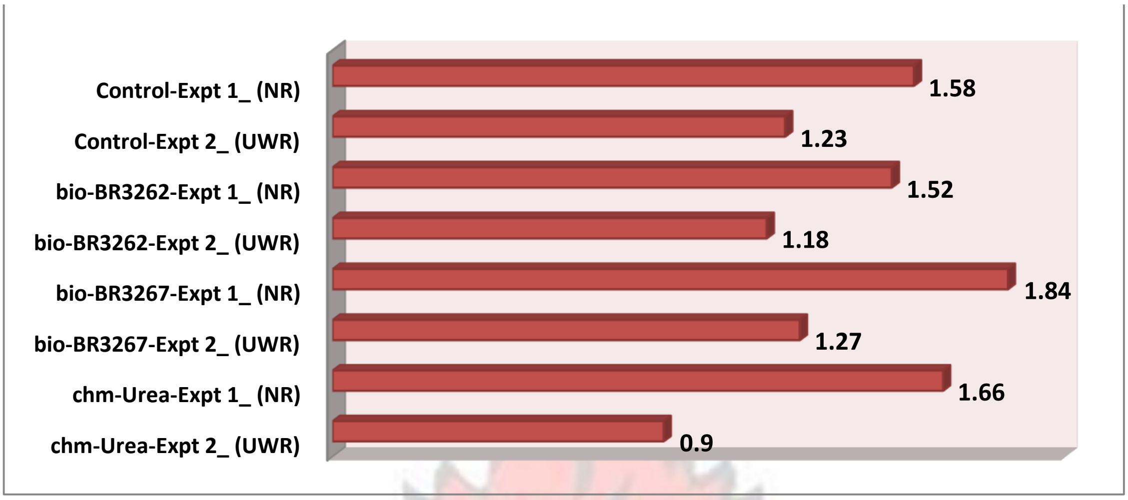
Figure 4.6: Benefit Cost Ratios of Different SFM Treatments for Soyb ean Production



Source: Generated from Authors Own Calculations, 2016.

The BCRs generated for cowpea production under the different SFM technologies showed that the most financially rewarding SFM technology was the biofertilizer under the treatment BR3267 in the Northern Region with a BCR of 1.84 (Figure 4.7). Its equivalent treatment in the UWR however resulted in a rather low BCR value (1.27). Evidently however output values as against production cost of cowpea under the various treatments in the UWR were generally low as compared to that of NR; thereby resulting in lower BCR values in UWR.

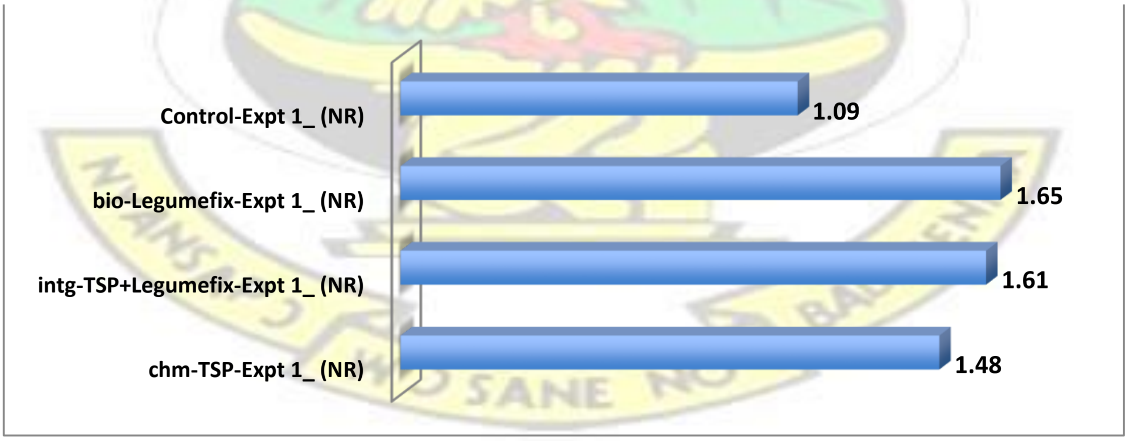
Figure 4.7: Benefit Cost Ratios of Different SFM Treatments for Cowpea Production



Source: Generated from Authors Own Calculations, 2016.

Figure 4.8 displays graphically the BCR values for the groundnut trials. From the chart, the best and financially rewarding fertilizer treatment was the biofertilizer treatment; LEGUMEFIX. It was associated with the highest BCR value of 1.65 when compared to the other SFM treatments.

Figure 4.8: Benefit Cost Ratios of Different SFM Treatments for Groundnut Production



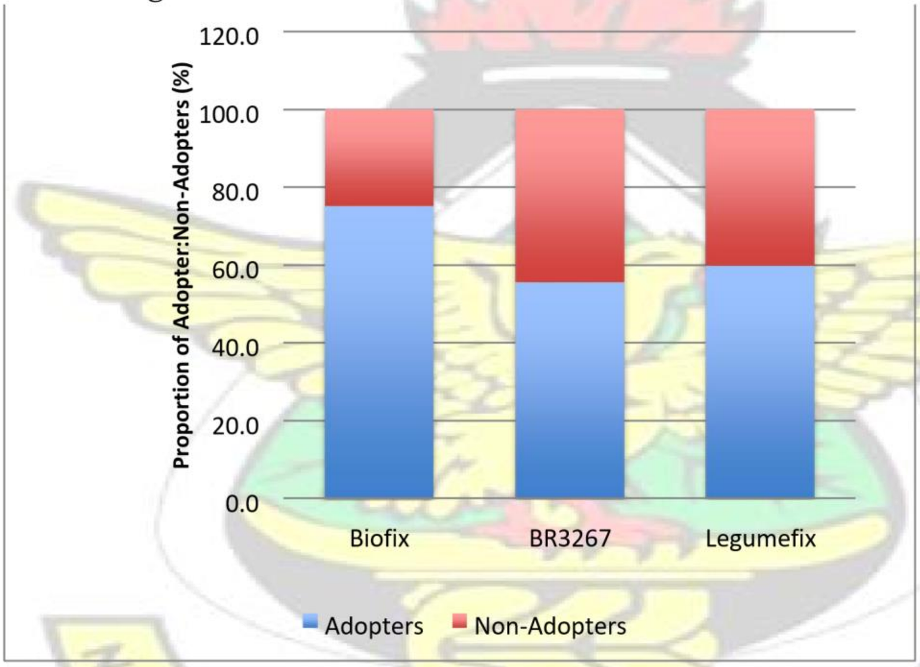
Source: Generated from Authors Own Calculations, 2016.

4.4 Ex-ante Adoption of Financially Rewarding Biofertilizer Technologies by Legume Farmers

Based on the analysis above, Biofix, BR3267 and Legumefix were the most financially rewarding technologies for soya, cowpea and groundnut production respectively. These technologies were described and presented to legume farmers to gauge their future adoption decision. Figure 4.9 show that more than 50% of legume farmers will adopt these biofertilizers when they are made available on the market, with the highest rate of adopters recorded for Biofix (75%).

Table 4.16 provides descriptive characteristics of adopters and non-adopters of the three biofertilizers.

Figure 4.9: Farmers' Decision to Adopt the Most Financially Rewarding SFM Techonologies



Source: Generated from Field Survey Data, 2016.

Table 4.16: Descriptive Statistics on Adopters and Non-Adopters of Best SFM Technologies

Variables	BIOFIX			BR3267			LEGUMEFIX		
	Adopters (N=300)	**Non-Adopters (N=100)**	**Chi$_2$**	**Adopters (N=222)**	**Non-Adopters (N=178)**	**Chi^2**	**Adopters (N=239)**	**Non-Adopters (N=161)**	**Chi^2**
GEN									
Male	198(66.0)	59(59.0)	1.600	138(62.2)	119(66.9)	0.947	168(70.3)	89(55.3)	9.440***
Female	102(34.0)	41(41.0)		84(37.8)	59(233.1)		71(29.7)	72(44.7)	
AGE									
< 20	2(0.7)	1(1.0)	25.312***	0(0.0)	3(1.7)	44.646***	1(0.4)	2(1.2)	32.427***
20-40	140(46.7)	75(75.0)		89(40.1)	126(70.8)		102(42.7)	113(70.2)	
41-60	119(39.6)	20(20.0)		99(44.6)	40(22.5)		101(42.3)	38(23.6)	
>60	39(13.0)	4(4.0)		34(15.3)	9(5.1)		35(14.6)	8(5.0)	
YEXP									
<10	28(9.3)	55(55.0)	103.677***	11(5.0)	72(40.4)	101.790***	14(5.9)	69(42.9)	103.867***
10-20	127(42.3)	34(34.0)		85(38.3)	76(42.7)		93(38.9)	68(42.2)	
21-30	83(27.7)	5(5.0)		68(30.6)	20(11.2)		75(31.4)	13(8.1)	
>30	62(20.7)	6(6.0)		58(26.1)	10(5.6)		57(23.8)	11(6.8)	

YEDU									
None	229(76.3)	61(61.0)	9.290**	172(77.5)	118(66.3)	9.021**	178(74.5)	112(69.6)	3.656*
Basic	48(16.0)	25(25.0)		36(16.2)	37(20.8)		43(18.0)	30(18.6)	
SHS	18(6.0)	10(10.0)		9(4.1)	19(10.7)		16(6.7)	12(7.5)	
Tertiary	5(1.7)	4(4.0)		5(2.2)	4(2.2)		2(0.8)	7(4.3)	

FBO									
Yes	183(61.0)	34(34.0)	22.029***	142(64.0)	75(42.1)	18.967***	139(58.2)	78(48.4)	2.431
No	117(39.0)	66(66.0)		80(36.0)	103(57.9)		100(41.8)	83(51.6)	
EXT									
Yes	258(86.0)	73(73.0)	8.880***	203(91.4)	128(71.9)	26.401***	205(85.8)	126(78.3)	3.804**
No	42(14.0)	27(27.0)		19(8.6)	50(28.1)		34(14.2)	35(21.7)	
CRDT									
Yes	111(37.0)	13(13.0)	20.196***	92(41.4)	32(18.0)	25.427***	86(36.0)	38(23.6)	6.894***
No	189(63.0)	87(87.0)		130(58.6)	146(82.0)		153(64.0)	123(76.4)	
FINC									
Yes	294(98.0)	97(97.0)	0.341	217(97.7)	174(97.8)	0.001	232(97.1)	159(98.8)	1.244
No	6(2.0)	3(3.0)		5(2.3)	4(2.2)		7(2.9)	2(1.2)	

OffAct									
Yes	175(58.3)	35(35.0)	16.374***	145(65.3)	65(36.5)	32.855***	146(61.1)	64(39.8)	17.561***
No	125(41.7)	65(65.0)		77(34.7)	113(63.5)		93(38.9)	97(60.2)	
LSTK									
Yes	124(41.3)	19(19.0)	16.286***	98(44.1)	45(25.3)	15.304***	110(46.0)	33(20.5)	27.293***
No	176(58.7)	81(81.0)		124(55.9)	133(74.7)		129(54.0)	128(79.5)	

Note: ***, **, * signifies statistical significance at 1%, 5% and 10% respectively

From the results of the Chi-square test, it can be established that the socio-economic characteristics of adopters of the biofertilizers differ from that of non-adopters and as such further analysis with the appropriate econometric models can be done to further explore the relationships between these variables and the future adoption decision of farmers.

The results of the multivariate probit model analysis on the future adoption decisions of farmers in the two regions (NR and UWR) are presented in Table 4.17. The decision of farmers to adopt the use of these biofertilizers reveal positive cross correlation coefficients except for Legumefix and Biofix in UWR. Statistical significance was also measured at 1% and 10% for the correlation between Biofix and BR3267 only, in NR and UWR respectively. This suggests that the adoption decisions made by farmers in relation to the biofertilizers are somewhat complementary, thereby endorsing the use of the joint estimation (multivariate) rather than single estimations (univariate) models.

Table 4.17: Multivariate Probit model on Determinants of Biofertilizers Adoption Decision for the Different Locations

Categories	Variables	Northern Region			Upper West Region		
		BIOFIX	**BR3267**	**LEGUMEFIX**	**BIOFIX**	**BR3267**	**LEGUMEFIX**
INDIVIDUAL CHARACTERISTICS	*CONSTANT*	0.2919 (0.62)	-1.3774 (-2.86)	0.5243 (1.14)	-1.9057 (-1.97)	-2.2165 (-2.78)	0.7778 (1.11)
	GEN	-0.0347 (-0.11)	-0.9060*** (-2.75)	0.2189 (0.73)	0.2987 (0.82)	0.5194 (0.18)	-0.0140 (-0.20)
	AGE	-0.0137 (-0.15)	0.0119 (0.95)	-0.0085 (-0.68)	-0.0112 (-0.67)	0.0004 (0.03)	-00078 (-0.56)
	YEDU	-0.0234 (-0.78)	0.0277 (0.89)	0.1246*** (2.61)	0.0135 (0.45)	-0.0019 (-0.07)	-0.0045 (-0.20)
FARM LEVEL CHARACTERISTICS	*YEXP*	0.0535*** (3.19)	0.0685*** (3.95)	0.0219 (1.43)	0.0953*** (4.44)	0.0629*** (3.81)	0.0065 (0.44)
	TFLC	0.0384 (1.34)	0.0178 (0.57)	-0.0382 (-1.43)	0.0334 (0.62)	-0.0253 (-0.54)	0.0179 (0.43)
	LSTK	-0.0778 (-0.33)	0.2525 (1.11)	-0.1041 (-0.45)	0.0722 (0.23)	-0.0767 (-0.30)	-0.3368 (-1.52)
	FInc	-	-	-	0.8139 (1.25)	0.3596 (0.64)	0.0768 (0.16)
	FBO	0.5255** (2.46)	0.5448** (2.51)	0.0981 (0.47)	0.6342** (2.43)	0.5937*** (2.80)	0.1385 (0.73)

INSTITUTIONAL CHARACTERISTICS	*DisEXT*	-0.0019 (-0.12)	-0.0181 (-1.20)	-0.0191 (-1.08)	-0.0003 (-0.01)	-0.0016 (-0.09)	-0.0155 (-0.99)

	DisAgro	-0.0061 (-0.32)	-0.1149 (-0.63)	-0.0304** (-1.99)	-0.0368** (-2.04)	-0.0019 (-0.13)	-0.0092 (-0.68)
	CRDTamt	0.0005 (0.58)	0.0003 (0.37)	0.0011 (1.07)	0.0042*** (3.34)	0.0001 (0.08)	0.0001 (0.08)
	OFFACT	0.0228 (0.11)	0.4984** (2.28)	0.0739 (0.35)	0.8139 (1.25)	0.4851** (1.99)	0.0032 (0.02)
Technology	*BIOAW*	0.0639 (0.21)	-0.2474 (-0.83)	0.4063 (1.34)	0.5446** (1.99)	0.4287* (1.95)	-0.0767 (-0.16)
Loglikelihood		-290.7023			-302.5065		
$Wald\chi^2$(36)-test		91.06***			101.40***		
Cross Equation Correlation		$\rho_{BR,BF}$ =0.3869*** $\rho_{LF,BF}$ =0.0181 $\rho_{LF,BR}$ =0.1704			$\rho_{BR,BF}$ =0.2754* $\rho_{LF,BF}$ =-0.0618 $\rho_{LF,BR}$ =0.0735		

Likelihood ratio test of	$\rho_{BR,BF} = \rho_{LF,BF} = \rho_{LF,BR} = 0$ $chi^2(3)$=10.788**	$\rho_{BR,BF} = \rho_{LF,BF} = \rho_{LF,BR} = 0$ $chi^2(3)$= 3.4508

Note: ***, **, * denote significance at 1, 5 and 10% respectively; z-values are in parenthesis*;* $P_{BR,BF}$, $P_{LF,BF}$ *and* $P_{LF,BR}$ denote the possible cross correlation between the biofertilizers (*Source: Authors Computation*, *2016.*

In terms of individual characteristics, the coefficient of the variable representing gender of respondent is negative and statistically significant at 1% for the adoption of BR3267 in NR. The negative sign suggests that females in the NR are more likely to adopt the use of BR3267 for the cultivation of their cowpea as compared to their male counterparts. Though this is in contrast with existing literature of the view that males who are mostly prime decision makers and in control of resources are mostly adopters of improved technologies (Mignouna *et al.,* 2011), women decision to adopt BR3267 for cowpea production can be attributed to cowpea being a food crop mostly cultivated by women in the study area. Number of years of formal education is statistically significant for the adoption of Legumefix for groundnut production in NR implying higher education increases the likelihood of adoption as reported by (Ajewole, 2010; Mignouna *et al.*, 2011; Namara *et al.*, 2013).

Under farm level characteristics, only the coefficient of the variable representing number of years of farming experience emerged positive and statistically significant at 1% for the adoption of Biofix and BR3267 in both regions. This outcome is in conformity with previous studies that postulated a significantly positive correlation between farmers with more experience in farming and the adoption of improved agricultural technologies (Edemeades *et al.,* 2008; Onumadu and Osahon, 2014).

The coefficient of membership of a farmer-based organization as expected was positive and statistically different from zero for Biofix and BR3267 in both NR and UWR. This finding accords with the results of other researchers (Foster and Rosenzweig 1995; Conley and Udry 2010; Katungi and Akankwasa, 2010) who proposed advancement in agricultural technology adoption through FBO membership. The negative sign of all the distance variables is much anticipated since distance has been known to impede the progress of most activities. Hence the farther away extension offices and agro input shops are from farmers, the less likely they are able to access production information and production inputs thus impeding adoption of improved technologies. This results in farmers being less informed about the prospects of improved agricultural technologies as well as limited access to the technology even if it is available on the market. The distance variable was however only significantly different from zero at 5% for the adoption of Legumefix in NR and Biofix in UWR.

Recognized as a key-stimulating factor for agricultural development in developing countries (Kiplimo, 2015), amount of credit borrowed during the 2015 cropping season was generally positive for all the biofertilizer adoption parameters. This is consistent with an extensive amount of literature all postulating a positive impact of credit on adoption decision (Andre and Mulat, 1996; Cornejo and McBrid 2002; Hazarika and Alwang, 2003). This variable was statistically significant for the adoption of only Biofix in NR.

Noted as an efficient alternative to borrowed capital especially in developing countries, off-farm income has been known to positively impact on the adoption of improved agricultural technologies (Diiro, 2013). This is evident from the study as farmer's participation in off-farm income generating activities is positive correlated with the adoption decision for all three biofertilizers and statistically significant for the adoption of BR3267 in both regions.

Although a novel agricultural SFM technology, demonstration fields established by a couple of research institutes and organizations including SARI and IITA in northern Ghana created some sort of awareness of the biofertilizer technology. The variable representing farmers' awareness of the biofertilizers emerged positive for most of the adoption parameters except BR3267 in NR and Legumefix in UWR but was positive and statistically significant for Biofix in NR and BR3267 in UWR. This finding is consistent with a priori expectation since awareness has been known to reduce performance uncertainties and as such correlates positively with the adoption of new technologies (Caswell *et al.*, 2001; Bonabana- Wabbi 2002).

The multivariate probit model estimates for the pooled sample are presented in Table 4.18. The female gender was associated with the adoption of biofertilizer as found in the individual models for the different locations.

Table 4.18: Multivariate Probit model on Determinants of Biofertilizers Adoption Decision for Pooled Sample

Categories	Variables	BIOFIX	BR3267	LEGUMEFIX
	CONSTANT	-0.5371 (-0.85)	-1.3110**	0.3957 (0.72)
INDIVIDUAL CHARACTERISTICS		-0.0490 (-0.25)		0.2620 (1.55)
	AGE	-0.0077 (-0.79)	0.0081 (0.86)	-0.0078 (-0.89)
	YEDU	-0.0101 (-0.53)	0.0244 (1.27)	0.0081 (0.47)
FARM LEVEL CHARACTERISTICS	*YEXP*	0.0545*** (4.82)	0.0540*** (5.04)	0.0074 (0.78)
	TFLC	-0.0119 (-0.47)	-0.0106 (-0.42)	-0.0027 (-0.13)
	LSTK	0.1238 (0.70)	0.9993 (0.61)	0.2991** (2.00)
	FInc	0.4191** (0.78)	1.4059** (1.97)	0.2174 (0.47)
INSTITUTIONAL CHARACTERISTICS	*FBO*	0.5581*** (1.85)	0.4953*** (3.31)	0.0103 (0.08)
	DisEXT	-0.0001 (-0.01)	-0.0184* (-1.69)	-0.0254** (-2.56)
	DisAgro	-0.0149 (-1.23)	-0.0080 (-0.68)	-0.0112 (-1.08)
	CRDTamt	0.0015* (1.85)	0.0035*** (4.01)	0.0001 (0.16)
	OFFACT	1.0001 (0.62)	0.1295 (0.85)	0.3042 (2.19)
Technology	*BIOAW*	0.1885 (1.06)	0.1740 (0.18)	0.1410 (0.96)
Loglikelihood		-618.8175		
Wald χ^2**(39)-test**		180.04 [0.000]		
Cross Equation Correlation			$\rho_{BR,BF}$ = **0.0988***** $\rho_{LF,BF}$ = **-0.0156** $\rho_{LF,BR}$=**0.0859**	

ρ ρ $=\rho_{LF,BR} = 0$

		(-2.12)	
GEN		-0.5163*** (-2.75)	

Likelihood ratio test of: $_{BR,BF}$ = $_{LF,BF}$ *chi*$_2$**(3)=9.7473**

prob>chi^2= **0.0024**

Note: ***, **, * denote significance at 1, 5 and 10% respectively; Absolute t-values are in parenthesis; $P_{BR,BF,}$ $P_{LF,BF}$ *and* $P_{LF,BR}$ denote the possible cross correlation between the biofertilizers

Source: Authors Computation, 2016.

Age variable was negative and statistically insignificant for all except BR3267. This negative sign implies younger farmers have a higher tendency to adopt BR3267 technology than their older counterparts. This analogy is backed by studies of (Mauceri *et al,*. 2005; Alexander and Van Mellor,2005) who found a negative correlation with the argument that younger generations are likely to be less risk-averse due to the availability of information at their disposal and as such will exhibit more flexibility towards the adoption of a new technology.

The coefficient of the variable representing number of years of experience in farming was positive for all the adoption parameters and statistically significant at 1% for all with the exception of Legumefix. This suggests that farmers with more experience in legume production are the more likely to adopt these SFM technologies. This outcome concords with the findings of other studies (Edemeades *et al.*, 2008; Onumadu and Osahon, 2014).

The effect of land allocated to legume production on adoption decision of Legumefix was positive and statistically significant at 5% . This positive relationship is consistent with previous findings from studies by Ahmed, (2004), Uaiene *et al.*, (2009) and Mignouna *et al.*, (2011). This finding indicates that farmers who cultivate grain legumes on large scale and for commercial purposes are more likely to adopt new improved technologies that will enhance their profitability.

Farm income as major source of household income was positive for all SFM technologies but only statistically significant at 5% for Biofix and BR3267. This implies that for these two SFM technologies, farm income plays a vital role in farmer's decision to adopt their use.

As expected and consistent with the results for the individual location models, FBO membership had a positive relationship with all adoption decisions in the pooled model.

Farmer's engagement in off-farm activities was positive for all the SFM technologies but statistically significant at 5% for BR3267. This outcome shows that farmers involved in off-farm activities are more likely to adopt this SFM technology as compared to their counterparts who do not indulge in any off-farm activity. Off farm activities has been identified as an alternative to borrowed capital, which is mostly a major constraint in developing countries (Diiro, 2013).

4.5 Willingness to Pay for SFM Technologies

4.5.1 Determinants of Farmers' Willingness to Pay for Selected SFM Technologies

Following the selection of the financially rewarding SFM technologies for the three legumes, a bidding game was conducted to determine farmers' WTP for each of the technologies. Based on the bids or prices proposed (Table 4.19) for each of the technologies, farmer's responses were varied.

Table 4.19: Proposed Bid Prices (GHC) for the Selected SFM Technologies

Biofertilizer	Bid 1	Higher Bid	Lower Bid
Biofix	28.00	56.00	14.00
BR3267	55.00	110.00	28.00
Legumefix	40.00	80.00	20.00

Source: Authors Computation, 2016.

From Table 4.20, responses show that less than 10% of farmers were willing to pay for the recommended biofertilizers at their respective initial bids/prices. However, when the initial bids/prices were reduced by 50%, about 50% of legume farmers were willing to pay for Biofix, 40% were willing to pay for Legumefix and some 20% were willing to pay for BR3267. Farmer's willingness to pay for BR3267 was generally lower for all its proposed bid prices as compared to Biofix and Legumefix. This could be attributed to its high cost relative to the other biofertilizers.

Generally, despite farmers' willingness to adopt the use of biofertilizers in the near future as presented and discussed earlier, they are more or less adamant in buying these biofertilizers at their current ex-factory prices. This could result from their inadequate knowledge on the biofertilizer technology as well as use since it is still a novel technology to farmers in Ghana. Also farmers in the study area are generally smallholder farmers who are considered "poor" and mostly resource and credit constrained.

Table 4.20: Farmers Willingness to Pay for Bid Prices (Pooled Sample)

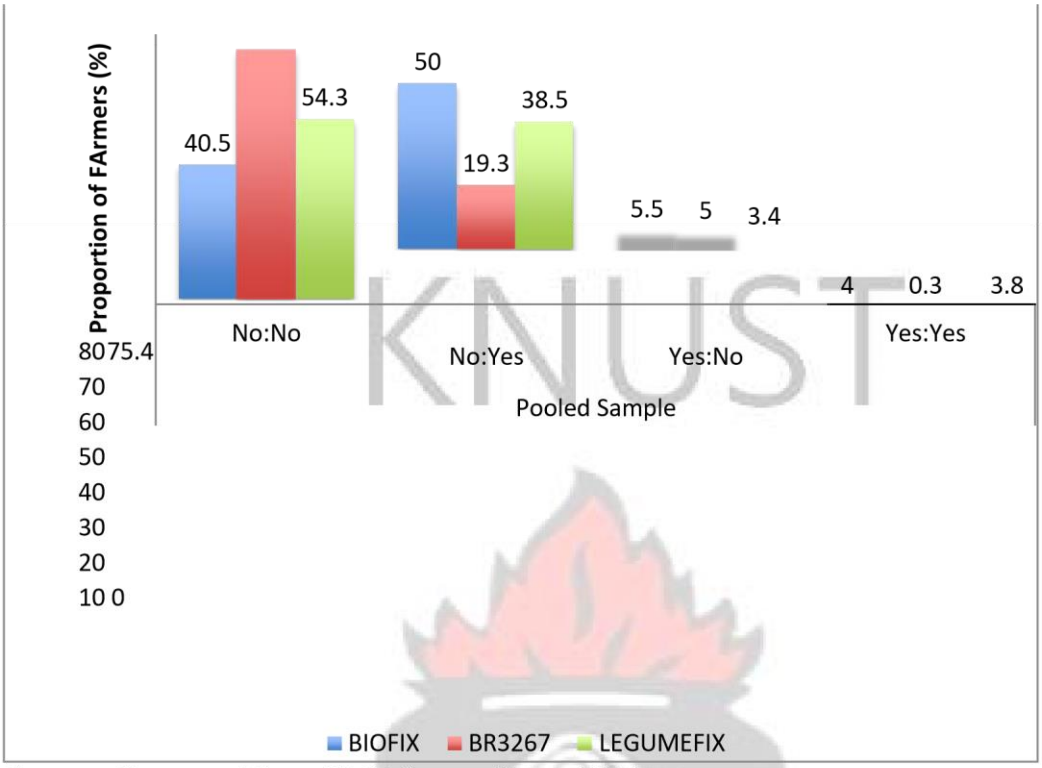
Biofertilizers	**Bid 1**	**High Bid**	**Low Bid**
	37(9.3)	16(4.0)	200(50)
BR3267	21(5.3)	1(0.3)	78(19.5)
Legumefix	28(7.0)	15(3.8)	158(39.5)

Source: Generated from Field Survey Data, 2016.

Centered on farmer's response to the willingness to pay questions presented to them as displayed above, for the purpose of the econometric analysis, two bid variables (Bid 1 and Bid 2) were then generated. Bid 1 represented the proposed ongoing price of the biofertilizer packages (Biofix=28.00, BR3267=55.00 and Legumefix=40.00) and Bid 2 generated based on farmers' response to the initial willingness to pay questions. Based on this approach, the responses were either; No:No, No:Yes, Yes:No or Yes:Yes.

Farmers' refusal to pay for the individual biofertilizers at the initial prices as well as their associated lower bids represented a No:No response; their refusal but however acceptance of the lower bid represented a No:Yes response; their acceptance of the proposed first bids but rejection of the associated higher bid denoted a Yes:No response and their acceptance of both first and higher bids denoted a Yes:Yes (Figure 4.10). From the figures, it is realized that about 60%, 25% and 46% of farmers were willing to pay for the selected biofertilizers (Biofix, BR3267 and Legumefix respectively) for not more than the lower bids of GHC 14.00, GHC 28.00 and GHC 20.00 proposed per 0.2kg of each sachet of the biofertilizers.

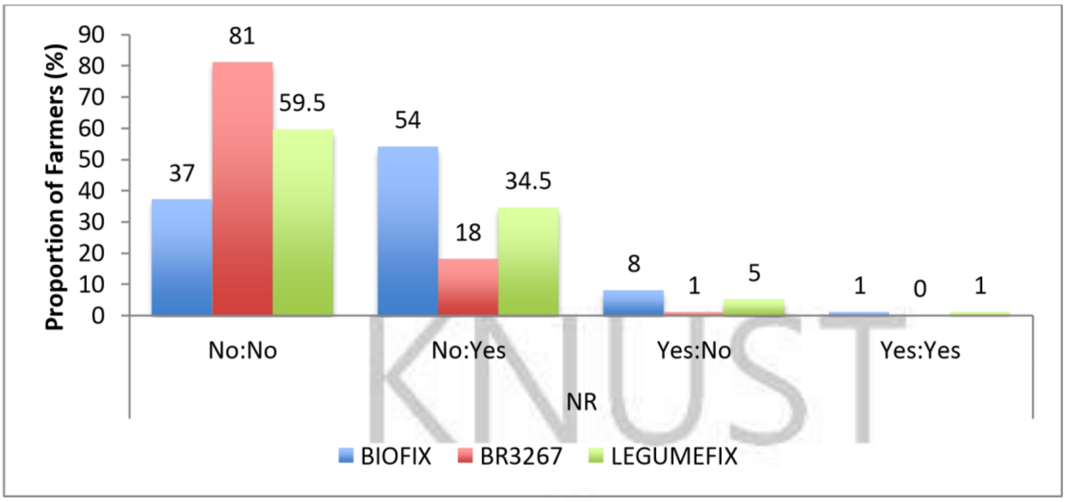
Figure 4.10: Generated Responses to Proposed Biofertilizer Bid Prices



Source: Generated from Field Survey Data, 2016.

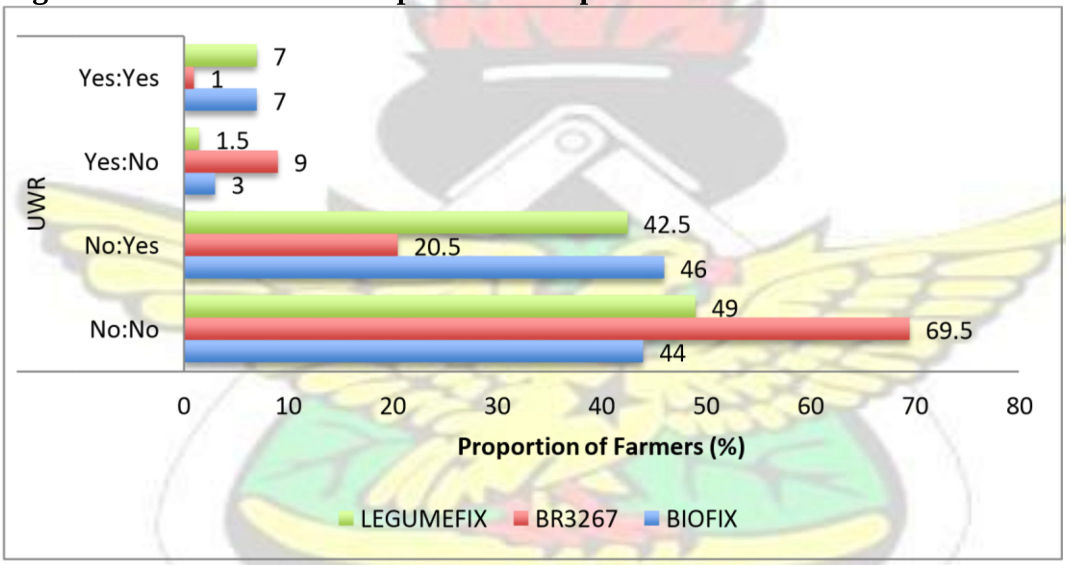
On regional basis as presented by Figure 4.11 (a&b), the highest response is recorded for the lower bid of Biofix and this occurred in the NR where about 54% of the farmers were willing to pay the proposed lower bid. This is followed by 46% in UWR for the same lower bid associated with the use of Biofix. Legumefix was second to Biofix in both regions where about 35% and 43% of farmers were willing to pay for its use at its proposed lower bid (GHC 20.00). All the farmers in NR rejected the higher bid of BR3267 (GHC 110.00) and less than 2% accepted it in UWR. The proposed higher bids of all the biofertilizers had less than 10% of farmers willing to pay for them at those prices.

Figure 4.11a: Generated Responses to Proposed Biofertilizer Bid Prices in NR.



Source: Generated from Field Survey Data, 2016.

Figure 4.11b: Generated Responses to Proposed Biofertilizer Bid Prices in UWR.



Source: Generated from Field Survey Data, 2016.

Table 4.21 provides a summary description of variables used in the willingness to pay (WTP) model estimation for the selected biofertilizer technologies (Biofix, BR3267 and Legumefix).

Table 4.21: Summary Statistics of Variables Used in Willingness to Pay Model

Variables	BIOFIX	BR3267	LEGUMEFIX
Bid 1	28.00(0.0)	55.00(0.0)	40.00(0.0)
	Mean (SD)	Mean (SD)	Mean (SD)
Bid 2	17.89(12.2)	32.31(18.3)	24.20(15.3)
WTP 1 (response 1)	0.09(0.3)	0.05(0.2)	0.07(0.3)
WTP 2 (response 2)	0.54(0.50)	0.20(0.4)	0.43(0.50)

GEN (1=male)	0.64(0.50)
AGE (years)	41.67(13.9)
YEDU (years)	2.43(4.40)
YEXP (years)	20.02(12.6)
TFLC (acres)	3.82(3.4)
FBO (1=yes)	0.83(0.4)
DisEXT (km)	13.77(7.5)
DisAgro (km)	8.66(7.1)
CRDTamt (GHC)	55.80(112.1)
OFFact (1=yes)	0.53(0.5)
BIOAW (1=yes)	0.34(0.5)
BIOU (1=yes)	0.04(0.2)

Note: (SD) donates Standard Deviation
Source: Generated from Field Survey Data, 2016.

The results for the maximum likelihood function used to estimate the determinants of farmers' willingness to pay for the three biofertilizers are presented in (Table 4.22).

Considering the results of the maximum likelihood estimation of farmers' willingness to pay for selected biofertilizer technologies in the different locations (NR and UWR) as presented in (Table 4.22), the coefficients of the gender variable and years of formal education were positive and statistically significant in the Legumefix model for NR. This suggests that males are more willing to pay for Legumefix; thereby supporting the widely known assertion that males are economically more endowed than females and will therefore be more capable of paying for improved agricultural technologies, all things being equal. Hence although females have been identified to be more involved in the cultivation of grain legumes (CGIAR, 2016), when it comes to paying for improved SFM technologies inline with their cultivation, their male counterparts are more financially capable to afford these technologies as noted by CGIAR (2013). Also educated farmers are more willing to pay for this biofertilizer and this could be explained by the advantages of awareness and knowledge that comes with higher education, ceteris paribus.

Table 4.22: Maximum Likelihood Estimations of Determinants of Willingness to Pay Across the two Locations

Categories	Variables	Northern Region			Upper West Region			Pooled S	
		BIOFIX	BR3267	LEGUMEFIX	BIOFIX	BR3267	LEGUMEFIX	BIOFIX	BR3267
HOUSEHOLD CHARACTERISTICS	CONSTANT	13.3587 (3.64)	2.6365 (0.26)	19.0075 (2.94)	8.2555 (12.24)	-21.9835 (-0.83)	7.6473 (0.42)	14.3473 (18.24)	-16.23 (- 0.
	AGE	-0.0922 (-0.93)	-0.1311 (-0.56)	-0.1471 (-0.84)	-0.08118 (-0.36)	-0.1779 (-0.38)	-0.1342 (-0.38)	-0.0811 (-0.74)	-0. (-0
	GEN	2.8284 (1.25)	-3.4516 (-0.65)	12.3115*** (2.97)	0.4173 (0.11)	4.5244 (0.56)	-0.7833 (-0.13)	1.2487 (0.62)	-2. (-0
	YEDU	-0.1455 (-0.66)	0.3681 (0.73)	0.7035* (1.88)	-0.0973 (-0.27)	0.0270 (0.03)	-0.2443 (-0.40)	0.0310 (0.15)	0.0 (1
FARM LEVEL CHARACTERISTICS	*YEXP*	0.1958* (1.65)	0.5991** (2.07)	0.0005 (0.00)	0.4177* (1.17)	0.7306 (1.43)	0.2351 (0.61)	0.3141** (2.59)	0.8708* (2.
	TFLC	0.4349* (1.89)	-0.4622 (-0.91)	2.6801 (0.63)	0.5347 (0.78)	-0.7433 (-0.50)	0.1562 (0.14)	0.6320** (2.27)	-1. (-1

	FarmInc	-	-	-	6.5606 (0.85)	15.1120 (0.83)	0.3905 (0.03)	4.7457 (0.82)	9.5 (

INSTITUTIONAL CHARACTERISTICS	*FBO*	5.7730*** (3.53)	8.7635** (2.05)	0.0726 (0.03)	6.0224** (1.96)	11.3268* (1.71)	1.6131 (0.32)	6.0686*** (3.60)	9.365 (2.
	DisEXT	0.0747 (0.64)	0.0829 (0.31)	0.1293 (0.62)	0.0413 (0.16)	0.1459 (0.26)	0.1342 (0.32)	0.7847 (0.65)	0. (0
	DisAgro	-0.0498 (-0.36)	0.1899 (0.59)	-0.2816 (-1.15)	-0.3753* (-1.68)	0.1931 (0.40)	-0.4538 (-1.28)	-0.0969* (-0.49)	0.0 (0
	CRDTamt	0.0011 (0.17)	0.0019 (0.12)	0.0031 (0.27)	0.0332* (1.88)	0.0025 (0.07)	0.0100 (0.38)	0.0079 (1.07)	0.0 (2
	OFFact	0.8928 (0.56)	0.1558 (0.04)	-2.6801 (-0.94)	-0.1413 (-0.04)	-35606 (-0.48)	5.3334 (0.94)	2.0222 (1.18)	6. (1
TECHNOLOGY AWARENESS AND USE	*BIOAW*	0.5742 (0.25)	8.1571 (1.30)	5.6354* (1.40)	7.0074** (2.21)	3.0032 (0.44)	4.7823 (0.93)	3.2464** (1.69)	0.9 (0
	BIOU	4.0806 (0.63	29.2371** (2.12)	0.0962 (0.01)	3.7667 (1.60)	15.1120 (0.83)	6.4018 (0.62)	2.8874 (0.68)	23.644 (2.
Loglikelihood		-187.3364	-95.1805	-201.5051	-236.4957	-156.8697	-208.3637	-445.6815	-259.38

Authors Computation, 2016

Wald chi^2(13)	25.75**	12.85	26.65***	26.24**	12.02	5.16	42.32***	30.07***	21.68*

Note: ***, **, * denote significance at 1, 5 and 10% respectively; z-values are in parenthesis *Source:*

Experience in farming had a positive and statistically significant correlation with farmers willing to pay for Biofix and BR3267 in NR and only Biofix in UWR suggesting farmers with more years in farming are more likely to pay for the use of biofertilizers. FBO memebership also showed a positive and statistically significant relationship with farmers' willing to pay for Biofix and BR3267 in both locations. This is expected since FBOs serve as units where farmers share information and gain insights into issues pertaining their production activities. This conforms to the findings from Uaine, (2011) who on his research on determinants of adoption of agricultural technologies identified FBO membership to be statistically significant.

Amount of credit borrowed for legume production during the 2015-cropping season was generally positive for all the adoption parameters in the different locations but only statistically significant for Biofix in UWR. This presupposes that farmers who have access to credit are more likely and willing to pay for Biofix. This finding is in line with previous studies that found credit availability to positively influence adoption since it increases affordability (Cornejo and McBrid 2002; Hazarika andAlwang, 2003).

Biofertilizer awareness and use were positive and statistically significant determinants of farmers' willingness to pay for Biofix in UWR and BR3267 in NR. With regards to the fact that technology awareness reduces performance uncertainties (Caswell *et al.*, 2001; Bonabana- Wabbi 2002), this finding implies that farmer's awareness of the Biofix technology makes them more informed about its potential, therefore increasing their willingness to pay for its use.

4.5.2 Mean WTP for Selected SFM Technologies

A key aspect of contingent valuation is the determination of the mean WTP. The 'doubleb' command of the maximum likelihood function in STATA directly estimates the mean WTP.

As shown in Table 4.23 for the two locations (NR and UWR) and pooled sample, the mean WTP for Biofix was about GHC17.00 in NR and GHC 14.00 in UWR. For BR3267 farmers were willing to pay GHC 12.00 per 0.2 kg in NR as against GHC 9.00 in UWR. For Legumefix approximately GHC 23.00 in NR and GHC 11.00 in

UWR were the average amounts farmers were willing to pay for 0.2 kg of the fertilize. Though the above mean prices deviate considerably from the initial prices proposed (GHC 28.00 for Biofix, GHC 55.00 for BR3267 and GHC 40.00 for Legumefix), comparatively farmers in NR were more willing to pay higher for the biofertilizer technology than their counterparts in UWR.

Table 4.23: Mean WTP for 0.2 kg of Selected SFM Technologies (GHC)

SFM Technology	NR	UWR	Pooled Sample
Biofix	16.59	14.43	15.68
BR3267	11.64	8.73	9.62
Legumefix	23.04	11.20	19.00

Source: Generated for Field Data, 2016.

4.6 Constraints Hindering Adoption of SFM Technologies

The full potential of farmer's adoption of SFM technologies/practices in legume production can only be attained if their constraints and challenges are addressed. The farmers in this study were therefore presented with some possible constraints obstructing their adoption of SFM and asked to confirm them by ranking them under a five point Likert scale. The mean ranks of these constraints as can be seen in Table 4.24.

Table 4. 24: Key Constraints to SFM Technology Adoption

Constraints	Mean Rank NR	UWR	Pooled
Technology is too expensive	1.74	1.69	1.71
Inputs not readily available	2.68	2.41	2.54
Inadequate information on the potential of SFM technologies	2.84	3.06	2.95
Intensive labour use	3.17	3.23	3.20
Yield performance of technology packages not encouraging	4.58	4.62	4.6
N	200	200	400

Kendall's coefficient (W)	0.522	0.572	0.543
Df	4	4	4
Chi2	417.464***	457.380***	868.856***

Note: Scale: 1=Strongly Agree (SA); 2=Agree (A); 3=Neutral (N); 4=Disagree (D); 5=Strongly Disagree (SD)
(SD) implies Standard Deviation
Note: *** denotes statistical significance at 1%
Source: Field Survey, 2016.

The legume farmers under the study ranked the expensive nature of SFM technologies as the topmost of all the five constraints in both regions (NR and UWR). Since mineral fertilizers is the most widespread SFM technology for crop production known to farmers in the study area, their costly nature serves as a limitation to their use as acknowledged by Mishra and Dash (2014). SFM technology inputs not being readily available as and when needed was ranked as the second most pressing constraint in the two locations. This finding is in agreement with previous studies identifying unavailability and inaccessibility of agricultural technologies as impediments to innovation adoption (Foster and Rosenzweig, 2010; Carletto *et al*,. 2007). Whereas farmers in NR slightly agreed (2.84) to the inadequacy of knowledge about the potential of SFM technologies on their legume production, farmers in UWR rather remained quite neutral (3.06) on that point. Farmers in both locations however remain neutral when it came to intensive labour use involved in practicing SFM technologies in their legume production as a constraint to adoption. The perceived notion of limited performance of SFM technologies in terms of yield had a mean rank of 4.60 implying farmers in the study generally disagreed quite strongly. This means that farmers have positive perception regarding the yield potential of SFM technologies.

Using Kendall's coefficient of concordance, additional analysis was done to test the extent of agreement among the farmers with respect to the constraints ranked. The estimated Kendall's W was 0.52 and 0.57 in NR and UWR respectively, suggesting that there is 52% and 57% level of agreement among the legume farmers in the two locations. Test on the statistical significance of the estimated Kendall's W using the Chi-square (F-statistic). The F values obtained for the two separate locations give the indication that the constraints ranked were statistically significant at 1% for both locations as well as the pooled sample. Thereby rejecting the null hypothesis of no agreement among the respondents regarding the ranked constraints.

ThIS finding implies that the identified constraints are not isolated cases in few communities but rather broad constraints that face almost all grain legume farmers in

Northern Ghana with respect to SFM technology adoption conforming to a study by Amedi (2014) on the agronomic constraints among rice farmers under the MiDA in the Hohoe Municipality.

CHAPTER FIVE

5.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

This chapter provides a summary of key findings from the study, the conclusion drawn and recommendations based on these findings.

5.1 Summary of Key Findings and Conclusion

The general high cost of mineral fertilizers and their negative environmental impact have led to calls for the use of more cost-effective and eco-friendly SFM technologies especially among resource-constrained smallholder farmers in sub-Saharan Africa. This study assessed costs and returns associated with different SFM trials under grain legume farming system (soya, cowpea and groundnut) in an attempt to examine the future adoption decision and farmers' willingness to pay for the most financially viable technologies. Both experimental and socio-economic survey data were collected from 120 experimental sites and 400 grain legume farmers in Northern and Upper West Regions. Gross Margin analysis, multivariate probit model and contingent valuation method using the double-bounded dichotomous choice format (bidding game) were employed to assess the profitability of SFM trials, farmers' adoption decision and willingness to pay for the most financially rewarding SFM technologies respectively.

Majority of grain legume farmers used for the study were males (73%), middle aged, mostly married with large household sizes and largely without any formal education. From the benefit-cost ratio analysis, the biofertilizer technologies (*Biofix, BR3267* and *Legumefix*) distinguished themselves as the most financially viable SFM technology for soybean, cowpea and groundnut production in northern Ghana respectively. The ratio of potential future adopters and non-adopters differed significantly across the two different locations and type of legume, with more than 50% of farmers under each legume crop willing to adopt the respective SFM technology. Evidence from the study has shown that farming experience, membership of Farmer Based Organizations (FBOs), farm income, amount of credit used and distance to extension office are the critical determinants of farmers' decision to adopt the financially rewarding SFM technologies, *ex-ante*.

The study revealed that about 60%, 25% and 46% of farmers were willing to pay for Biofix, BR3267 and Legumefix respectively when the bid price is not greater than GHC 14.00, GHC 28.00 and GHC 20.00 per 0.2 kg sachet of the biofertilizers. Generally, legume farmers in Northern Region were willing to pay higher for the three biofertilizer packages as compared to their counterparts in Upper West Region. For 0.2 kg each of *Biofix, BR3267* and *Legumefix*, farmers in Northern Region were willing to pay approximately GHC 17.00, GHC 12.00 and GHC 23.00 respectively whereas those in Upper West Region were willing to pay GHC 14.00, GHC 9.00 and GHC 11.00 for the same quantity of biofertilizers respectively. The study has also shown that farming experience, FBO membership, awareness and use of biofertilizers are the significant factors that influence farmers' willingness to pay for biofertilizers. The most critical constraints hindering adoption of SFM technologies among grain legume farmers were identified to be high cost of technologies, unavailability and inadequacy of information on potentials of SFM technologies.

The study concludes that adoption of biofertilizers hold the key to resolving the soil fertility problems and low crop yield in grain legume production in northern Ghana. Though farmers have the desire to adopt them in the near future when they are made available on the market, the mean amounts they are willing to pay for these technologies are far lower than their ex-factory prices. Also, the most financially rewarding SFM technologies (i.e. biofertilizers) are quite new in Ghana and most farmers are unaware of their use in grain legume production. When awareness level improves and adoption is stimulated, productivity levels for grain legume crops and returns on investment in grain legume production will improve in northern Ghana.

5.2 Recommendations

Based on the findings from the study the following recommendations are made:

I. For higher returns to investment, it is recommended that legume producers should adopt the use of biofertilizer technology for their production (*Biofix* for soya, *BR3267* for cowpea and *Legumefix* for groundnut).

II. Agricultural extension agents should embark on sustained awareness creation through periodic education and sensitization of farmers by using FBOs as leverage points.

III. In pricing biofertilizers for legume production, dealers should not go beyond GHC 16.00, GHC 10.00, and GHC 19.00 for 0.2 kg of *Biofix*, *BR3267* and *Legumefix* respectively. Hence for the time being marketers of the technology must not price the biofertilizers beyond this threshold until adoption has been enhanced and farmers have come to terms with the full potential of the SFM technology.

IV. Since the average prices farmers are WTP are way below the ex-factory prices, the government of Ghana through the Ministry of Agriculture as part of its policy strategies should focus and strengthen the fertilizer subsidy program and expand the coverage to include biofertilizers as a means of encouraging adoption by farmers and offering commercial benefits and investment opportunities to producers and other stakeholders of the biofertilizer technology.

V. The distribution of biofertilizers should be decentralized and sold in agro-input shops at district and community levels to make them more accessible to farmers.

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APPENDICES

Appendix A: Choice Cards

CHOICE CARD FOR SOYBEAN SFM TECHNOLOGIES

ATTRIBUTES								
FERTILIZER TYPE	**Crop type**		**Qty applied (kg/ac)**	**Application method**	**Cost/ac (GHC)**		**Yield/ac (No. of 100kg bags)**	
Biofertilizer (Inoculant)							Max	Min
Biofix	**Soya**		**0.20**	**Seed**	**28.00**		**12.58**	**7.44**
Chemical								
Urea	**Soya**		**86.88**	**Soil**	**165.07**		**14.53**	**7.74**
Biofertilizer+Chemical		**TSP**	**L'FIX**		**TSP**	**L'FIX**		
TSP+Legumefix	Soya	49.20	0.2	Seed+Soil	86.58	40.00	**5.86**	**5.38**
		49.40			**128.56**			
Farmer Practice								
No fertilizer	Soya	**0**		**-**	**0**		**4.23**	**3.13**

➢ Will you be willing to adopt the use of Biofix? 1. Yes [ ] 0. No [ ]

CHOICE CARD FOR COWPEA SFM TECHNOLOGIES

ATTRIBUTES						
FERTILIZER TYPE	**Crop type**	**Qty applied (kg/ac)**	**Application method**	**Cost/ac (GHC)**	**Yield/ac (kg)**	
Biofertilizer (Inoculant)					Max	Min
BR3267	**Cowpea**	**0.28**	**Seed**	**55.00**	**743**	**319**
Chemical						
Urea	**Cowpea**	**86.88**	**Soil**	**165.07**	**803**	**204**
Farmer Practice						
No fertilizer	**Cowpea**	**0**	**0**	**0**	**563**	**144**
➢ Will you be willing to adopt the use of BR3267? 1. Yes [ ] 0. No [ ]						

CHOICE CARD FOR GROUNDNUTS SFM TECHNOLOGIES

ATTRIBUTES						
FERTILIZER TYPE	**Crop type**	**Qty applied (kg/ac)**	**Application method**	**Cost/ac (GHC)**	**Yield/ac (kg)**	
Biofertilizer (Inoculant)					Max	Min

Legumefix	**G.nut**	**0.20**		**Seed**		**28.00**	**680**	**300**
Chemical								
TSP	G.nut	**49.20**		Soil	**86.88**		**680**	**260**
Biofertilizer+Chemical		**TSP**	**L'FIX**		**TSP**	**L'FIX**		
TSP+Legumefix	G.nut	49.20	0.2	Seed+Soil	86.58	40.00	**840**	**280**
		49.40			**128.56**			
Farmer Practice								
No fertilizer	Groundnut	**0**	-		**0**		**310**	**210**

➢ Will you be willing to adopt the use of Legumefix? 1. Yes [ ] 0. No [ ]

Appendix B: Questionnaire

DEMOGRAPHIC CHARACTERISTICES OF FARMERS AND GENERAL INFORMATION

1. Name of Village:**…………………………………………………………………**

2. District**:……………………………………………………………………………**

3. Region: **1=NR[ ] 2=UWR [ ]**

4. Name of respondent**:…………………………………………………………..**

5. Age of respondent**:……………………………..(yrs)**

6. Telephone No. ofrespondent**:………………………………………**

7. Sex: **1=Male [ ] 0=Female [ ]**

8. Marital status:**1=Single [ ] 2=Married[ ] 3=Divorced/Widowed/Separated[**

9. Main occupation of respondent: 1**=Farmer [ ] 2=Public Servant [ ]**
3=Trader [ ] 4=Other (specify)……………………..

10a. Level of Formal Education: **0=None[ ] 1=Basic [ ] 2=SHS [ ] 3=Tertiary[**

10b. No. of years of formal education**:………………….(yrs)**

11. Total Number of Household Members: **Males………. Females…………**

12. Number of Household Members who can read and write**:……………………**

13. Farming Experience of Respondent**:……………………………(yrs)**

14a. Do you belong to or have you ever belonged to an FBO? **1=Yes [ ] 0=No [**

14b. How long have you been (or where you) a member of FBO**?....................(yrs)**

15a. Distance to the nearest Agric Extension Office**…………………(km)**

15b. Number of extension visits received during previous cropping season**:…..…**

16. Distance to nearest agro-input shop**…………………………..….(km)**

17. Distance from home to nearest market…………………………..**(km)**

18. Distance from home to: Nearest legume farm……..………...…**(km)**
Furthest legume farm……..………..….**(km)**

B. CROP PRODUCTION INFORMATION

1. Total land owned by Household……………………..**(acs)**

2. Proportion of land currently cultivated…………………....**(acs)**

3. Proportion of land currently used for legume crop production………....**(acs)**

4. Cost of renting an acre of farmland for one cropping season……….**(GHC)**

Major Crops Cultivated During Last Season (2015)

Crop	1=Yes 0=No	Rank in order of importance 1=most	Area allocation (acres)	Planting material 1=improved 2=Traditional	Planting material (kg)	Qty harvested (kg)	No. of bags sold (kg)	Unit Price (GHC /kg)	Total revenue from sales (GHC)
Maize									
Soya									
G.nuts									
Cowpea									
Millet									
Rice									
Yam									
Others (specify									

INPUTS USE INFORMATION

Labour Inputs for Main Grain Legumes per Acre Basis during Last Season (2015)

	SOYA			GROUNDNUTS			COWPEA		
Activity	**Man days**	**Unit rate**	**Total cost**	**Man days**	**Unit rate**	**Total cost**	**Man days**	**Unit rate**	**Total cost**
Land clearing									
Land preparation									
Planting									
1st weeding									
2nd weeding									
1st fertilizer appli.									
2nd fertilizer appli.									
1st Herbicide appli.									
2nd Herbicide appli									
Insecticide appli									
Harvesting									
Gathering									
Shelling/threshing									
Transportation									
Others (specify)									

Use of Inputs for Legume Crop Production per Acre Basis during Last Season (2015)

	SOYA			GROUNDNUTS			COWPEA		
	Qty/ac (kg or lt)	**Unit. Cost (GHC)**	**Total Cost (GHC)**	**Qty/ac (kg or lt)**	**Unit Cost (GHC)**	**Total Cost (GHC)**	**Qty/ac (kg or lt)**	**Unit Cost (GHC)**	**Total Cost (GH C)**
Seeds									
Chemical									
Urea									
TSP									
SA									
Organic									
FYM									
Biofertilizer									
Inoculant									
Herbicide									
Insecticide									

Others (specify)									

Technologies Used For Legume Crop Production: ***Awareness And Usage***

Technology/ Practice	Are you aware? 1=Yes 0=No	Have you ever used it? 1=Yes 0= No	Did you use it last season 1= yes 0=No	Total Qty used (kg)	Area covered (acres)
Mineral fertilizers (chemical)					
SA (Ammonia)					
Urea					
TSP (Triple Super Phosphate)					
Organic fertilizers (FYM)					
Cattle Manure					
Poultry droppings					
Biofertilizers(Inoculants)					
LegumeFix					
Fertisol					
Biofix					
Mineral + Organic Ferts					
Urea+FYM					
SA+FYM					
TSP+FYM					
Mineral + Bioferts(Ino)					
TSP+inoculant					
Urea+inoculant					
Organic + Bioferts(Ino)					
FYM+Inoculant					
Mineral + Organic +Bioferts					

Urea+Inoculant+FYM					
SA+Inoculant+FYM					
TSP+Inoculant+FYM					
Other SFM Practices					
Crop rotation					
Intercropping					
Ploughing back of crop residues					
Zero tillage					
Slush and burn					
Cover Cropping					

SOURCES	**PERCENTAGE (%)**
Farming	
Soya	
Groundnuts	

Cowpea	

1. Did you use any form of credit for you leguminous crops production last season?
1=Yes [ ] 0=No [ ]

1a. If **YES**, what was the amount of credit used?............................(GHC)

1b. Source of credit used during last season? **1=Bank [ ] 2=NGO [ ]**
3=Credit Union [ ] 4=Microfinance [ ] 5=Susu 6=friends/relatives [ ]
7= others(specify)…………………

2. What is your major source of production information? **1=AEA [ ] 2=Media [ ] 3= other farmers [ ] 4=market [ ] 5=others (specify)…………….[**

Distribution of Total Harvest of Legumes During Last Season (2015)

	Total Harvested (kg)	Sold (kg)	Stored (kg)	Consumption (kg)	Seed (kg)	Gifts (kg)
SOYA						
G.NUTS						
COWPEA						

What is the Percentage Contribution of the Following Sources of Income to your Household?

Maize	
Millet	
Rice	
Yam	
Others (specify)	
Off-farm income	
Livestock production	
Remittances	
Casual labour on others' farms	
Others (Specify)	

Ranking of Possible Constraints Hindering Adoption of SFM Technology Practices

CONTRAINTS		STRONGLY AGREE	AGREE	NEUTRAL	DISAGREE	STONGLY DISAGREE
1	Technology is too expensive	1	2	3	4	5
2	Inputs not readily available	1	2	3	4	5
3	Yield performance of technology packages not encouraging	1	2	3	4	5
4	Inadequate information on the potentials of SFM technologies	1	2	3	4	5
5	It entails much more labour use	1	2	3	4	5

WILLINGNESS TO PAY QUESTIONS: DOUBLE BOUNDED DICHOTOMOUS CHOICE FORMAT

After presenting and demonstrating to farmers using the choice cards designed and samples of the various inoculant packages selected per the initial cost-benefit analysis carried out on the experimental fields, the following questions were asked to ascertain their adoption and willingness to pay decisions

SOYA

1. Will you be willing to adopt the use of **BIOFIX (Inoculant)** for the cultivation of Soya?

   1. Yes [ ] 0. No [ ].

   If **No**, move to the next crop

1a. Will you be willing to pay GHC**28.00** for 0.2kg of Biofix (for planting 1ac of 40kg of seed)?

1. Yes [ ] 0. No [ ]

1b. If **YES** to **(1a),** will you be willing to pay GHC **56.00** for 0.2kg of Biofix (for planting 1ac of 40kg of seed)?

1. Yes [ ] 0. No [ ]

1c. If **NO** to **(1a),** will you be willing to pay GHC **14.00** for 0.2kg of Biofix (for planting 1ac of 40kg of seed)?

1. Yes [ ] 0. No [ ]

If **NO** to **(1c),** how much will you be willing to pay**?.........................(GHC)**

COWPEA

2. Will you be willing to adopt the use of **BR3267 (Inoculant)** for the cultivation of Cowpea? **1. Yes [ ] 0. No [ ]**

   If **No,** move to the next crop

2a. Will you be willing to pay GHC **55.00** for 0.3kg of BR3267 (for planting 1ac of 55kg of seed)?

1. Yes [ ] 0. No [ ]

2b. If **YES** to **(2a),** will you be willing to pay GHC **110.00** for 0.3kg of BR3267 (for planting 1ac of 55kg of seed)?

1. Yes [ ] 0. No [ ]

2c. If **NO** to (**2a)**, will you be willing to pay GHC **28.00** for 0.3kg of BR3267 (for planting 1ac of 55kg of seed)?
1. Yes [ ] 0. No [ ]

If **NO** to (**2c)**, how much will you be willing to pay**?.........................(GHC)**

GROUNDNUTS

3. Will you be willing to adopt the use of **LEGUMEFIX (Inoculant)** for the cultivation of groundnuts? **1. Yes [ ] 0. No [ ]**

If No, do not proceed with follow-up questions

3a. Will you be willing to pay GHC **40.00** for 0.2kg of Legumefix (for planting 1ac of 40kg of seed)?
1. Yes [ ] 0. No [ ]

3b. If **YES** to (**3a)**, will you be willing to pay GHC **80.00** for 0.2kg of Legumefix (for planting 1ac of 40kg of seed)?
1. Yes [ ] 0. No [ ]

3c. If **NO** to **(3a)**, will you be willing to pay GHC **20.00** for 0.2kg of Legumefix (for planting 1ac of 40kg of seed)?
1. Yes [ ] 0. No [ ]

If **NO** to (**3c)**, how much will you be willing to pay**?.........................(GHC)**

THANK YOU