Adoption Pathways project discussion paper 10

February 2015

Crop Choice and Adoption of Sustainable Agricultural Intensification Practices in Kenya

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Abstract.

This study uses a stochastic production function model and data from 536 randomly sampled smallholder households from eastern and western Kenya to identify yield enhancing factors across sustainable agricultural intensification (SAI) innovations and cropping choice, and complimentary factors that determine the cropping choice. We find that the level of fertilizer and improved variety use is positively correlated with yield across the cropping type. Furthermore, access to credit positively affects the farmers' choice of cropping systems; the elderly farmers practice more intercropping; low soil fertility significantly reduced the growing of pure maize stand; and limited incomes favors more intercropping. These results suggest that a better understanding of the determinants of cropping choices for smallholder farmers would be beneficial for better targeting of SAIs for adoption and subsequently improving crop productivity with less use of commercial inputs.

Keywords: Adoption, Sustainable agricultural intensification practices, Crop choice, Kenya

JEL codes: O13, Q12, Q15, Q16

1. Introduction

The need for persistent agricultural development, accelerated delivery and adoption of research results aimed at mitigating food insecurity effects through improving agricultural productivity and sustainable intensification is critical in Sub Saharan Africa. The adoption rates of sustainable agricultural intensification (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). Moreover, 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. Ellias, (1999) 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.

A body of empirical 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 between (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 Köhlin, 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.

Though (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, 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.

We aim to fill this knowledge gap by modeling plot specific cropping choices rather than over the entire farm that a farmer owns. We then test if with a given set of SAI technologies available to the farmer and the variation in yield influences cropping systems as practiced by farmers.

2. Model specification and empirical analysis

A Stochastic production function model was used in the analysis that sought to determine the relationship between cropping choices and technology uptake. Initially, stochastic production function model was developed for testing technical efficiency. Recent studies have used the model to determine capacity utilization and estimation. 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:

$$y_{pk} = f_k\left(\mathrm{X}_p\right) + u_{pk}, \tag{1}$$

and

$$f_k\left(X_p\right) = \exp\left(\beta_i T_i + \sum_{ko=1}^{ko} \beta_{k0} D_{K0} + \beta_P' D_P\right) \tag{2}$$

where y_{pk} is the yield of a given crop 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 (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:

$$u_{pk} = c_{pk} h_k^{1/2}\left(\mathrm{X}_p\right) \tag{3}$$

Where $E\left[u_{pk}\right] = 0$ and $E\left[u_{pk}u_{qk}\right] = 0$, for $p \neq q$

3. Study Areas and Data

The data used in this study was obtained from a farm household survey in Kenya carried out during the period October–November 2013 by a team from the Adoption Pathways Project (APP) in collaboration with the International Maize and Wheat Improvement Center (CIMMYT). The sample consisted of 536 farm households. Data were collected in western and eastern regions of Kenya. Five counties were purposively selected, based on agro ecological zones (high altitude-eastern and lower altitude-western). This was based on their maize-legume production potential. A multi stage sampling was then employed to select lower levels sampling clusters: divisions, locations, sub-locations and villages.

4. Results and Discussion

4.1. Descriptive results

Using a structured questionnaire the sample farmers were interviewed. Information on household socio-economic characteristics, plot and village data including input and output market access, household composition, the age, gender and education level attained by a household head, asset ownership, various sources of income, participation in credit markets, membership of formal and informal organizations, labour use, participation and frequency of contact with extension personnel, cropping pattern, crop production, land tenure, soil fertility, land size, access to credit and sub plot distance from home.

Table 1 shows description of variables that were used with choice of explanatory variables based on literature review findings. A description of these variables is discussed, with specific mean and standard deviation.

Gender (gender of household head) is used as a dummy variable with 1 to represent male and 0 to represent 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) 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) is a continuous variable measured in terms of number of persons living together. Family size may be associated with labour. So that large families may have adequate labour that would enhance adoption of SAI technologies. Larger household could also translate to more income if members of that spesific households are engauged in activities that could earn them more income to enable them adopt SAI technologies.

The variable *Farmsize* **(**farm size in acres) is a continuous variable measured in acres. Land is an indicator of wealth, thus it is hypothesized that increase in size would positively influence adoption. In addition it is expected that the small pieces of land would promote farmers to practice mixed farming in order to meet their household food demand. *TAssetvalue* (total value of assets) is a continuous variable measured in terms of Kenya Shillings (KES). It is expected that farmers with high asset value are likely to adopt a multiple of SAI technologies since they are more endowed.

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. Agricultural extension agents are mandated to deliver and implement agricultural-related services and goods to farmers. Agricultural inputs and supply of credit are delivered to rural farmers through government's local extension argent. This affects the return from technology adoption and affects adoption of technologies Farmers who have more contacts with extension agents tend to get more information and are likely to adopt more of SAI technologies.

The variable *Crdacc* (if farmer needed credit) is measured as a dummy. 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 ready money that they can use to purchase farm inputs 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 variable measured as 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. With inadequate information sources and imperfect markets and transactions costs, social networks are expected to facilitate the exchange of information, This increases farmers' bargaining power, helping farmers 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 *Occupation* **(**main occupation of household head) is a categorical variable showing various activities that farmers are involved in to earn their livelihood. This is likely to enhance the incomes of the farmers. This may enable the farmers to purchase inputs. As a result occupation is expected to positively or negatively influence use of SAI practices.

Distmkt (distance to the market) is a continuous variable measured in terms of walking distance to the market in minutes. The distance to markets can influence farmers' decision making in various ways. Better access to the market can influence the use of output and input markets, and the availability of information. It is expected that farmers living near the market would easily access market for their farm produce hence readily practice maize-legume farming. Therefor distance to the market would positively or negatively influence uptake of SAI technologies.

The variable *Plottenure* (tenure of farmer's plot) is a categorical variable showing if the plot is owned by a farmer, if it's borrowed or rented. Security of land proprietorship has a substantial effect on the agricultural performance of farmers. Better tenure security raises the likelihood that farmers will capture the proceeds from their investments. Since land is a scarce resource is assumed that farmers who don't own land have to spend extra cash to rent land, hence reducing their income and in the long run are unable to adopt a multiple of SAI technologies.

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

In Table 2 the gross margin for maize (pure stand and intercropped with beans) and beans across SAI technologies and / or a combination of technologies are presented. In this study 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 used technologies.

Under maize bean intercrop, the use of animal manure and pesticide in combination had the highest margin (48185.59) followed by use of all the four technologies (improved seed, animal manure, pesticide and fertilizer) in combination (44476.32), while the use of fertilizer in isolation gave the lowest margin of (26730.86). This implies that technology adoption is nonlinear in process. Majority of the farmers use these technologies in isolation hence get very low margin. The practice of maize legume intercrop also gives higher output as compared to growing of maize and beans as pure stands across all technologies.

4.2 Econometric Results

Table 3 presents the production function results on the relationship between the nine SAI technology uptake considered in this study and smallholder cropping systems. Crop rotation had a positive influence on pure stand maize and pure stand beans but negatively influenced intercropping of maize and beans system. This indicated 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 nitrogen fixation and carbon sequestration as rotation would do.

Fertilizer was seen 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: Jhamtani, 2011), that showed that intercrop can save farmers the cost of fertilizer since farmers appear to properly tribute nitrogen fixed by legume crops and to consider the soil fertility effects of maize legume intercrop because fertilizer use is either reduced or statistically 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 % confidence level being on intercrop and pure maize stand plots. This showed that adoption of improved maize seed is linearly linked with increased maize yield per unit area.

This was also consistent with the descriptive results that showed 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.

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.

Famers do not believe in the use of herbicide as a measure of weed control. This is depicted by the fact that herbicide use significantly reduced yields in plots of maize bean intercrop and pure stand maize plots. Furthermore descriptive results revealed that only 1.23% of the plots had been applied herbicide. 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 was in tandem with the findings by Hailemariam *et al*., (2012) who 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.

Though use of animal manure was seen to reduce 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. Previous studies have shown some complimentarily between animal manure, legume crop rotation and soil and water conservation. Likewise, studies have also shown that animal manure is a substitute of fertilizer

Having identified how SAI practices affect farmers' crop choices, farmers may still face a myriad of challenges concerning the variety of potential cropping system to choose between. 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 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 labour. This conforms to studies 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. Age being a proxy for experience in farming, the elderly tend to do more of intercrop system. The older farmers seem to know the benefits that come with maize legume intercrop including nitrogen fixation based on their experience. This conforms to study by Staal *et al.* (2006) who found investment level and experience to be highly correlated with age.

Farmers who believe that their soils are not fertile do not grow maize pure stands. Soil fertility significantly reduced the growing of pure maize stand. This could due to the fact that land degradation has led to poor soil fertility and land being a constrained; much fertilizer is needed to boost the soil nutrients so as to get the desired maize yields. 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

Income had a negative influence on growing of maize bean intercrop and maize pure stand. This could be explained by the descriptive results, that revealed income was a major constrain to farmers under maize production. This shows that production costs of under maize production are very high. A study by Zerfu, (2010) revealed 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, findings from previous studies show that higher education levels increase the likelihood of adopting SAI practices such as intercrop. Tey *et al*., (2012) confirmed 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.

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

Female decision makers were seen to practice more of intercrop on their plots. This could 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 conforms to findings by Peterman *et al*., (2011) who saw the need to document the position of gender in agricultural development in Africa due to challenges faced by women as a result of their need to access land, labour and input.

5. Conclusion and implication

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 pure stand of maize, pure stand of beans and maize bean intercrop considered in this study. The use of 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 minimum tillage and soil and water conservation practices. However, to report the highest return from their maize pure stand and bean pure stand plot, application of fertilizer and pesticide, respectively is necessary. In addition, in conditions of costly commercial chemical fertilizers and pesticides, (as is obtainable in smallholder agriculture) the trade-off between pure cropping and inter-cropping is in favor of the latter. Fertilizer increase yield in all the three cropping systems. Intercrop save farmers the cost of fertilizer since farmers appear to properly tribute nitrogen fixed by legume crops. Improved seed is an important strategy for increasing yields in maize plots

Secondly, decision-making on choice of cropping system was also influenced by several household and plot characteristics, hence considered multidisciplinary. Access to credit positively affects the farmers' choice of cropping systems. Age being a proxy for experience in farming, the elderly tend to do more of intercrop system. Similarly low soil fertility significantly reduced the growing of pure maize stand. Income was seen to be a major constrain to farmers under maize production. Farmers are likely to do intercrop if they have small pieces of land as compared to mono cropping. This illustrates a 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.

6. Acknowledgements

This study is supported by the Australian International Food Security Research Centre (AIFSRC) through the International Maize and Wheat Improvement Center (CIMMYT)-led Adoption Pathways Project.

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8. Appendices

Table 1. Definitions and summary statistics of the variables used in the analysis

Variable	Variable Description	Means	Standard deviation
Gender	Gender ,(1= Male, 0 = Female)	0.46	0.50
Aghh	Age of household in years	50.76	14.71
Educlevel	Education level, years in school	7.74	6.76
HHsize	Household size in number	5.81	2.71
Farmsize	Farm size acres	0.71	1.56
TAssetvalue	Total asset value in KES	172,944	42,202
TOtherincome	Total value of other income in KES	92,926	15,787
Frequentcontact	Extension contact,(Number of days/ year)	1.34	1.96
Crdacc	If farmer needed credit , (1= Yes. 0=No)	0.06	0.23
Grpmbr	Group membership, (1= Yes. 0=No)	0.47	0.49
Occupation	Occupation of the household head (1 = Agriculture self,2 = Non-agriculture self, 3 = Salaried,4= Retired)	1.56	1.49
Plotdist	Walking distance from home to plot	7.15	16.08
Soilfertility	Soil fertility(1=Good, 2=Medium, 3=Poor)	1.92	0.60
Plottenure	Plot ownership(1 = Owned2 = Rented in, 3 =Rented out, 4=Borrowed,)	1.19	0.64

Note: 1 KES = 80 US dollar at the time of survey.

Table 2. Crop system gross margins across technology and technology combinations.

Technology/ Technology combination	Pure maize stand		Pure bean stand		Maize bean intercrop	
	Number of plots	Mean (Std. Dev.)	Number of plots	Mean (Std. Dev.)	Number of plots	Mean (Std. Dev.)
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: Survey data, 2013

Table 3: Production function model coefficients of SAI technology uptake and smallholder cropping systems

Variable	Cropping Systems		
	Intercrop (Maize & Bean)	Pure stand Maize	Pure stand Bean
SAI Technologies Dummies			
Fertilizer use	0.054(0.051)	0.026(0.0462)**	0.037(0.046)
Pesticide use	-0.042(0.051)	0.098(0.0475)	0.099(0.018)**
Herbicide use	-0.201(0.094)**	-0.205(0.087)**	0.226(0.088)
Improved seed	0.355(0.043)*	0.285(0.035)***	0.141(0.035)
Minimum tillage	-0.016(0.068)	-0.042(0.063)	-0.035(0.063)**
Intercrop (maize & beans)			
Soil &water conservation	0.015(0.034)	0.011(0.032)	0.024(0.032)*
Animal manure use	0.046(0.037)	-0.026(0.034)	0.029(0.034)
Crop rotation	-0.179(0.053)*	0.167(0.049)***	0.154(0.049)***
Age	0.203(0.0475)	-1.241(0.512)	-0.087(1.094)
Education level	-0.009(0.002)	0.004(0.012)	0.005(0.001)
sex plot Decision maker	-0.036(0.022)**	0.025(0.020)	0.028(0.021)
Income	-0.007(0.014)*	-0.003(0.013)*	0.001(0.013)
Subplot tenure	-0.054(0.028)	0.007(0.026)	0.009(0.026)
Owner sub plot	0.004(0.002)	0.002(0.002)	0.002(0.002)
Soil fertility	-0.004(0.028)	-0.018(0.026)**	-0.015(0.026)
Region	-0.079(0.047)	0.125(0.043)	0.134(0.043)
Sub plot area	0.048(0.023)**	-0.027(0.021)	-0.026(0.021)
Access to credit	0.041(0.074)*	0.072(0.031)***	0.119(0.069)
Group membership	0.066(0.034)*	-0.082(0.031)**	-0.081(0.032)**
Ext contact frequency	0.013(0.036)	-0.018(0.033)	-0.015(0.033)
Labour	0.354(0.045)*	-0.003(0.005)*	-0.004(0.004)***
Sub plot distance	0.009(0.002)	-0.009(0.002)	-0.006(0.003)
_cons	0.432(0.186)**	0.626(0.173)***	0.563(0.174)***
Observation	546	303	239
Prob > F	0.000	0.003	0.001
R-squared	0.470	0.555	0.225
Adj R-squared	0.318	0.528	0.178
Root MSE	0.318	0.298	0.783

Note: Standard errors are in parenthesis.

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

Source: Survey data, 2013

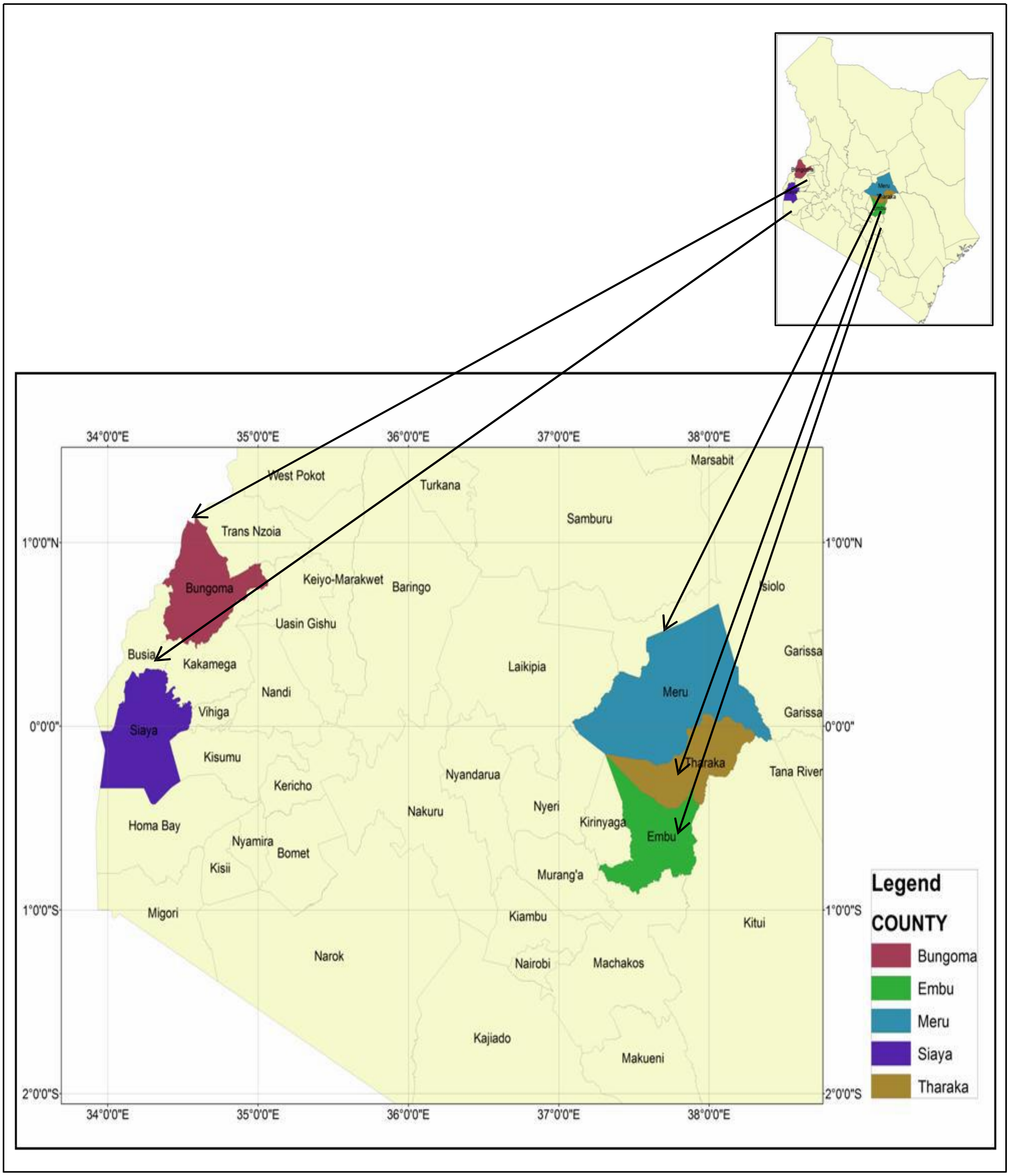
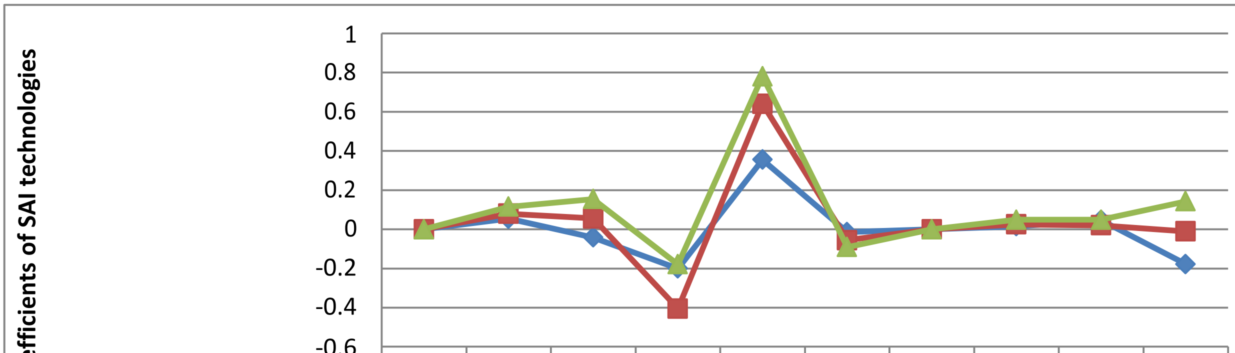


Figure 1: Map of study area.

Source: Virtual Kenya and Google Earth Pro. 2014



	SAI ologies Dummy	Fertiliz er use	Pestici de use	Herbici de use	ed seed	um tillage	Intercrop (maize & beans)	Soil &water conservation	Animal manure use	Crop rotation
Pure stand Bean		0.036	0.099	0.226	0.141	-0.035		0.024	0.029	0.154
Pure stand Maize		0.025	0.097	-0.205	0.285	-0.041		0.01	-0.026	0.167
Intercrop (Maize & Bean)		0.054	-0.042	-0.2	0.355	-0.015		0.015	0.046	-0.178

Cropping systems

Figure 2. Relationship between cropping system and SAI technology uptake