AN ANALYSIS OF THE DETERMINANTS OF DIFFUSION OF SUSTAINABLE AGRICULTURAL INTENSIFICATION PRACTICES IN A MAIZE-LEGUME SYSTEM IN KENYA

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DECLARATION AND RECOMMENDATION

Declaration

I declare that this thesis is my original work and has not been submitted in this or any other university for the award of a degree.

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Recommendation

This thesis has been submitted with our approval as the candidates' supervisors.

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DEDICATION

I dedicate this thesis to my husband Hezron Nyarindo Isaboke, my son Jasper Wren Nyarindo and my siblings for their continued support and prayers

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ABSTRACT

The adoption and diffusion of sustainable agricultural intensification (SAI) practices remain a major concern in the development-policy agenda for Sub-Saharan Africa. This will solve the problem of land degradation, low agricultural productivity and poverty. Despite the benefits such as increase in yields and improved soil fertility that SAI offer, it is unclear why smallholder farmers report low adoption levels. Further, gender roles in decision making on farm productivity remain largely and empirically unexploited. To increase agricultural production in the agricultural sector, there is need to use appropriate combination of SAI practices. This study analyzed if SAIs uptake is linear or nonlinear and the impact of SAIs on income and labor demand among genders. Data from a sample of 535 households from five counties in Eastern and Western Kenya under Adoption Pathways project were analyzed using Multinomial Endogenous Switching Regression (MESR), Ordered Probit (OP) and a Stochastic Production function. The OP results showed that the number of technologies adopted is significantly influenced by labor use intensity, family income, plot tenure, land size and contact frequency with extension service providers significantly determined adoption. The MESR results indicated that women are more involved in majority of farm operations compared to men who mostly access extension service. Extension message is likely to have more effect if those involved in farm operations are reached, and the use of SAI practices as a package earns farmers more income than in isolation. The stochastic production function results showed that the level of fertilizer and improved variety use were positively correlated with yield across the cropping type. Further, access to credit positively affected the farmers' choice of cropping systems, the elderly farmers practiced more intercropping, low soil fertility significantly reduced the growing of pure maize stand and limited incomes favored more intercropping. These results can help in packaging SAI practices for enhanced uptake by smallholder farmers especially in the presence of declining soil fertility and high commercial input costs. Furthermore, the results suggest that a better understanding of the determinants of cropping choices for smallholder farmers can be beneficial for better targeting of SAIs for adoption and subsequently improving crop productivity with less use of commercial inputs.

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LIST OF ABBREVIATIONS AND ACRONYMS

AIFSC	Australian International Food Security Center
APP	Adoption Pathways Project
CIMMYT	International Maize and Wheat Improvement Center
DH	Double Hurdle
FHHs	Female Headed Households
HH	Household
INRM	Improved Natural Resource Management
KES	Kenya shillings
MESRM	Multinomial Endogenous Switching Regression Model
MHHs	Male Headed Households
SAI	Sustainable Agricultural Intensification Practices
SIMLESA	Sustainable Intensification of maize-legume in Eastern and Southern Africa
SSA	Sub Sahara Africa

CHAPTER ONE
INTRODUCTION

1.1 Background information

In Sub-Sahara Africa (SSA) maize is an important food crop. It accounts for 30% of the total area under cereal production in this region (Food and Agriculture Organization (FAO), 2010). Despite its role as a key crop for food security and economic growth its yields have remained low (Shiferaw *et al*., 2011). Maize is predominantly grown in smallholder farming systems under rain fed conditions with limited fertilizer use, in areas with low soil fertility, inadequate rainfall, weeds, pests and inappropriate seed varieties may explain the trend of low yields. Studies have also shown that maize yield has increased in over 70% of the growing areas. However, there are worrying trends of stagnation for many years (Ray *et al*., 2012). Alongside this deliberate efforts have been made to boost productivity and enhance the incomes of the small holder farmers. Such include development of high yielding varieties, farming systems and sustainable agricultural intensification such as crop rotation, intercropping and use of organic fertilizers.

A study by Kristjanson *et al.* (2012) ascertained that most households adapt to changing circumstance and their changes tend to be minimal rather than transformational in nature, with relatively little uptake of existing innovations. Moreover, many studies have advocated consistently for approaching agriculture and food security investment from gender perspective Gender inequalities and lack of attention to gender in agricultural development contribute to lower productivity and higher levels of poverty as well as under-nutrition (FAO, 2011). As a result, there is increasing concern about the implementation and continual use of innovations by the smallholder farmer.

There is a growing body of literature on gender differences in uptake of technologies and agricultural productivity, most of which is partial in terms of methodological treatment and geographical coverage while focusing primarily on fertilizers and improved seeds (Quisumbing, 1996; Peterman *et al*., 2011). This indicates that it may be inappropriate to generally use gender as a determinant of technology uptake and agricultural productivity where MHHs and FHHs are used as a proxy for gender.

Maize is a dominant food crop in Kenya; its production and yield per unit area is influenced by many different factors including total planted area and inputs used in production. Producing higher maize yields on existing cultivated land is the surest way of generating the extra grain required to feed the nation. The formulation of a strategy to pursue sustainable maize production in Kenya is necessary mainly because of the scarcity of good agricultural land and rapid population growth (Wokabi, 2000). Hence increase in maize productivity presents an excellent opportunity to increase rural household incomes, strengthen rural economies and improve nutritional value.

Recent studies show that yields have stagnated at below 2 tons, while area per hectare has remained at about 1.5 million hectares (De Groote *et al*., 2011). With limited arable land area and resource constrain, Kenya will have to rely relatively more on yield improvement than area expansion for future increases in maize production. One way to increase yield in agricultural production is by using sustainable agricultural intensification (SAI) practices in combination. The SAI practices considered in this study include: improved varieties, pesticide, herbicide, fertilizer, maize legume intercropping, maize legume rotations, conservation agriculture practices, organic manure, and use of different types of modern inputs. The SAI practices are important because they aid in producing more output from the same piece of land while reducing the negative environmental impacts.

This study is part of a broader development project on adoption pathways in Eastern and Southern Africa funded by AIFSC. The general objective of the project is to address the knowledge gap which leads to decisions made based on imperfect information due to limited in depth understanding of the economics of farming decisions under uncertainty, technology scaling out interventions and policy decisions. The project aims to draw on and expand existing data sets assembled through SIMLESA to initiate panel data sets in sentinel villages which represent maize legume based farming systems in East and Southern Africa including Kenya. In Kenya the study was carried out in five counties namely: Bungoma and Siaya in Western region and Embu, Meru and Tharaka-Nithi in the Eastern region.

1.2 The statement of the research problem

There has been tremendous breakthrough in innovations and dissemination targeting enhanced production of maize among smallholder farmers. This has been through development of high yielding varieties, farming systems and sustainable agricultural intensification practices such as crop rotation, intercropping and use of organic fertilizers. Despite the benefits such as increase in yields and improved soil fertility that sustainable agricultural intensification practices offer, it is unclear why smallholder farmers report low adoption levels, and climate variability continue to affect farm productivity. Further, gender roles in decision making on farm productivity remain largely empirically unexploited. This study therefore addressed this knowledge gaps by econometrically analyzing constraints that smallholder farmers face in uptake of sustainable agricultural intensification practices as a package.

1.3 The study objectives

The general objective of the study is to better understand how socio-economic factors including gender and changes in farming systems as well as external factors like climate variability and policies shape innovation processes, productivity and risks faced by smallholder farmers. The specific objectives were:

1. To determine whether technology adoption decision is linear or nonlinear in process and the impact of farmers' choice of technology combination on income and labor use.
2. To evaluate the determinants of the number of SAI technologies used.
3. To determine the relationship between cropping choices and technology uptake.

1.4 Hypotheses

The following hypotheses were postulated to guide the study:

1. The application of SAI practices is non-linear and a farmer's choice of SAI practices has no significant impact on income and labor use.
2. There are no significant differences in the determinants of use of one or more SAI technologies.
3. There is no significant causal relationship between cropping choices and technology uptake.

1.5 Justification

Maize is a vital crop for food security and economic growth in Eastern and Southern Africa. In Kenya it is the main staple food. Except in South Africa, maize is the largest and widely cultivated cereal in the region (Shiferaw *et al*., 2011). In Sub Saharan Africa, the role of women is downplayed in embracing technology to the extent of only using gender as a proxy for male and female. Similarly decision making process may not be necessarily dual in structure either male or female making decision, but rather there is a third dimension the idea that male and female make decisions jointly which is empirically and extensively unexploited. The World Development report on gender equality and development warns that the failure to recognize the roles, differences and inequities between men and women poses a serious threat to the effectiveness of agricultural development (World Bank, 2012). Therefore, a better understanding of innovation constraints according to gender will improve policy makers' knowledge on gender relevant and responsive technologies which contribute towards empowering women and more equitable development strategies. This will go a long way in addressing the third Millennium Development Goal on reduction of gender inequality and empowering women. Investigating the drivers and constraints to efficient production with focus on role of gender in innovative practices can check the food insecurity and underdevelopment problems.

1.6 Scope and limitation

This study only focused on selected smallholder maize legume farmers in Eastern and Western Kenya. There are other aspects entailed in the integrated agro enterprise approach such as value addition, marketing and business organization which are beyond the scope of this study. Therefore, it only laid emphasis on maize legume production and use of multiple technologies. This is because most small scale farmers in Kenya practice maize legume intercrop as staple food on their plots. For instance, Shiferaw *et al*. (2011), note that nearly 50% of the cultivated area of major staple crops is devoted to maize.

1.7 Definition of terms

Smallholder - This study considered small-holder farmers as those having 5 ha of land and below.

Sustainable Agricultural Intensification – This means the process of producing more output from the same piece of land while reducing the negative environmental impacts and at the same time increasing contributions to the natural capital and the flow of environmental services (Godfray *et al*., 2010).

Poverty – This is a situation where farmers live below a dollar per day and inability to meet daily basic needs (definition by United Nations (UN)).

Food security - It is defined as the "state when all people at all times have both physical and economic access to sufficient food to meet their dietary needs for a productive and healthy life'' (USAID, 1995).

Household – Is an independent male or female producer and his/her dependents with whom must have lived together for a period of not less than six months (Ellis, 1988). The members are answerable to one person who makes most decision and share the same eating arrangement.

Gender - The socially constructed roles, behavior, activities and attributes that a particular society considers appropriate for men and women (WHO, 2013).

Innovation - An idea, practice, or object that is perceived as new by an individual or other unit of adoption (Rogers, 1983).

Cropping system- The order in which crops are cultivated on a piece of land over fixed period.

Cropping choice - The choices and sequence of rotating crops.

1.8 Outline of the thesis

This thesis is organized in eight chapters. Chapter one provides the background of the research problem. Chapter two presents the literature review, the conceptual and theoretical frameworks. In chapter three the study area, sampling procedure and data collection approaches and a description of variables used in various models in this study, are presented and discussed. In chapter four, descriptive statistics from the survey are presented and succinctly discussed. In chapter five, the impact of adopting SAI practices as a package on income and labor use is analyzed using endogenous switching regression model and the results presented and discussed. In chapter six, an ordered probit model is applied to analyze and determine factors that influence the number of SAI technologies used by farmers, and the results presented and discussed. Chapter seven addresses the relationship between cropping choices and technology uptake using a stochastic production function, with the results presented and discussed. Summary, conclusions and implications are presented in chapter eight.

CHAPTER TWO

LITERATURE REVIEW

2.1 Trends of technology uptake

Several studies have been conducted to collect vital information regarding diffusion of innovative technologies in agriculture (Marenya *et al*., 2007; Muricho *et al*., 2012; Ouma *et al*., 2011; Omiti, 2003; Olwande *et al*., 2009; Shiferaw *et al*., 2009) . Such include innovation on improved seed varieties, use of organic fertilizers among others. Shiferaw *et al*. (2009) carried out a study on adoption and adaptation of natural resource management innovations in smallholder agriculture. Their findings revealed that in order to address the externalities and institutional failures that thwart private and joint investments for management of agricultural landscapes, it will call for innovative kinds of institutional mechanisms for empowering households through local collective action. This would guarantee expansive participation and fair distributions of the gains from joint conservation investments.

In another study of adoption of fertilizer use by smallholder farmers, Olwande *et al*. (2009) used a Double Hurdle model panel data and found that education, credit, growing cash crop, distance to the market and agro ecological potential as statistically significant in influencing the probability of adopting fertilizer. Place *et al*. (2003) used descriptive analysis to review organic nutrient management practices. They found that no single component of integrated soil fertility management can stand on its own in meeting the requirements of sustainable soil fertility management. They also noted that patterns of use varied across heterogeneous agro-ecological conditions, communities and households. This variation appeared to be stimulated by profitable commercially oriented agricultural opportunities. Like mineral fertilizer, there appeared to be more interest in, and impact from, the use of organics and integrated systems on higher value crops. Because of their low cash requirements, some organic-based systems reached poorer households that otherwise are scarcely using any fertilizer

Using a logit model on cross-sectional data Ouma *et al*. (2002) analyzed the adoption of maize seed and fertilizer technologies in Embu District. They found that gender, manure use, hiring of labor, and extension were statistically significant in explaining adoption of improved maize variety. Likewise, gender, manure use, hiring of labor, and extension were important variables in explaining the amounts of basal fertilizers farmers applied. Furthermore in analyzing the factors influencing farm level fertilizer adoption decisions under an era of liberalized markets in Kenya using Tobit model, Freeman and Omiti (2003) found that the level of education of the household head, experience using fertilizer, growing a cash crop, availability of fertilizer in rural retail outlets, availability in small packages, and land pressure positively influenced fertilizer use, while the size of family labor and location in the drier semi-arid zone were negatively associated with fertilizer use. A study by Ouma *et al*. (2011) used the Heckman two-stage regression to model determinants of adoption of improved maize seed and fertilizer in Kenya. The study reveal that the ability to access hired labor was positively associated with adoption of improved maize varieties and fertilizer in maize growing zones of Kenya.

A study by Muricho *et al*. (2012) used descriptive statistics on characterizing maize-legume farming systems and farm households in Kenya. It further On analyzed technology choice, resource use, gender, risk management, food security and poverty profiles and concluded that a higher proportion of households in eastern Kenya districts (Embu, Imenti South and Meru South) were more food secure compared to their counterparts from western Kenya. Using Multivariate Discrete choice modeling on longitudinal data in determining adoption of improved natural resources management practices among smallholder farmers in western Kenya, resource constraint was found a major limit to farmers' up take of improved natural resource management (NRM) practices (Marenya *et al*., 2007).

These studies have put less emphasis on output supply and input demands and their associated markets especially on fertilizer use and yield obtained, more so there is much focus on technology uptake in piecemeal rather than as a multiple of processes which could be a major cause for its slow rate of diffusion. Due to the fact that technology uptake is path dependent, this study will fill the gap created by focusing on technology uptake and its impact in isolation. The choice of technology used currently by farmers is partly dependent on decisions made in previous periods and earlier technology choices.

There is also limited focus on integrated agriculture (environment and agricultural production link) in the technology uptake process; the dynamic nature of production and technology uptake and associated impacts are less accounted for in the reviewed literature and yet they do matter. Moreover the socio-economic context within which these dynamics occur, and how they drive or are driven by the subsequent outcomes are less clear. Hence this study will fill this gap by focusing on integrated approaches based on principles of conservation agriculture while also reducing negative environmental impacts. In order to accelerate investments in environmentally friendly agricultural technologies, this study will incorporate farmer incentive and social economic conditions to promote integrated practice for improving productivity.

Most prior adoption studies on research of a particular technology use single equation models (such as probit or logit). Conversely, farmers are faced with technology alternatives that may be adopted simultaneously as complements, substitutes or supplements to deal with their overlapping constraints. Microeconomic impact and adoption studies need to capture these dynamics of technology uptake decisions. The models used in the above studies are not robust and rigorous to enhance technology uptake and change, and to identify viable pathways for overcoming poverty and food security. Hence, this study employed Endogenous Switching Regression model which is particularly suitable for studying social-economic interactions, direct-indirect effects of interventions and the drivers of change in farming systems.(Holden and Shiferaw, 2004; Holden and Lofgren, 2005).

2.2 Determinants of technology uptake

While focusing on incentives and drivers to technology uptake studies have found that farmer characteristics, technology traits, farm traits, institutional and economic factors to be major factors determining farmer's decision to either adopt new agricultural technology or not. On their study on adoption of improved wheat technologies and fertilizer by small- scale farmers in Tanzania, Mussei *et al*. (2001) used a Tobit analysis to show that farm size, family size and the use of hired labor were significant factors affecting the proportion of land allocated to improved wheat. Whereas farm size, family size hired labor and credit significantly affected the amount of fertilizer used, other factors like distance to the wheat market, level of education, attitude towards improved technology, access to extension service and farmers membership to organizations were not addressed.

Using Heckman two-stage model to analyze factors determining use of improved maize variety and fertilizer in Kenya, Ouma *et al*. (2011) ascertained that credit was vital in explaining the use of improved maize seed variety and fertilizer. Similarly the ability to access hired labor was positively associated with use of superior maize varieties and fertilizer. Number of extension contacts and the level of education of household head significantly determined adoption of improved maize varieties. Variables such as ability to hire labor, provision of credit and strengthening of research/extension farmer's linkages are likely to take part in enhancing the use of improved maize seed and fertilizer and therefore increasing maize productivity in Kenya. In addition, Karki (2004) assessed the impact of foreign-aided project in technology adoption and food security in case of smallholder peasants in Nepal. His results showed that timely availability of credit, years of schooling, off-farm income, extension services, project intervention, farm size and experience of the farmer to significantly influence the adoption decision. The study did not address issues relating to farmers membership to an organization, distance to market, household labor and farmer attitude.

A study on new approach to securing sustained growth in Kenya's maize sector by Lyman *et al*. (1998) used logit model to ascertain that increase in information flow is crucial to making the decisions that will lead to sustained growth in maize productivity matter when designing effective matters, strategies and targeting of maize technology, technology support systems, and market liberalization. Farm size affects adoption of agricultural technologies positively. On the other hand, households that receive off-farm income are less likely to pursue on-farm diversification as a method of reducing financial risk (Rana *et al*., 2000). Use of improved seed varieties and inorganic fertilizer are key inputs in enhancing productivity of maize in Kenya (Ouma *et al*., 2011). While using descriptive analyses to study maize production in Kenya, De Groote *et al*. (2005) determined that adoption of improved maize and inorganic fertilizer was shown to have increased. However, small-holder farmers apply inorganic fertilizer below the recommended rates and this is attributed to high cost of fertilizer.

Another investigation on adoption patterns of integrated nutrient management (INM) components was carried out using logit model, (Odendo *et al*., 2009). They found that animal manure was the most widely applied soil management practice. About 25% of the households applied combinations of organic and inorganic inputs. They also found the determinants of the adoption of INM practices vary across the INM practices surveyed. However, education level of household head, livestock units and the district where the farm is located had significant positive effects on integrated use of organic and inorganic inputs. Similarly Jayne *et al*. (2006) used Probit and Truncated Ordinary Least Square and Tobit models, on panel data to determine the specific factors at national, region and household level that are associated with smallholders' use of improved maize technologies in Kenya and Zambia. They found that over 25% of the farms use improved maize technology. Their further analysis showed that household characteristics including distance to market, regional differences and education of head significantly determined technology uptake. Furthermore a study on adoption of commercial poultry production among farmers in Kericho municipality in Kenya, Ngeno *et al*. (2009) used a two-limit tobit model and reported production system, education and employment of women as significant determinants of the degree of control by women over poultry enterprises.

There are intrinsic characteristics of innovation such as relative advantage, compatibility, complexity / simplicity, trial ability and observability that are not considered yet they are vital for diffusion process and as determinants of technology uptake (Rogers, 1995). Technology is not only limited to fertilizer uptake but rather a combination of technologies that are environmental friendly and sustainable within the small holder farmer context. From the literature reviewed, it is not possible to infer any study that has accounted for these variables.

2.2.1 Gender and technology uptake among smallholder farmers

A study conducted on understanding the complexity surrounding gender differences in agricultural productivity in Nigeria and Uganda by Peterman *et al*. (2011) revealed that there is growing literature on gender differences in technology uptake and agricultural productivity. Their study also showed that due to challenges faced by women as a result of their need to access land, labor and inputs, they get less return from the farm output, hence this discourage them from putting much more effort in the farms. Likewise Doss and Morris (2001) carried out a study in Ghana using two-stage probit model to determine the effects of gender on technology adoption process, and the differences in adoption between men and women. The study found that gender-linked differences in the adoption of modern technologies are not attributed to intrinsic uniqueness of the technologies themselves, but result from gender-linked differences in access to key farm inputs. They further pointed out that ensuring more widespread and equitable adoption of improved technologies may not require changes in the research system, but rather an introduction of procedures that guarantee improved access for women to complementary inputs, especially land, labor, and extension services.

An analysis of adoption of agricultural innovations by smallholder farmers in the context of HIV/AIDS in Kenya revealed that, women are responsible for feeding their families hence crops produced for subsistence are associated with women (Njeri, 2007). The study also found that men grow cash crops because they are responsible for providing cash income for the family and a result, women’s overall responsibilities affect poor households’ capacity to adopt new activities especially when additional family or hired labor is not available. Further the study found that unlike men, women lack access and control over production resources such as land, information, credit and labor. The findings confirmed that persons with greater contact to resources are more able to benefit from a change in circumstances than less powerful and poorer individuals. Doss, (2001) assessed women farmers in Africa using cooperative and non-cooperative bargaining models in Ghana. The findings revealed that African households are complex and heterogeneous, gender roles in African households and communities cannot be simply summarized and that gender roles and responsibilities are dynamic as they respond to changing economic circumstances.

Similarly, while studying gender, agricultural production, and the theory of the household, Udry, (1996) found that plots controlled by women were farmed much less intensively than similar plots within the household farmed by men due to inefficient factor allocation within the household. Household models assume that the allocation of resources is efficient. In African households, most agricultural production occurs on plots farmed by different members of the household. Pareto efficiency implies that factors should be allocated efficiently across these plots.

Studies by (Peterman *et al*. 2011; Doss and Morris 2001; Njeri, 2007; Doss, 2001 and Udry, 1996) have used gender as one of the determinants of technology uptake and agricultural productivity. By using MHHs and FHHs as a proxy for gender, studies have ignored women in male-headed households and the heterogeneity in resource endowment in different types of male and FHHs. This affects technology uptake and risk taking behavior. In the long run it may lead to gender technology adoption potential and lead to incorrect policy diagnosis. Therefore, this study will enhance the understanding of dynamics in adoption process and changes in the livelihood strategies, famer's perception and response to climate risks, cropping mechanisms and management of natural resource.

2.2.2 Gender of household head and food security links

Studies have revealed that FHHs are more susceptible to food insecurity and non-income aspects of poverty. An example was a gender based research on determinants of food security in Kenya Kassie *et al*. (2012) that used ordered probit model and found that the FHHs in general are more likely to be food insecure compared to their male counterparts. Their analysis revealed that FHHs' food security increases with quality of extension workers, land quality, and farm size while distance to the market reduces the probability of food security. A gender-based analysis of vulnerability to food insecurity in Nigeria by Babatunde *et al*. (2008) used indices of household coping strategies and FHHs were more vulnerable to food insecurity than male headed households. They also found that increase in farm size and crop output reduces vulnerability to food insecurity in MHHs. Generally, food insecurity is related to high food prices, poverty and low agricultural output.

A study by Muricho *et al*. (2012) used descriptive statistics to characterize maize-legume farming systems and farm households and concluded that a higher proportion of households in eastern Kenya districts were more food secure compared to their counterparts from western Kenya districts. About 54.3% of the surveyed households had daily per capita expenditure of below the internationally defined poverty line and a higher proportion of FHHs (57.1%) were living below the international defined poverty line as compared to the male headed households (53.6%).

Buvinic and Gupta, (1997) asserts that women's lower average earnings compared to men, less access to remunerative jobs, and productive resources such as land and capital contribute to the economic vulnerability of female-headed households. Households with single women as the head can potentially face even a higher risk of poverty because of the cultural and social stigmas attached to their marital status.

In order to facilitate the formulation of robust pro-poor and gender equitable policies to target innovation and promote diffusion of technologies, this study will focus on SAI technologies including improved seed variety, fertilizer, maize-legume intercropping, maize-legume rotation conservation agriculture practices, organic manure and use of modern inputs. This will also help to narrow the gap by generating gender-disaggregated data and conducting systematic analysis of determinants of joint SAI adoption decisions.

2.3 Impact of improved maize legume farming systems on farmer's welfare

Unobserved heterogeneity and possible endogeneity are some of the challenges that econometric analysis of welfare implication of agricultural technologies may face, this is due to the relationship between technology uptake and farmers wellbeing. Therefore there is need to account for endogeneity of adoption decision to assess the robustness of the results. Resource constraint and lack the market surplus is a major challenge to most farmers, proper utilization of the scarce resources so as to increase farm incomes is essential, hence this depends on the farmer's ability to operate most favorable combination of cost-effective farm enterprises.

According to a study by Ishtiaq (2005), choosing optimal combination of crops to produce is a challenge due to resource constraint thus farmer's profit maximization objective cannot be achieved if cropping blend chosen is not optimal. Further, Anderson (2003) elaborates that a combination of some agricultural enterprises at sub-optimal levels leads to reduction in farm incomes. In addition Anderson criticized the adoption of cash crops on the grounds that they compete with production of food crops and therefore subjects the households to food insecurity hence driving them to low living standards.

On their study on welfare measures, Diao *et al*. (2008) used descriptive analyses to substantiated that rapid growth in staple production, together with more integrated regional markets, would cut down food prices by roughly 20–40% for consumers and 10–20% for producers among the major crops, which translates into a huge rise in farm revenues, annual agricultural growth rates of

6.5% or higher, broader income growth and food security, and over 70 million Africans being lifted out of poverty. Higher farm productivity is perceived to improve household's wellbeing.

Essentially studies consider the impact of improved maize farming systems on farmer's welfare, yet most small scale farmers carry out maize legume farming system. Thus this study will therefore evaluate the potential impact of using the modern agricultural technology on rural maize legume farmer's welfare. This will be measured by farm outputs obtained by the farmers by utilizing Endogenous Switching Regression to assess results of robustness in order to estimate true welfare effects multiple technology uptake and adoption decisions.

2.4 Theoretical framework

Given a set of the technologies a producer chooses that technology which does not constrain their income, resources and is easier to implement. Random utility theory predicts that whereas the reasons for a given choice cannot be deduced prior, observed producer attributes and other characteristics can explain the observed choice. The observed choice is assumed to satisfy or maximize an underlying utility hence, an individual decision maker is assumed to select only that alternative with the highest utility from amongst available alternatives in a set of choices. The underlying utility could then be the output level obtained for example, be it for the home consumption or for sale.

The adoption of farming technologies and the output levels obtained can therefore be analyzed as a choice problem using utility theory. In this case a common specification is the linear random utility model (Caviglia-Harris, 2003). Suppose an individual farmer's utility after adopting the new technology for a given vector of economic, social, and physical factors *(A)* is denoted by $E(U_i \mid A)$, and the utility without adoption by $E(U_i \mid N)$. Then, the preference for adopting or not adopting can be defined as a linear relationship thus

$$E(U_i \mid A) = f(X_i) + e_i \tag{2.1}$$

and

$$E(U_i \mid N) = f(W_i) + e_i \tag{2.2}$$

where, X_i and W_i are independent variables which denote farmer characteristics, physical and economic, influencing the decision and e_i is error term. The expected net utility from each of the decisions is then compared such that:

$E(U_i \mid A) - E(U_i \mid N) > 0$ or $E(U_i \mid A) - E(U_i \mid N) < 0$, D_i is then used as an indicator of whether household *i* adopt given technologies or not, so that $D_i=1$ if adopted and $D_i=0$ if not.

$$D_i = 1 \quad if \quad E(U_i \mid A) - E(U_i \mid N) > 0 \tag{2.3}$$

and

$$D_i = 0 \quad if \quad E(U_i \mid A) - E(U_i \mid N) < 0 \tag{2.4}$$

The interpretation of equation (2.3) and (2.4) is that, the probability that the household *i* adopts the use of given technologies is the probability that the expected net utility derived from adoption of the given technology is greater than the expected net utility derived from not using the same (Caviglia-Harris, 2003). Therefore a household decision on the alternative choices appeals to this theoretical framework.

2.5 Conceptual framework

The conceptual framework in Figure 2.1 illustrates the interrelationships of the key variables identified and how they relate on the basis of the study's specific objectives. The decision to take up a new technology or not is understood to be determined by several factors: household (education, age, gender, household size, and income), intrinsic characteristic of innovation (Relative advantage, Compatibility, Complexity/simplicity, Trial ability, Observability) physical and institutional (climate shocks, credit, soils, farm size policies, value chain linkages) characteristics. Therefore, the rationale behind this study is that not all farmers use multiple SAI technologies.

A number of household, physical, institutional and plot characteristics are assumed to determine the number of technologies that small scale farmers use on their plot. For instance, the age of the household head can be a measure of the farmer's experience. This implies that older farmers are likely to adopt new technology because of accumulated knowledge, capital and experience. However younger farmers may also readily take up risks of adopting new technology (Abdulai and Huffman, 2005). Educated farmers are likely to adopt maize legume intercrop because they have knowledge of soil and water conservation and nitrogen fixation from legumes than less educated farmers. Farmers whose perceive their plots to be of low soil fertility are also less likely to use fertilizer and manure.

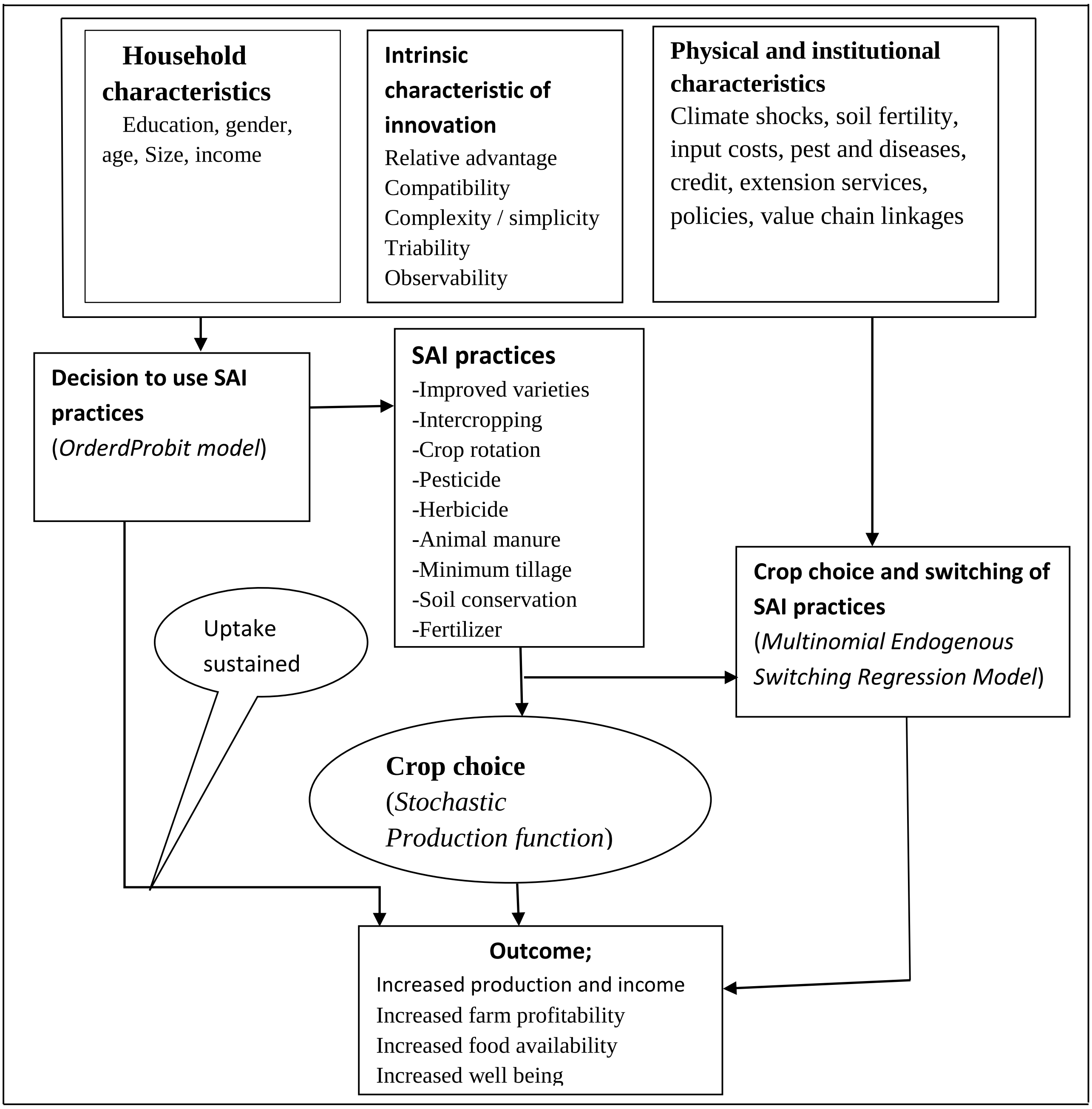


Figure 2.1: Conceptual framework.

Source: Own conceptualization.

Uptake of SAI technologies in combination is assumed to provide more economic benefits and better regulate input use than adopting them individually; this will help in identifying a combination of technologies that deliver the highest payoff. The choice of a given package of SAI practices is expected to have an impact on labor use and farmers income. This is because different technologies would demand for different amount of labor. Hence any rational farmer is expected to switch to a combination that would earn him or her highest payoff and one that would demand less labor.

This study also postulates that the technologies that are available to the farmers affect their crop choice hence influencing yield. An entrenched literature has identified many key factors affecting farmers' crop choices such as climate, soil type, and input prices and availability. After accounting for these factors, farmers may still face a variety of potential crops to choose from. Oftentimes the observed year to year cropping patterns are driven by SAI technologies at the farmers' disposal. Choosing optimal combination of crops to produce is a challenge due to resource constrain as such farmer's profit maximization objective cannot be achieved if cropping blend chosen is not optimal (Ishtiaq (2005). Farmers with higher output are expected to participate more in multiple technology uptake. Hence the number of SAI technologies that are available at the farmer's disposal will determine farmer's crop choice.

Finally it is believed that the adopters can only maximize profits from the new technology if they practice proper utilization of scarce resources by investing more on SAI practices, hence increasing their farm output. This will in the long run increase food availability and wellbeing if the uptake of SAI technologies is sustainable, hence has a significant effect on agricultural productivity and food security.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Study area

This study was conducted in Embu, Meru and Tharaka-Nithi Counties in the Eastern Region formerly known as Eastern Province and in Bungoma and Siaya Counties in Western and Nyanza Regions respectively .The map of the study area is shown in Figure (3.1).

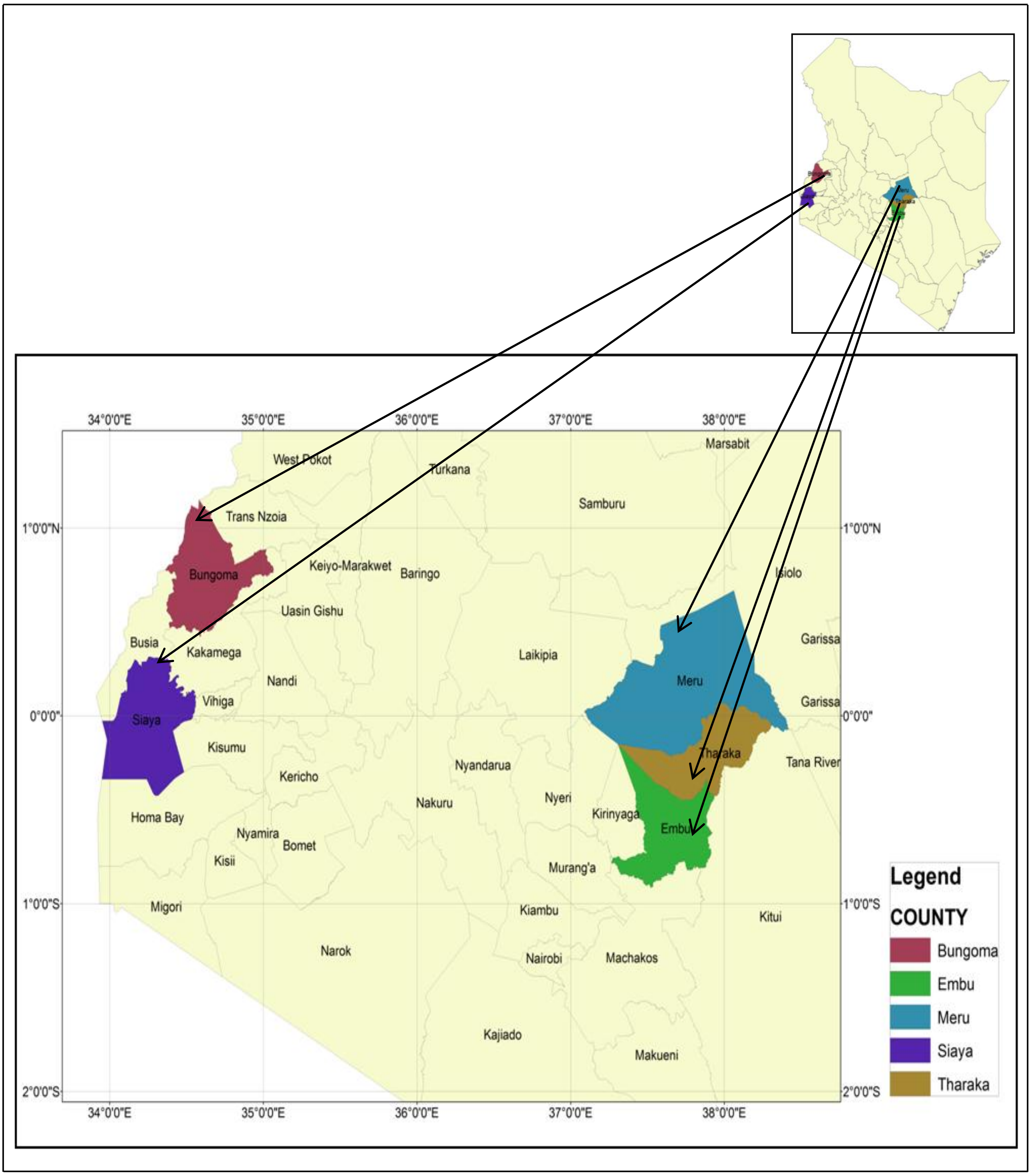


Figure 3.1: Map of study area.
Source: Virtual Kenya and Google Earth Pro. 2014.

Embu County borders Tharaka-Nithi to the north and covers an area of 2,818 per square km. Embu County borders Tharaka-Nithi to the north, Kitui to the east, Machakos to the south, Muranga to the south west, Kirinyaga to the west and Meru to the North West. The County covers an area of 2,818 per square km with a population density is 183 people per square km. In addition the county is characterized by bimodal rain pattern, with the peak rainfall generally occurring between March and June.

Meru County has a total population of 1,356,301; 320,616 households and covers an area of 6,936.9 per square km, with a population density of 195.5 (GoK, 2009). Temperatures range from a minimum of 16°C to a maximum of 23°C. The rainfall ranges between 500mm and 2600mm per annum. The main agricultural activity include; dairying, french beans, yam, cassava, pumpkin, millet and sorghum. Nevertheless, poverty levels of 41% and and 47.3% in Meru Central and Meru North, respectively, are still high.

Siaya County has a population of 842,304; with 199,034 households and covers an area of 2,530.5 per square km. The Population density is 332 per square km and 57.9% of the population live below the poverty line. The area receives an annual rainfall of between 1,170 mm and 1,450 mm with a mean annual temperature of 21.75^{o}C and a range of 15^{o}C and 30^{o}C (GoK, 2009). The poverty level is high ranging from 57.9% (rural) and 37.9% (urban). Other than agricultural land, the area has vital resources such as fisheries, indigenous forests, rivers and timber with main economic activities including subsistence farming, livestock keeping, fishing, rice farming and small scale trading.

Bungoma County is in the Western region of Kenya. It has a population of 1,375,063 and an area of 3,032.2 square km with a population density: 453.5 people per square km (GoK, 2009). The economy of the county is mainly agricultural, centering on the sugarcane and maize industries. The area experiences high rainfall throughout the year, and is home to several large rivers, which are used for small-scale irrigation. The temperatures range between 15 - 20 °C. Although the county produces sugar, coffee, maize, milk, tobacco, bananas and sweet potatoes, 53 % of its population still lives below poverty line.

Tharaka-Nithi County lies in eastern region. It has a population of 356,330; 88,803 households and covers an area of 2,638.8 square km with temperatures ranging between 11°C and 25.9°C, while rainfall ranges between 200mm and 800mm per annum. The Population density is 138 people square km and 65% of the population lives below the poverty line. Some assets of Tharaka-Nithi County include; natural resources as arable land, sand quarries, forests, wildlife and tourist attractions, with the main economic activities being farming, pastoralism, gemstones and stone quarry.

The conditions in these five counties therefore provide a climate that is suitable for the establishment and growth of maize and legumes with the potential for poverty reduction in these counties characterized by high poverty levels with low income levels of less than 1US Dollar per day (GoK, 2005).

3.2 Sampling procedure

Data were collected from Siaya Bungoma, Embu, Tharaka-Nithi and Meru. These counties were purposively selected, based on agro ecological zones (high altitude-eastern and lower altitude-western) and their maize-legume production potential. A multi stage sampling was employed to select lower levels sample clusters including: divisions, locations, sub-locations and villages. Determination of sample size followed proportionate to size sampling approach (Groebner and Shannon, 2005), according to the following formula:

$$n = \frac{\left(pqz^{2}\right)}{d^{2}}$$

where, '*n*' is the sample size, '*z*' = 1.96, '*p*' is proportion of the population of interest. Based on adoption rates of 70% from previous adoption studies *p* was set at 0.70 (Ouma and De Groote, 2011). The variable'*d*' is the significance level and was set at 3.885% as this was considered sufficient to eliminate 95% bias in sampling. This also led to a '*z*' value of 1.96. Variable '*q*' is the weighting variable and is computed as *1-p*. Therefore, the sample size that was used is:

$$n = \frac{0.7 * 0.3(1.96)^{2}}{(0.03885)^{2}} = 535$$

3.3 Data collection and analysis

Primary data were collected from selected smallholder maize legume farmers in the selected sentinel villages among the five counties mentioned above. The formal survey involved recruiting and training of enumerators who administered the structured questionnaires. Data from the smallholder maize farmers comprising of the basic household characteristics such as family size, education levels of household members, occupation, membership to farmer groups/associations, income diversification, livestock and crop inventory, access to markets and market access were obtained.

Data was cleaned, organized and analyzed using SPSS and STATA to obtain both descriptive and inferential statistics. The first objective that sought to determine whether technology adoption decision is linear or nonlinear in process and the impact of farmers' choice of technology combination on income and labor use was analyzed using Multinomial Endogenous Switching Regression Model. The model was chosen since it corrects for self-selection when choosing combined and potentially interdependent packages of SAI practices and the interaction between them (Hailemariam *et al.,* 2012). A detailed empirical specification of the model is described in chapter five.

For the second objective, an ordered probit model was used to estimate the factors that determine the use of one or more practices. Given the assertion that over time there are more than just two identified groups (adopters and non-adopters), it is possible to have a more refined distinction of adopters and non-adopters. Based on the number of SAI technologies that a farmer uses on each plot, we have farmers using one, two or more technologies. Since there are multiple choices and particular interest lies in the individual effects of explanatory variables on each outcome. Having the measure of technology adopted as number across plots, the number of SAPs adopted by farmers are treated as an ordinal variable and used as the dependent variable measuring determinants of adoption SAI practices (Wollni *et al.,* 2010). That is, given a unit change in the explanatory variable the model will capture the qualitative differences between different categories of number of SAI used, hence accounting for the categorical nature of dependent variables as well as its ordinal nature. A detailed empirical specification of the model is described in chapter six.

The third objective that sought to evaluate if there exists a relationship between cropping choices and technology uptake was analyzed using stochastic production function. The study considers three choices: pure stand of maize, pure stand of beans and maize bean intercrop. Farmers grow these crop alternatives and each plot requires use different SAI technologies, with different expected return. While estimating yield for pure maize, pure bean and maize bean intercrop plots, as a function of SAI technologies and plot characteristics, cropping patterns appear in each of the production function as the dependent variables, as described in detail in chapter seven.

3.4 Description of variables used in the analysis.

Table 3.1 shows description of variables that were used in various econometric models with choice of explanatory variables based on literature review findings. A description of these variables is discussed, with specific variables hypothesized to influence the uptake of different SAI practices presented and their expected direction of influence as shown in Table 3.1.

Table 3.1: Description of variables for the multinomial endogenous switching regression (MESR), ordered probit (OP) and Stochastic production function (SP).

Variable	Variable Description	Variable Type	Units of Measurement	Model	Expected sign
Dependent					
NoSAItech	Number of SAI technologies used	Ordinal	1=Use of one technology,…,6=Use of six technologies	OP	None
ChioceSAIcomb	HH choice of SAI technology combination	Categorical	1=Use of SF,…,8= Use of SFMP	MESR	None
Income	Income earned / hectares	Continuous	KES	MESR	None
Labouruse	Time spent working	Continuous	Man Days	MESR	None
Cropchoice	Type of crop farmer plants	Categorical	1=Intercrop(M&B), 2=maize, 3=beans	SP	None
Independent					
Genderhh	Gender of household head	Dummy	0 = Female, 1= Male	OP, MESR, SP	+/-
Aghh	Age of household head	Continuous	Number of years	OP, MESR, SP	+/-
Educlevel	Education level of HHH	Continuous	Number of years in school	OP, MESR, SP	+/-
HHsize	Household size	Continuous	Number of persons	OP, MESR, SP	+
Farmsize	Farm size	Continuous	Farm size in hectares	OP, MESR, SP	+
Income	Income earned	Continuous	KES	OP, SP	+
Labouruse	Time spent working	Continuous	Man Days	OP, SP	+
Frequentcontact	Frequency of contact with extension personnel	Continuous	Number of days/ year	MESR, OP	+
Crdacc	If farmer accessed credit	Dummy	1= Yes. 0=No	OP, MESR, SP	+
Grpmbr	Group membership	Dummy	1= Yes. 0=No	OP, MESR, SP	+
Pltdscmakr	Plot decision maker	Categorical	0 = Female, 1= Male, 3=Both	OP, MESR, SP	+/-
Plotslop	Slop of plot	Categorical	0=Flat, 1=Gentle, 2= Steep	OP, MESR, SP	+/-
Plotdist	Plot distance from home	Continuous	Walking distance in minutes	OP, MESR	-
Soilfertility	Soil fertility	Categorical	0=Good, 1=Medium, 2=Poor	OP, MESR, SP	+/-
Plottenure	Plot tenure	Categorical	0=Borrowed , 1 = Rented , 2 = Owned	MESR, OP	+/-

Note; S= Improved seed, F= Fertilizer, M=Animal manure, P=Pesticide. HHH= Household head. M=Maize, B=Beans.

Genderhh (gender of household head) is used as a dummy variable with 1 representing male and 0 female. It has been argued that women have less access to critical farm resources (land, labor, and cash) and are generally discriminated against in terms of access to external inputs and information. It is postulated that male farmers are more likely to adopt new technologies because they are more endowed with resources compared to their female counterparts.

Aghh (age of household head) is used as continuous variable with the assumption that older farmers are likely to adopt new technology due to their experience or reject all together while younger farmers may be less risk averse. Age means more exposure to production technologies and greater accumulation of physical and social capital. However, age can also be associated with loss of energy as well as being more risk averse. Hence it is expected that age may positively or negatively affect adoption of SAI technologies.

Educlevel (educational Level of household head) is a continuous variable measured in terms of number of years a farmer was in school. Households with more education may have greater access to non-farm income and thus be more able to purchase inputs. Educated farmers may also be more aware of the benefits of modern technologies and may have a greater ability to learn new information hence easily adopt new technologies. Likewise educated households may be less likely to invest in labor-intensive technologies and practices, since they may be able to earn higher returns from their other sources of income. It is expected that education would increase the chances of a farmer accessing information and also enhancing the farmer's chance to adopt SAI technologies.

The variabl*e HHsize* (number of persons in a household per adult equivalent) is a continuous variable measured in terms of number of persons living together. Family size may be associated with labor. So that large families may have adequate labor that would enhance adoption of SAI technologies. Larger household could also translate to more income if members of that specific households are engaged in activities that could earn them more income to enable them adopt SAI technologies.

The variable *Farmsize* **(**farm size) is a continuous variable measured in hectares. Land is an indicator of wealth, thus it is hypothesized that increase in size would positively influence adoption. Farm size is therefore expected to positively or negatively influence adoption of SAI technologies.

Income (total income earned per household) is a continuous variable measured in KES. Farmers with high total incomes are likely to adopt more SAI practices because they are able to meet farm production expenses including labour, fertilizer and seeds. Increased income is also likely to enable farmers invest more on farm production hence positively influencing uptake of SAI practices.

Labuoruse (total time spent working on farm) is a continuous variable measured in man days. Labour is an essential input in farming activities especially in adoption of SAI practices as most of the technologies are labour intensive. It is expected that households that can afford to pay for the labour that they need in order to farm their plots will adopt more of SAI technologies.

Frequentcontact (frequency of contact with extension personnel) is a continuous variable measured in terms of number of contacts in days/year that a farmer has with the service providers such as ministry of Agriculture personnel. A study on Aggregate and Individual Governance Indicators by Kaufmann, (2007) showed that agricultural extension agents are mandated to deliver and implement agricultural-related services and goods to farmers. That farmer's confidence in adoption of new technologies is often shaped by the extension agents as they interact. Depending on the type of information that farmers get and how it is packaged, we postulate that farmers who have more contacts with extension agents tend to get more information.

If a farmer need credit variable (*Crdacc*) is a dummy taking the value 1 if the answer is yes, 0, otherwise. In this study it is expected that those smallholder farmers who do not need credit would be in a better position to take up new technology because they have no financial constraint that is likely to limit the purchase of farm input and other services when need arises. Hence, this will increase their chances of adopting SAI technologies in maize legume farming.

Grpmbr (membership to an organization) is a dummy. Group membership is a form of social network expected to affect technology adoption. Farmers involved in informal and/or formal organizations would be in a better position, compared to other farmer's in terms of access to information and possibly market access. Studies by (Lee, 2005; and Wollni *et al*. 2010) have shown that with inadequate information sources and imperfect markets and transactions costs, social networks are expected to facilitate the exchange of information. This would minimize market asymmetry hence help farmers to earn higher returns when marketing their products. Thus it is hypothesized that membership to an organization would positively influence uptake of SAI technologies.

The variable *plotdcsnmaker (*Main plot decision maker) is used as a categorical variable with 1 representing male. In most households today, household head may not necessarily be the plot decision maker. It has been argued that women have less access to critical farm resources (land, labor, and cash) and are generally discriminated against in terms of access to external inputs and information. A study by Peterman *et al*., (2011) which analyzed the position of gender in agricultural development in Africa found that women are faced with a lot of challenges and have inadequate access to land, labor and input. It is postulated that male plot decision makers are more likely to adopt new technologies because they are more endowed with resources compared to their female counterparts.

The variable *plotslopo* **(**slop of the plot) is a categorical variable showing the terrain of the farmers plot. The slop of the plot is likely to influence the type of SAI practices that a farmer can adopt. For instant farmers whose plots have steep terrain are likely to adopt minimum tillage due to much soil erosion experienced on such terrains.

Plotdist (distance from farmers' home to the plot) is a continuous variable measured in terms of walking distance to the plot in minutes. The distance to plot can influence farmers' decision making in various ways. A study by Jansen *et al.* (2006) on land management decisions and agricultural productivity in Honduras confirmed that quick access to the plot can influence the use of inputs, and the availability of information. It is expected that plots near farmers' homesteads can easily be accessed, hence readily practice maize-legume farming and adopt SAI technologies. Therefore distance to the plot would negatively influence uptake of SAI technologies.

Soil fertility (how fertile the plot is) is used as a categorical variable showing how fertile the plot is. For instance, farmers whose plots are of good soil fertility are likely to use less of inorganic fertilizer and animal manure compared to plots with poor soil fertility. Soil fertility can positively or negatively influence uptake of SAI practices.

The variable (*Plottenure*) tenure of farmer's plot is a dummy, with 1 representing owned and 0 otherwise. Several studies including (Besly, 1995 and Kassie *et al*. 2007) ascertained that land proprietorship have a substantial effect on the agricultural performance of farmers. Plot tenure security, just as land tenure security, raises the likelihood that farmers will get the proceeds from their investments. Since land is a scarce resource it is assumed that farmers who don't own land have to spend extra cash to rent land, which reduce their income and in the long run are unable to adopt a multiple of SAI technologies. A Land use right is likely to influence the type of investment that a farmer would put into the plot or land. For example, rented plots or land have regulations on specific activities that can be done.

CHAPTER FOUR

DESCRIPTIVE ANALYSIS OF ADOPTION AND DIFFUSION OF SAI MODELS

4.1 Introduction

This chapter provides descriptive summaries of how households adopt sustainable agricultural intensification (SAI) technologies based on gender differences and access to resources. Generally the chapter presents information on key famers' households, physical, institutional and plot characteristics. A number of variables show significant mean differences between MHHs and FHHs in the study areas. More emphasis was given to conservation agriculture practices, input use and sources, production constraints, labor requirements, decision making, income sources and gross margins.

4.2 Descriptive summary statistics.

Overall, male respondents are more than female respondents with most households comprising of six members as indicated in Table 4.1. A majority of the maize legume farmers are the elderly with a mean age of 56.8 years, an indication that most of the youths are engaged in other non-agricultural activities as their source of livelihood. Age translates to more experience to production technologies and greater accumulation of physical and social capital. Further, most household make farm and other household decisions jointly as a family. A study by Pender *et al*. (2007) on determinants of agricultural and land management practices and impacts on crop production and household income Ethiopia found household characteristics such as age , household size and gender of household head to affect decisions to adopt SAPs because of the imperfect markets.

Most of the farmers completed primary education with a few having completed secondary education. Kassie *et al* .(2011) carried out a study on agricultural technology, crop income, and poverty alleviation in Uganda and found that more educated farmers may have more off-farm income and thus be able to adopt more technologies since they could be much more informed about the benefits of modern technologies and use appropriate technologies to relieve their production constraints.

Nearly half of the farmers carrying out maize legume farming are involved in formal or informal groups. While studying determinants of agricultural and land management practices and impacts on crop production and household income in Ethiopia (Pender *et al*. 2007) reveal that, reduced transaction costs and increased farmers' bargaining power can be as a result of farmers engaging in social networks. This also helps farmers earn higher returns when marketing their products and in turn can affect technology adoption. Similarly, Kassie *et al*. (2012) in their study on adoption of interrelated sustainable agricultural practices in Tanzania found that farmers who do not have contacts with extension agents may still find out about new technologies from their networks, as they share information and learn from each other.

Majority of farmers hardly get extension services from the extension personnel as they meet them less than twice in a year. In Kenya rural farmers get farm inputs and agricultural extension services through the government extension personnel. According to Zerfu (2010) inadequacy of the governance system affects farmers in terms of costly access to agricultural input and credit. This affects the return from technology adoption and, hence, discourages adoption of technologies.

Source of credit has been evident as a major challenge that most farmers face since they do not easily acquire credit that they need so as to help them in farm production. Similarly most of the households income is relatively small hence the reason for production challenges such as high input prices. A study by Nyangena, (2011) on the role of social capital in sustainable development in Kenya, found that wealthier households are better able to bear possible risks associated with adoption of practices and may be more able to finance purchase of inputs, such as fertilizer and improved seeds.

Most households own the plots though, with land holding of less than one hectare. Better tenure security raises the probability that farmers will capture the returns from their investments. Deininger *et al*. (2009) asserts that security of land ownership has a significant effect on farm productivity and increases returns from investments.

The study found that most plots are located next to the farmers homestead with majority walking on averagely seven minutes to the farms. Studies (Jansen *et al*. 2006; Wollni *et al*. 2010) found easy accessibility to farms facilitates adoption of SAI technologies. Generally farmers perceive that their plots do not have a steep slope and they also have moderate soil fertility which are significant determinants of soil conservation and fertility management practices.

Table 4.1 Model variable definition and summary statistics.

Variable	Variable Description	Means	Standard deviation
Social economic characteristics			
Aghh	Age of household in years	56.8	14.71
Log(*Educlevel*)	Education level, years in school	8.05	1.15
Genderhh	Gender (1= Male, 0= Female)	0.56	0.50
HHsize	Household size in number	5.81	2.71
Income	Total household income per adult equivalent	35516.41	1832.13
Labouruse	Labour use in man days	14.95	1,42
Frequentcontact	Extension contact,(Number of days/ year)	1.34	1.96
Crdacc	If farmer accessed credit (1= Yes, 0=No.)	0.06	0.23
Grpmbr	Group membership (1= Yes, 0=No.)	0.47	0.19
Maldscnmk(ref)	If plot decision maker is male (1= Yes, 0=No.)	0.18	0.05
Fdscnmak	If plot decision maker is female (1= Yes, 0=No.)	0.24	0.06
Jointdscnmaker	If farmer do joint plot decision making (1= Yes, 0=No.)	0.54	0.08
Plot characteristics			
Farmsize	Farm size in hectares	0.34	0.23
Plotdist	Walking distance in minutes to plot	6.86	1,68
Flatplotsolp(ref)	If farmer perceives plot slop to be flat (1= Yes, 0=No.)	0.51	0.18
Gentlplotsolp	If farmer perceives plot slop to be gentle (1= Yes, 0=No.)	0.36	0.12
Steepplotsolp	If farmer perceives plot slop to be steep (1= Yes, 0=No.)	0.15	0.04
Goodsolfert(ref)	If farmer perceives soil fertility to be good (1= Yes, 0=No.)	0.17	0.06
Mediusolfert	If farmer perceives soil fertility to be moderate (1= Yes, 0=No.)	0.51	0,08
Poorsolfert	If farmer perceives soil fertility to be poor (1= Yes, 0=No.)	0.32	0.04
Plottnure	If plot is owned or otherwise (1= Owned, 0=Not owned.)	0.71	0.06

Note: 1 KES was equivalent to 80 US dollar at the time of survey. Ref: denotes the reference category.

Source: Own source.

4.3 Resource use and technology adoption by gender

Resource endowments have important roles on adoption of sustainable agricultural intensification practices. This is because most of the SAI practices, for example minimum tillage requires more capital in terms of labour for making farrows and ridges especially at the initial stage. The *t* test shows significant differences between means for labor man days provided by males and females in all farming activities. Females provided more of family labor in the plots than their male counterpart and this suggests that women were mostly involved in household farm activities while men went to earn other non-farm income.

Table 4.2: Means of labor contribution by gender.

Variable	Total labor man days			Land preparation and planting		Weeding		Harvesting		Threshing	
	Obs	Mean	*t*	Mean	*t*	Mean	*t*	Mean	*t*	Mean	*t*
Female	4298.00	5.41 (9.10)	7.75*	1.27 (1.18)	3.08*	1.70 (3.86)	10.11*	1.50 (3.64)	2.17**	0.95	7.64*
Male	4298.00	3.95 (8.29)		1.07 (1.00)		0.98 (2.71)		1.30 (4.67)		0.61	

Note: Figures in parenthesis are standard deviations.

** and * denote significance at 5% and 10% confidence levels.

Source: Adoption Pathways Survey Report, 2013.

In plots with males as the primary decision makers, fertilizer, herbicide, pesticide, minimum tillage, improved seed and crop rotation were adopted than plots with females as the main decision makers. The difference in technology adoption between the males and females was significant for fertilizer use, pesticide use, use of improved seed, minimum tillage and maize bean intercropping at 10% level of significance. While the difference in technology adoption between the males and females were significant at 5% level for herbicide use.

More females adopted water and soil conservation, manure, intercropping than males with difference in intercrop technology adoption being significant at 1% level. The difference in adoption of maize legume intercrop technology could be explained by women having limited resource for commercial inputs than men.

Table 4.3: Technology adoption by gender

SAI practices		Female	Male	χ^2
Fertilizer use	No	19	41	53.19*
	Yes	490	355	
Pesticide use	No	361	260	6.71*
	Yes	129	136	
Herbicide use	No	471	368	4.45**
	Yes	19	28	
Improved seed	No	131	61	16.56*
	Yes	359	335	
Minimum tillage	No	454	345	7.57*
	Yes	36	51	
Soil and water conservation	No	224	189	0.35
	Yes	266	207	
Animal manure	No	298	230	0.68
	Yes	192	166	
Legume inter-crop	No	164	169	7.91*
	Yes	326	227	
Crop rotation	No	409	327	0.12
	Yes	81	69	

** and* denote significance at 5% and 10% confidence levels.

Source: Adoption Pathways Survey Report, 2013

4.4 Constraints to maize and legume production

4.4.1 Constraints in accessing key inputs in maize production

High fertilizer costs and improved seed prices are the major constraints in maize production coupled with inaccessibility of credit to buy fertilizers and seeds as shown in Figure 4.1. Inefficiencies in the governance systems affect farmers in terms of costly access to agricultural credit and inputs (Zerfu, 2010). Inadequate access to and timely availability of quality improved seeds accounted for 8% and 6% of maize production constraints and were also highly ranked between 1 and 6. When this happens, farmers opt for local recycled varieties resulting to low yields. About 5% and 6% of the sampled farmers experienced constraints in accessing output and input markets respectively, while access to labor was observed in 7% of the farmers. Labor constraints tremendously increase the cost of production as farmers have to pay more for the limited resource available.

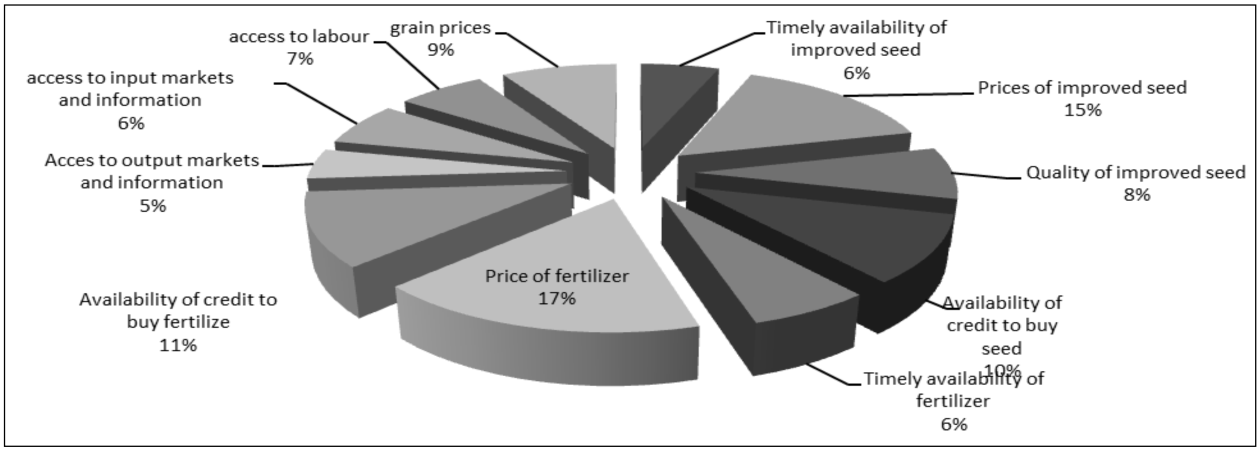


Figure 4.1: Constraints in accessing key inputs in maize production

4.4.2 Constraints in accessing key inputs in legume production

Similarly, Figure 4.2 shows that high prices of fertilizer and improved seed are among the highly ranked challenges in legume production.

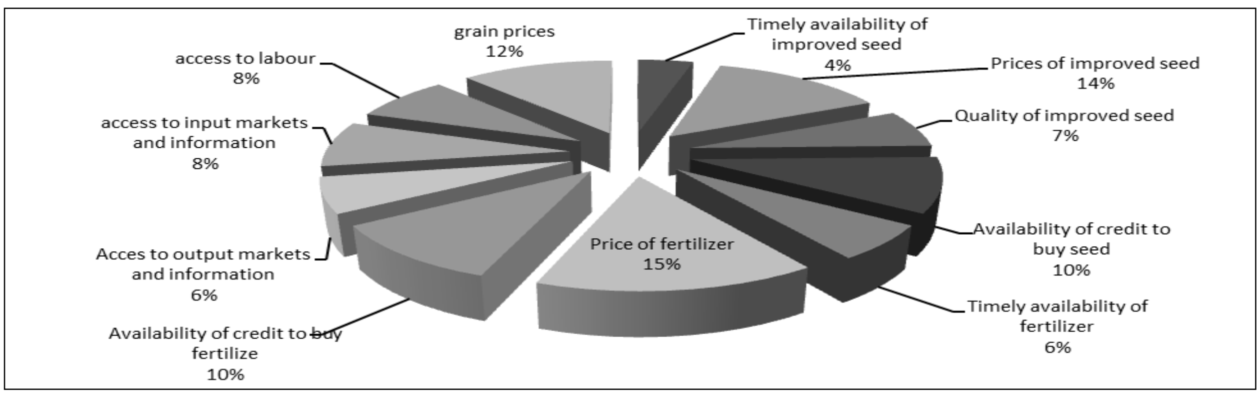


Figure 4.2: Constraints in accessing key inputs in legume production

Constraints in output and input market were observed in 6% and 8% of the sampled farmers and were ranked between 6 and 7 in terms of concern to farmers with regard to other constraints. Availability of credit to buy fertilizers and improved legume seeds were also observed in 10% of the farmers. Timely availability of improved seed is a constraint to only 4% of the farmers sampled compared to 6% in maize production.

4.5 Correlation of maize yield per acre with SAI practices and input quantities

4.5.1 Correlation of maize yield per acre with SAI practices

The correlation between maize yield per unit area measured in acres and use of improved seed variety technology was highest compared to all other SAI technologies. The correlation coefficient of 0.34 is significantly different from zero implying that adoption of improved seed technologies is linearly linked with increased maize yield per unit area.

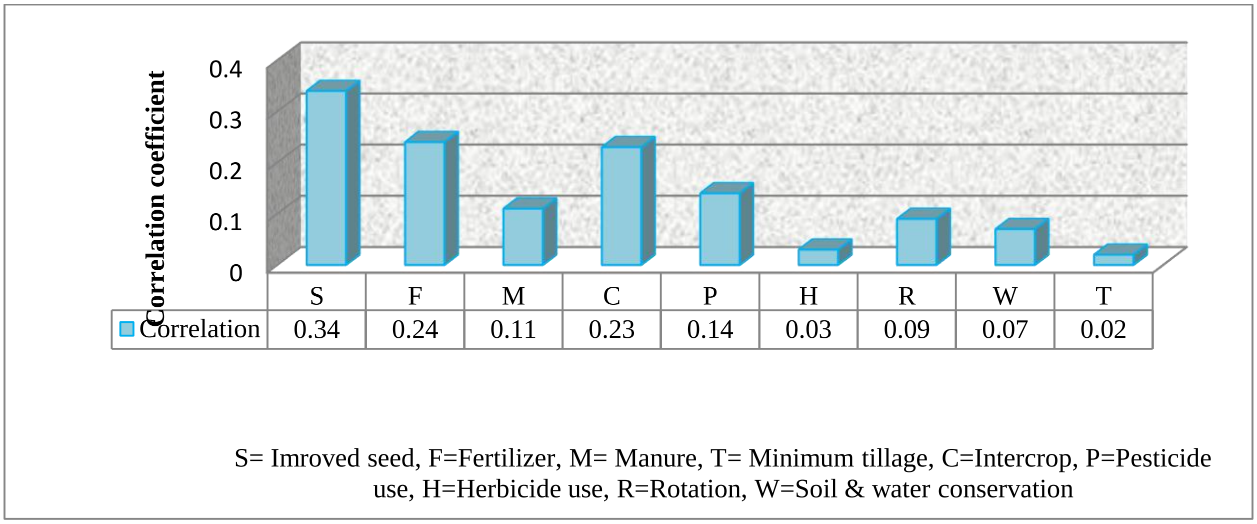


Figure 4.3: Correlation of maize yield per acre with SAI practices
Source: Adoption Pathways Survey Report, 2013

Minimum tillage and herbicide practices had minimum but positive correlation with maize yield. However the coefficients are not significantly different from zero indicating that although the correlation is positive, the degree of cova-riability is relatively negligible.

4.6 Gross margin analysis

The Gross margin was calculated from the incomes of the maize and beans. The contribution of use of different SAI practices towards the household crop income was established via gross margin and presented in Table 4.4. The results show that in general, adoption of technologies in combination yield more output than adoption in isolation across all crop choices.

Use of improved seed, fertilizer, animal manure and pesticide were found to be the most frequently used practices. Though the number of farmers who used pesticide is very small under maize bean intercrop, the use of animal manure and pesticide in combination had the highest margin (48185.59) followed by the other four practices (improved seed, animal manure, pesticide and fertilizer) used in combination (44476.32).Use of fertilizer in isolation gave the lowest gross margin of (26730.86). This implies that technology adoption is non-linear in process. Majority of the farmers use these technologies in isolation hence get very low margin.

Table 4.4: Crop system gross margins across technologies and technology combinations

SAIP/ SAIP combination	Pure maize stand		Pure bean stand		Maize bean intercrop	
	Number of plots	Mean gross margins	Number of plots	Mean gross margins	Number of plots	Mean gross margins
Use of fertilizer	259	11051.28 (18652.71)	228	13605.61 (26880.60)	599	27977.29 (54472.36)
Use of improved seed	245	16542.47 (83151.01)	190	13847.02 (28473.25)	520	26730.86 (44342.71)
Use of animal manure	110	12539.31 (18820.32)	107	12706.08 (22409.22)	292	39351.01 (79692.47)
Use of pesticide	134	11087.28 (20276.39)	79	14846.09 (34525.42)	143	36067.62 (63603.58)
Use of fertilizer and improved seed	215	11250.81 (18639.93)	190	13847.02 (28473.25)	464	27550.57 (46338.58)
Use of fertilizer and animal manure	99	12135.52 (19209.64)	107	12706.08 (22409.22)	252	39372.91 (77632.67)
Use of fertilizer and pesticide	129	10570.25 (20040.29)	79	14846.09 (34525.42)	137	37006.43 (64694.31)
Use of improved seed and animal manure	88	12379.33 (20169.32)	93	12705.43 (23443.36)	235	34510.45 (59993.18)
Use of improved seed and pesticide	125	10900.56 (19873.44)	75	14787.21 (35213.48)	134	33692.34 (60242.20)
Use of animal manure and pesticide	60	11051.28 (18652.71)	93	12705.43 (23443.36)	83	48185.59 (77667.56)
Use of fertilizer, improved seed and animal manure.	84	12666.68 (20578.46)	93	12705.43 (23443.36)	213	35810.42 (62586.63)
Use of improved seed, animal manure and pesticide	122	10889.92 (19919.53)	75	14787.21 (35213.48)	128	34585.82 (61351.46)
Use of improved seed, pesticide and fertilizer.	42	11315.86 (22385.00)	40	14538.87 (72389.97)	76	44476.32 (74083.95)
Use of improved seed, animal manure, pesticide and fertilizer.	41	11601.61 (22585.40)	39	12787.09 (25479.69)	74	44712.44 (75050.03)

Note: Figures in parenthesis are standard deviations. Source: Adoption Pathways Survey Report, 2013.

The practice of maize legume intercrop also gives higher output as compared to growing of maize and beans as pure stands across all technologies. The standard deviations are larger than the means in most cases. This means that return to investments gap on SAIPS is very wide, meaning that more farmers are likely to benefit from SAIP investments if the gap was narrowed.

CHAPTER FIVE

SUSTAINABLE AGRICULTURAL INTENSIFICATION PRACTICES COMBINATIONS AND IMPACTS ON INCOME AND LABOR DEMAND

5.1 Introduction

Smallholder farmers face challenges while trying to increase production levels in a sustainable manner in order to achieve worldwide poverty reduction and environmental management objectives (FAO, 2010). Reducing land degradation by letting the land lie fallow for long periods are quickly becoming unfeasible, hence the only alternative that farmers have is to continuously farm their pieces of land to have food on their tables. This results to land degradation, low farm output and increase in poverty levels.

Substantial efforts both nationally and internationally to encourage farmers to invest in SAI adoption in an attempt to curb land degradation remains low in rural areas of developing countries (Kassie *et al*., 2009; Wollni *et al*., 2010). Despite the multiple benefits of SAI practices such as increase in yields and improved soil fertility that sustainable agricultural intensification practices offer, it is unclear why smallholders farmers still obtain poor yields, low adoption levels, and climate variability continue to affect farm productivity. Studies have focused on technology adoption as practiced in isolation, whereas farmers adopt technologies as complements or substitutes. Further, gender differences remain largely empirically unexplored.

The adoption of sustainable agricultural intensification practices (SAIs) is central to improving agricultural sustainability (Reimer *et al*., 2012). In addition there is a need to address this challenge in order to promote and obtain an extensive and robust adoption of technologies for sustainable agricultural production. Therefore, understanding this phenomenon is vital in an effort to maximize SAI adoption. Considering adoption of multiple SAPs in isolation can lose important cross-technology correlation effects, and potentially yield biased estimates hence the cross-technology correlation may have important policy implications that a policy change that can affect one SAP may have spillover effects on other SAPs (Hailemariam *et al*., 2012).

To overcome these limitations, this study postulates a better understanding of the effects of using a combination of SAI practices on output productivity of maize legume farming, while determining factors affecting the use of one or more SAI practices. It will also show if SAI adoption is a linear or non-linear in process, and how the SAIs, once adopted impact on income and labor use across gender. This study therefore contributes to the growing adoption literature on SAI practices. To demonstrate these, survey data from smallholder maize legume farmers are analyzed to give policy implications for fostering agricultural sustainability.

5.2 Modeling strategy

5.2.1 Multinomial endogenous switching regression model

The first stage of evaluating the interdependence of SAI uptake is done using a multinomial adoption selection model. Assuming that farmers aim to maximize their profit, U_i by comparing the profit provided by *m* alternative packages, therefor the condition for farmer *i* to select any package, j , over any alternative package, *m*, is that $U_{ij} > U_{im} m \neq j$, or equally $\Delta U_{im} = U_{ij} - U_{im} > 0 m \neq j$. The expected profit, U_{ij}^* which the farmer acquires from the adoption of package j , is a latent variable determined by observed household and plot characteristics (X_{ij}) and unobserved characteristics (ε_{ij}):

$$U_{ij}^* = X_i \beta_j + \varepsilon_{ij} \tag{5.1}$$

where, X_i is observed exogenous variables (household and plot characteristics) and ε_{ij} is unobserved characteristics. Let (*I*) be an index that indicates the farmer's choice of package, such that:

$$I = \begin{cases} 1 & iff \quad U_{i1}^* > \max_{m \neq j} \left(U_{im}^* \right) \quad or \quad \eta_{i1} < 0 \\ \vdots & \vdots \quad \vdots \qquad\qquad\qquad\qquad\qquad\qquad for \quad all \quad m \neq j \\ J & iff \quad U_{ij}^* > \max_{m \neq j} \left(U_{im}^* \right) \quad or \quad \eta_{ij} < 0 \end{cases} \tag{5.2}$$

where, $\eta_{ij} = \max_{m \neq j} \left(U^*_{im} - U^*_{ij} \right) < 0$ (Bourguignon *et al*., 2007). Eq. (5.1) implies that the i^{th} farmer will adopt package j to maximize his expected profit if package *j* offers more expected profit than any other package $m \neq j$, that is, if $\eta_{ij} = \max_{m \neq j} \left(U^*_{ij} - U^*_{im} \right) < 0$.

Assuming that ε are identically and independently distributed, the probability that farmer *i* with characteristics *X* will choose package *j* can be modeled using a multinomial logit, according to McFadden (1973), as:

$$P_{ij} = \Pr\left(\eta_{ij} < 0 \mid X_i\right)\frac{\exp\left(X_i\beta_j\right)}{\sum_{m=1}^{J}\exp\left(X_i\beta_m\right)} \tag{5.3}$$

In the second stage of multinomial ESR, the relationship between the outcome variables and a vector of exogenous variable *Z* (including plot and household characteristics) is estimated for the chosen package. In the SAI practices description, the base category, for non-adopters of SAI practices, is denoted as *j* = 1. From all the other packages (*j* = 2… 9), at least one package is used by the farmer. The outcome equation for each possible practice *j* is given as:

$$\begin{array}{ll} \text{Package 1: } Q_{i1} = Z_i\alpha_1 + \mu_{i1} & \text{if } I = 1 \\ \vdots & \vdots \\ \text{Package } j\text{: } Q_{ij} = Z_i\alpha_{ij} + \mu_{ij} & \text{if } I = j \end{array} \tag{5.4}$$

where $Q_{ij}'s$ are the outcome variables for the i^{th} farmer in regime *j*, and the error terms (*u's*) are distributed with $E\left(\mu_{ij} \mid X, Z\right) = 0$ and outcome Q_{ij} is observed if, and only if, package *j* is used. This is realized when $U^*_{ij} > \max_{m \neq j}\left(U^*_{im}\right)$. If the $\varepsilon's$ and $\mu's$ are not independent, OLS estimates in Eq. (5.4) will be biased. A consistent estimation of α_j requires inclusion of the selection correction terms of the alternative choices in Eq. (5.4). The model assumes the following linearity assumption:

$$\mathrm{E}(\mu_{ij} \mid \varepsilon_{i1} \ldots\ldots \varepsilon_{ij}) = \sigma_j \sum_{m \neq j}^{i} r_j \left(\varepsilon_{jm} - E\left(\varepsilon_{im}\right)\right)$$

with $\sum_{m}^{j} = 1 r_j = 0$ (assuming, the correlation between $\varepsilon's$ and $\mu's$ sums to zero). Using this assumption, equation (5.4) can be re-specified as:

Package 1: $Q_{i1} = Z_i\alpha_1 + \sigma_i\lambda_1 + \omega_{i1}$ if $i = 1$

$\vdots$ $\vdots$

$\vdots$ $\vdots$ (5.5)

$\vdots$ $\vdots$

Package j: $Q_{ij} = Z_i\alpha_j + \sigma_i\lambda_j + \omega_{ij}$ if $i = j$

where σ_j is the covariance between $\varepsilon's$ and $u's$, and λ_j is the inverse Mills ratio.

The Mills ratio is computed from the estimated probabilities in equation (5.5) as:

$$\lambda_j = \sum_{m \neq j}^{j} \rho_j \left(\frac{P_{im} \ln(P_{im})}{1 - P_{im}} + \ln(P_{ij})\right) \quad (5.6)$$

where ρ is the correlation coefficient between $\varepsilon's$ and $u's$, and $\omega's$ are error terms the multinomial choice setting, there are $j - 1$ selection correction terms, one for each regime. The standard errors in equation (5.4) are bootstrapped to account for the heteroscedasticity arising from the generated regressors (λ_j).

Estimation of Average Treatment Effects

The MESR framework can be used to examine the average treatment effects (ATT) by comparing the expected outcomes of adopters with and without treatment (adoption), and non-adopters with potential treatment (hereby considered as counterfactual). The challenge of impact evaluation using observational data is to estimate the counterfactual outcome, which is the adopters' outcome arising out of non-adoption of a given regime. Following Carter and Milon (2005) and Di Falco and Veronesi (2011), we compute the ATT in the actual and counterfactual scenarios as:

Adopters with adoption (actual adoption observed in the sample):

$$E\left(Q_{i2} \mid I = 2\right) = Z_i\alpha_2 + \sigma_2\lambda_2 \quad (5.7a)$$

$\vdots$ $\vdots$ $\vdots$

$$E\left(Q_{iJ} \mid I = J\right) = Z_i\alpha_J + \sigma_J\lambda_J \quad (5.7b)$$

Adopters, had they decided not adopted (counterfactual):

$$E\left(Q_{i1} \mid I = 2\right) = Z_i\alpha_1 + \sigma_1\lambda_2 \tag{5.8a}$$

⋮ ⋮ ⋮

$$E\left(Q_{i1} \mid I = J\right) = Z_i\alpha_1 + \sigma_1\lambda_J \tag{5.8b}$$

These expected outcomes are used to derive unbiased estimates of the ATT. The ATT is defined as the difference between the expected outcomes derived from equations (5.6a) and (5.7a) or equations (5.6b) and (5.7b). For instance, the difference between equations (5.6a) and (5.7a) is given as:

$$ATT = E(Q_{i2} \mid I = 2) - E(Q_{i1} \mid 1 = 2) = Z_i(\alpha_2 - \alpha_1) + \lambda_2(\sigma_2 - \sigma_1) \tag{5.9}$$

The first term on the right-hand side of equation (5.8) represents the expected change in adopters' mean outcome, if adopters' characteristics had the same return as non-adopters, i.e., if adopters had the same characteristics as non-adopters. The second term (λ_j) is the selection term that captures all potential effects of difference in unobserved variables.

5.3 Results and discussions: MESR estimates

5.3.1 SAI Packages used on different sub plots

Table 5.1: SAI packages used by maize legume farmers on different sub plots

	SAI packages	S	P	F	M	C	T	W
1	SF	√		√				
2	FC			√		√		
3	SFP	√	√	√				
4	FMS	√		√	√			√
5	WTF			√			√	√
6	WTS	√					√	√
7	WTCF			√		√	√	√
8	SFMC	√		√	√	√		

Note: S=Improved seed, F= Organic fertilizer, M= animal manure, P= Pesticide, C= Intercrop, T= Minimum tillage and W = Soil and water conservation. √: Denotes adoption of the specified practice.

Among the SAI practices considered, different packages of improved seed, pesticide use, fertilizer use, animal manure, intercrop, minimum tillage and soil and water conservation had the highest frequency.

5.3.2 Factors explaining the adoption decision of SAI packages

The findings suggest that both socioeconomic and plot characteristics are key in shaping the households' adoption decisions as presented in Table 5.2. The outcomes are compared to the reference package of none adoption of any of the technologies. In terms of household characteristics, the education level of farm decision maker positively influences uptake of (FC), (SFM), (SFP) and (SFMC). This might be because a package combining use of fertilizer, improved seed and pesticide is relatively knowledge intensive and requires considerably higher management skills. Bluffstone and Köhlin (2011) studied the role of social capital in sustainable development and soil conservation in rural Kenya. Their findings show that households with more education may have greater access to non-farm income and thus can be in a better position to buy inputs. Similarly Highly educated farmers are able to search for information and interpret extension services.

Though not significant, household head positively influence adoption of packages of all the packages considered. Age translates to more experience to production technologies and greater accumulation of physical and social capital. Further, most household make farm and other household decisions jointly as a family. However; age can also be related with loss of energy and being more risk averse. Wealthier households can bear possible risks related with adoption of practices and may be more able to finance purchase of inputs, such as fertilizer and improved seeds (Pender and Gebremedhin 2007).

The results also show that farmers contact with extension personnel influences uptake of (SFP), (WTF) and (FSMC) positively but negatively influence uptake of (FC), (FSM). In Kenya rural farmers get farm inputs and agricultural extension services through the government extension personnel. Farmers seem not to depend on extension personnel in order to adopt inter-crop and use of animal manure. The possibility of adopting (SF) and (SFP) packages increases with increase in farmers' income. Farmers' income influences uptake of SAI packages that had fertilizer and improved seed. This can be attributed to the fact that most farmers pointed out the prices of fertilizer and improved seed to be a major challenge.

Table 5.2: Multinomial logit coefficients estimates of adoption of SAI packages.

	SF	FC	SFP	SFM	WTF	WTS	WTCF	SFMC
Gender of	-0.169	0.037	0.038	0.030	-0.062	-0.274	-1.235**	0.030
HHH	(0.184)	(0.160)	(0.161)	(0.217)	(0.147)	(0.322)	(0.674)	(0.217)
	0.001	0.005	0.015	0.006	-0.005	0.003	-0.012	0.006
Age	(0.007)	(0.006)	(0.006)	(0.008)	(0.005)	(0.012)	(0.022)	(0.008)
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Age Squared	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Education	-0.013	0.018**	0.019**	0.036***	-0.008	-0.028	0.017	0.036***
level	(0.009)	(0.007	(0.007)	(0.008)	(0.009)	(0.045)	(0.025)	(0.008)
Distance to	-0.011	0.008	0.038	0.009	-0.002	-0.012	-0.035	0.000
plot	(0.008)	(0.005)	(0.015)	(0.003)	(0.005)	(0.015)	(0.026)	(0.005)
	0.215	0.117	0.116	0.329**	-0.126	-0.245	-2.476	0.329*
Plot size in Ha	(0.181)	(0.156)	(0.156)	(0.181)	(0.148)	(0.430)	(1.862)	(0.181)
	0.006	0.005	0.005	0.011***	-0.003	0.009	0.022**	0.011***
Labour	(0.004)	(0.003)	(0.003)	(0.004)	(0.003)	(0.005)	(0.011)	(0.004)
Group	-0.068	-0.219	-0.208	-0.128	0.056	-0.542	-0.911	-0.128
member	(0.186)	(0.163)	(0.162)	(0.222)	(0.147)	(0.336)	(0.711)	(0.222)
	0.014	-0.041	-0.041	0.240	-0.031	1.270***	1.094	0.240
Credit access	(0.064)	(0.059)	(0.059)	(0.392)	(0.050)	(0.446)	(0.932)	(0.392)
	0.058	-0.189*	-0.188*	-0.481**	-0.041	0.061	0.570**	-0.481**
Plot tenure	(0.121)	(0.112)	(0.112)	(0.211)	(0.094)	(0.213)	(0.295)	(0.211)
	0.088**	0.068	0.003**	0.044	-0.064	0.061	0.214	0.044
Log Income	(0.072)	(0.073)	(0.061)	(0.081)	(0.056)	(0.124)	(0.268)	(0.081)
Extension	0.217	-0.401***	0.384**	-0.435**	0.235*	0.012	0.287	0.435**
contact	(0.177)	(0.154)	(0.154)	(0.207)	(0.140)	(0.298)	(0.592)	(0.207)
Female plot	0.803***	0.818***	0.785***	1.154***	0.560***	3.865***	1.813**	1.154***
decsn	(0.235)	(0.237)	(0.238)	(0.345)	(0.212)	(1.039)	(0.938)	(0.345)
	1.718***	0.958***	0.957***	1.235***	0.717***	3.071***	0.869	1.235***
Joint decsn	(0.200)	(0.193)	(0.193)	(0.301)	(0.165)	(1.027)	(0.907)	(0.301)
Modorate	-0.071	0.048	0.035	-0.449**	-0.132	-0.506	-0.927	-0.449**
fertility	(0.187)	(0.164)	(0.164)	(0.221)	(0.150)	(0.345)	(0.705)	(0.221)
	-0.403	-0.450	-0.450	-0.737*	-0.731**	0.242	0.247	-0.737*
Poor fertility	(0.408)	(0.324)	(0.324)	(0.430)	(0.302)	(0.507)	(0.927)	(0.430)
	-0.446**	0.505***	0.519***	0.781	0.197	0.878***	1.101***	0.781***
Modorate slop	(0.199)	(0.166)	(0.166)	(0.221)	(0.154)	(0.334)	(0.693)	(0.221)

Steep slop	-0.937** (0.442)	0.552 (0.329)	0.561 (0.329)	0.889** (0.421)	1.275*** (0.326)	1.077** (0.548)	1.428*** (0.959)	0.889** (0.421)
_cons	-0.625 (0.447)	-1.815*** (0.406)	-1.811 (0.764)	-3.460*** (1.046)	0.315 (0.694)	- 6.041*** (1.782)	-7.095** (3.289)	-3.460*** (1.046)
Number of observation				2635				
LR $\chi^2(18)$				52.06				
Prob > χ^2				0.000				
Pseudo R^2				0.0406				
Log likelihood				-615.69				

Note: Standard errors are in parenthesis; S=Improved seed, F= Organic fertilizer, M= animal manure, P= Pesticide, C= Intercrop, T= Minimum tillage and W = Soil and water conservation.

***, ** and* denote significance at 1%, 5% and 10% confidence levels, respectively..

On the other hand gender of plot decision maker results indicate that joint decision making contribute to adoption decisions and they significantly influence adoption of all the considered packages except (WTCF) and (SFMC). On studying gender and generation, De Groote and Coulibaly (1998) did an intra-household analysis on access to resources in southern Mali. Their findings revealed that women have less access to critical farm resources (land, labor, and cash) and are generally discriminated against in terms of access inputs and information. Despite these challenges that women face, female decision makers were found to have a significant effect on adoption of all the specified packages.

The input use, availability of labor was found to be crucial in adoption of (SFM), (WTCF), and (SFMC) Packages. This could be because packages containing fertilizer, manure and intercrop tend to use more labor. Probably because they are labor intensive. This result corroborates to findings by Teklewold *et al*. (2013) who analyzed cropping system diversification, conservation tillage and modern seed adoption in Ethiopia, and their impact on household income, agrochemical use and demand for labor. They concluded that, for farmers who adopted system diversification, conservation tillage, the average labor demand both for females and males is significantly higher than it would have been if the farmers had not adopted.

Plot characteristics are also significant determinants of adoption choices. Moderate and steep slope significantly influenced adoption of the considered packages. In particular, adoption of packages which contain minimum tillage and soil and water conservation is more likely on plots with moderate to steep slopes, while the likelihood of adopting (SF) is less likely. However, distance covered to sub plot did not significantly influence adoption of the considered packages. A study by Amsalu and De Graaff (2006) on determinants of adoption of stone terraces for soil and water conservation in Ethiopia, ascertained that plot slope, plot altitude, and plot size are significant determinants of soil conservation and soil fertility management practices.

The results further indicate the importance of soil fertility in determining adoption of (FC), (SFM), (SFP), (WTS), (WTCF) and (SFMC) packages. This can be a reason when the soil fertility is good farmers do not use fertilizer and manure. With good soil fertility there is little use of fertilizer and manure.

The adoption of (SFM) and (FSMC) packages is significantly and positively influenced by the area of farmer's sub plot. Farmers who have small pieces of land use more than two technologies on their sub plots, probably because they intend to increase production so as to have adequate food for their families. Farmers who have small pieces of land use more than two technologies on their sub plots. Pender *et al*. (2007) study on determinants of agricultural and land management practices and impacts on crop production and household income in the Ethiopia found that population pressure leads to land shortage hence causing farmers to intensify agricultural production using land-saving and yield-augmenting technologies.

Plot tenure was found to be significant and positively influenced adoption of (WTCF) and (SFMC) but negatively influenced adoption of (FC), (FSM) and (SFP). It implies that farmers prefer to use long-term soil fertility improvements on their own plots, and short-term soil fertility augmentations on rented or borrowed plots due to tenure insecurity. This is consistent with prior studies on technology adoption Tenge *et al*. (2004), who studied social and economic factors affecting adoption of soil and water conservation in Tanzania. They found that land tenure influences adoption of conservation tillage, soil and water conservation and animal manure, which is more common on owner-cultivated plots than on rented in (or borrowed) plots.

5.3.3 Impact of farmers' choice of SAI technology combination on labor use and income

The impact of use of SAIs on income and labour use is shown on table 5.3 with various level effect and treatment / returns effect. With X_1 representing the treated package and X_2 representing untreated, β_1 represents treated characteristics and β_2 untreated characteristic. The level effect is the difference in quantity of resource use as a result of adoption of the specified package. Hence, the level effect for the treated characteristic is $\beta_1(X_1 - X_2)$, while that of untreated characteristic is $\beta_2(X_1 - X_2)$. The treatment / returns effect is the difference in coefficients / return as a result of adoption of the specified package. There for, the treatment / returns effect for the treated is $X_1(\beta_1 - \beta_2)$, while that of untreated is $X_2(\beta_1 - \beta_2)$. The impact is as a result of the difference between treated with treatment characteristics and the untreated with untreated characteristics $(\beta_1 X_1) - (\beta_2 X_2)$.

With regard to SAI uptake on labor use, results reveal that farmers who adopted SAI packages significantly demand more labor than it would have been if they had not adopted the specified SAI packages. Similarly adoption of packages containing (FSMC), (FMS) and (FS) demanded the highest labour in man days of 11.58, 11.16 and 10.84 respectively. This is probably because manure use, use of improved seed and fertilizer application is labor intensive.

Table 5.3: Impact of SAI technologies combinations on labor use in man days and income in KSH.

Combination	Experiment	Labour use			Income		
		Treated characteristic(β_1)	Untreated characteristic (β_2)	Treatment / Returns effect	Treated characteristics (β_1)	Untreated characteristics (β_2)	Returns/ treatment effect
SF	Treated (X_1)	29.05(0.66)	26.08(1.01)	**2.97**	45074.46(2710.29)	26353.46(3688.21)	**18721.00*** **
	Untreated(X_2)	19.29(1.03)	18.21(1.39)	**1.08**	20326.78(1036.61)	12095.03(1477.17)	**8231.75*** **
	Level effect	**9.76*** **	**7.86*** **	**Impact 10.84**	**24747.68*** **	**14258.43*** **	**Impact 32979.43**
FC	Treated (X_1)	29.78(0.91)	24.93(0.59)	**4.85*** **	41267.50(2841.97)	26465.16(3799.67)	**14802.34*** **
	Untreated(X_2)	23.01(1.50)	22.12(0.91)	**0.90**	20127.85(1042.14)	11811.01(1527.46)	**8316.84*** **
	Level effect	**6.77*** **	**2.82**	**Impact *7.67***	**21139.65*** **	**14654.15*** **	**Impact 29456.49**
SFP	Treated (X_1)	31.06(1.44)	26.51(1.10)	**4.54*** **	33707.47(3041.26)	22921.05(1807.80)	**10786.42*** **
	Untreated(X_2)	24.99(0.79)	23.24(0.52)	**1.75**	18569.74(989.19)	12902.47(628.47)	**5667.27**
	Level effect	**6.07*** **	**3.28*** **	**Impact 7.82**	**15137.73*** **	**10018.58*** **	**Impact 20805.00**
FMS	Treated (X_1)	33.31(2.41)	24.22(1.17)	**9.09*** **	26933.57(4006.97)	13735.83(1242.63)	**13197.74*** **
	Untreated(X_2)	26.37(1.03)	22.15(0.52)	**4.22*** **	22915.52(1244.73)	22181.20(1289.19)	**734.32**
	Level effect	**6.94*** **	**2.07**	**Impact 11.16**	**4018.05**	**-8445.37**	**Impact 4752.37**
WTF	Treated (X_1)	27.04(0.81)	24.86(0.91)	**2.18**	44289.63(2043.85)	16331.66(1161.53)	**27957.97*** **
	Untreated(X_2)	27.24(0.24)	26.50(0.75)	**0.74**	25555.71(2428.39)	12109.63(1478.72)	**13446.08*** **
	Level effect	**-0.20**	**-1.64**	**Impact 0.54**	**18733.92*** **	**20345.63**	**Impact 32180.00**
WTS	Treated (X_1)	35.47(0.45)	30.32(0.57)	**5.15*** **	47511.26(3214.25)	21874.91(956.74)	**25636.35*** **
	Untreated(X_2)	42.99(0.74)	37.94(0.18)	**5.06*** **	26850.00(2876.34)	14265.00(1011.23)	**12585.00*** **
	Level effect	**-7.52*** **	**-7.61*** **	**Impact -2.47**	**20661.26*** **	**7609.91*** **	**Impact 33246.26**
WTCF	Treated (X_1)	26.10(3.19)	25.49(0.57)	**0.61*** **	44242.34(1707.61)	21391.00(2757.84)	**22851.34*** **
	Untreated(X_2)	32.28(7.24)	29.51(4.81)	**2.77*** **	17595.13(1269.44)	10595.13(1134.58)	**8298.34**
	Level effect	**-6.18*** **	**-4.02*** **	**Impact -3.41**	**25348.87*** **	**10795.87*** **	**Impact33647.21**
SFMC	Treated (X_1)	35.33(2.53)	24.59(1.42)	**10.74*** **	45933.57(1244.72)	22181.20(4006.97)	**23752.37*** **
	Untreated(X_2)	27.52(0.93)	23.75(0.50)	**3.76**	22915.59(3388.14)	13735.83(1242.63)	**9179.76*** **
	Level effect	**7.81*** **	**0.83**	**Impact 11.58**	**23017.98*** **	**8445.37**	**Impact 32197.74**

Note: Standard errors are in parenthesis. F= Inorganic fertilizer, S= Improved seed, M= animal manure, P= pesticide, C=Intercrop, T=Minimum tillage, W =Soil and water conservation. *** P<0.001.

On the other hand, adoption of (WTCF) and (WTS) packages significantly decreased labor demands. This implies that use minimum tillage and soil and water conservation save farmers labour required as compared to those who practice convectional tillage. This result contradicts the findings by Hailemariam *et al*. (2013) who analyzed the impacts of cropping system diversification, conservation tillage and modern seed adoption on household income, agrochemical use and demand for labor in Ethiopia. They found that conservation tillage increased pesticide application and labor demand. This is probably due to the fact that initial costs of putting up ridges and farrows for minimum tillage could be very high and very low cost if any in the consecutive years. Hence the costs of maintaining minimum tillage and soil and water conservation are very minimal in the consecutive years resulting to decreased labor demands. Similarly, other studies (Hajjar *et al*. 2008 and Tilman *et al*. 2002) have revealed that system diversification helps to maintain soil biodiversity, which can reduce pest and weed infestations that otherwise must be controlled by pesticides and or additional labor.

The findings also showed that adoption of (WTCF) saves farmers 3.41 labour demand in man days. For non-adopters of (WTCF) to fill the gap by saving 3.41 labour in man days, they have to reduce their resource use by 6.18 man days (possibly spent on convectional tillage) and save their labour returns by 2.77 man days. Alternatively they can also reduce their resource use by 4.02 man days and save their labour returns by 0.61 man days.

The impact of farmers' choice of SAI technology combination on income, results generally reveal that adoption of SAI practices in combination increases farmer's income than adoption in isolation. The highest returns are achieved when SAI practices are adopted in combination rather than in isolation. The results also show that adoption of (WTCF), (FS), (WTS) and (FSMC) packages gave highest income of 33647.21, 33246.26, 32979.43, and 32197.74 Kenya shillings respectively. This implies that soil and water conservation and minimum tillage significantly increases farmer's yields. Previous studies (Fuglie, 1999; Woodfine, 2009) have shown that conservation tillage can lead to substantial ecosystem service benefits by reducing soil erosion and nutrient depletion and conserving soil moisture.

Though the package that had improved seed and fertilizer did not give a significant high impact on income, previous studies have related the use of more pesticides in the package that contains improved seed. Since most farmers would also like to avoid risk, as high yielding varieties are prone to pest outbreaks, farmers use pesticide as a risk mitigation strategy (Jhamtani, 2011; Hailemariam *et al.*, 2013). Likewise, the use of (FMS) in the same package gives the least income. Using fertilizer and manure on the same plot may also reduce farm income in cases of severe drought.

Results showed that adoption of (FS) gave an impact of 32979.43 KHS. For non-adopters of (FS) to fill the gap of 32979.43 KHS, they have to increase their resource use by 24747.68 KHS and also increase their returns by 8231.75 KHS. Alternatively they can also increase their resource use by 14258.43KHS and at the same time increase their returns by 18721.00 KHS.

5.3.3.1 Relationship between SAI technologies combinations on labor use in man days by gender.

The average labor demand both for females and males is significantly higher than it would have been if the adopters had not adopted. Adoption of SAI packages considered increases women workload contributed to both family and hired labor compared to their male counterparts. This has different effects on male and female labor time allocation. Generally, both genders from most households allocate more time to family labour than hired labour.

In general, adoption of SAI packages leads to more time spent working on the farm for females than for males, hence increasing women workload contributed to both family and hired labor compared to their male counterparts. More women depend on agriculture wage labor as a source of livelihood. This is in line with the findings of Njeri (2007) who found that in African societies, women are responsible for feeding their families hence crops produced for subsistence are associated with women, while men grow cash crops because they are responsible for providing cash income for the family.

Use of (WTF), (WTS) and (SFMC) application is labor intensive than other technologies. Men's labor contribution was significantly high in packages containing (WTF), (FC) and (SFP) in both family and hired labor. Perhaps because men have greater contact to resources and extension services than women, they may have more knowledge on adoption of such technologies, therefore enhancing their ability to use more SAIPs than women. For example, Doss and Morris (2001) found that in Ghana, gender-linked differences in the adoption of modern technologies are not attributed to intrinsic uniqueness of the technologies themselves but instead result from gender-linked differences in access to key inputs.

Table 5.4: Relationship between SAI technologies combinations on labor use in man days by gender.

SAI combination	**Family labor Women**		**Family labor Men**		**Hired labor Women**		**Hired labor Men**	
	ATT	ATU	ATT	ATU	ATT	ATU	ATT	ATU
SF	9.970	9.521***	6.799	5.302**	2.413***	2.236	1.390***	1.180***
	(0.252)	(0.420)	(0.226)	(0.341)	(0.071)	(0.130)	(0.042)	(0.075)
FC	9.229**	9.229**	7.571***	7.571***	2.360	2.360	1.651	1.651
	(0.348)	(0.348)	(0.178)	(0.178)	(0.125)	(0.125)	(0.091)	(0.091)
SFP	10.007***	9.507**	7.311***	5.885	2.861	2.548	1.719	1.575***
	(0.395)	(0.252)	(0.341)	(0.218)	(0.125)	(0.084)	(0.091)	(0.054)
FMS	11.239**	9.592	6.871	6.164	3.283*	2.552*	1.802	1.582
	(0.589)	(0.271)	(0.488)	(0.194)	(0.228)	(0.123)	(0.156)	(0.076)
WTF	11.309***	9.311*	8.643***	4.985	3.226***	2.455***	1.651	1.036***
	(0.224)	(0.479)	(0.282)	(0.465)	(0.113)	(0.185)	(0.050)	(0.074)
WTS	11.742**	9.592	6.871	4.819	3.283*	2.552*	1.802	1.582
	(0.589)	(0.271)	(0.488)	(0.194)	(0.228)	(0.123)	(0.156)	(0.076)
WTCF	9.742***	8.145**	6.779***	5.085**	2.759**	2.882**	1.551	1.871**
	(0.265)	(0.421)	(0.331)	(0.132)	(0.222)	(0.219)	(0.068)	(0412)
SFMC	10.082**	9.713	6.970	6.158	3.243*	2.236	1.809	1.180***
	(0.557)	(0.227)	(0.477)	(0.195)	(0.227)	(0.130)	(0.155)	(0.075)

Note: Standard errors are in parenthesis; ATT=Average treatment for the treated, ATU= Average treatment for the untreated.
S=Improved seed, F= organic fertilizer, M= animal manure, P= pesticide, W=Soil & Water Conservation, T= Minimum Tillage, C= Intercrop.
1 man day = 8 working hours

***$P<0.001$, ** $P<0.05$ and *$P<0.1$

5.4 Conclusion

This chapter sort to analyze the factors that influence adoption of various SAI packages and their impact on income and labour use using multinomial logit endogenous switching regression model. The variables considered in the study to influence adoption of SAI practices were observable plot, household and village characteristics. These Include farmers' income, age, education level, family size, farm size, farmers income, frequency of contact with extension workers, access to credit ,social network, plot tenure and soil fertility. The results revealed that education level positively influences the farmers' decision to adopt a given SAI packages.

The findings also showed that in order to improve the adoption of SAI practices, local rural institutions and service providers should be supported to enable them efficiently assist smallholder farmers by providing farm inputs, information needed, and credit facilities. Further the result showed that farmers who perceive their plots to be fertile rarely use fertilizer and manure, whereas those with small pieces of land use more than two technologies on their sub plots to maximize production so as to have adequate food for their families. Similarly, farmers prefer to use long-term soil fertility improvements on their own plots, and short-term soil fertility augmentations on rented or borrowed plots due to tenure insecurity. Farmers' income influences uptake of more SAI technologies more so those that had fertilizer, while use of minimum tillage and soil and water conservation save farmers labour required as compared to those who practice conventional tillage.

The highest impact on income is achieved when packages that contain soil and water conservation and minimum tillage are used. Conservation tillage leads to substantial ecosystem service benefits by reducing soil erosion, nutrient depletion and conserving soil moisture, while at the same time reducing labour costs. Results showed that adoption of (WTCF), (FS), (WTS) and (FSMC) packages gave highest impact of 33647.21, 33246.26, 32979.43, and 32197.74 KHS respectively, yet adoption of (WTCF) and (WTS) packages significantly decreased labor demands by 3.41 and 2.47 man days respectively. For non-adopters of (WTCF) to fill the gap of 33647.21 KHS, they have to increase their resource use by 25348.87 KHS and also increase their returns by 8298.34 KHS. Alternatively they can also increase their resource use by 10795.87 KHS and at the same time increase their returns by 22851.34 KHS.

Consequently, the findings show that highest proceeds are achieved when SAI practices are adopted in combination rather than in isolation, hence adoption of SAI practices is linear in process. Since some of this practices are complements, while others are substitutes or compete for the same scarce resources, there is need to informs policy makers to put in place strategies that would promote uptake of these technologies into appropriate packages in order to increase farmers output and hence food security. For instance, famers should be provided with a basket of practices from which they can be able to choose according to their socio-economic circumstance. The “one size fits all” phrase does not hold.

Likewise, the significant role that women play in providing both family and hired labor suggests that agricultural intensification technology interventions is not gender neutral. There is need to facilitate the formulation of robust pro-poor and gender equitable policies to target innovation and promote diffusion of technologies including, increasing the accessibility of extension personnel to women farmers.

CHAPTER SIX
DETERMINANTS OF NUMBER OF SAI PRACTICES ADOPTED

6.1 Introduction

African smallholder farmers still face several challenges including, access to information and uptake of new technologies through effective dissemination pathways that are crucial in optimizing the adoption process especially of 'knowledge- based' innovations (Padel, 2001). However, limited effort has been given to the factors that impede or aid in the adoption of Sustainable Agricultural Intensification (SAI) practices as a package, hence the need to better recognize factors that facilitate or impede farmers' adoption behavior. Naturally, farmers are rational and would always want to earn as much as possible from their farms. If adopting a given number of technologies would provide an assurance of maximizing their output, they would definitely go for that. For this to be realized, There is need to control for technology interdependence and simultaneous adoption in complex farming systems to avoid underestimating or overestimating the influence of various factors on the technology choices (Wu and Babcock, 1998).

With the low adoption rate of SAI practices still experienced in developing countries Kenya included, substantial efforts have been put in place by national and international organizations to encourage farmers to invest in them (Kassie *et al.*, 2009; Wollni *et al.*, 2010). A study by Hailemariam *et al*. (2012) on adoption of multiple sustainable agricultural practices in rural Ethiopia showed that the probability and extent of adoption of SAPs are influenced by several factors: a household's trust in government support, credit constraints, spouse education, rainfall and plot-level disturbances, household wealth, social capital and networks, labor availability, plot and market access.

Various studies (Tey and Brindal, 2012; Kassie *et al.*, 2009; Bradshaw, 2007) have shown that, common factors that influence the adoption of SAI practices can be categorized as; socio-economic factors, institutional factors, informational factors, agro-ecological factors, psychological factors, and the perceived attributes of SAI practices. Knowledge of farmers' preferences for uptake of various SAI technologies is vital in evaluating the effectiveness in the adoption pathways. Though some researchers believe that this body of research may have reached its edge in contributing to a refined understanding, particularly with respect to the voluntary uptake of SAPs (Knowler and Bradshaw 2007), common managerial factors include those related to human capital; gender, age, education levels, ethnicity, and experience are also important.

While trying to make decision concerning the number of technologies to use on their plots small scale farmers are faced with myriad challenges. This therefore, calls for a need to redesign favorable policies that could motivate adoption of SAI practices and in the long run increase agricultural productivity. This chapter determines a better understanding of the relative importance of social-economic, household and plot characteristics including (farmers' education level, age, gender, farmers' main occupation, membership to groups, frequency to extension services, sub plot tenure and area, Soil fertility and farmers' income) in shaping the probability and the number of SAI practices adopted.

6.2 Modeling strategy

In the second objective, ordered probit model was used to estimate the factors that determine the use of one or more practices. Given the assertion that over time there are more than just two identified groups (adopters and non-adopters), it is possible to have a more refined distinction of adopters. Based on the number of SAI technologies that a farmer uses on each plot, we have farmers using one, two or more technologies. Since there are multiple choices and particular interest lies in the individual effects of explanatory variables on each outcome. The ordered probit model recognizes unequal differences between ordinal categories in the dependent variables. That is given a unit change in the explanatory variable the model captures the qualitative differences between different categories of number of SAI used, hence accounting for the categorical nature of dependent variables as well as its ordinal nature.

Having the measure of technology adopted as number across plots, we treat the number of SAPs adopted by farmers as an ordinal variable and use it as dependent variable measuring determinants of adoption (Wollni *et al.*, 2010). The model is then specified as;

$$Y^* = \beta' X + \varepsilon \qquad (6.1)$$

Y* is the dependent variable (number of technologies) taking the values (1, 2, 3, 4, 5 and 6). The β' is the vector of estimated parameters and X is a vector of explanatory variables. ε is the error term which is assumed to be normally distributed (zero mean and unit variance) with cumulative distribution denoted by Φ. The number of technologies used Y are related to the underlying latent variable Y* through threshold μ_n where n= 1… 6, then we have the following probability distribution;

$$prob(Y = n) = \varphi(\mu_n - \beta' X) - (\mu_{n-1}\beta' X) \qquad n = 1 \ldots 5 \qquad (6.2)$$

Hence the ordered probit estimation will give the thresholds with μ and parameters β .

The threshold μ show the range of normal distribution associated with the specific values of the response variables. The remaining parameters, β , represent the effect of changes in explanatory variables on the underlying scale. A measure of goodness of fit is obtained by calculating;

$$\rho^2 = 1[\ln L_h / \ln L_0] \qquad (6.3)$$

where $\ln L_h$ is the log likelihood and $\ln L_0$ is log likelihood computed at zero. Although ρ^2 cannot equal to one, a value close to one shows a very good fit. The study hypothesize that the use of one or more SAI technology in a specific plot is influenced by a number of socioeconomic and plot characteristics, used in this study as the explanatory variables. The basis for the hypothesis is theoretical considerations found in the literature.

6.3 Results and discussion

Table 6.1 presents coefficient estimates and marginal effects of the ordered probit model, for the various factors influencing farmers' preferences for the number Sustainable Agricultural Intensification (SAI) practices used. The estimated thresholds or cut-off points (μ) indicates the range of normal distribution associated with the specific values of the response variable and satisfy the conditions $\mu_1 < \mu_2 < \mu_3$ implying that the categories are ordered in an ascending manner (Knight et al. 2005). The ordering was informed by the fact that, the probability of adopting one SAI practice could differ from the probability of adopting two, three, four or five SAI practices, This is because in latter case the farmer could have already gained some experience with adoption of the first SAI and may have been exposed to information about the practice. The first cut-off point (Y =1 for 'use of one technology') was used as reference for comparison purposes.

Marginal effects were estimated in order to understand the link between the dependent and independent variables, since the interpretation of coefficients in ordered probit alone are not very informative. Hence, the marginal effects (partial derivatives) which denote the probabilities of the number of SAI practices that farmers' adopt ranked from one to six. This shows the impact of a change in an explanatory variable on the predicted probabilities.

Table 6.1: Coefficient estimates and Marginal effects of the ordered probit model

Variables	Marginal effects					
Land size (10^{-2})	0.064(0.082)	0.077(0.091)	0.208(0.012)	-0.002(0.004)	-0.154(0.010) *	-0.003(0.002)
Gender	-0.194(0.407)	-0.232(0.453)	-0.062(0.095)	0.076(0.017)	0.046(0.072)	0.009(0.015)
Age	-0.014 (0.021)	-0.017 (0.024)	-0.046(0.004)	0.054(0.001)	0.003(0.003)	0.007(0.007)
Age Squared	0.000(0.000)	0.136(1.421)	0.003(0.004)	0.434(0.007)	0.233(0.013)	0.567(0.017)
Education level	-0.105(0.130)	-0.127(0.146)	-0.433(0.016) **	0.040(0.007)	0.026 (0.012) **	0 .006(0.003)
Labor (10^{-2})	-0.006(0.772)	-0.731(0.854)	-0.198(0.095) **	0.023(0.043)	0.148(0.073) **	0.030(0.021)
Gender plot decision maker (10^{-2})	-0.121(0.228)	-0.145(0.271)	-0.039(0.059)	0.046(0.011)	0.029(0.044)	0.059(0.009)
Sub plot distance	-0.308(0.006)	-0.004(0.007)	-0.101(0.002)	0.012(0.002)	0.007(0.001)	0.015(0.003)
Soil fertility(10^{-2})	-0.053(0.259)	-0.064(0.305)	-0.172(0.081)	0.202(0.010)	0.013(0.060)	0.003(0.012)
Plot slope(10^{-2})	-0.250(0.361)	-0.302(0.416)	-0.082(0.071)	0.096(0.019)	0.061(0.053)	0.012(0.013)
Extension contact	-0.124(1.289)	-0.125(1.353)	-0.311 (0.089) ***	-0.052(0.063)	0.247(0.077) ***	0.065(0.039)
Group membership (10^{-2})	0.047(0.306)	0.057(0.365)	0.016(0.096)	-0.019(0.013)	-0.011(0.070)	-0.023(0.014)
Credit access(10^{-2})	0.340(1.656)	0.441(1.694)	0.094(0.279)	-0.027(0.125)	-0.060 (0.157)	-0.010(0.024)
Income	0.138(0.546)	0.251(0.129)	0.234(0.132)**	-0.182(0.191)	-0.159(0.671)**	-0.067(0.075)
Plot tenure (10^{-2})	-0.044(0.251)	0.054(0.305)	-0.015(0.081)	0.176(0.017)	0.011(0.061)	0.022(0.012)
Predicted Probabilities						
Prob(Y=1|X)	0.003					
Prob(Y=2|X)	0.004					
Prob(Y=3|X)	0.254					
Prob(Y=4|X)	0.527					
Prob(Y=5|X)	0.185					
Prob(Y=6|X)	0.021					
Number of observations	67					
LR $\chi^2(15)$	28.47					
Pseudo R^2	0.1533					
Log likelihood	78.629					

Note: Figures in parenthesis under marginal effects are standard errors; values in bracket under variable name denote the values are raised to powers

***P<0.001, **P<0.05 and *P<0.01

The effect of the variable *Gender* (gender of household head) on the number of technologies adopted was not significant it had a positive marginal effect in the adoption of more than three technologies. Male Headed Households (MHHs) use more than three technologies on their plots implying that male farmers are endowed with more resources compared to their female counterparts. The result also agrees well with findings by Buvinic and Gupta (1997), which reveal that women have lower average earnings compared to men, less access to remunerative jobs and productive resources such as land and capital, contribute to the economic vulnerability of Female-Headed Households (FHHs).

Credit availability has a positive impact on use of less than three SAI technologies while it reduces the probability of using four, five and six technologies on a given plot by a margin of 2.7%, 6% and 1%, respectively. This suggests that adoption of some of the SAI technologies such as minimum tillage has very high initial costs, yet access to credit is a major challenge to most small scale farmers. This is consistent with findings by (Hobbs *et al*. 2008; Blanco and Lal, 2008) which show that credit constraints was found to affect adoption, particularly when initial investment costs are high (such as purchase of cover crop seeds, herbicides, sprayers), given the evidence that the benefits of Conservation Agriculture (CA) are usually realized after around 4years.

Secure land access or tenure impacts on the adoption decisions positively. Farmers with tenure rights have higher probability of adopting more than three technologies. Tenure rights and tenure security can affect adoption decisions in multiple ways. First, farmers choose to use long-term soil fertility improvements on their own plots, and short-term soil fertility improvements on rented in plots. Kassie *et al*. (2007) analyzed sharecropping efficiency in Ethiopia. They found that in an area where land is scarce and search costs are high, tenants are likely to use more short-term inputs on rented plots than owned plots because of the threat of eviction from use of the plot. With substantial cost expenditures and benefits to conservation agriculture deemed to delay, tenure insecurity will reduce farmers' incentives to adopt (Arslan *et al*., 2013).

Membership of group (*Grpmember)* had a negative effect on adoption of less than three technologies and a positive effect on the adoption of more than three technologies. The probability of using four, five and six technologies on a single plot declines by 1.9%, 1.1% and 2.3% respectively if one is not a member of any group. Perhaps this is because farmers who belong to organized groups are expected to benefit from the established social capital, which is likely to enhance information and knowledge sharing. This implies that such farmers would desire to get information from colleagues with whom they interact. Pender *et al*. (2007) also confirmed that reduced transaction costs and increased farmers' bargaining power can be as a result of farmers engaging in social networks. This helps farmers earn higher returns when marketing their produce and in turn can affect technology adoption.

Farmers' education level significantly influence dis adoption of three technologies and adoption of five technologies with a margin of 43.3% and 2.6% respectively. Likewise education level was found to increase the use of more than three technologies in a single plot. It means that education compliments the easements of the benefits of more practices as compared to fewer. A similar result is noted by Murage *et al.* (2011) who found that educated farmers are more flexible in acquisition of information sources and would often consult depending on the prevailing circumstances to meet their information needs. Another study by Kassie *et al* .(2011) on agricultural technology, crop income, and poverty alleviation in Uganda and found that more educated farmers may have more off-farm income and thus be able to adopt more technologies since they could be more informed about the benefits of modern technologies and use appropriate technologies to relieve their production constraints.

The variable *Aghh* (age of household head) was not significant in this study. Older farmers were found to adopt more SAI technologies compared to young farmers. An increase in age would lead to adopting four, five and six technologies by 5.4%, 0.3% and 0.7% respectively. Older farmers are considered to have expertise through own experience compared to the young ones and therefore more likely to adopt new farming methods without consulting external information sources. Likewise as age increase farmers are likely to be endowed with resources accrued from continued savings for a long period. Hence they are able to meet higher cost associated with use of SAI practices more so at initial.

Access to labor was found to increase the probability of using more than three technologies on a single plot, though this was only significant for the use of five technologies with a margin of 14.8%. A study by Mussei *et al*., (2001) found labor to be a significant factor affecting farm production. These findings imply that most of the farmers still do not use minimum tillage on their plots. Therefore farmers should do more of conservation tillage to cut production costs by reducing labour demand and at the same time increase their farm yields

Female plot decision makers adopt less than three technologies on a single plot as compared to their male counter parts, with a margin of adopting four, five and six technologies of 2.6%, 4.9% and 5.9% respectively. A similar pattern emerges with respect to soil fertility for farmers who perceived their plots to be fertile. Low soil fertility increased the probability of adopting four, five and six technologies by margins of 20.2%, 1.3% and 0.3% respectively. The frequency of contact between farmers and extension officers significantly influence dis adoption of three technologies and adoption of five technologies with a margin of 31.1% and 24.7% respectively. In addition low farmer's income reduces the probability of adopting four, five and six technologies by margins of 18.2%, 15.9% and 0.6% respectively.

6.4 Conclusion

This chapter sought to evaluate the determinants of the number of SAI technologies used by farmers on their plots. The role of social economic, household and plot characteristics in shaping adoption process has been of interest in the recent past. This study examined how various social-economic, household and plot characteristics aid in shaping the probability and the number of SAI practices adopted. There was a strong and robust relationship between labor required and the number of SAI practices used as well as the primary occupation of the smallholder farmers. This study indicates that size of land that farmers own and their education level plays a vital role in determining the number of SAI practices used. Likewise famers' Income was also important in determining the number of technologies they would use on their plots. Another key and robust finding is the frequency of contact between extension officers and farmers that positively affects the number of SAI technologies used. Generally socio-economic and plot characteristics such as; slop of sub plot, gender of household head, soil fertility, sub plot tenure, access to credit and distance to the sub plot soil had a less clear role in determining the number of SAI practices used on a given plot.

Therefore in order to ensure that farmers adopt more SAI practices on a given plot, frequent contact with extension officers is paramount. Since SAI practices are labor-intensive, labor plays a key role in farm management. The relationship between labor required and the number of SAI practices used implies that policies that will make micro-credit from government and non-governmental agencies accessible to these farmers will go a long way in addressing their resource use. These would help farmers to purchase critical inputs and paying for hired labor. This can be achieved through the enactment and enforcement of requisite legal framework whose aim will be to facilitate farmer access to cheaper credit facilities to finance SAI technology uptake. Farmers should also do more of conservation tillage to cut production costs by reducing labour demand while at the same time increase their farm yields.

In addition, farmers should be encouraged to mobilize their savings through the establishment of Savings and Credit Cooperative Organizations and the strengthening of community based lending systems that would improve their bargaining power. The significant relationship between land and the number of SAI practices used implies that policies aimed at expanding the area under maize legume production need to be encouraged so as to maximize production. This may be through the government, or other stakeholders formulating and implementing strategies to encourage large scale of operation hence minimize land subdivision.

CHAPTER SEVEN

RELATIONSHIP BETWEEN CROPPING SYSTEMS AND SAI PRACTICES UPTAKE

7.1 Introduction

The adoption rates of SAI practices remain below expected levels although it's anticipated to be a way of tackling the problem of land degradation, low agricultural productivity and high poverty levels experienced by smallholder farmers in Africa (Hailemariam *et al.*, 2013). However, rural households in developing countries normally cultivate different crops on different or same piece of land each cropping season. They do so using different SAI technologies, with different expected return and risk from these crop alternatives on each plot. In addition, Ellias (2000) ascertained that portfolio diversification is a key motive to the different cropping systems practiced by farmers in developing counties. Oftentimes the observed year to year cropping patterns are driven by SAI technologies at the farmers' disposal. According to (Ishtiaq *et al*. 2005) choosing optimal combination of crops to produce is a challenge, due to resource constrain they reiterated that farmer's profit maximization objective cannot be achieved if cropping blend chosen is not optimal

An entrenched literature has identified many key factors affecting farmers' crop choices such as climate, soil type, and input prices and availability. After accounting for these factors, farmers may still face a variety of potential crops to choose from (Kurukulasuriya and Mendelsohn, 2008). Likewise, adoption analysis of agricultural technologies has long been emphasized for green-revolution technologies (irrigation, chemical fertilizer and improved seeds) and physical soil and water conservation technologies (Bluffstone and Ko¨ hlin, 2011; Kassie *et al*., 2011). However, little is known about decision making mechanism behind observed smallholder cropping systems and its relationship with SAI technology uptake.

Furthermore, Hailemariam *et al*. (2013) found that technology-adoption decisions are path dependent: the choice of technologies adopted most recently by farmers is partly dependent on their earlier technology choices, but it's still unclear if in a given cropping season SAI technologies used in a specific plot would affect the technologies that would be used on other plots owned by the same farmer. This shows that, possibly ineffective choices of technology adoption on different cropping systems by maize legume smallholder farmers in Kenya could be one of the reasons explaining cause of low farm production.

This study therefore aims at modeling cropping choices as a dynamic decision made on a plot to plot basis rather than over the entire farm that a farmer owns. It then tests if with a given set of

SAI technologies available to the farmer and the variation in yield could influence cropping systems practiced by farmers. This will help to determine capacity utilization of various SAI technologies on different cropping patterns. The information generated from this study can be used to draw insight on relevant interventions to ensure maize legume smallholder farmers enhance uptake of SAI technologies as a way of boosting yields. It will also enhance policy-makers and development practitioners to identify their strategies for improving agricultural technologies.

7.2 Modeling strategy

A Stochastic production function was used to analyze the third objective that sought to determine the relationship between cropping choices and technology uptake. The analysis builds upon other recent studies using stochastic production functions to evaluate technology use and cropping decisions. Farmers have three choices; these include growing pure stand of maize, pure stand of beans and maize bean intercrop. Farmers plant these crop alternatives and each plot would use different SAI technologies, different expected return and risk. While estimating yield for pure maize stand, pure bean stand and maize bean intercrop plots, as a function of SAI technologies and plot characteristics. Cropping patterns appear in each of the production function as the dependent variables the model is then specified as:

$$y_{pk} = f_k(\mathrm{X}_p) + u_{pk} \qquad (7.0)$$

$$f_k(\mathrm{X}_p) = \exp\left(\beta_1 T_1 + \ldots \beta_9 T_9 + \sum_{ko=1}^{ko} \beta_{k0} D_{K0} + \beta_P{}' D_P\right) \qquad (7.1)$$

where y_{pk} is the yield of a given crop choice on a plot, T represent the SAI technologies, D_p is a vector of plot characteristics for each crop k on plot p and u_{pk} is the error term. The effect of household choice of crop and technologies may show up in yield variance. Because the SAI technologies systematically affect the variance then the original specification in (7.1) ceases to be efficient. Following Just and Popes (1997) method, the error term u_{pk} in the yield function is modeled as a function of the same parameters in the yield equation, to permit for a consistent estimation of parameters as indicated below.

$$u_{pk} = c_{pk} h_k^{1/2}(\mathrm{X}_p) \qquad (7.2)$$

where $\mathrm{E}[u_{pk}] = 0$ and $E[u_{pk} u_{qk} = 0 \; forp \neq q]$ (7.3)

The farmer's decision of which crop to grow on each plot may depend on observed and unobserved characteristics of the farmer and the plot. These characteristics could introduce bias to the yield coefficients.

In deciding which crop to grow on plot *p* farmer *i* choses crop *k* over *l*

if $C_{ipk} \geq C_{ipl}$

Suppressing the notation for plot, this becomes:

$$C_{ik} = V_{ik} + \varepsilon_{ik} \tag{7.4}$$

Hence the farmer's choice to grow crop *k* is the result of comparison between the expected utility of growing *k* and that of all other alternative *l*.

7.3 Results and discussions

Table 7.1 presents the production function results on the relationship between the nine SAI technology uptake considered in the study and smallholder cropping systems. Crop rotation had a positive influence on pure maize stand and pure beans stand but negatively influenced intercropping of maize and beans system. This indicates that crop rotation is mostly practiced in plots where farmers plant pure stand crop varieties. This ascertains that the observed year - to - year crop allocation patterns on plots are driven by crop rotation choices. This underscores the importance of crop rotation in plots where intercrop is practiced since intercropping system also provides many ecosystem services, including atmospheric Nitrogen fixation and Carbon sequestration as rotation would do.

Fertilizer was found to increase the yield in all the three cropping systems, although this was only significant in the production of pure stand of maize. This is in line with the studies by (Di Falco *et al*., 2010 and Jhamtani, 2011), that show intercrop can save farmers the cost of fertilizer since farmers appear to atribute nitrogen fixed by legume crops and to consider the soil fertility effects of maize legume intercrop because fertilizer use is either reduced or insignificant when intercrop is used. In all the three cropping systems the use of improved seed was seen to increase the yields with a 5% and 1 % level of confidence being on intercrop and pure maize stand plots. This shows that adoption of improved maize seed is associated with increased maize yield per unit area. This is also consistent with the descriptive results that show only 4 % of the farmers who buy improved legume seeds for planting purposes as most farmers use local variety. This indicated that adoption of improved seeds is likely to be an important strategy for increasing yields in maize plots.

Table 7.1: Production function coefficients of SAI technology uptake across cropping systems

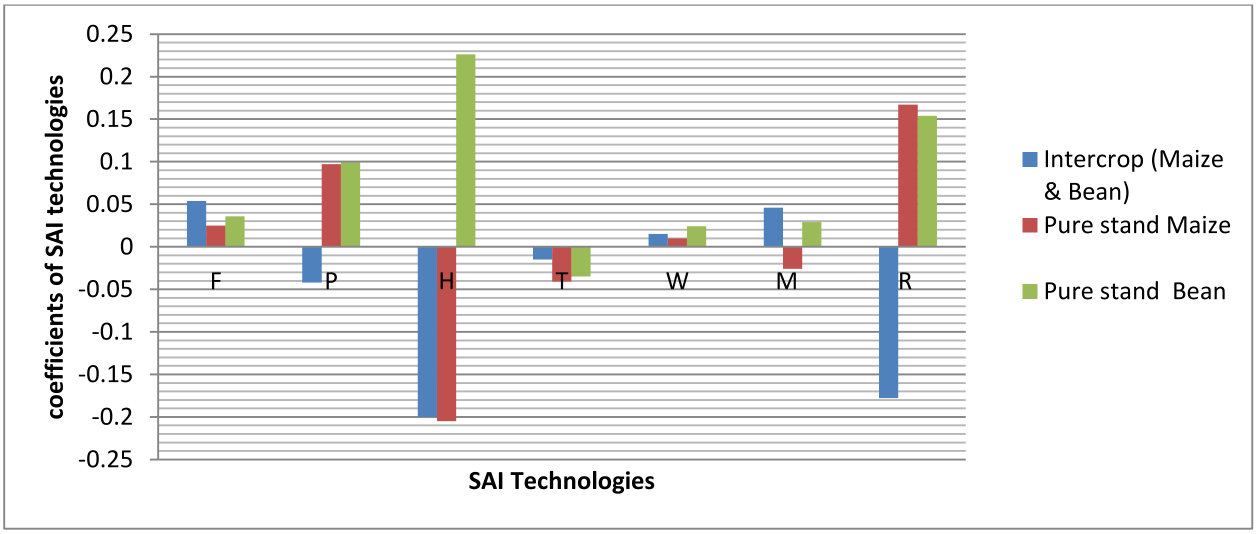
Variable	Cropping Systems		
	Intercrop (Maize & Bean)	Pure stand Maize	Pure stand Bean
SAI Technologies Dummies			
Fertilizer use	0.0541(0.0505)	0.0253(0.0462)**	0.0366(0.0465)
Pesticide use	-0.0421(0.0509)	0.0974(0.0475)	0.0999(0.0479)**
Herbicide use	-0.2007(0.0943)**	-0.2053(0.0872)**	0.2263(0.0878)
Improved seed	0.3553(0.0429)*	0.28534(0.0347)***	0.1412(0.0351)
Minimum tillage	-0.0155(0.0677)	-0.04198(0.0633)	-0.0357(0.0636)**
Soil &water conservation	0.0150(0.0342)	0.0109(0.0317)	0.0244(0.0319)*
Animal manure use	0.0469(0.0368)	-0.0264(0.0340)	0.0295(0.0342)
Crop rotation	-0.1789(0.0533)*	0.1672(0.0495)***	0.1542(0.0498)***
Age	0.2026(0.0475) **	-1.2412(0.5122)	-0.0818(1.0905)
Age Squared	0.0008(0.0001)	0.0004(0.0002)	0.0039(0.0016)
Education level	-0.0009(0.0014)	0.0004(0.0012)	0.0005(0.0011)
Female plot decision maker	-0.0355(0.0219)**	0.0252(0.0201)	0.0276(0.0202)
Joint plot decision maker	0.1118(0.1014) **	0.0170(0.0081) **	0.0553(0.0204)
Log Income	-0.0070(0.0138)*	-0.0003(0.0127)*	0.0012(0.0128)
Subplot tenure	-0.0542(0.0283)	0.0067(0.0262)	0.0095(0.0264)
Moderate fertility	0.0028.(0.0013)	0.0976(0.2448)	0.0768(0.0386)
Poor fertility	-0.0004(0.0283)	-0.0181(0.0261)**	-0.0154(0.0262)
Region	-0.0799(0.0471)	0.1247(0.0427)	0.1338(0.0430)
Sub plot area	0.0484(0.0227)**	-0.0265(0.0212)	-0.0259(0.0213)
Access to credit	0.0412(0.0741)*	0.0722(0.0313)***	0.1193(0.0692)
Group membership	0.0656(0.0339)*	-0.0817(0.0313)**	-0.0809(0.0316)**
Extension contact frequency	0.0129(0.0358)	-0.0175(0.0332)	-0.0145(0.0333)
Labor	0.3542(0.0450)*	-0.0003(0.0005)*	-0.0004(0.0004)***
Sub plot distance	0.0009(0.0015)	-0.0009(0.0014)	-0.0006(0.0014)
Constant	0.4319(0.1859)**	0.6256(0.1725)***	0.5626(0.1736)***
No. of observations	546	303	239
Prob > F	0.000	0.003	0.001
R^2	0.4701	0.5548	0.2252
Adjusted R^2	0.3177	0.5278	0.1783
Root MSE	0.3178	0.2969	0.7832

Note: Standard errors are in parenthesis.

***P<0.001, **P<0.05 and*P<0.01.

Majority of farmers do not use herbicide as a measure of weed control as shown in Figure 7.1. This is depicted by the fact that herbicide use significantly reduced yields in plots of maize bean intercrop and pure stand maize plots. Earlier descriptive analysis revealed that only 1.23% of the plots had herbicide applied upon. Similarly, minimum tillage that was only adopted in 2.67% of the plots had a negative influence in all the three cropping systems. The results further affirm the correlation existing between minimum tillage and herbicide use, since herbicide use is the only significant compliment of minimum tillage to ensure minimum soil disturbance. Hailemariam *et al*. (2013) also observed that farmers apply herbicides to kill weeds before planting under zero till system.

Soil and water conservation lead to increased yields in all the three cropping systems though not significant on intercrop and pure maize stand plots. Interestingly households that owned plots with pure bean stand recorded significant increase in yields with a low adoption rate of 8% of soil and water conservation technology from the descriptive results. This is in-tandem with the findings by Hailemariam *et al*. (2012) which found that, despite accelerated erosion and considerable efforts to promote various soil and water conservation technologies, the adoption of many recommended measures is minimal, and soil degradation continues to be a major constraint to productivity growth and sustainable intensification.



Note: F= Fertilizer, P= Pesticide, H=Herbicide, W= Soil & Water conservation, T=Minimum Tillage, M= Animal manure, R= Crop rotation

Figure 7.1: Relationship between cropping system and SAI technology uptake

The use of animal manure reduced maize yield under pure stand, it positively increased yields in plots under maize bean intercrop and pure stand bean plots. This could be attributed to the fact that most farmers use fertilizer on their maize plots, as descriptive results showed a 24.05% adoption of fertilizer which was the highest among SAI technologies considered. This is because of the complimentarily that exists between animal manure, legume crop rotation and soil and water conservation. Yields increased under pure bean plots but decreased on plots under maize bean intercrop when pesticide was used. This is in line with a study by Hailemariam *et al*. (2012) which revealed that pesticide application would not significantly increase when conservation tillage and system diversification are jointly used with traditional maize varieties.

Having identified how SAI practices affect farmers' crop choices, farmers may still face myriad challenges concerning the variety of potential cropping system to choose. Based on the fact that the final choice of crops should be sensitive to household and plot a characteristic that affects farmer's decision making. The sub plot distance to the market had a negative influence on farmers' choice of pure bean and pure maize stand cropping systems. This could be because distance increases the transaction cost that farmers incur while acquiring inputs, the affordability of the inputs required for production. Distance is a proxy for accessibility hence can influence use of inputs and availability of information (Jansen *et al*., 2006; Pender and Gebremedhin, 2007). A study by Barret and Christopher (2008) on Smallholder Market Participation in Eastern and Southern Africa found that reduced cost of transaction by improvement of market infrastructure increase sales.

The hypothesis that accessibility to credit positively affects the farmers' choice of cropping systems is confirmed. This is because credit access enables farmers to overcome liquidity constraints due to inadequate income hence farmers are able to buy inputs and pay for hired labor. This conforms to findings by Abdulai and Eberlin (2001) on the influence of credit access and farmers efficiency.

The practice of growing pure stand cropping systems was negatively influenced by the age of the household head. Farmers age positively and significantly influence the practice of maize bean intercrop. Age being a proxy for experience in farming, the elderly tend to do more of intercrop system. The older farmers seem to think that the benefits that come with maize legume intercrop including nitrogen fixation based on their experience. This is consistent to Staal *et al.* (2006) assertion that investment level and experience are highly correlated with age.

Farmers who perceive their soils to be of poor fertility do not grow maize in a pure stand. This perception significantly reduced the growing of pure maize stands. This could be due to poor soil fertility and land being a constraint; much fertilizer is needed to boost the soil nutrients so as to get the desired maize yields. Moderate soil fertility positively influence choice of the crop though not under the stress of land degradation, farmers may tend to sacrifice long-term sustainability by preferring conventional practices such as synthetic fertilizers as an immediate guarantee of positive results (Tey *et al.*, 2013).

Income showed a negative influence on growing of maize bean intercrop and maize pure stand. This suggests a possible relationship between income and crop choice as per the descriptive results, which point income as a constraint to farmers undertaking maize production. In typical rural set up very small quantities of farm produce can be sold for being expensive due to lack of access to markets. Similarly, Obare *et al.* (2003) affirms that high market access costs are a major constraint among smallholder farmers. In addition the production costs of maize production are relatively high. A study by Zerfu, (2010) also reveal that the high costs could be due to inefficiencies in the governance systems affect farmers in terms of costly access to agricultural credit and inputs.

Although the farmers' education level had no significant impact on choice of any of the three cropping systems, higher education levels could increase the likelihood of adopting SAI practices such as intercrop. In addition, Tey *et al.* (2013) established that risk evaluation and application of these SAPs is knowledge based. Hence, higher educated farmers are more willing to take ''reasonable'' risks and accept operation.

The size of land that farmers own positively influences the practice of intercrop system. Farmers are likely to do intercrop if they have small pieces of land as compared to mono cropping. This is likely to explain the inverse relationship between cropping system and land size. Farmers who have small pieces of land grow more than one crop on their sub plots, probably because they intend to increase production through diversification so as to have adequate food for their families hence reduce risk. Pender *et al*. (2007) affirms that that population pressure leads to land shortage hence causing farmers to maximize agricultural production, using land-saving and yield-augmenting technologies

The results further indicate that labor availability increased yields under all the cropping systems. This finding could be explained by the fact that all the three cropping systems are labor intensive and labor is more often assigned to effective production activities. This conforms to a study by Mussei *et al*., (2001) which revealed that labor inluenced the proportion of land allocated to improved wheat.

The female decision makers practice more of intercrop on their plots. This can be explained by the fact that they do so in order to meet their household responsibility including feeding of their families. Since they are constrained with resources including land, they try to maximize the land they own through intercrop. This finding agrees with Peterman *et al*. (2011) that analyzed the position of gender in agricultural development in Africa due to challenges faced by women as a result of their need to access land, labor and input.

7.4 Conclusion

This chapter has made two contributions in obtaining a refined understanding of the relationship existing between SAI technology uptake and smallholder cropping choices. First, it has shown that crop rotation increases yield under all the three cropping systems considered in this study. Improved seed also increases yield when used on maize bean intercrop and pure maize stand systems. Further, the study found that an increase in yields under bean pure stand required use of minimum tillage and soil and water conservation. To ensure that farmers get the highest return from their maize pure stand and bean pure stand plot, application of fertilizer and pesticide were paramount respectively.

Use of herbicide drastically reduces farmers' income on intercrop and pure maize stand plots. Secondly, since decision-making on choice of cropping system involves multidisciplinary considerations, the study also identified household and plot characteristics that affect crop choice. The major role of social capital on adoption shows the need for establishing and strengthening local institutions and service providers to hasten and sustain technology uptake. Farmers need to join farmer group hence improve their bargaining power and enable them to acquire credit facilities, Development of rural infrastructure such as roads is vital for farmers to access key inputs and market information. Sex of plot decision maker is essential in choice of crop system hence the call for gender sensitive agriculture.

CHAPTER EIGHT
SUMMARY AND IMPLICATIONS

8.1 Introduction

In sub-Saharan Africa (SSA), where farming is characterized by poor soil fertility condition and low levels of agricultural technology use, understanding the prospect of adoption of SAI practices is a policy issue. The fate of the agricultural sector directly affects economic development, food security and poverty alleviation. Despite its role as a key crop for food security and economic growth its yields have remained low (Shiferaw *et al*., 2011). Maize is predominantly grown in smallholder farming systems under rain fed conditions with limited input use. This and other causes like low soil fertility, drought stress, weeds, pests and inappropriate seed varieties may explain the trend of low yields.

As a result many innovations have been developed to address this challenge. Studies have also shown that maize yield has increased in over 70% of the growing areas. However, there are worrying trends of stagnation for many years (Ray *et al*., 2012). Alongside this deliberate efforts have been made to boost productivity and enhance the incomes of the small holder farmers. Such include development of high yielding varieties, farming systems and sustainable agricultural intensification such as crop rotation, intercropping and use of organic fertilizers.

Gender inequalities and lack of attention to gender in agricultural development contribute to lower productivity and higher levels of poverty as well as under-nutrition (FAO, 2011). There is an increasing concern about the implementation and continual use of innovations by the smallholder farmer. This is as a result of failure to address the actual issues such as gender, changes in farming systems, external factors like climate variability and policies shaping production efficiency and risks faced by the smallholder farmers. Moreover, many studies have advocated consistently for approaching agriculture and food security investment from gender perspective. The impact of gender on food security is the ultimate object of new technologies and innovations however, such has received little attention. This indicates that it may be inappropriate to generally use gender as a determinant of technology uptake and agricultural productivity where MHHs and FHHs are used as a proxy for gender.

Maize production in Kenya is a dominant food crop with its production and yield per unit area affected by many different factors including total planted area and productivity. Producing higher maize yields on existing cultivated land is the surest way of generating the extra grain required to feed the nation and consequently reduce the rising poverty. Hence maize presents an excellent opportunity to increase rural household incomes, strengthen rural economies and improve nutritional value.

8.2 Adoption of SAI packages

The center of green revolution relied on use of improved seed varieties and fertilizer. In Kenya, there is need for a more balanced approach that aims at improving agricultural productivity. One way of minimizing land degradation which is a major challenge, is letting the land lie fallow for long periods of time. But this is quickly becoming unfeasible, hence the only alternative that farmers have is to continuously farm their pieces of land to have food on their tables. This has resulted to land degradation, low farm output and increase in poverty levels. Even with the substantial efforts both nationally and internationally to encourage farmers to invest in SAI adoption, this has remained low in rural areas of developing countries (Kassie *et al*., 2009; Wollni *et al*., 2010).

The adoption of sustainable agricultural intensification practices (SAIs) is therefore, central to improving agricultural sustainability (Reimer *et al*., 2012). Hence in order to recognize, promote and realize an extensive and robust adoption of technologies for sustainable agricultural intensification lies at the heart of addressing this challenge. Furthermore, understanding this phenomenon is vital to maximize SAI adoption. Considering adoption of multiple SAPs in isolation could lose important cross-technology correlation effects, and potentially yield biased estimates hence the cross-technology correlation may have important policy implications in that a policy change that can affect one SAP may have spillover effects on other SAPs (Hailemariam *et al*., 2012).

This study analyzed if adoption of SAI practices is a single or a multiple process while determining factors affecting the use of particular SAI packages. The variables that were found to significantly influence adoption of SAI practices include: Include market access, farmers' income, age, education level, family size, farm size, total asset value, frequency of contact with extension workers, access to credit ,social network, plot tenure and soil fertility. These results suggest that in order to improve the adoption of SAI practices, local rural institutions and service providers should be supported to enable them efficiently assist smallholder farmers by providing farm inputs, information needed, and credit facilities. Further the result show that farmers in organized groups tend to adopt more of improved seed variety and fertilizer. Age being a proxy for experience in farming, the elderly tend to adopt more of fertilizer and manure packages. The results further indicate the importance of soil fertility in determining adoption of fertilizer and pesticide packages. Farmers who have small pieces of land use more than two technologies on their sub plots. Similarly farmers' income influences uptake of more SAI technologies more so those that had fertilizer. Packages containing fertilizer, manure and pesticide demanded more labor, probably because they are labor intensive.

8.3 Impact of farmers' SAIPs on income and labor use

The study analyzed the impacts of farmers' choice of technology combination on income and labor use among genders. It showed the effect of using a combination of SAI practices on output productivity of maize legume farming. The results reveal that adoption of packages that contain soil and water conservation and minimum tillage gives the highest income. Previous studies have shown that conservation tillage can lead to substantial ecosystem service benefits by reducing soil erosion and nutrient depletion and conserving soil moisture (Fuglie, 1999; Woodfine, 2009).

The SAI uptake on labor use, results illustrate that farmers who adopted SAI packages significantly demand more labor than it would have been if they had not adopted the specified SAI packages. In general, adoption of SAI packages increases women workload contributed to both family and hired labor compared to their male counterparts. More women depend on agriculture wage labor as a source of livelihood. As a result, women's overall responsibilities affect poor households' capacity to adopt new activities especially when additional family or hired labor is not available. Farmers also save much labour costs when they practice conservation tillage.

Studies have shown that conservation tillage can lead to substantial ecosystem service benefits by reducing soil erosion and nutrient depletion and conserving soil moisture. The study further indicates that that adoption of packages that contain soil and water conservation and minimum tillage gives the highest income. In addition, highest proceeds are achieved when SAI practices are adopted in combination rather than in isolation, hence the need to informs policy makers to put in place strategies that would promote uptake of these technologies in appropriate packages in order to increase farmers output and hence food security. Similarly, there is need to facilitate the formulation of robust pro-poor and gender equitable policies to target innovation and promote diffusion of technologies including, increasing the accessibility of extension personnel to women farmers.

8.4 Determinants of number SAI technologies adopted

Increasing the level of returns to smallholder farming in a sustainable manner is a central challenge to attaining poverty reduction and environmental management objectives globally (FAO, 2012a). With the low use of SAI practices still experienced in developing countries Kenya being not an exception, substantial efforts have been put by national and international organizations to encourage farmers to invest in them (Kassie *et al*., 2009; Wollni *et al*., 2010). Research show that common factors that influence the adoption of SAI practices can be categorized into socio-economic factors, institutional factors, informational factors, agro-ecological factors, psychological factors, and the perceived attributes of SAI practices (Tey and Brindal 2012; Kassie *et al*., 2009; Knowler and Bradshaw 2007).

Knowledge of farmers' preferences for uptake of various SAI technologies is vital in evaluating the effectiveness in the adoption pathways. Though some researchers believe that this body of research may have reached its edge in contributing to a refined understanding, particularly in respect to the voluntary uptake of SAPs (Knowler and Bradshaw 2007), common managerial factors include those related to human capital: gender, age, education levels, ethnicity, and experience are also important

The inferential ordered probit model results revealed that, size of land that farmers own, famers' Income, the frequency of contact between extension personnel and farmers and farmers' education level plays a vital role in determining the number of SAI practices used. Generally socio-economic and plot characteristics such as: slop of sub plot, gender of household head, soil fertility, sub plot tenure, access to credit and distance to the sub plot Soil had a less clear role in determining the number of SAI practices used on a given plot. Larger household size means greater availability of labor. The relationship between labor required and the number of SAI practices used implies that policies that will make micro-credit from government and nongovernmental agencies accessible to these farmers will go a long way in addressing their resource use. In addition, farmers should be encouraged to mobilize their savings through the establishment of SACCOs and the strengthening of community based lending systems that would improve their bargaining power.

8.5 SAI technology uptake and smallholder cropping choices

Smallholder farmers in developing countries typically cultivate different crops on different on the same piece of land each cropping season. A study by Ellias, (2000) found out that portfolio diversification is a key motive to the different cropping systems practiced by farmers in developing counties. Oftentimes the observed year to year cropping patterns are driven by SAI technologies at the farmers' disposal. According to Ishtiaq *et al*. (2005), choosing optimal combination of crops to produce is a challenge, due to resource constrain they reiterated that farmer's profit maximization objective cannot be achieved if cropping blend chosen is not optimal.

In addition, little is known about decision making mechanism behind observed smallholder cropping systems and its relationship with SAI technology uptake. According to (Hailemariam *et al*., 2013) technology-adoption decisions are path dependent: the choice of technologies adopted most recently by farmers is partly dependent on their earlier technology choices, it's still unclear if in a given cropping season SAI technologies used in a specific plot would affect the technologies that would be used on other plots owned by the same farmer.

This study makes the case for a more nuanced treatment of farmers' cropping choices. It used a unique dataset from adoption pathways project of maize legume farmers to investigate if the available SAI technologies can influence farmers' decision making on cropping choices. It concludes that farmers' decision making on crop choices is determined by several household and plot characteristics.

The social capital was found to play a major role on uptake of SAI practices hence the need for establishing and strengthening local institutions and service providers to hasten and sustain technology uptake. Farmers need to join farmer group hence improve their bargaining power and enable them to acquire credit facilities, Development of rural infrastructure such as roads is vital for farmers to access key inputs and market information. Sex of plot decision maker is essential in choice of crop system hence the call for gender sensitive agriculture. Further, the study found that an increase in yields under bean pure stand required use minimum tillage and soil and water conservation. To ensure that farmers get the highest return from their maize pure stand and bean pure stand plot, application of fertilizer and pesticide were important respectively.

8.6 Policy implications

Broad policy implications can be gathered from the relative importance of statistically significant factors across the selected SAIs. The results showed that adoption of a combination of SAI technologies results into more output than adoption in isolation. The concerned stakeholders including the government and NGOs should rethink and put in place demand driven agriculture extension methodologies so as to achieve desired productivity and environmental outcomes. Investment in rural extension services should focus to teaching farmers agronomic practices as a package that is specific and suitable to a particular region. A better understanding of constraints that condition farmers' behavior in uptake of this technologies is therefore key in redesigning promising pro-poor policies that could increase their adoption level and increase productivity.

There is need for equitable access to agricultural resources and education by both genders. This would lead to an increase in farm output since the female farmers also play an important role in the uptake of SAI technologies. Rural development should encourage policies that are likely to develop infrastructure in order to ensure that farmers have easy access to output and inputs markets. These imply that improving rural incomes is likely to significantly enhance the uptake of sustainable intensification practices which is beneficial to the long term soil health and improvements in household livelihoods.

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APPENDICES

Appendix 1: Structured questionnaire

TITLE: Factors Affecting Diffusion of Agro-Innovations among Smallholder Farmers in Kenya.

The purpose of this exercise is purely academic. It is aimed at identifying some of your reasons for using a single or multiple of technologies in maize legume farming. You have been randomly selected from the farmers in your village. As a respondent you are kindly requested to participate in answering this questionnaire and you are assured that all information shared will be treated strictly as confidential and none will be released to anyone except for this study.

QUESTIONNAIRE SERIAL NUMBER………………..

INTERVIEW DETAIL

Date of interview (dd/mm/yyyy) ……………………………………….

Time started (24 HR) ………………………………………

Name of enumerator: ………………………………………

Region ………………………………………

County ………………………………………

Division ……………………………………….

Location ………………………………………

Sub-Location ……………………………………….

Name of data entry clerk ………………………………………

MODULE1; HOUSEHOLD COMPOSITION AND STRUCTURE

1a) Name of the respondent

1b) Sex of respondent

1c**)** Name of Farmer (household head) ………………………………………………

1d) Phone Number……………………………………….

1e). Gender of (household head) Male [0] Female [1]

1f). Age of Household head (years)…………………...

1g). Marital status: (1).Married (2).Single (3).Divorced/Separated (4). widowed

1h). Education level:

None	(1)……years	Primary incomplete	(2) ……years
Primary complete	(3)……years	Secondary incomplete	(4)….…years
Secondary complete	(5) …...years	Middle level college	(6) ……years
University	(7) …..years		

1i). Occupation

(1)Unemployed (2) Agriculture self employment

(3)Non agriculture self-employment (4) Salaried employment

(5) Retired

1j). Family Size (Number of dependents living with you)………………………………..

MODULE2; FARM CHARACTERISTICS

2a) what is the size of your farm in acres? ………………………………

2b). under what type of ownership is your farm?

(1)Owned (with title) specify acres……………………

(2)Owned (without title specify acres…………………….

2c). Do you carry out farming activities?

(0)Yes (1) No

2d).If yes how much of your farm (in acres) do you use for farming activities? ....

2e).What farming activities do you carry out in your farm?

(1) Crop farming (4) Fish farming

(2) Livestock farming (5) Poultry farming

(3) Others (specify)………………….

MODULE3; FINANCIAL CAPITAL

3a).What is the income status of the household? (Total household income per month). Tick where applicable.

(1) <5000 (2) 5001-10000 (3)10001-20000 (4) 20001-30000 (5) >30000

3b). has any member of the household saved money in the last one year?

(0)Yes (1) No

3c). Where was the money saved? (1) Home (2) Bank (3) cooperative

(4) Other (specify)……………………………

3d).What was the use of the money? (1) Maize legume farming (2) other farming activities

(3) Off-farm activities (4)other (specify)…………

3e). Have you applied for a loan from any financial institution in the past one year?

(0)Yes (1) No

3f). If yes indicate source and use.

Source	Use
1) Bank…………………………………..	
2) Cooperative……………………………	
3) Merry go round……………………….	
4) Micro finance…………………………	
5) Informal lender ……………………….	
6) Employer ……………………………..	
7) Other (specify)…………………………	

(1) Home consumption (2) non home consumption i.e (fees, health)

(2) Farm input &equipments (4) Buying livestock

(5) Buy land / House (6) others (specify………………..

3g).Did you obtain free farm inputs (seeds/chemicals) in the last one year?

(0) Yes (1) No

3h).Indicate source (1) Government (2) NGOs (3)Others………………

3i). Were the farm inputs helpful/ important? (0)Yes (1) No

3j). How?

………………………………………………………………………………………….

MODULE4; SOCIAL CAPITAL

4a). Are you or any of household a members of an organization, group or association?

(0) Yes (1) No.

4b).If yes which one? (1) Youth group (2) Women group

(3) Saving & credit society (4) other (specify)………………

4c). For how long has he/she been a member of that group? ....

4d). what benefits or services does the group/association offer?

(1) Education/training (2) Credit (3) Farming

(4) Irrigation (5) Farming information (6) Marketing produce

(7) Tree planting (7) Other (specify)………………………….

MODULE 5HOUSEHOLD LIVELYHOOD ACTIVITIES AND ASSETS

5a). in the past 12 months which livelihood activities did your household carry out?

Farming	Employment	Trade	Fishing	Other(specify)

5b). Do you participate in off- farm activities? (0) Yes (1) No

5c). No of hours in a day spent on off farm activities ………………………………

5d).Indicate which other livelihood activities the household was involved in the past 12 months.

(1)Fishing (2) Employment

(3)Trade (4) others (specify) …………………………………….

5e). Indicate the assets currently owned by the household

Item		Current number	Unit Value	Item		Current Number	Unit Value
Item				**Item**			
Cow shed (s)	1			Spade/shovel	15		
Ox plough	2			Farm house(s)	16		
Food store	3			Furniture	17		
Water pump	4			Panga	18		
Milking shed	5			Jembe	19		
Fenced farm	6			Vehicle(s)	20		
Chuff cutter	7			Tractor	21		
Wheelbarrow	8			Tractor trailer	22		
Spray pump	9			Water tank	23		
Bicycle	10			Posho mill	24		
Feed troughs	11			Well water	25		
Milk Buckets	12			Power saw	26		
Motorcycle	13			Mobile phone	27		
Television	14			Radio	28		

5f). How else do you obtain the equipment named in (5e) among others?

(1)Borrow from friends (2) Hire (3) Borrow from extension office (if applicable)

(4)Other (specify) ………………………………………………………………..

MODULE6; IMPROVED TECHNOLOGY KNOWLEDGE

PART A: Maize variety knowledge, sources of information and seed adoption and dis-adoption

		Code
6Aa	In your household, who makes the decision on which improved maize varieties to use and dis-adopt?	(1)Self; (2) Spouse; (3)Self and spouse jointly; (4) other household members
6Ab	In your household, who mostly acquires maize seed from different sources?	(1)Self; (2)Spouse; (3)Self and spouse jointly; (4)other household members
6Ac	How certain are you about the origin and purity of the improved maize varieties that you have grown?	(1) Very; (2) Modest; (3) Not sure

6Ad	In your household, who mostly acquires extension services related to new maize varieties	(1)Self; (2)Spouse; (3)Self and spouse jointly; (4) other household members
6Ae	In your household, who mostly acquires credit (cash or in kind) services for purchase of maize seeds both improved and local varieties and other inputs (fertilizer, herbicides)	(1)Self; (2) Spouse; (3)Self and spouse jointly; (4) other household members

PART B: Legume variety knowledge, sources of information and seed, adoption and dis-adoption

		Code
6Ba	In your household, who makes the decision on which improved legume varieties to use and dis-adopt?	(1)Self; (2)Spouse; (3)Self and spouse jointly; (4) other household members
6Bb	In your household, who mostly acquires legume seeds from different seed sources?	(1)Self; (2)Spouse; (3)Self and spouse jointly; (4) other household members
6Bc	How certain are you about the origin and purity of the improved legume varieties that you have grown?	(1) Very; (2) Modest; (3) Not sure
6Bd	In your household, who mostly acquires extension services related to new legume varieties	(1)Self; (2)Spouse; (3)Self and spouse jointly; (4) other household members
B5	In your household, who mostly acquires credit (cash or in kind) services for purchase of legume seeds both improved and local varieties and other inputs (fertilizer, herbicides)	(1)Self; (2)Spouse; (3)Self and spouse jointly; (4) other household members

PART C Improved technology used

6Ca).Which of the following technologies do you use

(1) Improved variety (2) Timely/early planting (3) Minimum tillage

(4) Organic/inorganic fertilizers (5) modern inputs (6) Intercropping

(7) Crop rotation (8) Others specify……………..

6Cb).When did you start using the above named technologies? --
-

6Cc). How much of your farm is under the use of the above named technologies? .... Acres.

6Cd). Why did you decide to use the above named technology?

(1)Motivation by extension officers (2) influence by other farmers

(3)Observation from other farmers (4) Other (specify)………………………………

6Ce) Since you started using the above named technology, have you realized increase in output

(0) Yes (1) No

6Cf) Give reason for [6Ce] above ……………………………………………………….

6Cg) Have You attended farmer training school? (0)Yes (1) No

6Ch). what aspect of technology was trained? ………………………………

6Ci). Do you access extension services? (0) Yes (1) No

6Cj). Number extension contacts in the last year: ……………………………….

6Ck). Do you feel that you get adequate services from extension officers?

(0)Yes (!) No

6Cl). who provides the extension services?

(1) Government officers (2) NGOs (3) Private institutions

(4) Social groups (5) others (specify) ……………………

MODULE7; DECISION MAKING

Decision on ENUMERATOR: Ask A1 for all categories of activities before asking A2.If household does not engage in that particular activity, enter code8 for "No decision made" and proceed to next activity.		Did you participate in (decision) in the last 12 months? CODE 1	How much input did you have in decisions on the use of income generated from [ACTIVITY]? CODE 1
		A1	**A2**
7a	Food crop farming: crops that are grown		
7b	Cash crop farming: crops that are grown		
7c	What type of seed to buy?		
7d	What type of fertilizer to buy?		
7e	When or who would take crops to the market		
7f	Livestock raising?		
7g	When or who would take livestock to the market?		
7h	Non-farm business activity?		
7i	Your own (singular) wage or salary employment?		
7j	Major household expenditures? (Such as a large appliance for the house i.e. (refrigerator)		

7k	Minor household expenditures? (such food for daily consumption)		

<table>
<tr><th colspan="2">CODE 1</th><th>CODE 2</th></tr>
<tr><td>1. Mainly husband
2. Mainly wife
3. Husband and wife jointly
4. Someone else in the household
5. Jointly with someone else inside the household</td><td>6. Jointly with someone else outside the household
7. Someone outside the household/other
8. Decision not made</td><td>1. No input
2. Input to few decisions
3. Input to some decisions
4. Input to most decisions
5. Input to all decision</td></tr>
</table>

MODULE8; CROP PRODUCTION

(8) In the table below indicate major crops that the household produced in the past one year quantity produced, expenses, selling price and profit

Crop	Quantity produced	Land prep & weeding cost	Man hour cost	Seed &Fertilizer cost	Harvesting cost	Other expenses	Price	Total expenses	Profit

Crop code
1= Maize2= Bean 3= Vegetables 4= Sorghum 5= Millet 6= Fruits 7= Groundnut 8= others

8a) Do you sell any of your farm produce? (0) Yes (1) No

8b). If yes where do you sell?

(1)Local consumption (2) To middle men

(3)Take directly to market (4) Others (specify)……………………

8c) what is the average distance to the marker(s)………………………………. Km

8d). How do you transport produce to the market?

(1) Foot (2) Bicycle (3) Donkey

(4)Motor cycle (5) Matatu (6) Other (specify)……..……………

8e). what is the type of road to the local market?

(1) Muddy road (2) Murram road

(3)Tarmac road (4) Other (specify)……..……………

8f). Do you get market information? (0) Yes (1) No

8g). If yes how? (1) From other farmers (2) Extension officers

(3)Media (Radio, newspaper) (4) NGO

(5)Friends (6) Other (specify)…………………

8h). When do you ask/check on price information from the above sources?

(1)Daily (2)Weekly (3) Monthly (4) Annually (5) Rarely

MODULE9;LIVESTOCK PRODUCTION

9a). Did you own any livestock in your farm in the last one year? Yes [ ] No [ ]

9b).+ If yes, complete the table below:

Livestock	No. owned by household	No. sold	Unit selling price (Kshs)	No. purchased	Purchase price	No. consumed	No. died	No. kept for other Farmers	No. kept by other Farmers	No. owned by household
Goats										
Donkeys										
Sheep										
Indigenous chicken										
Broilers										
Layers										
Ducks										
Pigs										
Beehives										
Local cows										
Dairy(exotic)										
Local bulls										
Calves										

26c). Outline the livestock products income sources in Ksh.

Livestock Product	Average production/month	Unit of Production	Amount Sold /month	Price/Unit (Kshs)
Cow milk				
Goat milk				
Eggs				
Honey				
Hides and Skin				
Fish				
Manure				
Others(specify)				

26) Can you comment on any other relevant information or challenge facing maize legume farming……………………………………………………………………………………………
……………………………………………………………………………………………………
…………………………………………………………………………………………

Time finished interview (24 HR) ……

Thank you