ADOPTION OF INTEGRATED SOIL FERTILITY MANAGEMENT TECHNOLOGIES AND ITS EFFECT ON MAIZE PRODUCTIVITY: A CASE OF THE LEGUME BEST BETS PROJECT IN MKANAKHOTI EXTENSION PLANNING AREA OF KASUNGU DISTRICT IN CENTRAL MALAWI

MSc. (AGRICULTURAL AND APPLIED ECONOMICS) THESIS

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LILONGWE UNIVERSITY OF AGRICULTURE AND NATURAL RESOUIRCES

BUNDA CAMPUS

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LILONGWE UNIVERSITY OF AGRICULTURE AND NATURAL RESOUIRCES

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APRIL, 2017

DECLARATION

I, **Joseph S. Kanyamuka,** hereby declare that this thesis is a result of my own original effort and work, and that to the best of my knowledge, the findings have never been previously presented at the Lilongwe University of Agriculture and Natural Resources or elsewhere for the award of any academic qualification. It is original in design and in execution, and all referenced materials contained herein have been duly acknowledged.

Joseph S. Kanyamuka

Signature: ___________________________________

Date: _____________/_____________/_____________

CERTIFICATE OF APPROVAL

We, the undersigned, certify that this thesis is a result of the author's own work, and that to the best of our knowledge, it has never been submitted for any other academic qualification within the Lilongwe University of Agriculture and Natural Resources or elsewhere for the award of any academic qualification. The thesis is acceptable in form and content, and that satisfactory knowledge of the field covered by the thesis was demonstrated by the candidate during oral defence held on ___________________________.

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May the Almighty God bless you all!

DEDICATION

This research is fondly dedicated to my late grandfather, Mr. Nefutali Katengeza Banda. Your contribution to my life shall always be remembered. Until we meet again in His kingdom, continue to rest in eternal peace.

ABSTRACT

The main objective of this study was to identify and analyse determinants that influence adoption and productivity effects of Integrated Soil Fertility Management (ISFM) technologies in maize-based farming systems in Central Malawi. Data used in the analysis were collected from 200 randomly selected households from Mkanakhoti Extension Planning Area in Kasungu District. A multivariate probit model was used to analyse farmers multiple and joint adoption decisions while the Poisson regression model was used to analyse factors influencing the extent of adoption of ISFM technologies. An endogenous switching regression model was used to estimate the effect of adoption of ISFM technologies on maize productivity whilst accounting for unobservable selection bias. The results show that adoption of some components of ISFM technology package are substitutable while others are complimentary in nature. Significant factors for both adoption and sustainability by smallholders include access to legume seed, access to extension, secure land tenure, group membership and landholding size. For instance, access to extension was positive and significantly correlated with adoption of inorganic fertilizer and maize-legume intercropping while secure land tenure positively and significantly influenced adoption of legume-maize rotation system. Access to market, access to legume seed, and frequency of extension contacts, and household assets, all had positive and significant effect on both adoption and extent of adoption of ISFM technologies. Further, results also indicate that adoption of ISFM technologies had a positive and significant effect on maize yields with 10.52% increase from average among the ISFM adopters while non adopters would have increased their maize yield by16.2% had they adopted the ISFM technologies. The policy implications of the study findings are

as follows: (i) Increasing farmers' access to improved legume seed at affordable prices is critical for both adoption and upscaling of ISFM technologies. (ii) ISFM technology package in maize-based cropping systems that include use of inorganic fertilizer should be promoted together with complementary interventions such as maize-legume intercropping and improved seed. (iii) The need for policies to foster collective action where extension messages that emphasize the complementarities in adoption of ISFM technologies should emphasized. (iv) Promoting access to output markets for grain legumes such as pigeon peas is crucial to incentivise adoption of legume integration in maize-based farming system, and (v) Intensification of ISFM technologies should focus on those farmers with secure land tenure and boost female farmers access to productive resources.

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LIST OF ABBREVIATIONS AND ACRONYMS

ATET	Average Treatment Effects on the Treated
ATU	Average Treatment Effects on the Untreated
BB	Best Bets
CGE	Computable General Equilibrium
EPA	Extension Planning Area
ESR	Endogenous Switching Regression
FISP	Farm Input Subsidy Programme
FROT	Farmers Research Outreach Teams
GHK	Geweke-Hajivassiliou-Keane
HI	Harvest Index
ISFM	Integrated Soil Fertility Management
ITE	Indirect Treatment Effect
JTI	Japanese Tobacco International
KADD	Kasungu Agricultural Development Division
kg	Kilogramme
MALEZA	Malawi Enterprise Zone Association
MVN	Multivariate Normal
MVP	Multivariate Probit
NUE	Nitrogen Use Efficiency
OLS	Ordinary Least Squares
OMC	Organic Matter Content
OPV	Open Pollinated Varieties

PPS	Proportion to Population Size
PTD	Participatory Technology Development
PAM	Policy Analysis Matrix
RUM	Random Utility Model
SAM	Social Accounting Matrix
SAPs	Sustainable Agricultural Practices
SIPs	Sustainable Intensification Practices
SPSS	Statistical Package for Social Scientists
SSA	Sub Saharan Africa
MET	Multi Environment Trials

CHAPTER ONE

INTRODUCTION

1.1 Background

Declining soil fertility due to low and inappropriate fertilizer use, continuous mono-cropping and inappropriate crop residues management coupled with limited resources have been pointed out as major constraints to crop productivity in Sub-Saharan Africa (SSA) and Malawi in particular (Ngwira *et al*., 2012). In addition, Nakhumwa (2004) noted that soil erosion and soil nutrient mining through continuous cultivation of crops (mono-cropping), especially maize (staple crop) contribute to declining soil fertility and subsequent reduction in the productivity of soils in Malawi. To improve soil fertility and boost maize production, the Government of Malawi has been implementing the Farm Input Subsidy Program (FISP) since 2005 to enable farmers access chemical fertilizers (Holden and Lunduka, 2010). Following successive implementation of the programme, Malawi was able to achieve significant food production and productivity (primarily in maize) contributing to increased food security, high real wages and poverty reduction (Dorward and Chirwa, 2011).

However, FISP is largely implemented using government resources and takes up the largest share of total national budget thereby posing sustainability challenges in terms of cost of maintaining the programme every year. As noted by Dorward and Chirwa (2011), the latter years of the programme have been affected by high international fertilizer prices and import costs. Future Agricultures Consortium (FAC) (2010) noted that input subsidies such as the

FISP are difficult to remove and badly targeted such that only affluent famers get much of the benefits at the expense of poor farmers. Although FISP has helped to ease access to chemical fertilizer by farmers, studies have shown that fertilizer absorption by crops is affected by both chemical and physical properties of the soil. For instance, Fairhurst (2012) showed that soils with high organic matter content are more responsive to fertilizer than those with low organic matter content. This calls for a need to identify sustainable strategies that can make the FISP more effective and profitable to smallholder farmers. Among the technologies that have shown to raise the efficiency of fertilizer use and improve smallholder productivity are the Integrated Soil Fertility Management (ISFM) Technologies (Vanlauwe, 2015).

ISFM represents one of the sustainable, intensified nutrient concepts that have proven successful in famers' field (Ollenburger, 2012 and Sommer *et al.*, 2013). Fairhurst (2012) defined ISFM as a set of soil fertility management practices that necessarily includes the use of fertilizer, organic inputs and improved germplasm combined with the knowledge on how to adapt these practices to local conditions with the aim of optimizing agronomic use efficiency of the applied nutrients and improving crop productivity. Vanlauwe (2015), Mhango *et al.* (2012) and Ollenburger (2012) note that integrating legumes is key to implementation of ISFM.

1.2 Background of the Legume Best-Bets Project

To assist smallholder farmers to boost their agricultural production, LUANAR, formerly known as Bunda College of Agriculture with financial support from the McKnight

Foundation Collaborative Crops Research Program has been implementing a project titled "Legume Best Bets to Acquire Phosphorous and Nitrogen and Improve Family Nutrition" in Ekwendeni in Mzimba District of Northern Malawi and in Mkanakhoti Extension Planning Area (EPA) in Kasungu District of Central Malawi since 2006/07. The research project was designed to (a) investigate legume diversification for improved soil nutrition and family health; and (b) investigate participatory development approaches. The overall goal of the project was to improve household food and nutrition security through increased legume production and utilization as well as improved soil quality. Among the specific objectives of the project was to determine sets of characteristics of 'best bet' legumes and legume combinations which address nutritional and soil requirements. Under this project, multipurpose legumes (pigeon peas, soybeans, and groundnuts) are integrated with maize either in intercropping or rotation while incorporating crop residues within the traditional maize-based farming systems. The project was designed to train a limited number of farmers that would later transfer the knowledge and skills to a critical mass of farmers both in the project villages and surrounding villages.

1.2.1 Design of the Legume Best Bet Project

The project adopted a Participatory Technology Development (PTD) approach where researchers and farmers work together to conduct mother and baby trials. The goal of these trials was to identify potential 'best bet' technologies (soil fertility improvement practices) that can be used by smallholder farmers to improve soil fertility status and enhance crop productivity in a sustainable manner. Participation of farmers into the project was voluntary based on their interest and those who had land and willing to commit part of their land to the trials. The project participants hosting on farm trials are provided with farm inputs such as fertilizer, pesticides and seeds for maize and legumes by the project to stimulate adoption. These farmers serve as ‘lead’ farmers from whom ‘follower’ farmers would learn knowledge and skills needed for the adoption of ISFM practices. The main cropping system followed by the project is maize-legume intercropping in association with rotation. In addition, doubled up legume cropping system which involves growing two legumes with complementary growth habits on the same land simultaneously is also practiced.

1.2.2 Mother Trials

In the mother trial, researchers and farmers together evaluated about eleven treatments on demonstration plots: (a) maize monocrop stand (as a control) (b) different intercropping combinations of maize/pigeon pea, maize/groundnuts, and pigeon pea/groundnuts and (c) application of either pigeon pea leaf biomass or Urea. Table 1.1 summarises the trials.

Table 1.1 Treatments for Legume-Maize Rotations under Mother Trials Design

No.	Treatments 2008/09	Treatments 2009/10	Treatments 2010/11	Treatments 2011/12
1	Soya un-inoculated	MZ+23N, MZ + 46N	MZ + Soya	MZ+23N, MZ + 46N
2	Soya inoculated	MZ+23N, MZ + 46N	Soya	MZ+23N, MZ + 46N
3	Groundnuts (GN)	MZ+23N, MZ + 46N	GN	MZ+23N, MZ + 46N
4	Pigeon pea (PP)	MZ + rat PP + 23N, MZ +rat PP 46N	PP	MZ + rat PP + 23N, MZ + rat PP 46N
5	PP+GN	MZ + rat PP + 23N, MZ + rat PP + 46N	PP+GN	PP+GN MZ + rat PP + 23N, MZ + rat PP + 46N
6	PP + Soya (inoculated)	MZ + rat PP + 23N, MZ + rat PP + 46N	PP + Soya	MZ + rat PP + 23N, MZ + rat PP + 46N
7	Maize (MZ) + PP rat PP + 46N	MZ + rat PP + 23N, MZ + rat PP + 46N	MZ + PP	MZ + rat PP + 23N, MZ +
8	Maize + 92	MZ + 46N, MZ + 92N	N MZ + 92 N	MZ + 46N, MZ + 92N
9	*Maize*	*MZ + 0N, MZ + 23N*	*Maize*	*Maize MZ + 0N, MZ + 23N*

Key: rat PP = ratooned pigeon pea; 23 N = 23 kg N ha-1; 46 N = 46 kg N ha^{-1}; 92 N = 92 kg N ha^{-1}

Source: Kanyama-Phiri et al. (2012)

1.2.3 Baby Trials

On the other hand, baby trials were established in different farmers' fields where farmers chose up to 5 treatments form the mother trials based on their preferences and interests to manage on their own. The choice technologies were (a) maize/pigeon pea, maize/groundnut (c) application of either leaf biomass or Urea in different combinations. Specifically, the baby trials were: (i) Maize only (Control), (ii) Maize + Urea fertilizer at 92 Kg N/ha (recommended rate), Maize + Pigeon pea intercrop at 92 Kg N/ha, (iv) Pigeon pea + groundnut doubled up legume intercrop and (v) Maize + groundnut intercrop.

Table 1.2 Baby Trials in Mkanakhothi EPA, Kasungu District

Year	Number of treatments	Number of replicates
2007/08	5 treatments (a) sole maize stand (control) (b) maize + Urea at 92 Kg N/ha (c) Maize + pigeon intercrop at 92 Kg N/ha, (d) pigeon pea + groundnut legume intercrop and (d) Maize + groundnut intercrop	24
2008/09	5 treatments (a) sole maize stand (control) (b) maize + Urea at 92 Kg N/ha (c) Maize + pigeon intercrop at 92 Kg N/ha (d) pigeon pea + groundnut legume intercrop and (e) Maize + groundnut intercrop	100

1.2.4 Project Phases

The Legume Best Bets Project has spanned two phases so far with each phase running for four years. The first phase (BB I) ran from 2006-2010 and second phase (BB II) from 2010-2014. Currently, the project is in its third phase (BB III) (2015-2018).

Phase I (BB I)

Phase one (BB I) of the project explored through on-farm trials, "best-bet" combinations of legumes: groundnut, soya beans and pigeon peas planted in rotation with maize. This phase involved, among others, assessing legume technologies, quantifying nitrogen fixation in maize, maize nutrition, cropping system performance and soil improvement from legume 'best bet' technologies. Notable benefits associated with adoption of legumes technologies as experimented in phase one included improvement in soil fertility, improved nutrition and pests and disease control, among others.

Phase II (BB II)

Phase two (BB II) (2010-2014) is an extension of BB I which involved scaling out adoption and documenting legume 'best bet' impacts. The underlying objective of phase II was to evaluate the effect of 'best bet' legumes on soil fertility and crop productivity. In summary, phase two was aimed at expanding the knowledge base regarding how legumes impact farming system resilience, over the short term through cropping system diversity and over the long-term through improved soils, expanded market opportunities, and nutritious diets. Phase II of the project also saw new entrants into the project while others were dropping out. Worth noting, other non-project farmers started trying-out the legume technologies in their fields through interaction with project participants after observing the benefits associated with the technologies.

Phase III

The project has now just begun its third phase (2015-2018) with the overall goal to scale up maize-legume technologies through multi-environment trials (METs) and farmer research networks. The aim is to achieve multiple benefits of improved soil fertility, enhanced crop productivity, and better family nutrition through the use of METs in order to develop a better understanding of the factors influencing variability in the performance of maize-legume cropping systems in Malawi. Participating farmers include those from phase I and II as well as new entrants. These were 100 in total.

Project Spillover Effects

It is also worth noting that development projects involving technology adoption may result in both intended and unintended benefits also referred to as externalities or spillover effects. These spillover effects can either be positive or negative, transcending across a range of outcomes such as production, profit and costs and include interaction effects as well as general equilibrium effects. Winters *et al*. (2010) defined spillover effects as those indirect benefits accruing to households or individuals that were not direct beneficiaries of the project. Winters *et al.* (2010) identified three types of spillover effects. These are (i) externalities, (ii) interaction effects and (iii) general equilibrium effects.

Externalities define indirect effects that operate from the treated subjects to untreated population, and are common in the health sector. For example, the reconnaissance survey that was undertaken by the researcher in 2015 revealed that some non-project participants had begun practicing the legume technologies in their regular maize fields. These non-project farmers revealed that they had learnt the technologies from the project participants through interaction effects. As noted by Angelucci and Maro (2012), interaction effects occur when the local non-target population is also indirectly affected by the treatment through social and economic interaction with the treated. For example, the recipients of conditional cash transfers may share resources with, and affect the incentives to accumulate human capital of, ineligible households in treated localities. General equilibrium effects arise from interventions that affect equilibrium prices through changes in supply and demand and are common in labour market programs (Angelucci and Maro, 2012).

Externalities and interaction effects are common in agriculture since agricultural practices, both production practices as well as mechanisms for interacting with the market are often transferred from farmer to farmer. The Legume Best Bet Project was designed on this premise in that it sought to train a limited number of farmers in legume "best bets" technologies in order to create a critical mass of knowledge that would eventually spread to other non-targeted farmers. These non-targeted farmers are referred to as spillover adopters, those farmers not eligible to receive the intervention, or who are eligible to receive the intervention but have not received it, benefit from the intervention indirectly through a variety of ways (IITA, 2015) such as social interaction.

1.3 Problem Statement

The benefits of ISFM technologies in enhancing fertilizer use efficiency and improving maize productivity are widely acknowledged in literature (Marenya and Barrett, 2007; Fairhurst, 2012 and Lambrecht *et al.,* 2014a). However, their adoption among smallholder farmers remains fairly low (Kamau *et al.,* 2013 and Kassie *et al.,* 2012). This is despite several promotional efforts by both governments and non-governmental organisations as well as international research institutions. This is especially true with the Legume Best Bets Project as revealed by the reconnaissance survey that was undertaken by the researcher in July 2015.

Although the Legume Best Bets Project has been implemented in Kasungu District for almost a decade now, the reconnaissance survey revealed that the number of farmers adopting the ISFM technologies at farm level is still low. It was observed during the reconnaissance survey that farmers within the project area are still practising the various ISFM technologies on the 10m x 10m plots instead of scaling up to larger plots. This is despite promotional efforts that are geared towards upscaling and out-scaling of the ISFM technologies as stipulated in Legume Best Bets II and III. While the number of farmers adopting such ISFM technologies and practices in the initial stages of the project looked promising, the trend of such numbers over time has generally been on the decline. From the reconnaissance survey, about 80% of the 132 farmers that started working with the project in 2006/07 to 2008/09 season are still continuing while 20% have pulled out of the project and are no longer practising the technologies.

1.4 Justification of the Study

Sustainable intensification of smallholder farming systems is indispensable given the declining soil fertility. While ISFM practices offers one of the promising ways of achieving sustainable agricultural production, its adoption among smallholder farmers remains low. Besides, little is known about the effects of adoption of such technologies on crop productivity (especially the Malawian staple maize) beyond the demonstration plots under the Legume Best Bets Project.

A thorough understanding of the factors that influence adoption of the ISFM technologies that can be used in designing better strategies for upscaling of the technologies to the resource poor farmers who cannot afford mineral fertilizers is thus needed. This may also help technology promoters know who to target and what factors need to be considered when designing and promoting ISFM technologies (Rubas, 2004). As government is implementing the FISP to help farmers to access subsidized fertilizers, ISFM practices can help enhance the efficiency of fertilizer use as a complementary intervention. This study was therefore deemed necessary as, among others, it has generated new knowledge and information that will help to better design strategies for both up-scaling and out-scaling of the ISFM technologies that are necessary to raise the profitability of fertilizer use and improve maize productivity and thus overall household food security.

1.5 Objectives

1.5.1 Underlying Objective

The overall objective of this study was to identify the factors influencing adoption of ISFM technologies and its effect on maize productivity among smallholder farmers.

1.5.2 Specific Objectives

Specifically, the study sought to achieve the following objectives:

i. To determine factors that influence farmers' decisions to adopt ISFM technologies.
ii. To analyse the extent of adoption of ISFM technologies.
iii. To assess the effect of adoption of ISFM technologies on smallholder maize productivity.

1.6 Research Hypotheses

The following null hypotheses were tested:

i. Socio-economic factors such as age, gender, household size, education level, land size, credit and extension access do not significantly influence farmers' adoption decision and the extent of adoption of ISFM technologies.

ii. There are no significant differences in maize yield levels between ISFM adopters and non-adopters.

1.7 Research Questions

The study investigated the following research questions:

i. What drives smallholder farmers to adopt ISFM technologies?

ii. To what extent does adoption of ISFM technologies enhance maize productivity?

CHAPTER TWO

LITERATURE REVIEW

2.1 Benefits of ISFM Technologies

The benefits of ISFM technologies in enhancing fertilizer use efficiency and improving maize productivity are widely acknowledged in literature (Marenya and Barrett, 2007; Fairhurst, 2012; Lambrecht *et al.,* 2014a). According to Kamau *et al.* (2013), sustainable agricultural technologies (such as ISFM) have the potential to reduce the need for chemical fertilizers (which are mostly imported from other countries) owing to their ability to raise the efficiency of the applied nutrients. The adoption ISFM technologies can also lead to economic benefits if gains in profits due to improved input productivity exceed the cost of adoption. This may also result in environment benefits in that efficiency would reduce nitrogen residues in the soil thereby reducing run-off and leaching of nitrates to the environment. The use of inorganic and organic fertilisers such as compost manure, green manures, crop residues and legume integration in farming systems is one component of ISFM (Mhango *et al.,* 2012). These organic fertilisers improve soil organic matter, nutrient and water retention in soils.

One key aspect of ISFM technologies relates to their ability in enhancing fertilizer (Nitrogen) use efficiency and thereby improving crop productivity (Fairhurst, 2012). It is also known that ISFM technologies and practices such as integration of legumes and incorporation of crop residues improve to soil organic matter that improves better synchronization between the plants and the applied nutrients. For instance, Snapp *et al.*

(2014) reported that rotating maize with a legume crop is another factor that consistently influences maize yield response to nitrogen. To increase the use efficiency of mineral fertilizer further, ISFM encourages an integrated crop management approach and good agricultural practices such as applying mineral fertilizer on time and using right techniques for applying fertilizer as well as timely weed control.

2.2 Studies on Legume Best Bet technologies in Malawi

Mhango *et al.* (2012) conducted a study on opportunities and constraints to legume diversification for sustainable maize production on smallholder farms in Malawi. Using a sample size of 88 farmers, the exploratory study highlighted the main constraints and opportunities associated with adoption of legumes in southern Africa. The study found out that limited access to legume seed and pests and diseases are the major constraints to adoption of legume technologies in Ekwendeni, Northern Malawi.

Lefu (2012) conducted an economic analysis and evaluated determinants of labour requirements for best bet integrated soil fertility management technologies in Kasungu and Mzimba Districts in Central and Southern Malawi, respectively. Using data collected from 102 farming households, the study used gross margin analysis, return on investment and log-linear function analysis to quantify labour requirements, identify factors affecting the demand and profitability of the technologies. The results showed that fertilizer + legume + manure technologies were associated with high labour requirements while the least labour requirement was observed in legume only technologies. The study also found that legume only technologies gave the highest returns to land and labour while legume + manure technologies yielded high return on investment.

Njira *et al.* (2012) evaluated the effects of sole cropped and doubled-up legume systems (legume-legume intercrop) on biological nitrogen fixation on the ultisols of Kasungu district, Central Malawi. The study used the modified nitrogen difference method to estimate the amount of nitrogen fixed per hectare. The results showed that the total amount of nitrogen biologically fixed in each cropping system was significantly higher in the pigeon pea/groundnuts doubled-up cropping system than those of the sole groundnuts and sole pigeon pea. The study also found that the pigeon pea/soybean doubled-up fixed nitrogen was only significantly higher than that for the sole soybean but resulted in nitrogen amount similar to that for the sole pigeon pea which implying a large suppression on intercropped pigeon pea biological nitrogen fixation. The researchers noted that this could be attributed to competition for light and nutrients presented to the pigeon pea in the pigeon pea/soybean intercrop in early stages of development by the fast growing bushy solitaire soybean.

A study by Thawe (2012) analysed extension pathways and farmer adaptations of ISFM technologies in Kasungu and Mzimba Districts in Malawi. Using a total number of 190 farming households, the study focused on the following key ISFM technologies: inorganic fertilizer, compost manure, legume/fertilizer, compost/fertilizer, maize/legume intercrop and crop rotation and residue incorporation. The study found out that the main information and knowledge dissemination pathways for ISFM technologies were demonstrations/trials, group meetings, friends/relatives, informal meetings, field days and exchange visits. Of these, demonstrations were the most used (30.5%). The study applied a logistic regression to determine factors influencing farmers' use of demonstrations. Results showed that only farmer's participation in the Legume Best Bets Project was positively and significantly correlated with farmers' use of demonstrations. However, the study also revealed that farmers have not been able to extend the legume technologies to larger plots beyond the trials (10m x 10m plots). Nonetheless, the study acknowledged farmer adaptations and modifications of the ISFM technologies in a quest to save labour, apply to wider area, enhance performance and reduce costs.

A study by Ngwira *et al.* (2012) tested the role of Innovation Platforms (IP) in scaling out best fit legume technologies for soil fertility enhancement among smallholder farmers in Malawi. Innovation platforms (IP) built around learning centres located on smallholder farmers' fields in target locations were used as an approach to disseminate integrated soil fertility management (ISFM) technologies and build capacity of farmers, extension staff and other stakeholders. The study found that rotating maize with either groundnut or groundnut intercropped with pigeon pea increased maize grain yield (3678 and 3071 kg per hectare, respectively) compared to sole maize (2260 kg per hectare). Constraints associated with technology choice included limited legume seed availability, disease incidences, weeds infestations and livestock damage.

2.3 Empirical Studies on Adoption

A number of adoption studies on ISFM technologies have been conducted world-wide. For example, Chamdimba (2003) analysed the social economic factors affecting farmer adoption of organic soil fertility technologies in Malawi. Using data collected from 274 respondents, the study applied a Poisson regression model to estimate the factors affecting adoption of *Tephrosia vogelli* and *Mucuna pruriens,* where the number of seasons a farmer has been practicing the technology was taken as the dependent variable. The results showed that adoption of organic soil fertility technologies was positively and significantly influenced by extension while income and wealth status of the household negatively and significantly influenced adoption of the two technologies. For instance, adoption of *Tephrosia vogelli* was also positively and significantly influence by farmer participation in field days. However, the study identified lack of seed as the major constraint to adoption of *Mucuna pruriens* and established no evidence of adoption of Mucuna- maize rotation.

Chilongo (2004) analysed the competitiveness and socio-economic characteristics determining farmers' choice of best bet soil fertility technologies within maize-based cropping systems in Malawi. The study used data collected from 120 farming households in purposively-selected EPAs of Bembeke, Njolomole and Manjawira in Dedza and Ntcheu Rural Development Projects under the Lilongwe Agricultural Development Division (ADD). The study applied the policy analysis matrix (PAM) and the multinomial logit model to analyse the competitiveness and choice of the technologies, respectively. Results from PAM indicated that legume maize rotations exhibited better performance than intercrops and a mix of maize-legume technologies and fertilizer improved their competitiveness, while higher fertilizer rates were more competitive than lower rates The results of the study also revealed that male-headed households and labour availability were positively correlated with choice of the technologies while age and education level of the household head were negatively influenced choice of the technologies and legume-maize rotation and/or intercropping, respectively.

Another study by Kabuli (2005) analysed the economic performance of soybean-maize rotation against continuous maize and the factors affecting its subsequent adoption in Malawi. The study applied gross margin analysis and discounted net benefits to determine the profitability of incorporating soybean in maize-based cropping system and the Tobit model to analyse the factors affecting adoption. The results showed that cash constrained farmers were better off growing maize in rotation with soybeans than continuous maize while adoption of soybean-maize rotation was positively influenced by sex of the household head, farmer participation in on-farm demonstrations, education and age of the household head.

Tchale and Wobst (2006) analysed the factors determining smallholder farmers' choice of soil fertility management options in Malawi. Using household and plot level data collected in the three agro-ecological zones, a double-hurdle model was used to estimate the factors affecting the probability and intensity of adoption of ISFM technologies. Results indicated that relative input cost, wealth indicators, farmer education, market and credit access, food security index and land pressure were the main factors that largely influence farmers' choice and intensity of technology adoption. Although the study found a high and positive correlation between probability of adoption and intensity of application, they found that factors that influence adoption are not necessarily the same as those that influence the intensity of adoption of the technology.

Lambrecht *et al.* (2014b) analysed the adoption of chemical Fertilizer in eastern Democratic Republic of Congo (DRC) following a three step process namely (i) awareness, (ii) try-out and (iii) continued adoption. Using cross section farm-household data, bivariate and Heckman selection probit models were used to estimate the factors influencing adoption mineral fertilizer. Their results showed that awareness of the technology was mainly determined by education and social capital. Try-out was positively influenced by extension interventions while continued adoption was affected by capital constraints and not all extension interventions were effective for continued adoption. They found that wealth and access to financial capital have no impact on awareness and try-out, but positively affect adoption (conditional on try-out). They also found asset index and of access to off-farm income had significant positive effects on adoption, indicating that capital and credit constraints matter for the continued adoption of mineral fertilizer.

Yirga and Hassan (2008) analysed farmers' adoption of short and long-term soil fertility management practices in the Central highlands of Ethiopia focussing on seasonal fallowing, legume rotations and animal manure. Using data from 229 farming households, they fitted a multinomial logit to analyse the determinants of adoption of SFM practices. Their results revealed that tenure security and investment in farmers' education and access to credit, extension and improved livestock husbandry coupled with measures that increases oxen ownership (individually or collaborative) would be vital to enhance adoption of SFM practices.

Marenya and Barrett (2007) used panel data to analyse household level determinants of ISFM technologies in western Kenya. The study analysed the following ISFM technologies (i) use of stover/trash lines for nutrient recycling, (ii) agroforestry for soil nutrient replenishment using woody species (iii) use of livestock manure, and (iv) the use of inorganic chemical fertilizers. A multivariate probit (MVP) was used to model the incidence of adoption and the Tobit model for the intensity of adoption of ISFM technologies. The study found that the size of the farm owned by a household, the value of its livestock, off-farm income, family labour supply, and the educational attainment and gender of the household head all had a significant positive effect on the likelihood of adoption. Similar factors were also found to be statistically significant in discouraging abandonment of the practices under study.

Kamau *et al.* (2013) analysed factors affecting adoption of soil fertility management practices in Kenya. A multivariate probit model was used to identify the factors that determine use of inorganic fertilizer, other soil amendments, and practices to control soil erosion by smallholder farmers. Their results indicated that knowledge and plot tenure had a strong influence on use of soil fertility management practices. They also found that gender of household head positively affects the decision to adopt soil fertility management practices only in maize production.

Another study in Western Kenya by Martins *et al.* (2011) analysed the determinants of the speed of adoption of soil fertility enhancing technologies. Based on survey data from a random sample of 331 smallholder farmers, the study applied duration analysis. Results revealed that education level of the household head, cattle ownership, location of the farm, access to extension services, and participation in land management programmes accelerated the adoption of different practices. On the other hand, age of household head, relative farming experience and market liberalization retarded the adoption. However, factors that influenced timing of the adoption varied by the practices.

Nkegbe and Shankar (2014) analysed the determinants of intensity of adoption of soil and water conservation practices using data collected from 445 smallholder farmers in Northern Ghana. The study applied count data models (Gama and Poisson) and found out that access to information, social capital, per capita landholding size and wealth played a significant role in producers' decisions to intensively adopt soil and water conservation practices.

Ramfrez and Shultz (2000) applied a Poisson model to assess the impact of socio-economic, bio-physical, and institutional factors on the level adoption of integrated pest management, agroforestry, and soil conservation technologies among small farmers in three Central American countries of Costa Rica, Panama, and El Salvador. Using data collected from 72 farmers, the authors found that access to credit, use of hire labour and group membership were positive and significantly related to adoption of all the three agricultural and natural resource management technologies.

Paxton *et al.* (2011) analysed the intensity of adoption of precision Agriculture among 892 cotton farmers in the south eastern part of the United States of America (USA). Using the number of precision farming technologies adopted, the Poisson regression model was applied to estimate the factors affecting intensity of adoption. Their results showed that within-yield field variability, education and computer usage were positively and significantly correlated with the intensity of adoption of precision agriculture.

Jaleta *et al.* (2013) examined the adoption and intensity of use of improved maize varieties in Ethiopia. Using cross-sectional survey data collected from 2455 farm households from 39 districts in five regional states, the authors employed the Poisson model to assess the number of maize seed varieties known to farmers, adoption and use intensity of improved maize varieties. Results showed that family labour, wealth status social network credit access, better soil fertility, market opportunities were positively and significantly correlated with number of maize seed varieties known by the farmers.

2.4 Welfare Effects of Adoption of ISFM Technologies

Several studies have applied different techniques in analysing the welfare effects of agricultural technology adoption. A study by Simtowe *et al.* (2012) assessed the welfare effects of improved groundnut technologies on consumption expenditure and poverty in Malawi using PSM technique. The study used cross-sectional farm household level data from a sample of 594 households from rural Malawi. Their findings indicated that adoption of improved groundnut varieties had positive and significant impact on consumption expenditure and poverty reduction. However, Heinrich *et al.* (2010) argued that PSM is only effective in handling observable selection bias and thus unobservable selection bias remains largely unaccounted for.

Bezu *et al.* (2013) analysed the impact of adoption of improved maize on welfare of farm households in Malawi using a three year-household panel data of 1375 households in the period 2004-2009. The study applied control function approach and IV regression to control for endogeneity of input subsidy and improved maize adoption. The study found out that improved maize adoption has stronger impact on welfare of female headed households and poorer households.

Mutenje *et al.* (2015) analysed the welfare implications of agricultural innovations (including maize variety diversity) on food security in Malawi. The study used data from 892 randomly selected households from six districts of Malawi and employed a multinomial treatment effects model to account for unobservable heterogeneity that influences agricultural technology adoption decision and maize productivity. The study found that adoption of improved maize and storage technologies significantly increased maize output per unit area.

Mendola (2007) analysed the impact of improved seed adoption on poverty reduction in Bangladesh using survey data comprising 3800 rural households. Propensity score matching (PSM) techniques were used to analyse the impact of improved seed adoption on poverty reduction. The results revealed that adoption of improved agricultural technologies such as modern seed varieties had positive and significant impact on household rural incomes and thus decreased the propensity to fall below the poverty line. Another study by Negash (2012) analysed the impact of biofuels on household food security in Ethiopia by using an endogenous switching regression model. The study used household and community level survey data and found out that castor bean farming was positive and significantly related to household food security.

A study by Audu and Aye (2014) in Nigeria utilised the Ordinary Least Squares (OLS) regression to determine the welfare effects of improved maize technology adoption using 125 randomly selected households. The study found out that adoption of improved maize technology adoption was positively and significantly related to household welfare and contributed to moving farm households out of poverty. However, Asfaw *et al*. (2012), Negash (2012) and FAO (2015a) argued that the use of OLS regression in estimating the causal impact of agricultural technology adoption may yield biased and inconsistent estimates since technology assignment is not random. The authors note that there are unobservable heterogeneity effects that are likely to make the adoption decision endogenous to the outcome variable and thus ignoring this fact may lead to overestimating or underestimating of the impact.

Asfaw *et al.* (2012) evaluated the potential impact of improved legume technologies in rural Ethiopia and Tanzania using cross-sectional farm household level data from a randomly selected sample of 1313 households. The authors applied the endogenous switching regression to estimate the causal impact of technology while addressing unobservable selection bias. Their results revealed that adoption of improved legume technologies had a positive and significant impact on consumption expenditure in both rural Ethiopia and Tanzania. Among others, they also found that family size significantly reduced consumption for both adopters and on-adopters.

From the literature review, different techniques have been used to analyse (dis)adoption and welfare effects of ISFM technologies. For instance, common modelling techniques for adoption include single logit and probit models, multinomial and ordered probit or ordered logit, multivariate probit, Tobit and the double hurdle model. Each of them has its own strength and weaknesses. For instance, using a multinomial logit or a single series of probit and logit models to model adoption of a set of technologies that are complementary such as ISFM may result in flawed estimates since adoption decisions regarding ISFM technologies are interdependent (Kassie *et al.*, 2015a and Marenya and Barrett, 2007). This is so because adoption decisions regarding a set of ISFM technologies are inherently a multivariate one and engaging univariate modelling will likely exclude important information contained in interdependent and simultaneous adoption decisions.

The literature review (e.g. Kassie *et al.*, 2015a and, Marenya and Barrett, 2007) recommended the MVP in modelling (dis)adoption of ISFM technologies. According to Kassie *et al.* (2015a), the MVP recognizes the correlation in the error terms of adoption (unlike other models such as the MNL or MNP) equations and estimates a set of binary probit models simultaneously. Similarly, it has been acknowledged (e.g. by Negash, 2012) that measuring welfare impacts of agricultural technology adoption is not straightforward. One needs to account for both observable and unobservable heterogeneity effects associated with the adoption decision that is potentially endogenous to the outcome in order to obtain unbiased and consistent estimates.

The present research builds on the work of Marenya and Barret (2007), Lambrecht *et al.* (2014a) and Kassie *et al.* (2015a) with some modifications to analyse the determinants of adoption and the extent of adoption of ISFM technologies in Mkanakhoti EPA of Kasungu district. This was achieved by applying the MVP and the Poisson model to analyse adoption and the extent of adoption of ISFM technologies, respectively. The study also applied the endogenous switching regression model to analyse the yield effects of adoption of ISFM technologies (as applied in other studies such as Asfaw *et al.*, 2012 and Negash, 2012). The choice of the endogenous switching regression model was necessitated by potential existence of sample selection bias emanating from the design of the Legume Best Bets Project in which farmer participation was based on predefined criteria. The present study is also unique in that is the first of its kind in the history of the Legume Bests Bets Project to analyse the multiple adoption of ISFM technologies and its effects on the productivity of maize beyond the demonstration plots after a decade of the project's existence. Further, an attempt to address methodological issues observed in others studies (such as heterogeneity and endogeneity) makes the present study to stand out.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter presents the methodology, starting with the conceptual and the theoretical framework guiding the adoption decision. This is followed by the empirical models for both adoption and impact assessment of ISFM technologies. Finally, the chapter presents the sampling design, data collection techniques and type of data collected.

3.2 Conceptual Framework

This section highlights the conceptual framework for modelling adoption and yield effects of ISFM technologies. This study postulates that adoption of ISFM technologies is influenced by household characteristics (age, gender, education level of the household head, household size, household assets and wealth status), institutional factors (access to credit, access to extension, farmer group membership and land tenure), farm and plot characteristics (farm size, and soil fertility status) as well as technology attributes.

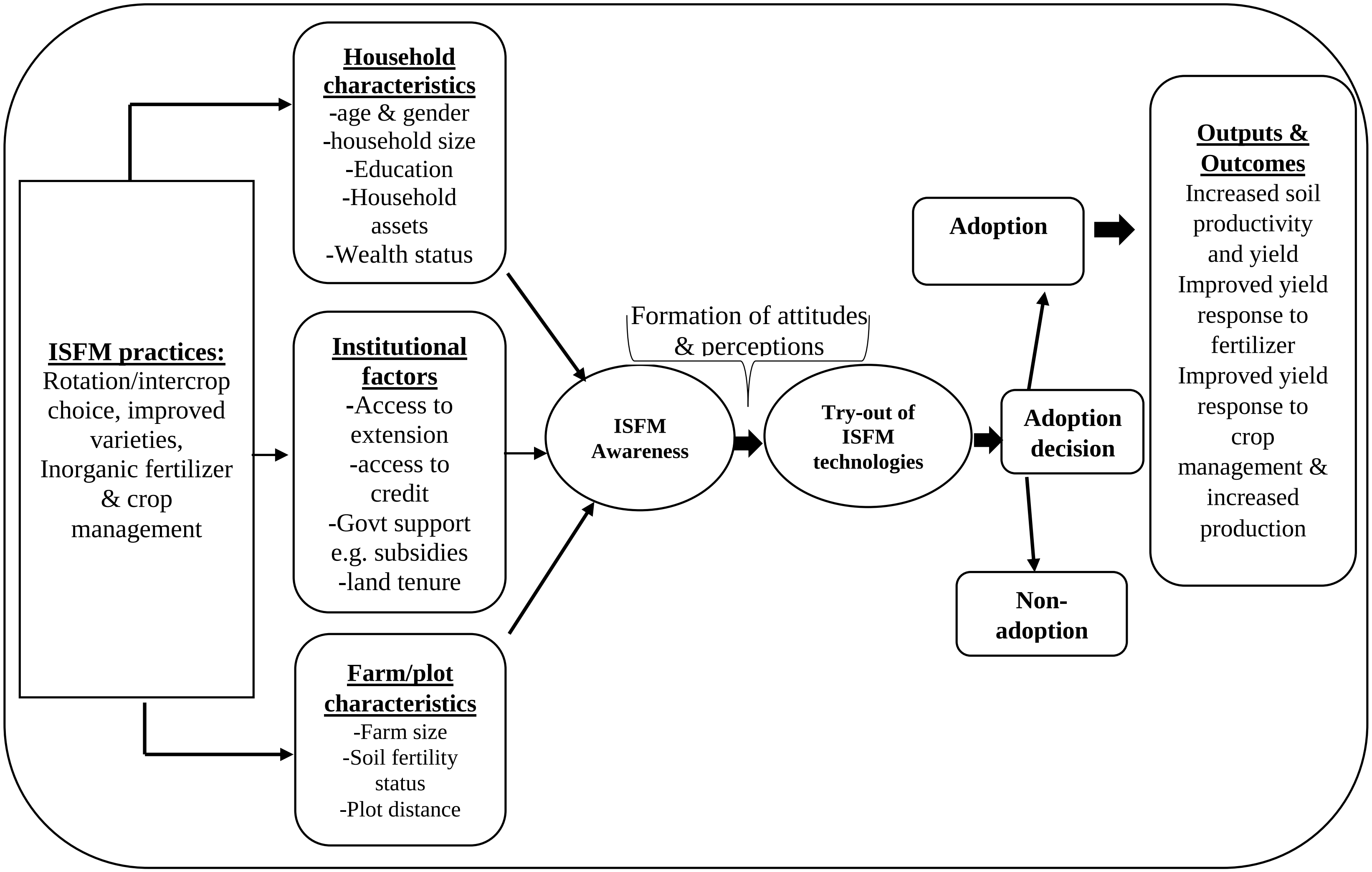

Figure 3.1 Conceptual Framework for Studying Adoption of ISFM Technologies and its Effect on Maize Productivity in Kasungu District, Central Malawi

Source: Adapted and modified from Mugwe et al. (2008)

The effect of household characteristics such as age on adoption of ISFM technologies is indeterminate while male headship is expected to have positive influence due to the comparative advantage in access to productive resources such as cash which is important to purchase inorganic fertilizer and improved seed. However, age of the household head may reflect farming experience and past investments in soil fertility enhancing technologies. Education level of the household head is hypothesised to influence adoption of ISFM technologies positively due to higher management skills, better understanding of concept of ISFM and its implementation as well as better positioned to source information related to the technologies (Tizale, 2007; Yirga and Hassan, 2008).

Institutional factors such as access to extension increases farmers' access to information which is a critical factor in agricultural technology adoption process while access to credit services facilitates farmers' access to productive resources (Lambrecht *et al.* 2014b). In the context of ISFM, inorganic fertilizer and improved seed are externally purchased and are deemed unaffordable among some of the resource-constrained smallholder farmers in the study area. Thus the expectation is that those farmers with access to credit are more likely to adopt ISFM technologies than those farmers without access to credit. Land tenure is expected to influence adoption of ISFM technologies positively in that those households with secure land tenure rights are more likely to invest in soil fertility enhancing technologies because of the guaranteed benefits despite the length of the return period, while those with insecure land tenure are more likely to abandon the ISFM technologies.

Plot characteristics such as landholding size have in literature been reported to have positive influence on adoption of agricultural technologies (e.g. Marenya and Barrett, 2007 and Tizale, 2007). However, in this study, the influence of landholding size on adoption of ISFM technologies is hypothesized to be either positive or negative depending on the type of technology under consideration. For instance, landholding size is expected to be negatively correlated with maize-legume intercropping and positively correlated with legume-maize rotation. Soil fertility status of the plot that can also influence adoption of ISFM technologies. Foster and Rosenzweig (2010) note that the marginal product of inorganic fertilizer tends to be higher 'better' soils than poor soils. Thus farmer perception of fertile soils is expected to influence adoption of ISFM technologies such as inorganic fertilizer and improved seed.

Technology attributes such as labour intensive nature of the technology may lead to dis-adoption of the technology by the farmer (Marenya and Barret, 2007). In addition, lack of and/or limited access to improved seed is hypothesised to positively influence dis-adoption of ISFM technologies such as maize-legume intercropping. On yield effects, the expectation from the study is that the adoption of ISFM technologies will lead to significantly higher yields among the adopters as compared to non-adopters. When successfully adopted, ISFM practices lead to increased productivity due to increased agronomic use efficiency of the applied nutrients. This therefore result in increased crop yield, production and less area expansion emanating from sustainable agricultural intensification (Fairhurst, 2012).

Following Kamau *et al.* (2013) and consistent with the random utility model, the individual components in the set of ISFM technologies adopted by the farming households are mutually exclusive. However, in real life, farming households apply a mix of two or more mutually exclusive soil fertility interventions to exploit the complementarities between alternative interventions such as improving soil fertility and reducing run-off. Adoption of ISFM technologies can be depicted to follow a three step general process of awareness, try-out and continued adoption as presented in Figure 3.1.

3.3 Theoretical Framework

The theoretical framework for analysing adoption decisions for a single or multiple ISFM technologies can be based on the random utility model (RUM). In this framework, a farmer considers a bundle (set) of possible technologies and chooses the particular technology or technology bundle that maximizes expected utility conditional on the adoption decision (Marenya and Barrett, 2007; Kassie *et al.*, 2012). The random utility model (RUM) underlying the adoption decisions could be specified as follows (Tizale, 2007):

$$U_j = \beta'_j X_i + \varepsilon_i \quad (1)$$

where U_j is the perceived utility of technology (or package of technology) j whose desirability is hypothesized to be influenced by a vector of explanatory variables (X_i) such as farm household characteristics and technology attributes, β_j are parameters to be estimated and ε_i is the error term assumed to be identically and independently distributed.

Foster and Rosenzweig (2010) noted that an important driver of adoption of a new technology is net gain or benefit to the agent from adoption, inclusive of all costs of using the new technology. Following Hassen (2015), let ${U_j}^n$ be the utility (or benefit) in the state of non-adoption (n) of a technology (or bundle of technologies) j and ${U_j}^a$ be the utility in the state of adoption (a). It therefore follows that the farmer will decide to adopt a technology (or a package of technologies) j on plot p if $Y^*_{ipj} = U^a{}_{ipj} - U^n{}_{ipj} > 0$ where Y^*_{ipj} is the latent net benefit of adopting a new technology (or package of technologies).

3.4 Empirical Strategy and Models

From the theoretical framework, it follows that the utility or satisfaction to the household is given as a linear function of individual and farm specific characteristics, attributes of the different available technologies and other institutional factors, including the stochastic component. The likelihood of adopting a particular technology is such that the utility derived from that specific alternative is greater than or equal to the utilities of all other alternative technologies in the choice bundle (Marenya and Barrett, 2007). Thus the decision to adopt an ISFM technology (or package) is joint and can be modelled as the difference between the benefit and cost of adoption – or continuation of a practice/technology. The latent adoption decision is determined by:

$$Y^*_{ipj} = X_{ipj}\beta_j + \epsilon_{ipj} \quad (2)$$

$$\epsilon_{ipj} = \alpha_{pj} + \eta_{ij} \quad (3)$$

Where Y^*_{ipj} reflects farm household's adoption on plot p of an ISFM technology (or package), j ($j =$ inorganic fertilizer, improved seed, maize-legume intercropping and legume-maize rotation). X_{ipj} is a matrix of regressors representing household and plot-specific attributes of adoption of technology j that explain constraints and preferences, β_j is a vector of parameters to be estimated for the j^{th} technology adoption equation and ϵ_{ipj} is a composite error term comprising plot-specific unobserved characteristics (α_{pj}) and unobserved individual farmer characteristics (η_{ij}). Adoption in this study was defined as the use or application of a particular ISFM technology on farmers' own fields (beyond the 10m x 10m plots introduced by the BB project) for at least two years consecutively, covering the 2014/15 growing season.

Nevertheless, we do not observe the net benefit of adoption, but only the choice of whether or not the farmer choses the technology/practice. Following the revealed preference assumption, the farmer practices the technology that generates more benefits than costs and does not practice a technology otherwise (Marenya and Barrett, 2007). Such benefits may include increased crop production and improved crop productivity. Thus the observed discrete choice of a technology/practice is related to latent (unobserved) variable such that equation (2) is transformed indicating whether a farm household is adopting an ISFM technology or not as follows:

$$Y_{ipj} = \begin{cases} 1 \ if \ Y^*_{ipj} > 0 \\ 0 \ \ if \ Y^*_{ipj} \leq 0 \end{cases} \tag{4}$$

3.4.1 Determinants of Adoption

In a quest to achieving sustainable agricultural production, the concept of ISFM promotes the use of more than just one agricultural technology. Thus farmers are more likely to adopt a mix of ISFM technologies in order to address of a number of agricultural production constraints. It follows that the choice of technologies lately adopted by farmers may be partly dependent on those technologies earlier chosen (Kassie *et al.* 2012). However, other studies on adoption of ISFM (Nata *et al.* 2014; Yirga and Hassan, 2008) have ignored the possible interrelationships between various practices, which is a limitation of such studies. Failure to consider such interrelationships may lead to overestimation of the factors affecting adoption of ISFM technologies (Kassie *et al.*, 2013).

This study applied a multivariate probit (MVP) to model (simultaneously) adoption decisions relating to the choice of ISFM technologies and/or practices. This addressed objective (i) and involved modelling the influence of a set of explanatory variables on each of the different technologies/practices while allowing the unobserved and measured factors, accounted for by error terms, to be freely correlated. Kassie *et al.* (2013) identifies one possible source of correlations: positive correlation and negative correlation depending on whether farmers consider the technologies as complements or substitutes.

The MVP model is preferred to univariate probit models in that univariate probit models overlook the potential correlation among unobserved disturbances in the adoption equations, besides the relationships that exist among the adoptions of different farming practices (Marenya and Barrett, 2007; Kassie *et al.* 2013). Therefore, following Kassie *et al.* (2013), the multivariate econometric model is characterised by a set binary dependent variables (Y_{hpj}) such that:

$$Y^*_{hpj} = X'_{hpj}\beta_j + \mu_{hpj}, \quad j = 1, \ldots, 4 \qquad (5)$$

and

$$Y_{hpj} = \begin{cases} 1 & if\ Y^*{}_{hpj} > 0 \\ 0 & otherwise \end{cases} \quad (6)$$

Where $Y^*{}_{hpj}$ reflects both the latent adoption and dis-adoption decision for h^{th} household on plot p of j^{th} technology (or package). $j = 1, \ldots, 4$ denotes the type of ISFM technology (inorganic fertilizer, improved seed, legume-maize rotation and maize-legume intercropping). Equation (5) is premised on the fact that a rational h^{th} farm household has latent variable, $Y^*{}_{hpj}$, which captures the unobserved preferences or demand associated with the j^{th} adoption of ISFM technology. The latent variable is assumed to be a linear combination of observed characteristics (X_{hpj}), both household and plot level characteristics that influences the adoption and dis-adoption of a j^{th} ISFM practice, as well as unobserved characteristics contained in the disturbance term, μ_{hpj}. β_j is the vector of parameter estimates obtained through the maximum likelihood estimation procedure.

In terms of adoption, $Y^*{}_{hpj}$ represent a set of binary discrete variables which capture whether or not the farmer practices a particular ISFM technology on plot p. Four ISFM technologies/practices were considered in this study. These are: (i) inorganic fertilizers, (ii) improved seed varieties, (iii) maize-legume and/or doubled up intercropping (involving pigeon peas, soya beans or groundnuts) and (iv) legume-maize rotations.

Adoption of a particular ISFM technology was defined as the use or application of the technology or practice by the farmer for at least two consecutive growing seasons. The two years were purposively chosen as it is considered minimum for the farmer to complete a full system (cycle) of maize legume-intercropping with rotation at the centre of each system. Therefore, the multivariate probit model was meant to address objectives (i) and (ii).

The multivariate probit model assumes interdependency of the adoption decisions for ISFM technology and that the error terms in equation (5) jointly follow a multivariate normal (MVN) distribution, having zero conditional mean and unity-normalised variance where $\mu_{hpj} \sim MVN\ (0, \Sigma)$ and covariance matrix given by:

$$\Sigma = \begin{bmatrix} 1 & \rho_{12} & \rho_{13} & \cdots & \rho_{1m} \\ \rho_{12} & 1 & \rho_{23} & \cdots & \rho_{2m} \\ \rho_{13} & \rho_{23} & 1 & \cdots & \rho_{3m} \\ \vdots & \vdots & \vdots & 1 & \vdots \\ \rho_{1m} & \rho_{2m} & \rho_{3m} & \cdots & 1 \end{bmatrix} \quad (7)$$

The off-diagonal element in the matrix represents the unobserved correlation between the j^{th} and m^{th} ISFM practice. It thus follows that equation (5) specifies a MVP model that jointly represents decisions to adopt a particular ISFM practice while allowing for correlation across the error terms of the unobserved equations. The MVP was chosen in favour from other models such as multinomial probit or multinomial logit because of its ability to capture the complementarities and substitutions of both adoption and dis-adoption decisions for the ISFM technologies.

3.4.2 Measuring the Extent of Adoption

The second objective of this study was to determine factors that influence farmers' decisions on the extent of adoption of ISFM technologies among smallholder farmers in maize-based farming systems in the study area. With regard to sustainable farming practices, statistical challenges of modelling adoption decisions involving packages or bundles of inputs have been addressed in a number of ways over the past few decades. Several recent studies about adoption of soil fertility management practices in Eastern and Southern Africa have used a series of single probit or logit equations to model the range of practices independently (Kamau *et al.* 2013, Kassie *et al.* 2015a).

However, adoption of ISFM involves individual components or a mix of technologies from a technology bundle in order to maximise the benefits from the potential interaction effects. Thus the number of technologies adopted by the farmer becomes critical subject to resource constraints. The number of technologies adopted in a given time period is count data, which is usually analysed using count data models (Taklewold *et al.* 2013). The two commonest count data models that exist in literature are the Poisson and Negative binomial regression models. The choice of either one of the two models depends on the assumptions under consideration.

Therefore, following Nkegbe and Shankar (2014) and Taklewold *et al.* (2013), this study used the number of ISFM technologies adopted as an indicator for the extent of ISFM technology adoption. The choice of the number of technologies adopted has also been necessitated by the fact that it was difficult to measure the intensity of adoption of some of the technologies under consideration in this study such as crop-rotation using the proportional of crop area. Besides, none of the correlation coefficients in the adoption decisions is above the 50% threshold level (Nkegbe and Shankar, 2014) and thus it is difficult to completely rule out that independency exist in the adoption decisions of the

ISFM technologies. This study used the Poisson regression model in estimating the factors affecting the level of ISFM adoption under the assumption of equidispersion.

The number of technologies adopted was calculated by summing the number of counts for the different ISFM technologies (inorganic fertilizer, improved seed varieties, intercropping and rotation) as follows:

$$Y_i = \sum_i X_i$$

where $i = 1,2, \ldots ,4$ and $X =$ (1 if a household adopted a particular ISFM technology and 0 otherwise). Y_i is the number of technologies adopted and ranged from 1 to 4. The dependent variable, $Y_{i\,,}$ represented by the number of technologies is a "count" variable. The empirical specification of this "count" variable assumes that it is random and, in a given time interval, has a Poisson distribution with probability density:

$$\Pr(y_i = n_i) = \frac{e^{-\lambda}{\lambda_i}^{n_i}}{n_i}, n_i = 1,2, \ldots ,4 \qquad (8)$$

where n_i is the realised value of the random variable. This is a one-parameter distribution with mean and variance of y_i equal to λ_i. Following Paxton *et al.* (2011), to incorporate a set of independent variables into the analysis and to ensure non-negativity of the mean, the parameter λ_i is specified such that:

$$E[y_i \mid X_i] = \lambda_i = \exp({x_i}'\beta) = \exp(\beta_1 + \beta_2 x_{2i} + \cdots \beta_k x_{ki}) \qquad (9)$$

However, one of the strong assumptions of the Poisson regression model is that the conditional mean and the variance of the distribution are equal (Piza, 2012 and Edriss, 2013). This is to say:

$$Var(y_i \mid x_i) = E(x'_i\beta) = E(y_i \mid x_i) \qquad (10)$$

This is also known as equidispersion assumption. When the assumption is relaxed (or violated), such that $Var(y_i \mid x_i) > exp(x'_i\beta)$ or $Var(y_i \mid x_i) < exp(x'_i\beta)$, a condition referred to as over-dispersion results, and the model collapses. The most commonly used model for count data when the equidispersion assumption is not met is the negative binomial regression model. The negative binomial regression model does not assume an equal mean and variance and particularly corrects for overdispersion in the data, i.e. when the variance is greater than the conditional mean (Piza 2012, 2010). Piza (2012) also noted that the negative binomial regression model is preferred to Poisson regression purely because the assumptions of Poisson models (equidispersion) are often not observed with social data. Thus evidence of overdispersion indicates inadequate fit of the Poisson model and leads to inefficient estimates with large standard errors. Test for over-dispersion yielded insignificant p-value and the null hypothesis was not rejected and concluded that there was no overdispersion and that the Poisson regression model fitted the data well. The Poisson regression model was estimated using the maximum likelihood estimation method.

The Poisson distribution of the number of technologies with conditional mean and variance u_j was specified as follows:

$$Pr(y_i = (y \mid x_i) = \frac{\exp(-\lambda_i u_j)(\lambda_j u_j)^y}{y!} \qquad (11)$$

A number of socio-economic factors that influence both the adoption and extent of adoption of ISFM technologies were considered as explanatory variables. These include age of the household head, gender of the household head, farm size, labour availability, asset status, livestock ownership, education level of the household head, contact with extension agent, land tenure system and credit access. The choice of these explanatory variables is based on previous studies, economic theory and specific attributes of the technologies under consideration (Marenya and Barrett, 2007; Martins et al., 2011; Yirga and Hassan, 2008). Table 3.1 presents the description of the specific variables hypothesized to influence adoption of ISFM technologies considered in this study.

Table 3.1 Description of the Explanatory Variables Hypothesized to Influence Adoption of ISFM Technologies

Variable	**Description and measurement**	**Expected sign**
Age	Age of the household head (years)	±
Gender	Gender of the household head (1=Male, 0=female)	±
Education	Highest formal education level attained by the household head	±
Household size	Household size proxy for labour availability measured as total number of persons in a household	+
Land holding size	Total household farm size (hectares)	±
Extension access	Access to extension services (1=Yes, 0=No)	+
Credit access	Access to credit (1=Yes, 0=No)	+
Land ownership	Proxy for land tenure system (1=own land, 0=otherwise)	+
Distance from house to plot	Measured in kilometres (km)	-
FISP access	Whether the farmer received a FISP coupon or not (1=Yes, 0=otherwise)	+
Group membership	Whether the farmer belongs to any group/association or not (1=Yes, 0=Otherwise)	+
Farming experience	The number of years the farmer has been in farming	±
Soil fertility perception		+

Farming experience

Several studies have examined the effect of farming experience on adoption decision of ISFM technologies. Experience in farming has an influence on planning horizon. For instance, short planning horizons is equated with older and more experienced farmers who may be reluctant to switch from traditional methods to new practices (Yirga and Hassan, 2008). As farmers' experience increase, their planning horizons shrink and so the incentives for them to invest in the future productivity of their farms diminish. Moreover, younger farmers may incur lower switching costs in implementing new practices since they only have limited experience and the learning and adjustment costs involved in adopting ISFM practices may be lower for them (Marenya and Barrett, 2007). Farming experience was measured as the number of years a farmer has been in farming.

Sex of the household head

Sex of the household head reflects differential access to productive resources that are critical for adoption of ISFM technologies. Kamau *et al.* (2013) found that male headship is expected to have a positive influence on investment in sustainable agricultural technologies. According to Kamau *et al.* (2013) female-headed households are known to have less access to critical resources, especially cash and labour thereby negatively affecting adoption of ISFM technologies and practices. In addition, women farmers are also known to have less access to information and technology.

Number of adults in the household

Number of adults in the household is also an important factor that can explain adoption of sustainable agricultural technologies such as ISFM. Several studies have used this variable as a proxy for labour availability in the household. According to Yirga and Hassan (2008), households with more adult residents are normally associated with a higher labour endowment that would enable a household to accomplish various agricultural tasks on timely bases. Conversely, households with more adult members may be forced to divert part of the labour force to off-farm activities in an attempt to earn income in order to ease the consumption pressure imposed by a large number of adults. Number of adults was captured as the number of persons in the household older or equal to 18 years.

Education level

Most studies have found a positive effect of education on adoption. According to Yirga and Hassan (2008), higher education is believed to be associated with the ability to obtain, process and utilize new information. This suggests that farming households with higher education levels are more likely to adopt ISFM technologies, as opposed to households with low levels of education. Education was measured as the level of education attainment such as none, primary, secondary and tertiary education levels.

Extension

Access to agricultural extension may be a source of information as it creates technology awareness which is one of the preconditions for technology adoption. This was measured in two ways: firstly, whether the farmer has access to extension services denoted by (1) and (0) otherwise. Secondly, as the number of contacts between an extension agent and the farmer in month in a growing season.

Land holding size

Land holding size will be measured in hectares. Larger land size may influence adoption of ISFM positively allowing for larger extent of adoption. On the other hand, small land holding size may encourage intercropping as farmers try to maximize land use (Yirga and Hassan, 2008). Thus the effect of land holding size on the adoption of ISFM may not be assigned a priori expectation in an empirical model. Landholding size was measured as the total land (hectares) owned by the household.

Land ownership

Land ownership is one of the factors that affect the suitability of various investments in land, including soil fertility enhancing technologies such as ISFM (Kamau *et al.*, 2013). Some ISFM technologies (for instance agroforestry trees) are long-term as far as realising their benefits is concerned. This may discourage adoption of such technologies among farmers who do not have their own land or are just renting land for a short period of time. Land tenure system will be measured as a dummy variable whether the farmers have their own private land or not.

Credit access

Access to credit facilitates access to productive resources. According to Lambrecht *et al.* (2014b), credit constraints are shown to inhibit the application of cash-intensive technologies such as mineral fertilizer or improved varieties. Thus, farmers with access to credit are more likely to adopt ISFM technologies as opposed to those with credit constraints. This was measured by whether a farmer had accessed any agricultural credit (such as fertilizer and seed) in the 2014/15 season or not.

Group membership

Farmer group membership was included to test the influence of social capital on adoption. As a form of social capital, group membership facilitates exchange of information and enables farmers access to inputs on time and help overcome credit constraints and shocks (Kassie *et al.* 2015a). In addition, farmer group membership can reduce transaction costs and increase farmers bargaining power. This eventually can affect technology adoption.

FISP access

Since ISFM constitute complementary interventions to FISP, the study will test the influence of farmers' access to subsidy coupon (fertilizer or seed) on adoption of ISFM technologies. FISP has been known to facilitate farmers' access to fertilizer and seed which couldn't have been acquired on their own.

Distance to plots

Distance to plots reflects transaction costs encountered by the farmer. Similarly, plot distance is negatively and significantly related with the use labour intensive technologies. The use of inorganic and some crop residues involved extra costs for hauling to distant plots. On the other hand, plots located near residences (backyard or a short distance from residences) are easy to manage and monitor and also represent low risk investments as the chance of losing them is minimal in the event of land redistribution.

3.5.3 Estimating the Productivity Effects of ISFM Technologies

Objective (iii) involved analysing the effects of ISFM technology adoption on maize productivity. However, estimating the causal effect of agricultural technology adoption on household welfare is not straightforward. Asfaw *et al.* (2012) noted that the adoption decision of smallholder farmers is potentially driven by both observed and unobserved characteristics which are also likely to influence the outcome variable, thereby leading to the twin problems of possible heterogeneity and endogeneity. While the simplest approach to analyse welfare implications of ISFM technology adoption on smallholder farmers would be to include a dummy variable for ISFM adoption in the welfare equation, and then, apply OLS, the approach is likely to yield biased and inconsistent estimates. This is so because it assumes that ISFM technology adoption is determined by exogenous factors while there are potential endogenous determinants (Falco and Yesuf, 2010). For instance, ISFM technology adoption may enhance crop productivity and welfare status for smallholder farmers, but it may also follow that wealthy status of the farmers facilitate more ISFM technology adoption.

There are several ways of addressing endogeneity caused by selection bias. One common approach is the use of sample selection models (Heckman, 1979) and propensity score matching. Sample selection models such as Heckman involves modelling the simultaneity nature of equations. However, the problem with selection models based on a pooled data estimation of both adopters and non -adopters assumes that the list of explanatory variables has the same impact on both groups of farmers and implies that participation has an average effect on the whole sample which may not be necessarily true (Negash, 2012). On the other hand, while PSM develops a counterfactual situation to address the problem of selection bias, but this is based only on observable characteristics. This means that selection bias based on unobservable heterogeneity remains largely unaccounted for (Shiferaw *et al.*, 2014).

To account for both observed and unobservable selection biases, the present study employed an endogenous switching regression model (ESR) that follows two steps: First, the decision to adopt ISFM technologies or not and secondly the outcome of ISFM technology adoption. Since ISFM aims at maximising the agronomic efficiency of applied nutrients to improve crop productivity, maize yield per hectare was used as an outcome indicator of household welfare proxy for household food security. Following Lokshin and Sajaia (2004), Negash (2012), and Asfaw *et al*. (2012), the endogenous switching regression model of maize yield where farmers are faced with two regimes is defined as follows:

$$d_i = \begin{cases} 1 \; if \; \gamma Z_i > u_i \\ 0 \; if \; \gamma Z_i \leq u_i \end{cases} \quad (12)$$

where d_i is a latent observed variable which is determined by both observed and unobserved characteristics that determine which regime the farmer falls. The latent equation for d_i is given by:

$$d_i^* = \gamma Z_i + u_i \quad (13)$$

The outcome equation for each farmer position is defined as follows:

Regime 1: $y_{1i} = \beta_1 X_{1i} + \varepsilon_{1i}$ (14)

Regime 2: $y_{2i} = \beta_2 X_{2i} + \varepsilon_{2i}$ (15)

Where y_{ji} are the dependent variables in the yield outcome equation, X_{1i} and X_{2i} are vectors of exogenous variables and ε_{1i}, ε_{2i} and u_i are parameters to be estimated. The error terms are assumed to have a trivariate normal distribution, with zero mean and covariance matrix denoted by sigma (σ) as presented below:

$$\sigma = cov(\varepsilon_{1i}, \varepsilon_{2i}\ u_i) = \begin{pmatrix} \sigma^2\varepsilon_1 & . & \sigma\varepsilon_1 u \\ . & \sigma^2\varepsilon_2 & \sigma\varepsilon_2 u \\ & & \sigma^2 u \end{pmatrix} \quad (16)$$

Where $\sigma^2 u$ is the covariance of the error term in the selection equation (13), $\sigma^2\varepsilon_1$ and $\sigma^2\varepsilon_2$ are the variances of the error term in the yield outcome functions (14) and (15) and $\sigma\varepsilon_1 u$ and $\sigma\varepsilon_2 u$ represents covariances of u_i ε_{1i} and ε_{2i}. The error structure has an important implication in that the error term of the selection (adoption) equation (12) is correlated with error terms of the yield outcome equations (14) and (15) (ε_{1i} and ε_{2i}). As a result, the expected values of ε_{1i} and ε_{2i} conditional on sample selection are non-zero (Asfaw *et al.*, 2012):

$$E[\varepsilon_{1i}|d_i = 1] = \sigma\varepsilon_1 u\ \frac{\phi(\beta X_i)}{\Phi(\beta X_i)} = \sigma\varepsilon_1 u\ \lambda_{1i} \quad (17)$$

$$E[\varepsilon_{2i}|d_i = 0] = \sigma\varepsilon_2 u\ \frac{\phi(\beta X_i)}{1-\Phi(\beta X_i)} = \sigma\varepsilon_2 u\ \lambda_{2i} \quad (18)$$

Where $\phi(.)$ is the standard normal probability function, $\Phi(.)$ the standard normal cumulative density function and $\lambda_{1i} = \frac{\phi(\beta X_i)}{\Phi(\beta X_i)}$ and$\lambda_{2i} = \frac{\phi(\beta X_i)}{1-\Phi(\beta X_i)}$. It therefore follows that if the covariances $\sigma\varepsilon_1 u$ and $\sigma\varepsilon_2 u$ are statistically significant, then the decision to adopt ISFM technologies and the yield (welfare) outcome variable are correlated; then there is enough evidence of endogenous switching and the null hypothesis of the absence of sample selection bias is rejected.

The endogenous switching regression is estimated by the full information maximum likelihood to yield efficient and consistent standard errors. This is done by firstly estimating the selection equation (probit criterion) followed by the regression equation. The log likelihood function of the systems of equations (13), (14) and (15) under the assumption of trivariate normal distribution of the error terms is given by:

$$LnLi = \sum_{i=1}^{N} d_i \left[ln\phi\left(\frac{\varepsilon_{1i}}{\sigma\varepsilon_1}\right) - \ln\ \sigma\varepsilon_1 + \ln\Phi(\varphi_{1i})\right] + (1-d_i)\left[\ln\phi\left(\frac{\varepsilon_{2i}}{\sigma\varepsilon_2}\right) - \ln\ \sigma\varepsilon_2 + \ln\left(1-\Phi(\varphi_{2i})\right)\right] \quad (19)$$

Where $\varphi_{ji} = \frac{(\beta X_i + \gamma_j \varepsilon_{ji/}\sigma_j)}{\sqrt{1-\gamma_j{}^2}}, ji = 1,2$

with γ representing the correlation coefficient between error terms u_i of the selection equation (13) and error term ε_{ij} of equations (14) and (15).

For identification purposes, ESR is estimated with instrumental variables (selection instruments) to allow for exclusion restriction on equation (20) (Asfaw *et al.,* 2012). Thus three instrumental variables that influence the probability of adoption ISFM of technologies were identified based on their reflection about access to information. These are radio ownership that may simulate farmers' access to information, access to government extension workers and group membership. Following Asfaw *et al.* (2012), the validity of the instruments was established by the test: if a variable is a valid instrument, it will affect the decision to adopt ISFM technologies but it will not affect yield outcome equation among non-adopter households. Results revealed that all the three variables proved to be valid instruments.

The ESR was also used to compare the expected yield levels between ISFM technology adopters (equation 22 and non-adopters (equation 23) and to examine the expected yield levels in the counterfactual hypothetical cases that adopters did not adopt (c) and non-adopters adopted (d). The conditional expectation for the expected yield levels in the four cases are defined as follows:

$E[Y_{1i}|d_i = 1] = \beta_1 X_{1i} + \sigma\varepsilon_1 u\, \lambda_{1i}$ (Observed adoption) 20 (a)

$E[Y_{2i}|d_i = 0] = \beta_2 X_{2i} + \sigma\varepsilon_2 u\, \lambda_{2i}$ (Observed non-adoption) 20 (b)

$E[Y_{2i}|d_i = 1] = \beta_2 X_{2i} + \sigma\varepsilon_2 u\, \lambda_{1i}$ (Counterfactual adoption) 20 (c)

$E[Y_{1i}|d_i = 0] = \beta_1 X_{1i} + \sigma\varepsilon_1 u\, \lambda_{2i}$ (Counterfactual non-adoption) 20 (d)

From the four equations above, the effect of the treatment (ISFM technology adoption) on the treated (adopters) (ATET) was calculated as the difference between 20 (a) and 20 (c) as follows:

$$ATT = E[Y_{1i}|d_i = 1] - E[Y_{2i}|d_i = 1] = X_{1i}(\beta_1 - \beta_2) + \lambda_{1i}\, (\sigma\varepsilon_1 u - \sigma\varepsilon_2 u) \qquad (21)$$

Similarly, the effect of the treatment on the untreated (ATU) for non-adopters was calculated as the difference between 21 (d)and21 (b) as follows:

$$ATU = E[Y_{1i}|d_i = 0] - E[Y_{2i}|d_i = 0] = X_{2i}(\beta_1 - \beta_2) + \lambda_{2i}\, (\sigma\varepsilon_1 u - \sigma\varepsilon_2 u) \qquad (22)$$

3.6 Study Area

The study was conducted in Kasungu Districts in Mkanakhoti EPA (120 35S, 330 31E) which falls under Kasungu Agricultural Development Division (KADD). The area is characterised by ultisols soil type of sandy texture with low organic matter content, low nitrogen and moderate to high phosphorus content. The specific study villages where the Legume Best Bets Project is being implemented included the following: Chisazima, Tchezo, Chaguma, Kaunda, Ndaya and Mjinge, which all fall under Traditional Authority (TA) Simlemba Figure 3.2 presents map of Malawi showing the study area.

3.7 Data Sources

The study used both primary and secondary data. Initially, a reconnaissance survey was conducted to establish, among others, common ISFM technologies being practiced by the farmers, trend in the number of farmers practicing and abandoning the ISFM technologies and challenges facing smallholder farmers with regard to adoption of the ISFM technologies. Primary data were collected at both household and plot level using a semi-structured questionnaire that was administered through a survey. Focus group discussions (FGDs) with the farmers and key informant interviews with project staff were also conducted. Data collected included household characteristics, plot characteristics, type of ISFM technologies practiced, yield levels and others.

3.8 Sampling Design and Sample Size

A three-stage stratified random sampling design was applied to draw sample for the study. The first stage involved purposive selection of Kasungu district, where LUANAR (Bunda

Campus) in collaboration with the McKnight Foundation has been implementing the Legume Best Bets Project since 2006/07. This was followed by the selection of Mkanakhoti EPA based on potential of ISFM technologies. From the EPA, six project villages were identified and individual farmers were randomly selected using probability proportional to size (PPS) sampling procedure. The sampling frame was obtained from the project lead farmers. The sample size comprised adopters and non-adopters of the four ISFM technologies as follows: Inorganic fertilizer (153 adopters and 47 non-adopters), improved seed (151 adopters and 49 non-adopters), maize-legume intercropping (92 adopters and 108 non-adopters) and legume-maize-rotation (133 adopters and 67 non-adopters).

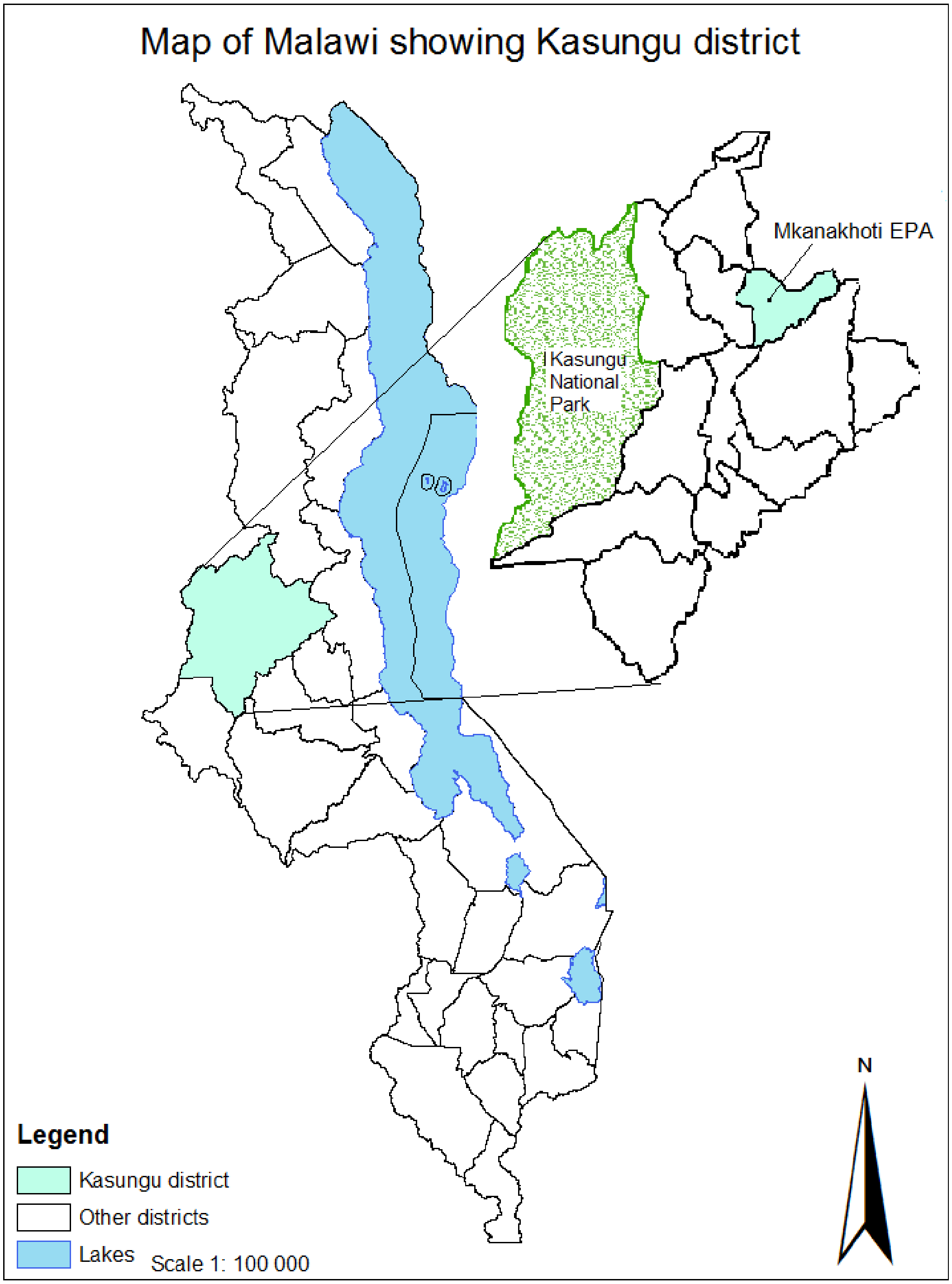

Figure 3.2 Map of Malawi showing Mkanakhoti EPA in Kasungu District

Source: Own generated by the researcher

CHAPTER FOUR

RESULTS AND DISCUSSION

This chapter presents the results of the study. These include descriptive statistics and discussion on factors affecting adoption and extent of adoption of ISFM Technologies. This is followed by discussion on productivity effects of ISFM technology adoption, conclusions and policy recommendations.

4.1 Demographic and Socio-Economic Characteristics of the Study Population

Table 4.1 presents a summary of key demographic and socio-economic characteristics by technology and farmer category. The table indicates that farmers adopted the technologies in different combinations, with inorganic fertilizer as the starting point. From inorganic fertilizer, the farmer was considered to move towards "complete ISFM" the more his/her technology combination comprised improved seed, maize-legume intercropping and rotation, in that order, coupled with proper crop management practices.

In terms of gender composition, the sample was dominated by male headed households across all the technologies and the pooled sample with 172 (86.0%) households being headed by males while 28 (14.0%) were headed by men. The mean age of adopters and non-adopters for maize-legume intercropping was 44.5 and 43.8, respectively, while that of legume-maize-rotation was 44.2 and 43.9 for adopters and non-adopters, respectively. The mean age for the total sample was 44.1 years. Landholding size, one of the factors that influence agricultural technology adoption, did not vary much among the four technologies and farmer groups. However, it is worth noting that for legume-maize rotation, adopters had considerable higher landholding size of 2.1 ha against 1.8 ha for non-adopters, on average. For improved, seed, both adopters and non-adopters had almost the same landholding size of 2.0 and 2.1 ha, respectively, while adopters of inorganic fertilizer had an average total landholding size of 2.0 as compared to non-adopters with 2.2 ha while the total sample had an average landholding size of 2.0 ha.

Table 4.1 shows that non-adopters had relatively large plot distance compared to adopters across almost all the technologies except for legume maize-rotation, where adopters had relatively larger plot distance than non-adopters. For example, the average distance from farmer homestead to the main plot among inorganic fertilizer adopters was 0.65 km while that among non-adopters was 0.75 km. The average plot distance for the pooled sample was 0.7 km. Access to FISP coupon reflects government's support towards improving smallholder farmers' access to productive resources. As shown in Table 4.1, access to FISP coupon was higher among adopters than non-adopters for inorganic fertilizer, improved seed and legume-maize rotation. For instance, 95 (62.1%) inorganic fertilizer adopters had access to FISP coupons while only 19 (40.4%) of the non-adopters had access to FISP coupons. This attest to the fact that FISP has indeed increased uptake of inorganic fertilizer among smallholder farmers. On the other hand, 58 (37.9%) of inorganic fertilizer adopters and 28 (59.6%) inorganic fertilizer non-adopters had no access to FISP coupons. This means that those who did not access FISP coupons but applied inorganic fertilizer had to finance purchase of the fertilizer on their own. As for improved seed, 91 (60.3%) of the adopters had access to FISP coupons against 60 (39.7%) who did not. On the other hand, 23 (46.9%) of the non-adopters had access to FISP coupons but reportedly sold the coupons compared to 26 (53.1%) who did not.

Table 4.1 also generally depicts limited access to credit among the adopters across all the four technologies with only 45 (22.5%) of the pooled sample having access to credit compared to 155 (77.55) who had no access to credit. This was not surprising as most of the farmers who had obtained credit were those who were engaged in the main cash crop (tobacco) than ISFM adopters who were specialising in maize production. The credit was obtained from private companies such as Japanese Tobacco International (JTI), Alliance One and Limbe Leaf was mainly in form of farming inputs such as fertilizer and fuelwood for processing the tobacco.

Table 4.1 Summary of Key Demographic and Socio-Economic Characteristics by Farmer and Technology Category

Variable		Inorganic fertilizer		Improved seed		Maize-legume intercropping		Legume-maize rotation		Total
		Adopters n=153	**Non-adopters n=47**	**Adopters n=151**	**Non-adopters n=49**	**Adopters n=92**	**Non-adopters n=108**	**Adopters n=133**	**Non-adopters n=67**	**n=200**
Age of the household head	(Years)	44.4 (12.7) ^{ns}	43.4 (13.03)^{ns}	44.6 (12.2)^{ns}	42.6 (14.23)^{ns}	44.5 (12.8)^{ns}	43.8 (12.82)^{ns}	44.2 (12.53)^{ns}	43.9 (13.33)^{ns}	44.1 (12.77)
Household size		5.8 (1.9448)^{a**}	5.3 (1.9772^{a**}	5.7 (2.0060)^{ns}	5.7 (1.8346)^{ns}	5.8 (2.0752) ^{ns}	5.6 (1.8597)^{ns}	5.8 (1.9387)^{ns}	5.6 (2.0010)^{ns}	5.7 (1.9609)
Number of adults		2.6 (1.1216)^{a**}	2.3 (0.7061)^{a**}	2.5 (1.0763)^{ns}	2.5 (0.9601)^{ns}	2.6 (1.1468) ^{a*}	2.4 (0.9476) ^{a*}	2.5 (1.0622) ^{ns}	2.4 (1.0173) ^{ns}	2.5 (1.0467)
Farming experience	(Years)	19.6 (11.55) ^{ns}	21.1 (12.17)^{ns}	20.0 (11.05)^{ns}	19.8 (13.55)^{ns}	20.9 (12.24) ^{ns}	19.1 (11.20) ^{ns}	20.3 (11.55) ^{ns}	19.2 (12.07) ^{ns}	20 (11.68)
Landholding size	(ha)	2.0 (1.6019)^{ns}	2.1 (3.1234) ^{ns}	2.0 (1.8416) ^{ns}	2.1 (2.6250)^{ns}	2.2 (1.9808)^{ns}	1.9 (2.1141)^{ns}	2.1^{ns}	1.8 (1.3486)^{ns}	2.0 (2.054)
Plot distance	(km)	0.65 ^{ns}	0.75 ^{ns}	0.62 ^{ns}	0.83 ^{ns}	0.56 ^{ns}	0.80 ^{ns}	0.70 ^{ns}	0.63 ^{ns}	0.7
Sex of the household head (%)	Male	135 (88.2)^{ns}	37 (78.7) ^{ns}	131 (86.7) ^{ns}	41 (83.7) ^{ns}	79 (85.9) ^{ns}	93 (86.1) ^{ns}	116 (87.2) ^{ns}	56 (83.6) ^{ns}	172 (86.0)
	Female	18 (11.8)	10 (21.3)	20 (13.3)	8 (16.3)	13 (14.1)	15 (13.9)	17 (12.8)	11 (16.4)	28 (14.0)
Education level of household head	Never attended	5 (3.3)	3 (6.4)	5 (3.3)	3 (6.1)	3 (3.3)	5 (4.6)	7 (5.3)	1 (1.5)	8 (4.0)
	Primary	111 (72.5)	33 (70.2)	104 (68.9)	40 (81.6)	70 (76.1)	74 (68.5)	92 (69.1)	52 (77.6)	143 (72.0)
	secondary	36 (23.5)	11 (23.4)	41 (27.1)*	6 (12.3)	18 (19.6)	29 (26.9)	33 (24.8)	14 (20.1)	47 (23.5)
	Tertiary	1 (0.7)	0 (0.0)	1 (0.7)	0 (0.0)	0 (0.0)	1 (1.0)	1 (0.8)	0 (0.0)	1 (0.5)

Figures in parentheses are percentages for categorical variables and Std. Dev. for continuous variables; [a] indicate t-test, [b] indicate chi-square test* *Significant at 10% (p<0.1), ** significant at 5% (p<0.05), and *** significant at 1% (p<0.01),* ^{ns} *Not significant*

Table 4.1 Cont'd

Variable		Inorganic fertilizer		Improved seed		Maize-legume intercropping		Legume-maize rotation		Total
		Adopters n=153	Non-adopters n=47	Adopters n=151	Non-adopters n=49	Adopters n=153	Non-adopters n=47	Adopters n=151	Non-adopters n=49	n=200
Access to fertilizer coupon	Yes	95 (62.1)^{b**}	19 (40.4)	91 (60.3)b*	23 (46.9)	52 (56.6)^{ns}	62 (57.4)	72 (54.2)^{ns}	42 (62.7)	114 (57.0)
	No	58 (37.9)	28 (59.6)	60 (39.7)	26 (53.1)	40 (43.4)	46 (42.8)	61 (45.8)	25 (37.3)	86 (43.0)
Group membership	Yes	94 (61.44)^{ns}	31(66.0)	100 (66.2)^{b**}	25 (51.0)	73 (79.35)^{b***}	52 (48.2)	80 (60.2)^{ns}	45 (67.2)	125 (62.5)
	No	59 (38.56)	16 (34.0)	51 (33.8)	24 (49.0)	19 (20.65)	56 (51.8)	53 (39.8)	22 (32.8)	75 (37.5)
Access to credit	Yes	34 (22.2)	11 (23.4)	38 (25.2)	7 (14.3)	21 (22.83)	24 (22.2)	35 (26.3)^{b*}	10 (14.9)	45 (22.5)
	No	119 (77.8)	36 (76.6)	113 (74.8)	42 (85.7)	71 (77.17)	84 (77.8)	98 (73.7)	57 (85.1)	155 (77.5)
Access to extension	Yes	108 (70.6)	28 (59.57)	107 (70.86)	29 (59.2)	76 (82.6)^{b***}	60 (55.6)	94 (70.7)	42 (62.7)	136 (68.0)
	No	45 (29.4)	19 (40.53)	44 (29.14)	20 (40.8)	16 (17.4)	48 (44.4)	39 (29.3)	25 (37.3)	64 (32.0)
ISFM training	Yes	73 (47.7)	18 (38.3)	76 (50.3)^{b**}	15 (30.6)	57 (62.0)^{b***}	34 (31.5)	57 (42.9)	34 (50.8)	91 (45.5)
	No	80 (52.3)	29 (61.7)	75 (46.7)	34 (69.4)	35 (38.0)	74 (68.5)	76 (57.1)	33 (49.2)	109 (54.5)

Figures in parentheses are percentages for categorical variables and Std. Dev. for continuous variables; [a] indicate t-test, [b] indicate chi-square test* *Significant at 10% (p<0.1), ** significant at 5% (p<0.05), and *** significant at 1% (p<0.01),* [ns] *Not significant*

4.2 Legume Integration

4.2.1 Awareness of Various Legume Technologies

Special focus in this study was given to maize intercropped with a legume crop or legume-maize rotations. The study focussed on the legumes which are being promoted by the Legume BB Project. These legumes include pigeon peas *(Cajanus cajan),* soybeans *(Glycine max)* and groundnuts *(Arachis hypogaea*) grown either as intercrops or in rotation with maize. Table 4.2 presents the levels of awareness of different maize-legume intercropping and rotation technologies. The results indicate that there is high level of awareness of the technologies among the farmers in the study area. For instance, all the farmers (100 %) indicated that they are aware of sole maize and inorganic fertilizer (Table 4.2). According to Fairhurst, (2012), mineral fertilizer is an entry point to ISFM. In regard to the maize-legume technologies, apart from maize and beans intercropping which is a traditional practice in the study area, soybean intercropped with maize exhibited the highest level of awareness among the farmers (69.5%) followed by soybean intercropped with pigeon peas (64.0%), groundnuts and pigeon pea intercropping (58.0%) and maize and pigeon pea intercropping (57.0%).

Crop rotation seems to be the most common practice in the study area regardless of farmer's BB project membership status. The highest recorded awareness level was with the traditional beans and sole maize rotation (74%) followed by soybean-sole maize rotation (72%) and groundnut-sole maize rotation (68.5%). The lowest awareness recorded was soya inoculation with only about 19.5 % of the farmers reported to have heard of the technology/practice.

Table 4.2 Awareness of Various Legume Technologies (Percentage)

Technology/practice	Awareness	
	Yes	**No**
Sole maize + inorganic fertiliser	200 (100)	0 (0.0)
Maize + pigeon pea intercrop	114 (57.0)	86 (43.0)
Maize + beans intercrop	184 (92.0)	16 (8.0)
Maize + soybeans intercrop	139 (69.5)	61(30.5)
Soya + pigeon pea intercrop	128 (64.0)	72 (36.0)
Groundnuts + pigeon pea intercrop	116 (58.0)	84 (42.0)
Maize + groundnuts intercrop	101 (50.5)	99 (49.5)
Pigeon pea/maize rotation	92 (46.0)	108 (54.0)
Bean/sole maize rotation	148 (74.0)	52 (26.0)
Soybean inoculation	39 (19.5)	161 (80.5)
Soybean/sole maize rotation	144 (72.0)	56 (28.0)
Groundnut/sole maize rotation	137 (68.5)	63 (31.5)
Soya + pigeon pea intercrop/sole maize rotation	99 (49.5)	101 (50.5)
Groundnuts +pigeon pea intercrop-sole maize rotation	94 (47)	106 (53)
Agroforestry trees	93 (46.5)	107 (53.5)

Figures in parentheses are percentages

4.2.2 Try-out of the technologies

Try-out is the second stage in the technology adoption process after awareness. In this study, try-out was defined as the first experimentation with the legume technologies in farmers' own fields beyond the 10m x 10m. While the level of awareness of the different technologies among the farmers in the study area is high, try-out of the technologies is low except for sole maize and inorganic fertilizer where all the farmers indicated to have tried the technologies. Crop rotation recorded the highest percentage for try-out as compared to intercropping technologies (Table 4.3). For instance, the highest percentage of rotation system was for soybean-sole maize rotation (86.9%) followed by groundnut-sole maize rotation (86.0%) and bean-sole maize rotation (82.85). While for intercropping, the highest percentage recorded was for the traditional maize and beans intercropping (90.2%) followed by maize and soybeans intercrop (62%) and soybeans and pigeon pea intercrop (56.0%). The lowest percentage for try-out was soybean inoculation. It was discovered that the prominence of soybean and groundnuts in study area is due to the fact that the two legumes serve as alternative cash crops to tobacco besides soil fertility improvement. Thus they are mostly grown as sole crops in rotation with maize.

Table 4.3 Try-out of Various Legume Technologies among the Sampled Farmers

Technology/practice	Try-out	
	Yes	**No**
Sole maize and inorganic fertiliser	200 (100)	0 (0.0)
Maize + pigeon pea intercrop	44 (40.0)	66 (60)
Maize + beans intercrop	165 (90.2)	18 (9.8)
Maize + soybeans intercrop	85 (62.0)	52 (38.0)
Soy bean + pigeon pea intercrop	75 (56.0)	59 (44.0)
Groundnuts + pigeon pea intercropping	62 (53.0)	54 (47.0)
Maize + groundnuts intercrop	47 (46.5)	54 (53.5)
Pigeon pea/maize rotation	49 (49.5)	50 (50.5)
Bean/sole maize rotation	120 (82.8)	25 (17.2)
Soybean inoculation	9 (15.5)	49 (84.5)
Soybean/sole maize rotation	126 (86.9)	19 (13.1)
Groundnut/sole maize rotation	117 (86.0)	19 (14.0)
Soya + pigeon pea intercrop/sole maize rotation	48 (47.1)	54 (52.9)
Groundnuts +pigeon pea intercrop-sole maize rotation	30 (31.9)	64 (68.1)
Agroforestry trees	34 (38.6)	54 (27.0)

Figures in parentheses are percentages

4.2.3 Reasons for Non-Try-out of Legume Technologies

The study also explored the reasons for non-try-out of the technologies among the farmers. As presented in Figure 4.1, the major constraint to legume diversification of the maize-based farming system in study area is lack of access to legume seed, as indicated by 72.2 % of the responses. Farmers are constrained either by cash to finance the purchase of improved legume seed or lack of input markets from which to buy critical farm inputs like seed. In addition, it is difficult for farmers to recycle improved legume seed due to decline in viability over time as well as failure to withstand pests and diseases. This is especially true for improved seed varieties. This finding concurs with what Mhango *et al.* (2012) who in the same study area found that important constraints to adoption of legume diversification in the maize-based farming system are limited grain markets and access to seed, among others.

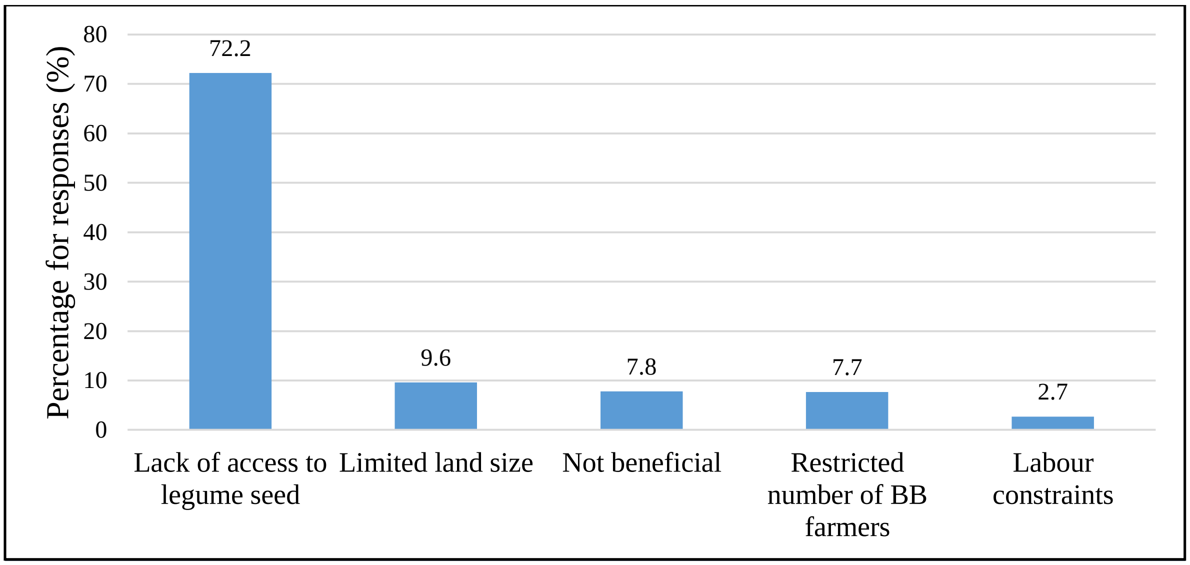

Figure 4.1 Reasons for Non-Try out/Not practicing of the Legume Technologies

Figure 4.2 shows the trend in the number of farmers practicing intercropping technologies for their first time over the years. The figure depicts that the trend has been very low and constant from 1966 to 2002. However, from 2006, there has been a sharp increase in the number of farmers trying-out the intercropping technologies. This may reflect a significant presence of the BB project in the study area which was introduced in 2006/07 growing season and has been running in phases with each phase spanning four years. As shown in figure 4.6 the second and third phases of the project reflect increasing trend in the number of farmers first trying-out the technologies with the third phase (which had just started during the 2014/15) season recording highest number of farmers. This can be attributed to increasing awareness as the project becomes established in the study area over time. Key Informant Interviews with the project staff revealed that the first phase of the project served as the trial stage to farmers with the expectation of continued adoption in the second and third phases.

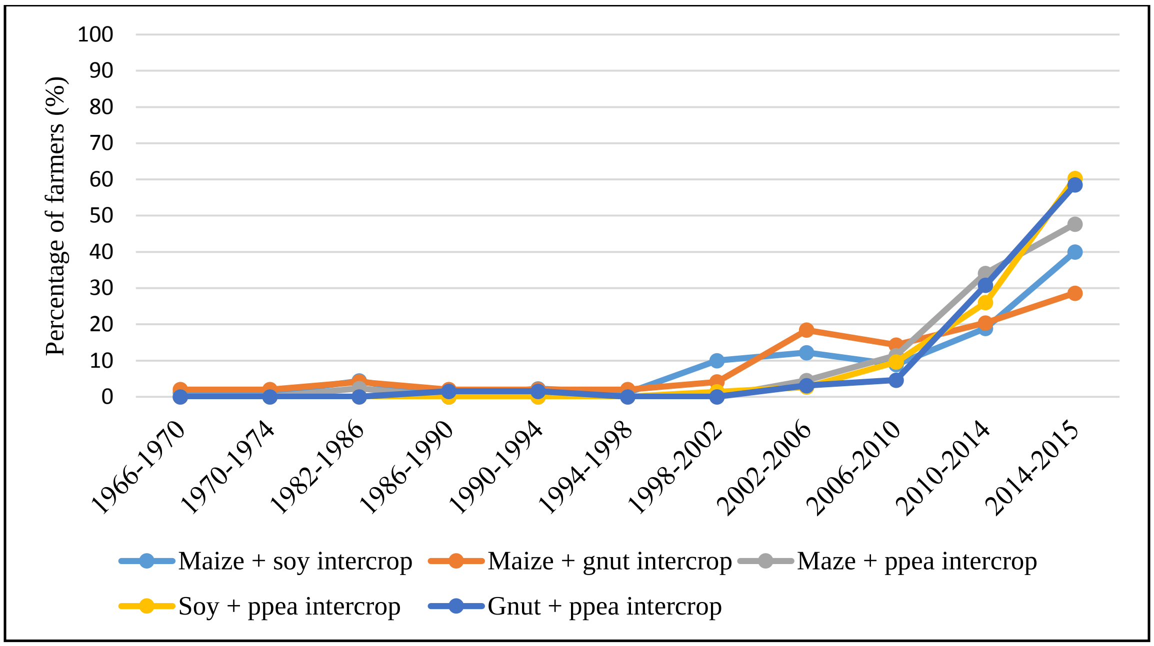

Figure 4.2 Trend in the Number of Farmers Trying Out Intercropping Technologies over Time

As for rotation technologies/cropping systems, it was observed that farmers in the study area have been practicing crop rotation before the introduction of the project though at a small scale. With the exception of pigeon peas, farmers in the maize-based farming system of the study area have been practicing soybean-sole maize rotation and groundnut-sole maize rotation since the 1980s. It was observed that pigeon peas are almost a new crop in the area that was introduced by the Legume BB Project as opposed in the southern region where the crop is grown traditionally with minimum crop management. Among others, pigeon peas are susceptible by pests and diseases and farmers also complained that the soils in the study area are not suitable for the crop. Figure 4.3 presents the trend in the percentage of farmers trying out rotation technologies in the study area.

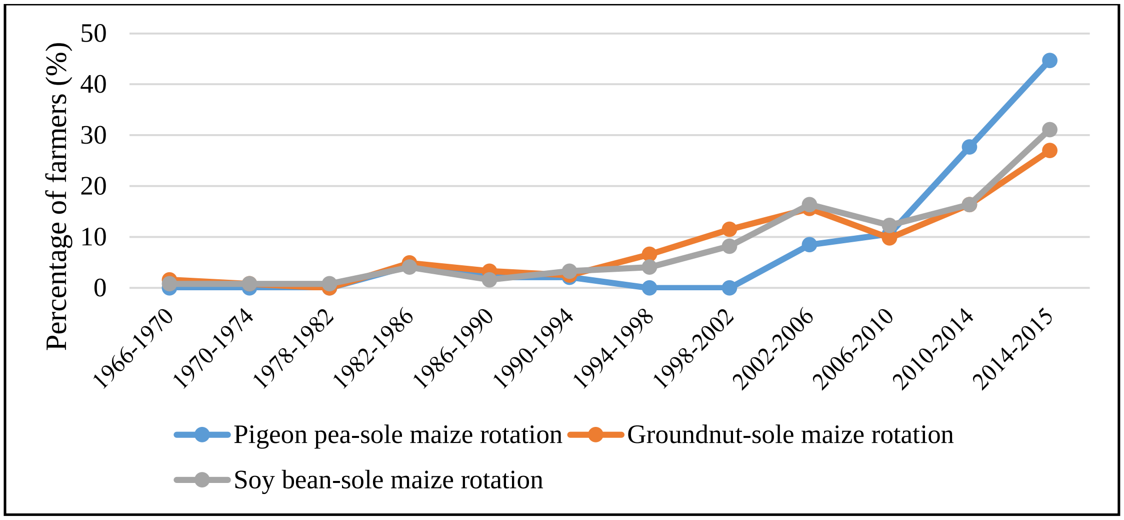

Figure 4.3 Trend in the Number of Farmers Trying Out-Legume Rotation Technologies

4.3 Adoption of Various ISFM technologies

This section presents the rate of adoption of various ISFM technologies in the study area. The four technologies considered in this study are inorganic fertilizer, improved seed, and maize-legume intercropping and legume-maize rotation. For maize, improved seed varieties comprised hybrid and open pollinated verities (OPVs). All these four technology categories form the core components of ISFM whose entry point is inorganic fertilizer.

The use of inorganic fertilizer has been highly heralded in Africa as panacea to crop productivity while the use of improved seed has contributed significantly to the achievement of food security worldwide. Maize–legume intercropping and/or rotation helps smallholder farmers to grow crops with different environmental needs and stress–response characteristics and allows crops to benefit from interactions among the individual crops, such as reducing the incidence of weeds, breaking pests and diseases cycles; improving soil fertility, organic matter content, and water-holding capacity. Besides, it makes diversification of the seasonal requirements of resources and potential stabilization of farm income over time necessary.

4.3.1 Factors Influencing Adoption of ISFM Technologies

This section presents the results of the multivariate probit model that was employed to determine factors influencing adoption of multiple ISFM technologies. Inorganic fertilizer, improved maize varieties (hybrid or OPVs), maize-legume (and/or doubled up) intercropping and legume-maize rotation were the major ISFM technology components that were assessed in this study. Inorganic fertilizer and improved maize seed variety are considered as input-intensive technologies while maize-legume intercropping and rotation are deemed low-input intensive technologies (Ahmed, 2015). Table 4.4 presents the results of the joint multivariate probit model for the adoption of ISFM technologies. The four adoption equations do not necessarily contain the same explanatory factors as these were carefully selected based on previous empirical studies and economic theory associated with adoption of each ISFM technologies.

Table 4.4 Results of the Multivariate Probit Model for Factors Influencing Adoption of ISFM Technologies

	ISFM technology			
Explanatory variable	**Inorganic fertilizer n=153**	**Improved seed n=151**	**Intercropping n=92**	**Rotation n=133**
Sex of household head (1=Male, 0=Female)	0.1120 (0.3810)	0.5426 (0.3562)	0.0737 (0.3269)	0.4619 (0.3231)
Age of household head (years)	-0.0175 (0.0105)*****	0.0107 (0.0091)	0.0030 (0.0077)	
Farm experience (years)				0.0126 (0.0090)
Land ownership (1=Own land, 0=otherwise)	0.4282 (0.4750)	0.6390 (0.4524)	0.1020 (0.2622)	0.5732 (0.2711)******
Land size (ha)			0.0080 (0.0538)	0.1010 (0.0574)*****
Number of adults	0.2322 (0.1452)			
Access to FISP coupon (1=Yes, 0=No)	1.0838 (0.2589)*******	0.1805 (0.2306)		
Soil fertility perception (1=average, 0=otherwise)	0.3871 (0.2611)	0.6798 (0.2339)*******		
Soil fertility perception (1=fertile, 0=otherwise)				0.4931 (0.2489)******
Education level of spouse (1=Senior primary, 0=otherwise)	0.0603 (0.2695)			.
Education level of spouse (1=Junior secondary, 0=otherwise)		0.7057 (0.4680)		
Extension access (1=Yes, 0=No)	0.6618 (0.2722)******		0.5257 (0.2380)******	
Log of household income (MK)	0.2153 (0.0930)******	0.2144 (0.0967)******		
Radio ownership (1=Yes, 0=No)		0.3630 (0.2539)		
ISFM training (1=Yes, 0=No)		0.5807595 (0.2450)******		-0.2590 (0.1979)
Legume seed access (1=Yes, 0=No)			0.6659 (0.2067)*******	-0.4047 (0.1984)******
Credit access (1=Yes, 0=No)		0.3794 (0.2892)	-0.3425 (0.2566)	0.5254 (0.2479)******
Market access (1=Yes, 0=No)			0.0021 (0.0005)******	0.2841 (0.2061)
Group membership (1=Yes, 0=No)			0.6521 (0.2228)*******	.
Constant	-2.4531 (1.2717)	-3.7936 (1.3068)	-1.4136 (0.5716)	-0.8797 (0.5406)

N = 178 Wald chi2(37) = 258.25 Prob > chi2 = 0.0000 Log pseudolikelihood = -330.66398

Likelihood ratio test of rho21 = rho31 = rho41 = rho32 = rho42 = rho43 = 0: chi2(6) = 17.3651 Prob > chi2 = 0.0080

Figures in parentheses are percentages Significant at 10% (p<0.1), ** significant at 5% (p<0.05), and *** significant at 1% (p<0.01)*

The model fits the data well with the Wald$x^2(37) = 258.25; p = 0.0000$, thereby rejecting the null hypothesis that all regression coefficients are jointly equal to zero. The results justify the application of the MVP model as shown by the likelihood ratio test for the overall correlation of error terms as indicated by correlation coefficients (rho) $[x^2(6) = 17; p = 0.0080)]$. This entails that the null hypotheses that the error terms are not correlated is rejected and conclude that the error terms are correlated. This is also confirmed by the significance of some of the pairwise correlation error terms as presented in table 4.5, indicating positive correlation and/or negative correlation between some of ISFM technologies. This implies that the adoption of a given ISFM technology is dependent on the adoption of other ISFM technologies and thus aggregating them into individual ISFM technologies (single-equation approach) would yield biased and inconsistent results.

Consistent with previous studies (e.g. Marenya and Barrett, 2007; Yirga and Hassan, 2008; Teklewold *et al.* 2013; Kamau *et al.* 2013 and Kassie *et al.* 2015a), the following variables were significant in influencing adoption of the four ISFM technologies in the study area: Age of the household head, land tenure, access to FISP coupons, access to extension, access to credit, access to markets, access to legume seed, household income, training in ISFM, soil fertility perception status, land holding size (hectares) and group membership. The selection of these variables was aided by a thorough literature review based on relevant economic theories. The following section discuss the individual effects of the variables on the adoption of a particular ISFM technology.

Age of the household head only significantly influenced adoption of inorganic fertilizer. Table 4.4 shows that age of the household negatively influenced the adoption of inorganic fertilizer at 10% alpha level. This finding concurs with the finding of Marenya and Barrett (2007). This shows that older farmers were less likely to adopt inorganic fertilizer as compared to younger farmers. This may suggest the innovative nature of young farmers who are actively trying out new technologies as opposed to old farmers who tend to cling to old ways of farming. According to Marenya and Barrett (2007), as decision-makers age, their planning curve diminishes and so is the incentive for them to invest in future productivity of their farming plots. On the other hand, younger farmers experience lower switching costs in adopting new technologies and thus healthier and energetic younger farmers are more likely to adopt ISFM technologies than their older colleagues.

Land ownership positively and significantly influenced the adoption legume-maize rotation at 5% alpha level. This suggests that the propensity to adopt legume-maize rotation is high on owner-cultivated plots than on rented and/or leased plots due to tenure insecurity. Because the long-term soil fertility investment benefits (such as legume-maize rotation) accrue over time, this implies that secure land tenure will influence positively on adoption decision (Teklewold *et al.* 2013). The effect of land ownership was also found to be positive in the rest of the three other ISFM technologies (inorganic fertilizer, improved seed variety and intercropping) though not significant. *Ceteris paribus*, this support the notion that farming households engage in long-term ISFM technologies on owned plots and short-term ISFM technologies such as inorganic fertilizer on leased-in plots with immediate effects (Yirga and Hassan, 2008). This finding is in consistent with the findings by Yirga and Hassan (2008) in Ethiopia, Kamau *et al.* (2013) in Kenya and Kassie *et al.* (2015a) in Ethiopia, Kenya, Malawi and Tanzania

As expected, access to subsidized fertilizer coupons was positive and highly significant in influencing adoption of inorganic fertilizer at 1% alpha level. This means that other things being equal, households with access to fertilizer coupons had the highest probability to adopt inorganic fertilizer than those households with no access to fertilizer coupons. This supports the notion that access to FISP has facilitated the adoption and use of inorganic fertilizer as revealed by other studies such as Kassie *et al.* (2015a) in Malawi and Matsumoto *et al.* (2013) in Uganda. The use of more inorganic fertilizer is considered as *panacea* for smallholder farm productivity growth. However, most of the smallholder farmers in Malawi and the study area in particular, are resource-constrained. As such the introduction subsidised fertilizer through FISP has enabled poor households to acquire inorganic fertilizer at a cheaper price as opposed to the market price.

Access to extension depicted positive and significant correlation with adoption of inorganic fertilizer and maize-legume intercropping. This suggests that holding other things equal, access to extension increases the likelihood of adopting both inorganic fertilizer and maize-legume intercropping. The effect of extension access on both inorganic fertilizer and maize-legume intercropping was significant at 5% alpha level. These results are in tandem with the findings by other previous studies such as Kassie *et al.* (2015a) who found that access to extension positively and significantly influenced adoption of inorganic fertilizer in Ethiopia and Tanzania. Awareness is a prerequisite stage to technology adoption and access to extension reflects access to information about a particular technology that increases the probability of adoption of the technology. Besides, ISFM technologies such as inorganic fertilizer and maize-legume intercropping are knowledge-intensive and require considerable management input. This therefore calls for quality extension services with a robust and dynamic extension system in place to promote adoption of such ISFM technologies.

It is thus obvious that the adoption maize-legume intercropping was positively correlated with the adoption of inorganic fertilizer as shown by the positive and significant correlation coefficient (rho) between the two practices in table 4.5 This suggests that the two practices have reinforcing complementary effects on soil fertility and thus on the productivity of maize, the staple food crop in the study area under consideration. Farmers that had adopted maize-legume intercropping are also encouraged to practice crop residue incorporation which improves soil organic matter content (OMC) and texture. This in turn enhances the response of the crop to applied fertilizer nutrients. As observed during the FGDs, farmers are able to harvest more even with little or no basal dressing fertilizer because of the synergies and better nutrient synchronisation emanating from the use of the two practices on the same plot. This forms an important crop management part of the concept of ISFM which is dependent upon quality extension services that impact on farmer knowledge in adapting to local conditions.

The complementary relationship that exist between adoption inorganic fertilizer and maize-legume intercropping raises important policy implications. The results suggest that inorganic fertilizer use must not be promoted (as in FISP) as a stand-alone practice for the management of soil fertility because the recommended fertilizer application rates are often beyond the reach of resource-constrained smallholder farmers. Therefore, combining the FISP package with complementary interventions such as legume seed with the aim of promoting maize-legume intercropping and rotations will help in raising the efficiency of fertilizer use by accelerating the release of nutrients into the soil while producing long-term benefits for sustainable crop production.

One of the important institutional factors that influences adoption of ISFM technologies is access to credit. The coefficient of access to credit was positive and only significant for the adoption of legume-maize and/or legume-legume rotation. This suggest that households with access to credit have greater likelihood of adopting legume-maize rotation than those households with no access to credit, holding other factors constant. This may be so because rotating a legume crop with cereal crop like maize required the use of improved seed varieties and thus inorganic fertilizer as well for greater harvest index. Thus credit was needed to overcome access to improved seed varieties and inorganic fertilizer constraints because these technologies are deemed high-input intensive technologies.

Similarly, access to credit was positive though insignificant in influencing adoption of improved seed varieties but negative and insignificant for the adoption of maize-legume intercropping. The negative relationship with maize-legume intercropping may be explained by the fact that most of the households that had access to credit were engaged in tobacco, the major cash crop in the study are whose cash prospects are high than a legume crop or maize which is mostly grown as a food crop. Credit was mainly in the form of farm inputs such as fertilizer from international companies like Alliance One, Limbe Leaf and JTI International who are specialising in tobacco production. Most of the farmers complained of lack of credit institutions that cater for legume crops as major reason for non-access to credit. It is thus recognised that overcoming access to seed constraint through credit provision would substantially increase adoption of legume diversification in smallholder maize-based farming system.

Access to market was measured by whether the household had interacted with in both input and output markets in any other way through market transaction. The results of the MVP model revealed a positive and highly significant relationship between access to output markets and adoption of maize-legume intercropping. This relationship was significant at 1% ($p<0.01$) alpha level. This finding is consistent with the findings of other previous studies such as Lambrecht *et al*. (2014b). Legumes such as soybean, pigeon peas and groundnuts comprises the second major cash crop after tobacco in the study area and thus despite soil fertility improvement and food and nutritional household requirements, legumes are grown for immediate cash purposes. This means that access to output markets for grain legumes is crucial in realising this objective. Access to market was also found to have a positive but insignificant effect on adoption of legume-maize rotation. This underscores the fact that markets provide a major source of farming inputs in agrarian societies such Mkanakhoti EPA. However, consistent with the predictions of non-separable model of agricultural household; market failures, imperfections or missing markets for some ISFM components or practices may lead to variations in the way they are adopted and applied by the farming households (Kamau *et al*. 2013).

Mhango *et al.* (2012) also noted that limited access to both input (mainly for seed) and output markets was one of the major constraints to adoption of maize-legume intercropping. Therefore, facilitating access to input and output markets among the smallholder farmers either by introduction of these markets in their vicinities or reducing transaction costs that farmers face in accessing the markets by improving the network of road conditions and provision of affordable transportation means would greatly increase the adoption of maize-legume intercropping. Vanlauwe *et al.* (2014) also argue in support that increasing the adoption of sustainable intensification strategies such maize-legume intercropping will, among others, require access to profitable output markets for enhanced productivity growth. According to Sanginga and Woomer 2009), maximum benefits from ISFM technologies can only be obtained within an enabling environment, where factors such as input and output markets are in place, coupled with functional service delivery institutions and progressive policies.

Access to legume seed was found to be positive and highly significant (p=0.001) in influencing adoption of maize-legume intercropping. This finding is in consistent with the findings by Amare *et al.* (2011) who, using a bivariate probit model, found a positive and significant relationship between access to legume seed and adoption of maize-pigeon pea intercropping. This is not surprising as most of the farmers in the sample size reported access to seed constraint as a major impediment to adoption of legume diversification in maize-based farming system. This was more pronounced among the non-adopters. The finding implies holding other things equal, access to legume seed increases the propensity to adopt maize-legume intercropping. Due to food insecurity and poverty challenges, it was revealed that it becomes difficult for farmers to recycle legume seed due to the pressure of household food (relish) requirement. Thus instead of keeping the seed for the next growing season, the temptation for immediate household consumption becomes so high such that farmers find themselves with no seed in the next growing season. Besides, income constraints mean that most of them cannot afford to buy the seed at market prices, let alone exacerbated by missing markets. Access to information about seed is starting point and impacts on access to seed and consequent adoption of legume diversification.

Total annual household income was used as a proxy indicator for wealth status of a household. The variable, total annual household income, was log transformed to normalise the data because of the problem of non-normality. The results of the MVP model revealed a positive and significant relationship between the log of household income and adoption of inorganic fertilizer and improved maize seed varieties at 5% alpha level. This finding was expected given the fact that inorganic fertilizer and improved seed varieties are considered as high-input intensive technologies requiring to be externally purchased from the market. This suggests that, other things equal, wealth farmers can pose the greater likelihood to adopt inorganic fertilizer and improved maize seed varieties than poor farmers. Therefore, it is not surprising that a positive and complementary relationship between the adoption of inorganic fertilizer and improved maize seed varieties was observed though not significant (see Table 4.5). These findings are in agreement with past adoption studies about improved varieties and inorganic fertilizer. For instance, Kassie *et al.* (2015a) found a complementary relationship between adoptions of inorganic fertilizer and improved maize seed varieties in Kenya, Malawi, Tanzania and Ethiopia. The sample size for the present study showed that the majority (over 75%) of the sample adopted both improved seed varieties and inorganic fertilizer.

Farmers' perception of soil fertility status is another important determinant of adoption of ISFM technologies. Farmers' perception of fertile soils was statistically significant ($p<0.05$) and positively influenced adoption of legume-maize rotation and improved seed varieties as opposed to poor (infertile) soils. This underscores the fact that the response of seed and fertilizer inputs is higher in fertile and responsive soils and lower in poor and non-responsive soils (ISFM-Africa, 2012). Thus farmers are more likely to adopt improved seed varieties and inorganic fertilizer on plots that are perceived to be fertile and enhance the efficiency of nutrient use. This may also be explained by the fact that fertile and responsive soils are required to convert more of total biomass product into harvested product in improved varieties thereby increasing harvest index (HI) than in unimproved varieties. Tizale (2007) found similar results in Ethiopia that farmers' perception of degraded soils reduced the probability of famers to invest in soil fertility improvement measures such as organic manure. Kassie *et al.* (2015a) also found that moderate soil fertility perception positively and significantly influenced adoption of inorganic fertilizer in Ethiopia and Tanzania.

Land holding size has a positive and significant influence on adoption of legume-maize rotation at 10% as indicated by a positive coefficient and p-value <0.1. This implies that the likelihood of adopting legume-maize rotation as opposed to mono-cropping is higher with households that have large landholding sizes than those households with smaller landholding size, ceteris paribus. Tizale (2007) found similar results in Ethiopia and showed that large landholding sizes make crop rotation such as legume-maize rotations more attractive than maize-legume intercropping which is practiced to maximise land use and spread economic risk, among others. Large landholding size gives a farmer the flexibility to use land intensive ISFM practices such as improved fallow and crop rotation. It is thus not surprising that land size was not significant in influencing adoption of maize-legume intercropping in the study area.

The findings in this present study confirmed the important role of social capital in facilitating adoption of ISFM technologies. Group membership was found to be positive and highly correlated with adoption of maize-legume intercropping suggesting that households that belong to any farmer group or rural institution pose high probability of adopting maize-legume intercrop as opposed to those households that do not. The finding was expected as group membership enables collective action that facilitates access to information, access to credit and extension services that are necessary for technology adoption (Taklowed, 2013; Amere 2011). ISFM technologies such as maize-legume intercropping are knowledge intensive and thus group/association membership provides the alternate source of quality extension messages to the ailing government extension system for the better management of ISFM technologies. Group membership was also found to facilitate access to legume seed as evidenced by the fact the legume BB project only target those farmers in groups for the provision of seed and inorganic fertilizer

As earlier pointed out, ISFM technologies are knowledge intensive requiring better management of the adopted technology components on the farm combined with adaptation to local conditions. The choice of the practice, field, and timing are all important for successful implementation of the concept and this requires substantial investment in local research and training capacity (Kamau *et al.* 2013). Training in ISFM has a positive and highly significant influence on adoption of improved seed maize varieties ($p<0.05$). This means that households that had undergone training in ISFM are more likely to adopt ISFM technologies such as improved varieties than those households that have not.

4.3.2 Correlation Analysis o of ISFM Technologies

One of the research questions in this study was to find out which technologies among the four broad categories are complementary and which ones substitutable and the extent are of these relationships. This was achieved through the use of the MVP model. Table 4.5 presents the covariance matrix of the adoption equations error terms depicting the different types of relationships that exist among the technologies.

Table 4.5 Correlation Coefficient Estimates (Covariance Matrix) of the Adoption Equations of the Joint MVP Model

Technology/practice	**Inorganic fertilizer (rho 1)**	**Improved seed (rho 2)**	**Maize-legume intercropping (rho 3)**
Improved seed	0.091 (0.164)		
Maize-legume intercropping	0.239 (0.141)*	0.027 (0.144)	
Legume-maize rotation (**(rho 4)**	-0.339 (0.146)**	-0.177 (0.126)	0.325 (0.113)***

*Figures in parentheses are standard errors; * significant at 10% (p<0.1), ** significant at 5% (p<0.05), and *** significant at 1% (p<0.01); ρ (rho) =correlation coefficient.*

Likelihood ratio test of rho21 = rho31 = rho41 = rho32 = rho42 = rho43 = 0: chi2(6) = 17.3651 Prob > chi2 = 0.0080

Table 4.5 indicates that the correlation coefficient between the adoption of inorganic fertilizer and improved seed varieties is positive implying the complementary relationship between the two technologies. Another complementary and significant relationship was observed between the adoption of inorganic fertilizer and maize-legume intercropping to an extent of about 24%. This may be so because most farmers who planted improved maize in intercropping with legume crop were forced to adopt inorganic fertilizer as well owing to the demand of improved seed for more of inorganic fertilizer. Thus the decision to adopt maize-legume intercropping was jointly made with the decision to adopt inorganic fertilizer. On the other hand, a negative and significant relationship was found between adoption of legume-maize rotation and inorganic fertilizer (about 34%) indicating that the two practices an extent of substitutability. This may be common among wealth households that would prefer to adopt inorganic fertilizer because of their ability to afford chemical fertilizers and practice continuous cultivation (mono-cropping) as compared to poor households that may need to exploit the long-term benefits of legume nitrogen fixation by opting for crop rotation.

The adoption of maize-legume intercropping and rotation also exhibited a significant and positive complementary relationship (32.5%). This may be explained by the fact that smallholder farmers were supposed to follow a two-three-year adoption cycle of legume diversification in the maize-based farming system as promoted by the Legume BB project that was characterised by crop rotation at the centre. This implies that the adoption of a particular cropping system in the current year was dependent on the cropping system practiced by the farmer in the previous season while the cropping system on the next growing system is conditional on the present cropping system employed by the farmer. This helps in building soil properties that are aimed at improving soil fertility for increased crop productivity growth. Maize –legume intercropping is also complementary to adoption of improved seed varieties.

4.3.3 Predicted probabilities of adoption

Table 4.6 shows the predicted probabilities of adoption of the four ISFM technologies among the smallholder farmers. The results indicate that the probability of smallholder farming households to adopt inorganic fertilizer, improved maize seed varieties, maize-legume intercropping and legume-maize rotation were 86%, 75%, 47% and 69%, respectively.

Table 4.6 Predicted Marginal Success Probabilities of Adoption of the Four ISFM Technologies

ISFM technology/practice	Mean	Observed (n)	Predicted (n)
Inorganic fertilizer	0.86	153	171
Improved seed	0.75	151	150
Maize-legume intercropping	0.47	92	94
Legume-maize rotation	0.69	133	131
Joint probability of success	0.23	39	41
Joint probability of failure	0.006	3	1

From table 4.6 above, the difference between observed and predicted sample size for each technology category did not vary much except for inorganic fertilizer only. While the observed sample for inorganic fertilizer adopters was 153, the model predicted higher sample size of 171 farming households who could have adopted inorganic fertilizer. For the rest of the technologies, the difference between observed and predicted values was very minimal. For instance, the observed sample size for improved seed was 151 against the predicted sample of 150 while the observed sample of adopters for maize-legume intercropping was 92 against the predicted sample of 94.

The joint predicted probability of success that the farmer is going to adopt all the four technologies is 23% with the observed sample size of 39 against the predicted sample of 41. On the other hand, the joint predicted probability of failure that the farmer is going to adopt none of the four technologies is 0.6% with the observed sample of 3 against the predicted sample of 1. This shows that it is almost impossible for a farmer not to adopt any of the four technologies. This reflects the importance of the four technologies in enhancing maize production and thus attainment of household food security. In addition, the government and the presence of several NGOs in the study area providing extension services has helped create awareness and thus promoting various ISFM practices.

4.4 Challenges to Legume Diversification in Maize-Based Farming System

Smallholder farmers identified a number of constraints to legume integration in the maize-based farming system in the study area as presented in table 4.7. The most frequently reported challenge was pests and diseases which accounted for about 29.1% of the responses. This was more pronounced with pigeon peas. According to Mhango *et al.* (2012), pigeon peas in the study area is highly susceptible to post-harvest weevil damage. Besides, the crop's main field pest, pollen beetle, feed on the plant's floral parts which results in low fertilization, pod set and eventually low yields. Poor rainfall pattern especially early cessation of rains was the second most frequently reported challenge to legume production. This is especially true during the last two consecutive growing seasons (2013/14 and 2014/15) that were characterised by late onset of rains and early cessation at a critical stage where the crops need most of the water for full maturation. The 2014/15 growing season was the worst affected year such that some farmers experienced total crop failure and lowest crop yields. Seed access constraints ranked third with about 20% of the responses. This was a common challenge across all the legume species. As pointed out by Mhango *et al.* (2012), limited access to seed is aggravated by lack of purchasing power and/or limited seed availability as well as food insecurity which puts pressure on the saved legume seed for home consumption

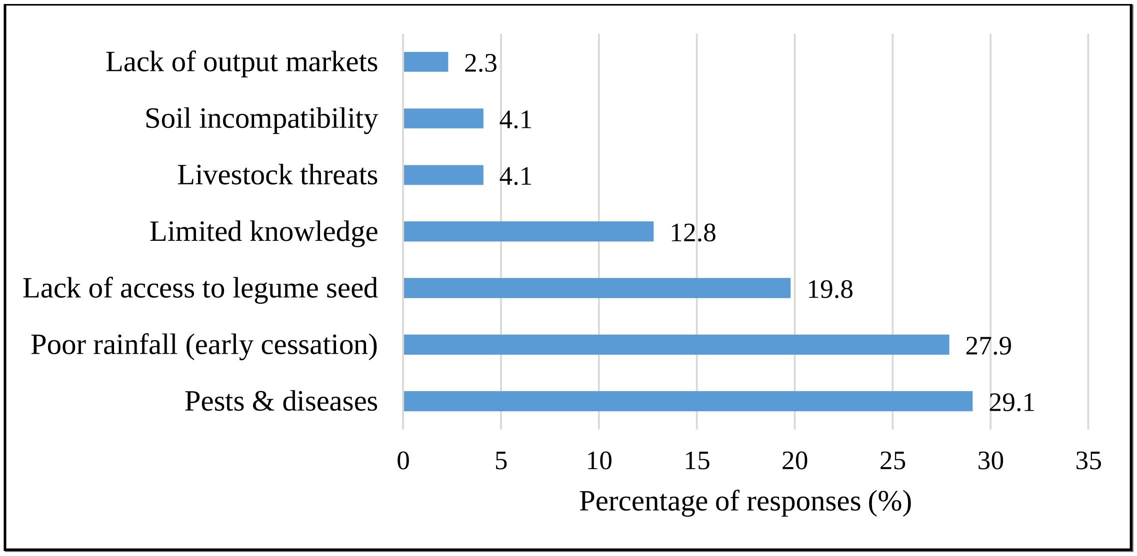

Figure 4.4 Challenges with Legume Integration in Smallholder Farming System

Other notable challenges to legume diversification reported by the farmers include limited knowledge to do with crop management, livestock threats, soil incompatibility problems and lack of output markets. Maize-legume (or doubled up legume) intercropping for instance is knowledge intensive and many farmers haven't been trained to manage such crops. This is also exacerbated by poor extension services. The study area is also known with livestock such goats and cattle which feed on the legumes while still in the field. Lack of output markets for legume grain acts as a disincentive to farmers since farmers since, despite soil fertility improvements, farmers are driven by the immediate benefits such as cash. This can only be achieved if there are ready and lucrative markets available for grain legumes.

4.5 Reasons for Non-Adoption of Various ISFM technologies

Non-adopters reported several reasons for not adopting the ISFM technologies. These are presented in figure 4.5. The table shows that the major reason for non-adoption is lack of access to seed (54.2%) followed by lack of awareness about the various ISFM technologies while others (laggards) reported that they are still waiting to see from fellow farmers.

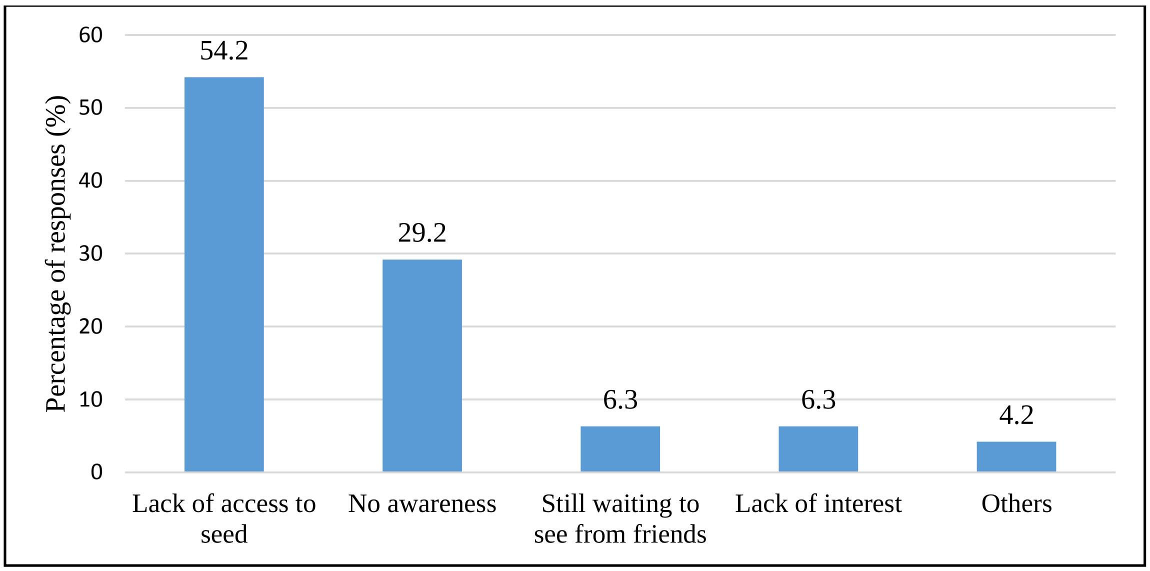

Figure 4.5 Reasons for Non-Adoption of Various ISFM Technologies

4.6 Determinants of the Extent of Adoption of ISFM Technologies

The second decision that farmers would make after adoption of any technology has to do with the level or intensity of adoption of the technology. As regards to ISFM, farmers would adopt a component or a mix of technology components from the package that would maximise their expected utility conditional on resource endowments. Different studies have measured the extent of adoption of agricultural technology in several ways. The commonest way has been the use of the proportional of land allocated to a particular technology or the amount/quantity of the technology applied, as used in such studies as

Tizale (2007), Kamau *et al.* (2013). These studies employed either the Tobit or the double hurdle models to estimate intensity of adoption. However, these and other studies paid little or no attention to the number of technologies adopted. According to Sanginga and Woomer (2009), the overall goal of ISFM is to maximize the interactions that result from the best-bet technology combination comprising mainly inorganic fertilizer, organic inputs and improved germplasm coupled with farmer knowledge and local adaptation for improved crop productivity.

Therefore, following Nkegbe and Shankar (2014) and Taklewold *et al.* (2013), this study used the number of ISFM technologies adopted as an indicator for the intensity of adoption. The choice of the number of technologies adopted has also been necessitated by the fact that it is difficult to measure the intensity of adoption of some of the technologies under consideration in this study such as crop-rotation using the proportional of crop area. Besides, none of the correlation coefficients in the adoption decisions is above the 50% threshold level (Nkegbe and Shankar, 2014) and thus it is difficult to completely rule out that independency exist in the adoption decisions of the ISFM technologies. The number of technologies adopted in a given period of time is count data, which is usually analysed using count data models. The two commonest count data models that exist in literature are the Poisson and negative binomial regression models. The choice of either one of the two models depends on the assumptions under consideration. This study used the poison regression model in estimating the factors affecting the level of ISFM adoption under the assumption of equidispersion. Table 4.9 presents the results of the Poisson regression model for the level of adoption of ISFM technologies.

Table 4.7 Results of the Poisson Regression Model for the Level of Adoption of ISFM Technologies

Explanatory variable	Dependent variable: Number of ISFM technologies adopted. Predicted value = 2.71	
	Coefficient	**Marginal effects**
Sex of household head	0.2362 (0.1025)**	0.5847 (0.2292)**
Age of the household head (years)	0.0018 (0.0021)	0.0049 (0.0056)
Land ownership (=Own land, 0=Otherwise)	0.0153 (0.0557)	0.0414 (0.1499)
Plot distance (km)	-0.0170 (0.0042)***	-0.0461 (0.0113)***
Number of adults in a household	0.0064 (0.0215)	0.0172 (0.0584)
Education level of the spouse (1=junior secondary, 0=otherwise)	0.0356 (0.0854)	0.0978 (0.2383)
Land size (ha)	0.0038 (0.0127)	0.0103 (0.0344)
Seed access (1=Yes, 0=No)	0.1270 (0.0469)***	0.3445 (0.1268)***
Frequency of extension contacts	0.0678 (0.0303)**	0.1838 (0.0823)**
Credit access (1=Yes, 0=No)	0.1004 (0.0509)**	0.2799 (0.1447)**
Group membership (1=Yes, 0=No)	0.1233 (0.0512)**	0.3297 (0.1360)**
Soil fertility perception status	-0.0086 (0.0503)	-0.0233 (0.1359)
Log of asset (MK)	-0.0046 (0.0169)	-0.0124 (0.0458)
Constant	0.5361 (0.2238)**	

n = 188 Wald x^2 (13) = 76.39 Prob > chi2 = 0.0000 Pseudo R2 = 0.0201
Log pseudolikelihood = -292.56262

Deviance goodness-of-fit: x^2 (174)= 49.26851 P-value = 1.0000

Pearson goodness-of-fit: x^2(174) = 46.65751 P-value = 1.0000

Overdispersion: Pearson statistic/DF =0.2681

The log pseudolikelihood of the model is -292.56262 with the Wald x^2 statistic of 76.39 and associated p-value of 0.0000. This means that the null hypothesis that all regression coefficients are equal to zero is rejected. The deviance goodness-of-fit x^2 (174) statistic is

49.26851 with a highly statistically insignificant p-value of 1.0000 means that the model reasonably fits the data well and supports the assumption that the error terms follow a Poisson distribution process. The test for overdispersion was carried by dividing the Pearson statistic by degrees of freedom (DF) and yielded a value (0.2681) much lower that the threshold of 2.72. This means that the null hypothesis that there is no overdispersion was not rejected thereby confirming the validity of the poisson regression model. The Poisson regression model was estimated using the maximum likelihood estimation method.

The results of the Poisson model indicate that six of the thirteen independent variables were significant in influencing the level of adoption of ISFM technologies. These are sex of the household head, plot distance, access to seed, and frequency of extension contacts, access to credit and group membership. It is also worth noting that some of the factors that influenced probability of adoption are the same factors influencing the level of adoption of ISFM technologies.

Sex of the household was positive and significant in influencing the number of ISFM technologies adopted at 5 % ($p<0.05$). The marginal effect of sex of the household head shows that male headship of the household increased the number of ISFM technologies adopted by 58 percentage points, other things being equal. This may be explained by the fact that men have more access to and control over productive resources than women and this puts them at an advantage to invest more into ISFM technologies.

Distance from the homestead to plots (plot distance) is also one of the factors that affect adoption of agricultural technologies. Plot distance was negatively and significantly correlated with the level of ISFM adoption ($p<0.05$). The results show that an increase in plot distance by a kilometre reduced the number of ISFM technologies adopted by 4.6 percentage points. This was significant at 1% ($p<0.01$). This implies that farmers whose plots are far from their homes are less likely to adopt a mix of ISFM technologies than those farmers whose plots are closer to their homes. The plausible explanation to this may be related to challenges with transportation means and cost implications as well as the opportunity cost of time involved in travelling to plots that are far from homes.

Access to both legume and maize seed was an important determinant that positively and significantly influenced the number of ISFM technologies. This is not surprising since the adoption of some of ISFM technology components such as maize-legume intercropping and rotation depend to a greater extent on access to seed. The marginal effects show that having access to seed increased the number of adoption for almost 34.5 percentage points. This implies that efforts that are aimed at scaling up ISFM technologies should tackle the problem of seed unavailability and shortage and increasing access to seed by farmers at a relatively affordable prices.

While access to extension is important in influencing adoption of ISFM technologies, the frequency of contacts between the farmer and extension personnel matters a great deal in influencing the level of ISFM technology adoption. The results of the Poisson regression model indicate that the frequency of extension contact per growing season positively and significantly ($p<0.05$) influenced the number of ISFM technologies adopted. This finding is consistent with Nkegbe and Shankar (2014) who found a similar role of extension in promoting conservation agriculture practices in Ghana. The marginal effects show that farmers who had more extension contacts stood a better chance of increasing the number of ISFM technologies by 18.4 percentage points. This is not surprising as ISFM technologies are knowledge intensive and the number of contacts with extension workers would help in improving input management on the farm as the number of technologies adopted increases. Sanginga and Woomer (2009) note that implementation of complete ISFM requires knowledge on how to adapt technologies and practices to each farm's conditions and opportunities.

Access to credit is also one of the determinants of the level of ISFM technology adoption, may be because of its central role in fostering access to inputs among smallholder farmers. Access to credit was positive and significantly correlated with the number of ISFM technologies at 5 % alpha level ($p<0.05$). Access to credit boost farmer's resource endowment upon which farmer' maximisation of utility is constrained. For instance, most of the farmers could not afford fertilizer at market prices and had to rely on private companies for credit. The marginal effects on the level of ISFM technology adoption indicates about 28 percentage points increase in the number of technologies adopted for those farmers who had access to credit.

Group membership as a common form of social capital in agrarian societies like Mkanakhoti EPA was also an important factor that influenced the level of ISFM technology adoption. As earlier pointed out, group membership provides a platform for knowledge sharing, collective action in accessing inputs and extension services and marketing of products and among others which all create a conducive environment for technology adoption. This finding is in agreement as well with the findings of Nkegbe and Shankar (2014).

4.7 Number of ISFM Technologies Adopted Versus Maize Production

An important element with the multiple adoption of ISFM technologies relates to the beneficial interactions of individual technologies whose adoption is interdependent. In this case, the probability of adoption of a particular technology is conditional upon an earlier technology (or technologies) adopted which produces reinforcing effects on crop yield. Thus technologies are adopted either as complements or substitutes. Table 4.10 presents the adoption of various ISFM technology combinations and their associated maize production levels.

Table 4.8 Adoption of Various ISFM Technology Combinations and Maize Production

Technology combination	n	Maize quantity harvested (kg)	Maize yield (kg/kg)
Inorganic fertilizer + improved seed + intercrop	16 (9.3)	732.3	1296
Inorganic fertilizer + improved seed + rotation	37 (21.4)	717.0	1247
Inorganic fertilizer + rotation	29 (16.8)	885	1235
Inorganic fertilizer + improved seed + intercrop + rotation	39 (22.5)	641.2	1226.6
Improved seed + intercrop	3 (1.7)	613.3	1141.8
Inorganic fertilizer + improved seed	26 (15.0)	750	1095
improved seed + rotation	20 (11.6)	599.5	952.5
Inorganic fertilizer + intercrop	3 (1.7)	376.7	508.3

Figures in parentheses are percentages; maize quantity and yield values are averages

Table 4.10 indicates that 39 (22.5%) of the ISFM adopters adopted all the four technologies (inorganic fertilizer, improved seed, intercropping and rotation) followed by 37 (21.4%) who adopted inorganic fertilizer, improved seed and legume maize-rotation, 29 (16.8) adopted inorganic fertilizer and rotation, 26 (15%) adopted inorganic fertilizer and improved seed while 16 (9.3%) adopted. The study also sought to find out which technology combination gave maximum maize production and yields. In terms of maize production, the highest quantity of maize harvested, on average, was observed with inorganic fertilizer + legume-maize rotation (885kg) followed by inorganic fertilizer + improved seed + maize-legume intercrop (732 kg), inorganic fertilizer + improved seed +

legume maize-rotation (717 kg). The least quantity of maize harvested was observed with legume-maize intercrop + inorganic fertilizer,

On the other hand, while maize-legume rotation + inorganic fertilizer gave the maximum maize production, the highest maize yield (productivity) level was observed with inorganic fertilizer + improved seed + maize-legume intercrop (1296 kg/ha) followed by inorganic fertilizer + improved seed + legume-maize rotation (1247 kg/ha) and inorganic fertilizer + legume-maize rotation (1235 kg/ha). The four technology combination (inorganic fertilizer + improved seed + intercrop + legume-maize rotation) is ranked fourth with 1226.6 kg/ha on average. The least productivity level was observed with maize-legume intercrop + inorganic fertilizer.

Interestingly, technologies that form the package (inorganic fertilizer + improved seed + maize-legume intercrop) that gave the highest productivity level are adopted as complements as revealed by the results of the multivariate probit model in table 4.5. This is consistent with adoption literature regarding sustainable agricultural intensification practices which stresses that adoption of a mix of technologies that are complementary in nature allows the crop to benefit from the interaction effects of individual technologies and/or practices thereby reinforcing crop yields (Kassie *et al.,* 2015a). While the second ranked technology package constitutes both positively and negatively correlated technologies (Inorganic fertilizer + improved seed + legume-maize rotation), Kassie *et al.* (2015a) observed that as the number of a mix of technologies increases, they are progressively likely to complement one another, even if individual components are negatively correlated when considered separately.

4.8 Productivity Effects of ISFM Technology Adoption

Table 4.11 below presents the results of the endogenous switching regression model obtained through the full information maximum likelihood (FIML) estimation procedure using the *movestay* command in Stata, followed by the post-estimation command, *mspredict.*

Table 4.9 Full Information Maximum Likelihood Estimates of the Endogenous Switching Regression Model (ISFM Adoption)

Explanatory variables	Dependent variable: Log of maize yield per hectare	
	ISFM Adopters	ISFM Non-adopters
Sex of the household head (1=Male, 0=Female)	-0.0229 (0.3063)	0.1317 (0.3272)
Age of the household head (years)	-0.0087 (0.0081)	0.0005 (0.0075)
Number of adults	0.1111 (0.0967)	0.1687 (0.1029)*
Education level of household head		
Senior primary (Standard 5-8)	0.8610 (0.2383)***	-0.0814 (0.2374)
Junior secondary (form 1-2)	0.9220 (0.3437)***	-0.0139 (0.3500)
Senior secondary (Form 2-4)	0.8871 (0.3621)**	-0.1672 (0.3576)
Maize area (ha)	-0.3503 (0.1126)***	-0.4085 (0.1236)***
Group membership (1=Yes, 0=No)	0.0804 (0.2041)	-0.3373 (0.2105)
Amount of fertilizer (kg/acre)	0.0021 (0.0014)	0.0045 (0.0017)***
Log of asset value (MK)	-0.0236 (0.0818)	0.1991 (0.0814)**
Early planting*weeding	0.0001 (0.0008)	0.0000 (0.0005)
Pests and disease control	.0003 (0.0003)	-0.0001(0.0003)
Constant	7.5985 (0.8339)***	5.3334 (0.8010)***
Sigma (σ)	1.0650 (0.1264)	1.0473 (0.1289)
Rho (ρ)	-1.94 (0.4716)***	1.19 (0.3702)***
LR test of independent equations:	$x^2(1)$ = 12.23	p-value = 0.0005
n = 193	Wald x^2 (12) = 41.68	p-value = 0.0000
Log likelihood = -336.92048		

*Figures in parentheses are robust standard errors; *significant at 10%, ** significant at 5% ***significant at 1%*

The results show that the correlation coefficients between the selection equation and the outcome variable for both groups of farmers are significant at 1 %. This suggests that there is enough evidence to believe that both observed and unobserved covariates exists that influence adoption of ISFM technologies, thereby making the adoption equation endogenous to the outcome variable, maize yield. This could have been a problem if not controlled. Among others, it would result in biased and inconsistent estimates (Asfaw *et al.* 2012; FAO, 2015a; FAO, 2015b). Since rho 1 and rho 2 have alternative signs, this implies that an individual decision to adopt ISFM technologies is based on comparative advantage i.e. self-selection occurred in the adoption of ISFM technologies. The joint likelihood ratio test of independent equations yielded a highly significant Wald x^2 (1) value of 12.23 with p-value=0.0005. This means that the null hypothesis of independent equations is highly rejected at 99% confidence level and concludes that adoption decision is endogenous to the outcome variable, thereby supporting the application of the endogenous switching regression model.

The significance of the correlation coefficient associated with adopters signifies that farmers who choose to adopt ISFM technologies (ISFM adopters) have higher yields under adoption than what a random farmer would have realised and non-adopters are worse off not adopting. In other words, adopters with maize yields above the average have higher likelihood of adopting ISFM technologies and have higher yields than a random farmer. On the other hand, farmers who decide not to adopt ISFM technologies had lower maize yields than what a random farmer would have realised.

The correlation between demographic, socio-economic and institutional farmers and maize yield is also discussed under the FIML endogenous switching regression. The results indicate that education level significantly increases maize yield only for adopters and not non-adopters. The results show that attainment of senior primary (standard 5-8), junior secondary (form 1-2) and senior secondary (form 2-4) increases maize yield by 86%, 92% and 88%, respectively among ISFM technology adopters. This may reflect the knowledge-intensive nature and input management demands associated with ISFM technologies and thus educated farmers have comparative advantage in accessing, understanding and processing information than uneducated ones. Amount of land allocated to maize is negatively and significantly correlated with maize yield for both adopters and non-adopters ($p<0.01$). The estimates of land show that an increase in maize area significantly reduces maize yields for both ISFM technology adopters and non-adopters by 35% and 40.9%, respectively, while holding other factors constant. This finding is in agreement with FAO (2015a) who also found similar results in Niger that land size was negatively correlated with crop productivity. However, while acknowledging errors in estimating and measuring land sizes, the finding is still consistent with results found in literature about the inverse relationship between land size and yield. This may reflect labour constraints and management crisis that is associated with larger plots as compared to smaller plots.

It is also worth noting that amount of inorganic fertilizer applied to maize (kg/acre) increases maize yields for both adopters and non-adopters, but the increase is significant only for non-adopters. The results show that an increase in the amount of fertilizer by a kg significantly increases maize yields by 0.45% for those households who chooses not to adopt ISFM technologies. This may suggest the increasing dependence of non-adopters on inorganic fertilizer to sustain maize yields than their counterparts (adopters) who are employing sustainable intensification strategies that are complementary to inorganic fertilizer such as legume-maize rotation and intercropping.

The results also show that the number of adults in the household, a proxy for labour endowment in this study, is positively correlated with maize yield for both adopters and non-adopters. However, it is significant only for non-adopters. The results indicate that maize yields increases by 11% for every adult member in the household with among the non-adopters. This means that maize yield increases significantly for those households with more labour among the non-adopters. The results also show that maize yields were higher among the non-adopters for those wealthy households with higher asset value by almost 20%. For instance, ownership of oxcarts and cattle was more pronounced among the non-adopters.

4.8.1 Simulated Net Effect of ISFM Technology Adoption on Maize Yield

The expected mean yield levels of farmers under the four cases from the ESR model were used to simulate the net impact of adoption of ISFM technologies on smallholder farmers. Table 4.12 presents the results of the treatment effects of adoption of ISFM technologies.

Table 4.10 Simulated Net Impact of ISFM Adoption on Maize Yield (kg/ha)

	Decision stage		
Subsample	**To adopt**	**Not to adopt**	**Treatment effects**
Adopters	810.04	735.50	$0.1^{ATET\ *}$
Non adopters	3943.73	3385.68	0.15^{ATU**}

ATET= Average treatment effect on the treatments ATU= Average treatment effects on the untreated **significant at 10%, ** significant at 5%***significant at 1%*

The results from the switching regression supports that ISFM technology adoption has a positive and significant impact on log of maize yield. It has been revealed that the treatment effect for ISFM adopters mean yield is 0.1. This translates to 10.52 % increase in yield level for adopters had they not adopted the ISFM technologies. On the other hand, when non-adopters had adopted the ISFM technologies, their yield levels per hectare would have increased by 16.2 % on average. These findings are consistent with the findings of Kassie *et al.* (2015b) who found a positive and significant impact of adoption of sustainable intensification practices (SIPs) (of which maize-legume intercropping and rotation was a major component) on maize yield in Malawi.

4.9 Limitations of the study

Despite the rigorous analysis and an attempt to address methodological challenges in modelling adoption and welfare effects of ISFM technology adoption, the study is not without limitations. In the first place, the categorisation of individual ISFM technologies into broad categories such as intercropping and rotation may mask important information associated with adoption of individual technologies deemed potential for improving crop productivity. Secondly, the researcher is aware of the existence of spillover effects associated with adoption of ISFM technologies. However, the dataset used in this study couldn't support the analysis of the extent of these spill over effects. Therefore, the study recommends that further research is needed to look into the multiple adoption of specific individual technologies as well as the quantification of spillover effects associated with adoption of ISFM technologies.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

This study has analysed and assessed the multiple adoption and productivity effects of ISFM technologies among the smallholder maize farmers. This has been achieved through the application of the MVP, Poisson and ESR models. Consistent with literature, results have revealed that adoption decisions regarding ISFM technologies are interdependent. The study has established complementary and substitutable relationships in the adoption decisions regarding ISFM technologies. For instance, inorganic fertilizer and maize legume intercropping are adopted as complements (24%) while inorganic fertilizer and legume-maize rotation adoption decisions depicted a 34% substitutability. The adoption of inorganic fertilizer and improved maize seed varieties exhibited a weak complementarity (1%) while maize-legume intercropping and rotation are adopted as complements (33%).

On the drivers of adoption, the key determinants are age of the household head, land tenure, access to FISP coupons, access to extension, access to credit, access to markets, access to legume seed, household income, training in ISFM, soil fertility perception status, land holding size (hectares) and group membership. Access to extension was positive and significantly correlated with adoption of inorganic fertilizer and maize-legume intercropping while land tenure positively and significantly influenced adoption of legume-maize rotation. Access to market and access to legume seed were positively and significantly correlated with adoption of maize-legume intercropping while landholding size had positive and significant influence on adoption of legume-maize rotation. Adoption of inorganic fertilizer was positively and significantly influenced by access to FISP coupons and household income. Farmers' perception of fertile soils was positively and significantly to adoption of improved maize seed and crop rotation while group membership significantly influenced the adoption of maize-legume intercropping.

The study also found that the extent of adoption of ISFM technologies is influenced by some of the same factors determining adoption. However, the extent of adoption of some of the ISFM technologies was determined by a different process. For instance, while access to extension encouraged adoption, it is the frequency of extension visits that is critical for the extent of adoption of ISFM technologies. The results have shown that the frequency of extension contacts increased the number of ISFM technologies by 18.4% while an increase in plot distance by a kilometre reduced the number of technologies by 4.6%, *ceteris paribus*. It was also shown that male-headship of the household significantly increased the extent of ISFM technology adoption by 58% while access to legume seed increased the extent of adoption by 34%, holding other things equal.

The study has also established that adoption of ISFM technologies has positive and significant effect on maize yields. The results have showed that ISFM technology adoption was associated with 0.1 and 0.15 ATET and ATU, respectively. This implies that ISFM adopters increased their mean yield level by 10.52% while non adopters would have increased their maize yield levels by 16.2% on average, had they adopted the ISFM technologies. This was after controlling for confounding factors.

5.1 Recommendations

The study has generated important knowledge and information from which a number of policy recommendations are drawn. In the first place, the study has found out that access to improved legume seed is one of the key determinants of adoption of ISFM practices such as maize-legume intercropping and rotation. This therefore underscores the importance of increasing access to improved legume seed among the smallholder farmers at affordable prices. This is crucial for both continued adoption and upscaling of the ISFM practices. This may be achieved through the establishment of a vibrant seed system to ensure that seed is available for the smallholder farmers on time.

Secondly, the complementarity in the adoption decisions suggest that ISFM practices that include inorganic fertilizer should not be promoted as individual components but as a package based on their ‘best-bet’ combinations. For instance, while the FISP has increased adoption of inorganic fertilizer and improved maize seed, more should be done to scale up the legume component so as to promote complementary interventions such as maize-legume intercropping and rotation. This may be achieved by including extension messages on the benefits of legume maize-rotation and intercropping.

The study also found out that access to grain legume markets was positively and highly correlated with adoption of ISFM practices. However, such markets are missing or non-existent in the study are. Therefore, there is need for introduction of both input and output markets for grain legumes (especially for pigeon peas) within farmers’ vicinities. This is important as it would help incentivise adoption while providing soil fertility benefits in farmers' fields.

It is also recommended to improve land tenure security in order to incentivize farmers to make long-term investments in their land. This is so because the study finds that those with secure tenure rights are more likely to invest in soil fertility enhancing practices such as maize- legume intercropping and rotations. There is also need for deliberate policies to foster collective action among smallholder farmers where extension messages that emphasize the complementarities in adoption of ISFM technologies will be concentrated. This is critical for both continued adoption and thus out-scaling of ISFM technologies.

Upscaling of maize-legume intercropping practice is likely to succeed if female farmers and those with small landholding sizes are the prime targets as these have shown to be more likely to adopt such a practice. Finally, there is need for rethinking the targeting criterion based on age by the Legume Best Bet project. The study is of the view that young and productive farmers should be more targeted against the current status quo of targeting 'vulnerable' groups such as the elderly as these are labour constrained and thus negatively affect crop productivity.

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APPENDIX

Household questionnaire

DETERMINANTS OF ADOPTION OF INTEGRATED SOIL FERTILITY MANAGEMENT TECHNOLOGIES AND ITS EFFECT ON MAIZE PRODUCTIVITY: A CASE OF THE LEGUME BEST BETS PROJECT IN MKANAKHOTI EXTENSION PLANNING AREA OF KASUNGU DISTRICT IN CENTRAL MALAWI

Household Questionnaire

INTRODUCTION

Good morning/afternoon. My name is **______________**. We have come from Bunda College of Agriculture and we are conducting a study on ***maize-legume intercropping and rotations.*** The overall objective of the study is **to *analyse and assess factors influencing adoption of maize legume intercropping and rotations and their contribution to crop productivity***. This research will also help to come up with ways of upscaling and out-scaling of the maize-legume intercropping and rotations. You are one of the persons who have been selected to participate in this research. The information collected will be strictly confidential and will only be used for the purposes of the study. Are you free to be interviewed? ***Dzina langa ndine_____________. Tachokera ku Bunda ndipo tikupanga kafukufuku okhudzana ndi ulimi wa mbewu za magulu a nyemba. Cholinga cha kafukufuku amenyu ndi kupeza njira zomwe tingatukulire ulimi umenewu. Zotsatira za kafukufuku uyu ndi zachisinsi ndipo zidzagwiritsidwa ntchito pa zolinga za kafukufuku uyu basi. Muli omasuka*** **kucheza nanu?**

SECTION A: IDENTIFICATION

A1	Name of enumerator	
A2	Name of the respondent	
A3	Name of village	1=Chisazima, 2=Kaunda, 3=Tchezo, 4=Chaguma, 5=Ndaya
A4	GVH	

A5	TA	
A6	Name of EPA	
A7	Section	1=Simlemba, 2=Ofesi, 3=Kapopo
A8	Farmer category	1=BB participant/adopter, 2=dis-adopter, 3=Non adopter, 4=spillover adopter
A9	Date of interview	
A10	Data entry clerk	

SECTION B: DEMOGRAPHIC AND SOCIO-ECONIMIC CHARACTERISTICS

B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**
Name of household member ***(Start with household head)***	**Relationship to household head** **CODES B2**	**Sex of household member** 1=Male 2=female	**Age of the household member** (years)	**Marital status:**	**Number of adults in the household** *(those>18 yrs)*	**Total household size**	**Education level attained:**	**Main occupation of the household member:**
1.								
2.								
3.								
4.								
5.								
6.								

CODES B2: 0=Household head, 1=spouse, 3=son/daughter, 4=grandchild, 5=mother/father, 6=mother/father in-law, 7=brother/sister, 8= brother/sister in-law, 9=uncle/auntie, 10=step/foster child, 12=other family members, 13=not related
CODES B5: 1=Never married, 2=Married, 3= Divorced/ Separated 4=Widowed

CODES B8: 1=None, 2=Junior primary (std 1-4), 3=Senior primary (std 5-8), 4=Junior secondary, 5=Senior secondary 4=Post-secondary or tertiary
CODES B9: 1=Smallholder farmer, 2=Commercial farmer, 3=Salaried employment, 4=Skilled employment, 5=Small scale business, 6=Petty trade, 7=Causal labour, 8=Student, 8=Others (specify)________

SECTION C: HOUSEHOLD AGRICULTURAL ACTIVITIES

C1. Do you have land for cultivation? **1=Yes, 2=No**

C2. If yes, how many plots of land do you have? __________

C3. Years of farming experience ____________

C3. Now I would like to ask you about land use practices during the 2014/15season

C3.1	C3.2	C3.3	C3.4	C3.5	C3.6	C3.7	C3.8
Plot ID	**Plot size** ***(Area planted for the crop)*** (acres)	**How far is the plot from your homestead** (km). *(If meters indicate)*	**How was the plot acquired?** **CODES C3.4**	**When was the plot acquired (year)**	**Which crop(s) did you plant during the 2014/15 season?** **CODES C3.4**	**Steepness of the land:** 1=Very steep 2=Moderate 3=Flat	**Soil fertility Perception** 1=Infertile, 2=Somehow fertile, 3=Very fertile, 99=Don't know
1							
2							
3							

CODES C3.6: 1=Maize, 2=groundnuts, 3=pigeon pea, 4=common beans, 5=cowpeas, 6=soya beans, 7=other legumes (specify), 8=Tobacco, 9=Cassava, 10=Sweet potatoes, 11=Paprika/chillies, 12=others (Specify)
CODES C3.4: 1=Inherited from parents, 2=given by the chief, 3=Bought with own cash, 4=Rented, 5=Others (specify)

C4. Crop production

C4.1	C4.2	C4.3	C4.4	C4.5	C4.6	C4.7	C4.8	C4.9	C4.10
Plot ID	**Crops planted during the 2014/15 season?** *(From C3.6)* **CODES C4.2**	**Varieties grown for the crop (Write actual varieties)** *(Ask only for maize and legumes)*	**Plot size** ***(Area planted for the crop)*** (acres)	**Was the crop planted in monocrop, intercrop or Rotation?** **CODES C4.5**	**What was the reason for growing the crop?** 1=Food, 2=Cash, 3=Both	**Amount of seed planted (kg)**	**What was the source of seed for the crop?** **CODES 4.8**	**Did you receive FISP coupon (fertilizer) during the 2014/15 season?** 1=Yes, 2=N0	**Quantity harvested** (kg)
1									
2									
3									
4									

CODES C4.2: 1=Maize, 2=groundnuts, 3=pigeon pea, 4=common beans, 5=cowpeas, 6=soya beans, 7=other legumes (specify), 8=Tobacco, 9=Cassava, 10=Sweet potatoes, 11=Paprika/chillies, 12=others (Specify)

CODES C4.5: 1=Monocropping,2=Maize-legume intercropping (at least one intercropped crop is a legume 3=Maize-legume rotation 4=Legume-legume intercropping 5=Legume-legume rotation, 6=other intercropping, 7=other rotation

CODES C4.8: 1=FISP, 2=BB, 3=Own purchase, 4=given by friend, 5=others (specify) ___________________

SECTION D: ISFM PRACTICES AND ADOPTION

D1. Now I would like to ask you about the following ISFM technologies and practices in your field

D1.1	**D1.2**	**D1.3**	**D1.4**	**D1.5**	**D1.6**	**D1.7**	**D1.8**	**D1.9**	**D1.10**	**D1.11**	**D1.12**
Practice/technology	**Are you aware of the following technology /practice:** 1=Yes 2=No	**How did you know about the technology/practice** **CODES D1.3**	**Have you ever tried/ practice dthe technology/ Practice ?** 1=Yes, 2=No	**If no, why are you not practicing the technology** **CODES D1.5**	**Who introduced you to the technology?** **CODES D1.6**	**When did you start practicing the technology** *(Year)*	**For how long have you been practicing the technology** *(years)*	**Are you still practicing the technology (including 2014/15 season) ?** 1=Yes, 2=No (go to D1.9)	**Why are you practicing the technology?** **CODES D1.10**	**When did you stop practicing the technology** **(Year)**	**Why did you stop practicing the technology?** **CODES D1.10**
1. Sole maize + inorganic fertiliser											
2. Maize + pigeon pea intercrop											
3.Maize + beans intercrop											
4. Maize + soybeans intercrop											
5.Soya + pigeon pea intercrop											
6. Gnuts + pigeon pea intercropping											

7. Maize + Gnut intercrop											
8. Pigeon pea/Maize rotation											
9. Maize + pigeon pea/Maize + Pigeon pea rotation											
Practice/technology	Are you aware of the following technology/ practice: **1=Yes 2=No**	How did you know about the technology/practice **CODES D1.3**	Have you ever tried/ technology/ Practice?**1=Yes, 2=No**	If no, why are you not practicing the technology **CODES D1.5**	Who introduced you to the technology? **CODES D1.6**	When did you start practicing the technology *(Year)*	For how long have you been practicing the technology *(years)*	Are you still practicing the technology (including 2014/15 season)? **1=Yes, 2=No (go to D1.9)**	Why are you practicing the technology? **CODES D1.10**	When did you stop practicing the technology (Year)	Why did you stop practicing the technology? **CODES D1.10**
10. Bean/sole maize rotation											
11. Soybean inoculation											
12. Soybean/sole maize rotation											
13. Groundnut/sole maize rotation											

14. Soya + pigeon pea intercrop/sole maize rotation											
15. Gnuts + pigeon pea intercrop followed by sole maize											
16. Agroforestry trees											
17. Others											

CODES D1.3: 1=BB Project, 2=govt extension worker, 3= Fellow farmers4=Lead farmers, 4= Radio, 5=NGOs, 6=Field vists/demos, 6=Others (specify)________

CODES D1.5: 1=Limited land size, 2=Not beneficial, 3=Labour constraints, 4=Lack of access to legume seed, 5=Restricted number of farmers by the project, 6=others

CODES D1.6: 1=BB Project, 2=govt extension worker, 3= Fellow farmers, 4=Lead farmers, 5=NGOs, 6=Others (specify)

CODES D1.10: 1=Soil fertility improvement, 2=Pests and diseases control, 3=For food, 4=For cash, 5=Others (specify)

CODES D1.12: 1=Not profitable, 2=Lack of seed, 3=Seed is expensive, 4=Lack of markets, 5=Labour intensive, 4=Limited land size, 5= Poor soils, 6= Pests, /diseases, 7= unpredictable rainfall pattern, 8=others _______

D2. Specific ISFM technologies and fertilizer use during the 2014/15 season

D2.1	**D2.2**	**D2.3**	**D2.4**	**D2.5**	**D2.6**			**D2.7**	**D2.8**
Plot ID	**Plot size**	**ISFM technology/practice being practiced** **CODES D2.3**	**Did you apply any type of fertilizer** 1=Yes 2=No	**Type of Fertilizer Applied** 1=23:21+04S, 2=Urea, 3=Others (specify)___	**Amount of fertilizer applied (kg)**			**Source of fertilizer:** **CODES D2.7**	**What was the average market price of fertilizer? (MK/50 kg bag)**
					23:21+04S	Urea	Others (Specify)		

1									
2									
3									
4									

CODES D2.3: 1=Sole maize + inorganic fertiliser, 2=Maize + pigeon pea intercrop, 3=Maize + beans intercrop, 4= Maize + soybeans intercrop, 5= Soya + pigeonpea intercrop, 6=Gnuts + pigeonpea intercropping, 7= Maize + gnut intercrop, 8=Pigeon pea/Maize rotation, 9= Maize + pigeon pea/Maize + Pigeon pea rotation, 10= Bean/sole maize rotation, 11= Soybean + inoculation, 12= Soybean/sole maize rotation, 13= Groundnut/sole maize rotation, 14= Soya + pigeon pea intercrop/sole maize rotation, 15= gnuts +pigeon pea intercrop/followed by sole maize

CODES D2.7: 1=Bought using own cash, 2=FISP, 3=Both Cash and FISP, 4=Bought on credit, 5=Given by friends, 6=Others (specify)________

D3. Are you a member/participant of the Legume Best Bets (BB) Project? **1=Yes, 2=No (If No, D18)**

D4. If yes, for how long have you been participating in BB? ___________ (years)

D5. How were you selected into the BB project? Any criteria?

____

____

D6. Apart from the 10m x 10 m plots you were introduced to, have you been able to extend to larger plots? **1=Yes, 2=No**

D7. If yes, to what extent? ___________ (acres)

D8. If NO, why have you not been able to extent to larger plots?

____

____

D9. What specific adaptations and modifications are you making to the ISFM technologies and practices as introduced by the Legume Best Bets Project?

____

____

D10. Have you ever inspired any non-BB Project farmers to adopt the ISFM technologies? **1=Yes, 2=No**

D11. If yes, have any non-BB Project participants/farmers adopted the ISFM technologies from you after being inspired? **1=Yes, 2=No (If No, D15)**

D12. If yes, how many of the non-BB project farmer are practicing the ISFM technologies in this community after being inspired by you? _______________

D13. If yes, how related are you?

____

D14. How far are they from your fields where you are practicing the technologies? _______ (m or km)

D15. Why are those non-BB project farmers who were inspired by you not practicing the ISFM technologies??

D16. What do you think can be done so that non BB project farmers should start adopting the ISFM technologies?

____

____

D17. What challenges are you facing as you are participating in the BB Project as regards to ISFM technologies (particularly maize-legume intercropping and rotation?

____

____

D18. How do you think these challenges can be addressed?

____

____

For dis-adopters:

D19. Why did you decide to abandon the ISFM (maize-legume intercropping and rotation) technologies that you were practicing?

____

____

For non-adopters:

D20. If yes, why are you not practicing ISFM (maize-legume intercropping and rotation) technologies?

____

D21. Crop Management Practices

D21.1	Did you weed your field crop in time?	**1=Yes 2=No**
D21.2	If yes, how many times was weeding done?	
D21.3	Did you plant with the first rains (on time)?	**1=Yes 2=No**
D21.4	Was fertilizer application done on time	**1=Yes 2=No**
D21.5	Were your field crops attacked by pests and diseases?	**1=Yes 2=No**
D21.6	Pests and disease control	**1=Yes 2=No**
D21.7	Was harvesting done on time	**1=Yes 2=No**

D22. Please estimate how much you spent on the following during the 2014/15 season?

D22.1	**D22.2**	**D22.3**
Input/Activity	**Amount Spent (MK)**	**Approximately how far did you travel to access inputs (km)?**
Seeds		

Basal dressing fertilizer-*wanthaka* (e.g. 23:21+4s)		
Top dressing fertilizer-*wobelektesa* (e.g urea)		
Other fertilizer		
Manure		
Draught power		
Hired labour		
Hired machinary		
Transport/marketing		
Payment for land rental		
Others (specify)		

D23. During the 2014/15 season, did you receive training in the following?

C23.1	**C23.2**	**C23.3**
Type of training	**Have you ever received this kind of training?** 1=Yes, 2=No	**If yes, who provided the training**
Maize-legume intercropping		
Maize-legume rotations		
Legume-legume intercropping and rotation		
Agroforestry		
Soil fertility management		

SECTION E: CROP MARKETING (2014/15 SEASON)

E1	**E2**	**E3**	**E4**	**E5**	**E6**
Type of crop grown during the 2014/15 season CODES E1	**Did you sell part of the produce?** 1=Yes 2=No	**Quantity sold (kg)**	**Where did you sell the produce?** **CODES E3: 1**	**What was the price of the crop growing season** (MK/kg)	**How far are the markets? (km)**

CODES E1: 1=Maize, 2=groundnuts, 3=pigeon pea, 4=common beans, 5cowpeas, 6=soya beans, 7=other legumes (specify), 8=Tobacco, 9=Cassava, 10=Sweet potatoes, 11=Paprika/chillies, 12=others (Specify)
CODES E3: 1=BB project, 2=Vendors, 3=Trading centres, 4=ADMARC, 5=NGO/Private organisation, 6=District market, 6=Others (specify) ______________

SECTION F: SOURCES OF INCOME

F1. Please provide your major sources of income during the 2014/15 season

	F1	**F2**	**F3**
	Income source	**Monthly income (MK)**	**Annual income (MK)**
1	Crop sales (farming)		
2	Business		
3	Employment		
4	Livestock sale		
5	Asset sales		
6	Casual labour		
7	Remittances		
8	Other off-farm income		
9	Others (specify)		

SECTION G: HOUSEHOLD ASSET OWNERSHIP

G1		**G2**	**G3**	**G4**	**G5**
Assets		**Ownership status** 1=Yes, 0=No	**Number of units owned**	**Average current unit value ((MK)**	**Total value (MK)**
1	Ox-cart				
2	Ox-plough				
3	Axe				
4	Hoe				
5	Knapsack sprayer				
6	Wheelbarrow				
7	Water pump				
8	Spade or shovel				
9	Wood stove *(mbaula)*				
10	Kerosene (paraffin) stove				
11	Bicycle				
12	Motorbike				
13	Car				
14	Bed				

15	Chairs				
16	Tables				
17	Cellophane				
18	Radio				
19	Solar panel				
20	*Panga* knife *(chikwanje)*				
21	Others (specify)_____				

SECTION H: LIVESTOCK OWNERSHIP

H1. Do you own any livestock? **1=Yes, 2=No**

H2If yes, what type of livestock do you own?

	H2.1	**H2.3**	**H2.4**	**H2.5**
	Type of livestock owned	**Ownership status:** 1=Yes, 2=No	**Number of livestock owned**	**Total current value (MK)**
1	Cattle			
2	Goats			
3	Sheep			
4	Pigs			
5	Ducks			
6	Chickens			
7	Others (specify)			

SECTION I: GROUP DYNAMICS

I1. Do you belong to any (farmer) group/association in this community? **1=Yes, 0=No**

12. If yes, which group (s) do you belong to?

1.2.1	**I2.2**	**I2.3**
Name/type of group	**Group activities**	**For how long have you been a member of this group? (years)**
1.		
2.		
3.		

I3. If you don't belong to any group, why?

1=No groups in the community, 2=I don't think they are important, 3=I used to be a member but stopped, 4=others (specify) _________________

SECTION J: ACCESS TO CREDIT SERVICES

H1. Did you you have access to credit services during the 2014/15 season? 1=**Yes, 2=No (Go to f5)**

H2	**H3**	**H4**	**H5**
If yes, who are the providers? 1=BB project, 2=Govt 3=Others(specify)____________	**Type of credit**	**Amount/value**	**If you didn't receive, credit, why?** 1= Have enough capital, 2=Lack of collateral, 3=Lack of institutions, 4=Fear of default, 5= other (specify

SECTION K: ACCESS TO EXTENSION SERVICES

I1. Do you have access to extension services during the 2014/15 season? **1=Yes, 0=No (Go to I4)**

	I2	**I3**	**I4**
	If yes, who are the providers?? **1=Legume BB, 2=Govt, 3=Fellow farmers, 4=Radio, 5=NGOs, 6=Field days/demos, other (specify**	Type of extension messages received	How many times did the extension worker visit you in the just ended season (2014/15)
1			
2			
3			

I5. If no, why don't you have access to extension service services?

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END OF QUESTIONNAIRE

(Remember to thank the respondent for the valuable time in the study)