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Full Length Research Paper

Technology adoption behaviours: Evidence from Maize producers in drought prone regions of Eastern Kenya

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The growth in agriculture holds the key to the economic growth and development in many Sub-Saharan African countries. However, for the past three decades, agricultural productivity in this part of the continent has been the lowest in the world. In many Sub-Saharan African countries, the low adoption rate of new agricultural technologies such as improved seeds is perhaps among the major causes of low agricultural productivity, food insecurity and poverty. This paper analyzed farmers' adoption of improved maize varieties over time, the determinants of adoption, and the impact of adoption on area expansion in the drought prone region of eastern Kenya. A multivariate probit model was estimated using data from the International Maize and Wheat Improvement Center (CIMMYT). The results show that only 19% of farmers used improved maize seeds during 2002 - 2006 while 21% used them for one or more years and then discontinued their use, and 60% did not use them at all. Liquidity constraints, poverty, poor infrastructure, and poor input and output markets were among the causes of the low adoption rate in the region. However, access to improved seeds, high yield, and membership in a farmers' association were among the determinants of area expansion. Efforts should be directed toward helping farmers get access to financial, input, and output markets in order to stimulate the adoption of improved agricultural technologies.

Key words: Technology adoption, improved maize, drought, multivariate probit, Kenya.

INTRODUCTION

Agriculture is an important factor for sustainable development and poverty reduction in many developing countries (Ouma and Groote, 2011). It is one of the most important sectors that can promote growth, reduce poverty and increase food security. Seventy percent of the poor in developing countries live in rural areas, and 80% of them practice agriculture as a livelihood (Muzari et al., 2012; Smale, Byerlee and Jayne, 2011). Therefore, rural and agricultural development remain an imperative condition for sustainable development and poverty reduction (World Bank, 2008).

For the past three decades, agricultural productivity in Sub-Saharan Africa has been extremely low, causing an increase in poverty (Ouma and De Groote, 2011; Suri, 2011). Low productivity is exacerbated by the low use of farm inputs, unreliable rainfall, drought, pest infection, crop disease, poor agricultural techniques, low soil fertility, and poor infrastructure. These factors have all affected yields.

Increasing yields of staple crops has been the goal of many African governments as well as non-governmental organizations. These institutions have been promoting and diffusing new agricultural technologies and high yielding crop varieties to farmers for decades. This is the case of the development and the diffusion of improved seed varieties for staple crops such as hybrid and open pollinated varieties (OPVs) of maize that aim to help

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farmers increase yields and stabilize annual food production. These improved varieties have one or more of the following characteristics: drought resistant, disease and/or pest resistant, low nitrogen requirements, and low toxicity (De Groote et al., 2005).

As far as staple production is concerned, maize is an important staple food in many Sub-Saharan African countries. In Eastern Africa, maize is the major crop cereal in term of production (Doss et al., 2003). Maize is an important source of iron, vitamin B, protein, and minerals. In addition, maize can be used in brewing industries and for livestock feed (Kudi et al., 2011).

Despite the emergence and the diffusion of these new crop varieties, farmers' choice to adopt improved varieties remains a very critical decision. In spite of some compelling success stories on the positive relation between the use of improved maize varieties and the increase in smallholder maize productivity, many farmers are still using traditional maize varieties (Johannes, Vabia and Malaa, 2010; Salasya et al., 2007; Kudi et al., 2011).

Almost all the studies on technology adoption in developing countries in general and Sub-Saharan Africa in particular have focused on a static analysis of the determinants of technology adoption and its effects on yields. To our knowledge, no study has so far focused on the analysis of adoption of improved maize varieties over time or on the relation between adoption and area expansion in Sub-Saharan Africa. This paper contributes to the literature on technology adoption by analyzing the adoption of improved maize varieties over time and the impact of adoption on area expansion in eastern Kenya. Specifically, in addition to the determinants of adoption, this paper seeks to determine if farmers who adopted improved maize in the first year, continued with the new varieties or discontinued using them in subsequent years. In addition, it investigates if those who did not adopt improved maize varieties in the first year adopted them in subsequent years.

The rest of the paper is organized as follows: we present the literature review in section 2, followed by the methodology in section 3. The empirical results are presented in section 4 followed by the conclusion and policy implications in section 5.

LITERATURE REVIEW

In Sub-Saharan Africa, maize covers 25 million hectares, mainly in smallholder systems. Between 2005 and 2008, the total production by these smallholders was estimated at 38 million kilograms, primarily for subsistence. During the same period, maize represented an average of 27% of total cereal area and 34% of cereal production. However, from 1961 to 2008, maize has dropped as a share of the total area in primary crops in Sub-Saharan Africa (Smale et al., 2011).

With an estimate of 88 million hectares of land that is not yet planted but suited for maize production, the potential for expanding maize production in Sub-Saharan Africa is huge (Kafle, 2010). Improving maize production can be an important strategy to fight food insecurity and reduce poverty (Kafle, 2010). As such, maize production has been the target of support from governments, non-governmental organizations (NGOs) and other development agencies (Mugisha and Diiro, 2010). However, despite the emergence and diffusion of new maize varieties, farmers' choice to adopt new varieties of maize remains a very critical decision. Over 70% of maize productions in the majority of the African countries are from smallholders using traditional methods of production with low crop yields (Muzari et al., 2012). These small farmers do not use new technologies due to many factors such as the lack of information, unavailability of the technology, sometimes the returns of the technology, liquidity constraint and the risk related to the use of a new technology (Doss et al., 2003; Kudi et al., 2011)

In general, the adoption of a new technology by farmers is usually based on profitability and the risk associated with the technology. Many farmers who are risk averse will go from cheaper to more costly technologies (Kaliba et al., 2000). In the case of maize varieties, farmers will generally adopt improved maize varieties that are stable in yields (Kafle, 2010) and avoid maize varieties that can cause food insecurity due to their high variability in yields. Furthermore, the decision of whether or not to adopt a new technology or use improved varieties of maize is also based on farmer and household characteristics (size, age and gender of the household head, wealth, education of the household head, access to information, and availability of cash needed to access technology, and labor). Other important technology characteristics include high yields, resistance to drought and pest infestation, and clean seed (Doss et al., 2003; Doss, 2006).

Technology adoption is defined as the "degree of use of a new technology in long run equilibrium when a farmer has full information about the new technology and its potential" (Feder et al., 1985). Based on this definition, the adoption of a new technology at the farm level indicates the realization of farmers' decision to use it in the production process (Kaliba, et al., 2000).

There is a wide range of literature on the adoption of new agricultural technologies in Sub-Saharan Africa and the adoption of improved varieties of maize. The very low adoption of improved varieties has been identified as the partial cause of low maize yield and food insecurity in many African countries (Salasya et al., 2007; Mwambu, et al., 2008; Langyintuo and Mekuria, 2008; Donkoh and Awuni, 2008; Abunga et al., 2012). However, understanding the factors of adoption is a key factor in the design and the implementation of successful policies and mechanisms to help farmers adopt them (Suri, 2011; Dos et al., 2003; Mwambu et al., 2008).

The examination of the existing literature on technology adoption in Eastern Africa by Doss et al. (2003) has shown that depending on the location of the study and the objective, it is difficult to indicate one factor as a key determinant of the adoption of improved technologies. However, a wide range of economic, social, and physical aspects of farming may influence farmers' acceptability to adopt new technologies (Johannes et al., 2010).

Various studies have shown that the availability and the profitability of the technology, access to credit by relaxing households' liquidity constraints, and access to information are among the factors that influence farmers' adoption process in Sub-Saharan Africa. In addition, socio-economic characteristics such as age, gender, education, household size, land holding and wealth are also important determinants in the adoption of new technologies (Doss et al., 2003; Moser and Barrett, 2005; Salasya et al., 2007; Legese et al., 2009; Kaguongo et al., 2011; Johannes et al., 2010; Salasya et al., 2010; Derwisch et al., 2011; Mugisha and Diiro, 2010; Feleke and Zegeye, 2006).

Other studies have pointed out that farm size, farmer's learning abilities, mostly through social networks or extension contacts, observed and unobserved differences among farmers as well as across farming systems, and farmers' perception of new technologies are factors that explain the adoption of new technologies by farmers in developing countries (Kafle, 2010; Suri, 2011; Muzari et al., 2012; Jackson and Watts, 2002).

Furthermore, other studies have revealed that farmers with more land may have easier access to new technologies and the capacity to bear risk in case of technology failure (Johannes et al., 2010; Feder et al., 1985; Nkonya et al., 1997). In addition, farmers with more education generally know more about the new technologies. Thus, they can efficiently evaluate and interpret the advantages and the disadvantages of the new technology (Wozniak, 1984).

The age of the farmer plays also an important role in the adoption of new technologies. However, the effect of age on the use of new technology is ambiguous. On the one hand, the literature suggests that as farmers get older they become more conservative and less open to new ideas. On the other hand, it is also argued that they gain more experience and they are more able to evaluate the benefits of new technologies (Johannes et al., 2010; Voh, 1982)

The existing literature on technology adoption has found a positive correlation between the use of improved maize varieties and high productivity, high yields and profitability (Johannes et al., 2010; Salasya et al., 2007; Derwisch et al., 2011; Mugisha and Diiro, 2010; Kudi et al., 2011; De Groote et al., 2011). However, in their study on the maize green revolution in Kenya, De Groote et al. (2005) argued that the increase in yields was mainly due to the use of fertilizer. The use of improved maize varieties did not affect yields. Their results imply that in some areas, farmers using local varieties can still do as well as those using improved varieties without fertilizers.

The use of improved varieties of maize has also been associated with poverty reduction and food security (Johannes et al., 2010; Mwambu et al., 2008). Based on their results, these scholars argued that the extension of high yielding varieties of maize in regions with high poverty constitutes an important strategy for poverty reduction and food security.

METHODOLOGY

THEORETICAL FRAMEWORK

Generally, due to the binary aspect of the dependent variable in technology adoption studies, Probit or Logit models are the most widely used depending on the distribution function chosen for the stochastic term. To determine the effect of adoption on yields or area cultivated, the simple Tobit model has been used by many researchers (De Groote et al., 2005; Kaliba et al., 2000). The Tobit model is the censoring model applied to the linear model with normal residuals. However, it may be the case that the censoring variable is different from the variable of interest itself but still correlated with it. In the case of adoption, the error term in the selection equation may be correlated with the error term in the outcome model.

Furthermore, studies using the simple Tobit model ignore the consequence of missing farmer records that may result from data cleaning done by those collecting the data, farmer unwillingness to provide data, or farmers self-selecting into or out of the survey or study which may lead to sample selection problem. Other studies have used the Heckman selection model (Mohammed et al., 2012), hurdle and double hurdle models (Legese et al., 2009) for the same purpose.

All the econometric models mentioned above have used cross sectional data and analyzed the adoption of modern agricultural technologies at a particular time. However, the data set used in this study covers a period of five years. In other words, information on the use of improved seeds by farmers was collected for a period of five years. In order to analyze the adoption of a technology over time, models that capture the potential interdependence between adoption decisions are required.

In order to capture the interdependence between the adoption decisions during the period under study (2002-2006), a multivariate probit (MVP) model is used in this study. The use of a multivariate probit model allows us to simultaneously capture the effect of explanatory variables in each of the different times, while allowing for the potential unobserved factors to be freely correlated (Teklewold et al., 2013). In addition, it allows the estimation of the joint probability of adopting improved maize varieties by farmers who did not adopt them in the first year (2002) of the study as well as the joint probability of continuing or discontinuing the use of improved maize varieties by farmers who did adopt in the first year.

Furthermore, in order to examine the relation between adoption and the change in the area allocated to improved maize varieties, a panel data model is used. The choice of a panel model is justified by the nature of the data used in this study. Although the data set was collected in 2007, each farmer was asked to provide information on the use of improved seed for the last five years (2002 – 2006). This gives the collected data a panel structure. In addition, it allows capturing the variation or the change in the area under maize cultivation over time.

This study assumes that the decisions to adopt new maize varieties were correlated over time. Almost all farmers who used improved varieties in the first year did not discontinue using them. In other words, the joint probability for farmers to discontinue using improved seeds is very low. Furthermore, many farmers who did not use improved seeds in the first year, may be due to liquidity constraints or risk aversion, had the opportunity to use them over time. However, we expect that the joint probability of not adopting improved varieties by a farmer during the five years of the study period (2002 to 2006) to be very low.

As far as the determinants of the adoption of improved maize varieties are concerned, the study assumes, as in most of these types of studies, that farmers' decision to adopt improved maize varieties depends on their socio-economic characteristics and the identifiable characteristics of the technologies (Doss et al., 2003; Kaguongo et al., 2011).

THE MULTIVARIATE PROBIT MODEL

We follow Teklewold et al. (2013) and Cappellari and Jenkins (2006) to model the individual adoption decision: Consider the i^{th} farmer $(i = 1, \dots \dots, N)$facing a decision to adopt or not adopt the available technology. Let U_0be the benefits from the use of traditional maize variety andU_1 the benefits from the adoption of the improved maize variety. A farmer will choose the improved maize variety if his/her net benefit(Y_i^*) is greater than zero,$Y_i^* = U_1 - U_0 > 0$. Where $Y_i^*$is a latent variable determined by observed farmer socio-economic and farm characteristics (X_i) as well as by unobserved characteristics (ε_i). Then,

$Y_{im}^* = X_{im}^{'}\beta_m + \varepsilon_{im} for m = 1, \dots, M$(1)

Where m represents the total number of equations in the multivariate probit model. In the case of this study *m* = 5, representing the adoption decision of improved maize varieties in the five years. The unobserved preferences from equation (1) can be expressed as observed binary outcomes equation for each period, using the indicator function, as follows:

$Y_{im} = 1\ if Y_m^* > 0\ and\ 0\ otherwise$(2)

The error terms ε_m , $(m = 1, \dots, M)$ are distributed as multivariate normal, each with a mean zero, and variance–covariance matrix Ω, where Ωhas values of 1 on the leading diagonal, for identification of the parameters, and correlations $\rho_{jk} = \rho_{kj}$ as off-diagonal elements for $j, k = 1, \dots, M$ and $j \neq k$ (Capillary and Jenkins, 2006).

The probabilities of adopting improved maize varieties are obtained by evaluating the multiple integrals, using numerical methods (Gedikoglu, 2013, Cameron and Trivedi, 2005).The probability of adopting improved maize varieties during all the years or outcomes is:

$\int_{-\infty}^{X_1\beta_1}\int_{-\infty}^{X_2\beta_2}\dots\dots\int_{-\infty}^{X_M\beta_M} \emptyset(\varepsilon_1\varepsilon_2, \dots\dots\dots, \varepsilon_M)d\varepsilon_1 d\varepsilon_2, \dots\dots d\varepsilon_M$(3)

PANEL DATA MODEL

We used the panel model to examine the relation between the adoption of improved maize varieties and the area expansion. The use of this model is justified by the panel aspect of the data set and the fact that the study aims to capture the change in area under maize cultivation over time. Following Dutsman and Rocina-Barrachina (2007), the panel model can be expressed as:

$\Delta A_{it} = X_{it}\beta + \alpha_i + \varepsilon_{it};\ i = 1, \dots, N;\ \ t = 1, \dots\dots, T$, (4)

$d_{it}^* = Z_{it}\gamma + \eta_i + \mu_{it};\ d_{it} = [d_{it}^* > 0]$ (5)

WhereΔA_{it}represents the change in area under maize cultivation from year (t)to year (t-1), β and γ arethe parameters to be estimated.$X_{it}$and$Z_{it}$are vectors of time variant (age of the household head, amount of seeds planted and maize production per hectare) and time invariant (gender of the household head, marital status, whether or not farmer belongs to farmer association) covariates respectively. Time variant covariates include the age of the household head, the amount of seedplanted and production per hectare. In addition,d_{it} is an indicator factor which is equal to 1 if $d_{it}^* > 0$ and 0 otherwise.In case of this study, d_{it}isequal to 1 if a farmer adopted the improved variety and 0 if he/she did not.

DATA AND SOURCE

The data used in this study is part of the data collected by the International Maize and Wheat Improvement Center

Table 1.Descriptive statistics of variables used in estimation.

	Description	Mean	Std Dev.
Adopt	Dummy,1= adopted improved maize, 0 = did not adopt	0.24	0.41
Gender	Dummy for Gender, 1= male, 0 = female	0.47	0.49
Age	Age of the household head	46.55	16.13
Married	Dummy for marital status, 1= married, 0 = not married	0.96	0.2
Education	Dummy for education of the household head, 1=secondary school, 0 = other	0.08	0.28
Famer	Dummy, 1= the farmer belongs to the farmers' association, 0=not	0.34	0.47
Seeds	Amount of seeds purchased (Kg)	11.31	9.62
Area	Area under improved maize	0.85	0.76
Yields	Maize yields (Kg/ha)	1105	1108
Drought	Dummy, 1= if the choice of improved maize is based drought resistant, 0 = other	0.11	0.32

Table 1 Cont.

Drought2001	Dummy, 1= If the farmer faced severe drought before 2002, 0 = not	0.19	0.39
Drought2002	Dummy, 1= If the farmer faced severe drought before 2003, 0 = not	0.12	0.33
Drought 2003	Dummy, 1= If the farmer faced severe drought before 2004, 0 = not	0.23	0.41
Drought 2004	Dummy, 1= If the farmer faced severe drought before 2005, 0 = not	0.14	0.3
Yield potential	Dummy, 1= if the choice of improved maize is based on yield potential, 0 = other	0.85	0.36
Drought risk	Dummy for drought risk perception,1= high 0 = low	0.14	0.34
Number of observations		300	

Source: Author's computation from CIMMYT data in 2007.

(CIMMYT) through the Drought Tolerant Maize for Africa (DTMA) initiative. This initiative joins the efforts of people, organization and projects supporting the development and dissemination of drought tolerant maize in 13 Sub-Saharan African countries (Erenstein et al., 2011). The purpose of the initiative is to decrease hunger and increase food and income security of resource-poor farm families in Sub-Saharan Africa through the development and dissemination of drought tolerant, well-adapted maize varieties. The data was collected in 2007; however, the survey asked farmers to provide the information on the adoption of improved seed and the different varieties used for the last five years.

This study uses the data collected from farmers' surveys in the eastern province of Kenya. The eastern province consists of 9 districts, from which the districts of Machakos and Makweni were chosen. From the two selected drought-prone maize-producing districts, a multi-stage random sample of farm households was selected with a number of random villages. Six villages (Muisuni, Kangondo, Kikabuani, Kawethei, Kakuyuni and Kivaani) in Machakos and 10 villages (Wathu, Mukuyuni, Kyasini, Iuani,Makongo, Kilala, Kiuva, Utaati, Kithunthi and NduuNdune) in Makweni were selected first, and from these, a random sample of 175 farmers was taken in each district (Muhammad et al., 2010; Erenstein et al., 2011), resulting in a total sample of 350 farmers in 2007.

Due to missing information from some respondents, 50 observations were dropped from the original sample. Therefore, a sample of 300 farmers was used to address the study objectives in our analyses. Table 1 provides the descriptive statistics of the variables used in the empirical model. (Table 1)

On average, 24% of the respondents adopted at least one improved maize variety during the five years, 47% were males, and the average age was 47 years. In addition 96% of the respondents were married, 8% had post-secondary school education, 34% were members of farmers' associations, and the average area under maize cultivation was 0.8 hectares. Eleven percent of the resp-

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Number of observations		300	

Table 1 Cont.

Source: Author's computation from CIMMYT data in 2007.

ondents chose improved seeds because they resist drought and 85% used them because of potential high yields. Furthermore, 19% of the respondents suffered from severe drought in 2001, 12% in 2002, 23% in 2003 and 14% in 2004. Given that the data set does not contain information on access to credit,this study usedthe amount of seed purchased by farmersas a proxy for liquidity constraints.In addition, the variable size of the household is not used in this study because it was available only for 2006.

RESULTS

The results from the multivariate probit estimation are presented in tables 2, 3 and 4. The estimated results for the impact of the adoption of improved maize varieties are reported in table 5.

The estimated coefficients in table 2 show that the age of the household head is negatively correlated with the propensity to use improved maize varie-

Table 2.Multivariate probit estimation results of the adoption of improved maize.

Dependent variable :Adoption of new maize varieties (1= yes,0 = no)	2002		2003		2004		2005		2006	
	Coef	**Robust Sdr. Err**	**Coef**	**Robust Sdr. Err**	**Coef**	**Robust Sdr. Err**	**Coef**	**Robust Sdr. Err**	**Coef**	**Robust Sdr. Err**
Gender	.052	.165	.165	.183	.511**	.230	-.062	.174	.218	.185
Age	-.03**	.005	-.005	.006	-.018*	.007	-.027**	.005	-.072**	.006
Married	.168	.449	-.178	.399	-.523	.501	-.291	.411	-.580	.448
Education	.433**	.213	.569**	.298	.788**	.349	.475	.294	.809*	.278
Famer's association (1= yes, 0 = no)	.03	.212	.372**	.184	.304**	.014	.541*	.200	.311**	.113
Seed (in kg)ᵀ	-.006	.004	.032**	.015	.079*	.019	.011***	.006	.045*	.013
Yield lag	-	-	.0017**	.0005	.005***	.0003	.007***	.0003	.007**	.0003
Area	-.161**	.078	.006	.098	-.089	.190	.118	.096	.074	.066
Drought resistant	.495	.575	1.02***	.579	1.754*	.652	.182	.509	1.196**	.501
Drought risk	-.192	.272	.194	.261	.342	.277	.412	.279	.273	.281

Table 2 Cont.

Yield potential	.826	.515	-.123	.396	-.248	.410	.349	.399	-.082	.372
Drought in 2001	.242**	.104	.498***	.234	.758*	.285	-.086	.227	.064	.263
Drought in 2002			.529**	.256	.106	.294	-.199	.241	-.299	.270
Drought in 2003					.678**	.263	.460***	.215	.386***	.122
Drought in 2004							.715**	.238	.473***	.217
Constant	-1.51**	.728	-.692	.608	.655**	.292	-.493	.650	.639*	.308
Observations	300		300		300		300		300	

*,**, and*** denotes significance at 1%, 5% and 10%, respectively
ᵀ Amount of seeds purchased by the farmer.

Table 3.Correlation Matrix of farmers' adoption decision between years.

	2002	2003	2004	2005	2006
2002	1.00				
2003	.855	1.00			
	(.0505)				
2004	.7854	.877	1.00		
	(.141)	(.069)			
2005	.770	.6795	.792	1.00	
	(.097)	(.080)	(.087)		
2006	.673	.612	.721	.815	1.00
	(.123)	(.084)	(.071)	(.050)	

Standard errors in parentheses.

ties during all the study period. In contrast, more educated farmers and those who were members of farmers' associations were more likely to adopt new maize varieties. These findings corroborate with the findings by earlier studies (Johannes et al., 2010; Voh, 1982; Wozniak suggests, 1984; Langyintuo and Mekuria, 2008; Abunga et al., 2012). As farmers get older, they become conservative and less likely to adopt improved technologies. In addition, farmers with more education are able to evaluate the advantages and the disadvantages of new technologies. Furthermore, as members of an organization, farmers can learn more about the new technology through interpersonal communication with peers and group leaders, and extension services. They can also participate in farm demonstrations and field days. Through the association farmers get technical and financial supports that increase their ability to access seeds and use them efficiently.

In Eastern Kenya, the Cereal Growers Association (CGA) in partnership with the Kenyan Maize Development Program (KMDP) has been providing many services to its members such as facilitating group action in input procurement, access to extension, marketing of their produce, and access to credit. Through extension services, the association has facilitated technology transfer through demonstration and field days. Besides the CGA, there is also the Producer Marketing Group (PMG) that helps members get better prices for their products and access to inputs, and helps them develop business skills (Shiferaw, Obare, and Muricho, 2006). As a result, the knowledge gained from this network increases farmers' propensity to adopt new technologies (Suri, 2011).

Furthermore, results in table 2 suggest that farmers who had access to more improved seeds and those who had good yields in the previous year were more likely to adopt new maize varieties in the following years. The access to more improved seed is used as a proxy for access to cash or credit in this study. Therefore, farmers without liquidity constraints are more likely to use new technologies. In addition, good yields in the previous year can encourage farmers to use more improved seeds in the following year. These findings support the findings by earlier scholars (Langyintuo and Mekuria, 2008; Legese et al., 2009; Abunga et al., 2012; Kudi et al., 2011).

Farmers who chose maize varieties for their resistance to drought, in addition to yield improvement, were more likely to adopt improved maize varieties. Even though the estimated coefficients in some of the years were not statistically significant, their signs were positive as expected. Since the area under study is a drought prone area, a positive relation between the adoption and the drought resistant aspect of the maize variety was expected. In addition, the sign of the estimated coefficients related to drought risk were as expected even if the coefficients across all the years were not statistically significant. Furthermore, farmers who affirmed having severe drought in the past years were more likely to adopt improved seeds.

However, surprisingly, although 85% of the respondents chose new maize varieties due to their potential to increase yields, none of the coefficients related to this variablewere statistically significant. In addition, in some years the estimated coefficients were negative. This result may explain why some farmers did discontinue the use of these varieties perhaps because they were not satisfied with the yields. Furthermore, all the correlations coefficients in table 3 are positive and statistically significant. These results indicate thatfarmers'decision to adopt new maize varieties in the next year was correlated with the decision in the previous year.In addition, the results confirm the choice of the multivariate probit model and the assumption about the interdependence between the adoption decisions over time(Table 3).

For example, the correlation coefficient of 0.855 indic-

Table 4.Joint probabilities of farmers' adoption decision over time.

	Adoption of new maize varieties in year					
	2002	**2003**	**2004**	**2005**	**2006**	**Probability**
A	1	1	1	1	1	.19
B	1	1	1	1	0	0.013
C	1	1	1	0	0	0.003
D	1	1	0	0	0	.0.02
E	1	0	0	0	0	.0003
F	1	1	0	1	1	0.003
G	0	1	1	1	1	0.01
H	0	0	1	1	1	0.02
I	1	1	0	0	1	0.003
J	0	0	0	1	1	0.06
K	0	0	0	0	1	0.07
L	0	0	0	0	0	0.603

Adopt = 1 and not adopt = 0

Table 5.Estimated results of the impact of the adoption of new maize variety on area expansion.

Dependent variable : Change in Area under maize production		
Variables	Coef.	Robust Std. Err
Gender of the HH. Head[a] (1= male,0 = female)	.115	.192
Age of the HH. Head	-.007	.006
Marital status (1 = Married,0 = Single)	-.303***	.176
Education of the HH. Head	.693	.501
HH member of farmer Ass. (1= yes, 0 = no)	.168	.109
Amount seeds purchased (Kg)	.028*	.001
Production per hectare (kg)	0.064**	.002
Drought resistant (1= yes,0 = no)	.246	.306
Yield potential	.348	.247
Drought risk	-.214**	.108
Inverse mill ratio	.283	.079
Constant	.275	.283
Observations [b]	69	

*, **, and*** denotes significance at 1%, 5% and 10%, respectively
[a]: HH: Household
[b]: Only farmers who adopted improved maize

atesthatfarmers' decision to adopt improved maize in 2003 was influenced by the results realized or obtained in 2002. As stated above, many studies on technology adoption have analyzed the determinants of technology adoption in general and the adoption of improved maize in particular at the same point of time or using cross sectional data. One of the main goals of this study was to analyze improved maize adoption over time.Table 4 contains the different joint probabilities on the adoption of improved maize over the period under study.

Based on the results in table 4, the joint probability of adopting the improved varieties by farmers in all the five years was 19%. Based on the overall sample, this implies that only 57 farmers over 300 in the sample did use improved maize varieties during all the five years. However, based on 70 farmers who used improved seeds in the first year, 81.42% used the improved varieties during all the period under study. The joint probability for not adopting during all the period under study was 60.33%. This implies that 181 farmers over 300 in the sample did not use improved maize varieties during all the period under study. Based on 230 farmers who did not used improved maize in the first year, the results imply that 78.6% of farmers did not used improved maize in all five years. These results contradict our expectations about famers' adoption behaviors over time. In addition, the findings on the low rate of adoption confirm the findings by earlier scholars (Bett et al., 2006; Muhammad et al., 2010).

Equations (4) and (5) were estimated by the Wooldridge method (Dutsman and Rachina-Barrachina, 2007). Results in table 5 indicate that the change in area allocated to improved maize varieties was positively correlated with the increase in seeds purchased and production per hectare. This result can be explained by the fact that farmers with more cash and less liquidity constraint are able to buy more seeds and allocate more land to new varieties than those with serious liquidity constraints. In addition, farmers who were satisfied with the higher yields allocated more land to improved seeds.

Farmers who were members of a farming association increased the area allocated to new varieties more than the non members. In fact, being a member of a farming association allows farmers to learn more about the new varieties from their peers or association leaders. In addition, members can get technical and financial supports from the group as well as easier access to inputs and outputs markets. As a consequence, they can be motivated to allocate more land to new varieties in order to produce more.

In contrast, the results in table 5 show that farmers with higher risk perception of drought have decreased the farming area under maize compared to those with low risk. In fact, Machakos and Makueni are part of the drought prone region of eastern Kenya. From the CIMMYT survey, drought was one of the major threats for maize producers in this part of Kenya. This may explain why farmers who have suffered from severe drought in recent years have reduced the area allocated to new maize varieties even if some of these varieties are drought resistant. (Table 5).

CONCLUSION

The low agricultural productivity in Sub-Saharan African countries has been a focus of many governments and non-governmental world organizations. For decades, these institutions have been diffusing and promoting new agricultural technologies and high yielding crop varieties to help farmers increase their production and stabilize yields. However, in many regions the overall rate of adoption remains low.

The purpose of this study was to analyze the adoption of improved maize varieties over time as well as the impact of the adoption of these improved varieties on the area expansion in the drought prone region of eastern Kenya.

Using data collected by CIMMYT in the district of Machakos and Makueni in Eastern Kenya, the empirical results indicate that the age of the household head was negatively correlated with the propensity to use improved maize varieties. However, more educated farmers, those who belong to farmers' associations, farmers who had access to seeds, and thosewho had good yields in the previous year, were more likely to adopt new maize varieties. In addition, both farmers who chose improved maize varieties due to their resistance to drought andfarmers who suffered from severe drought in the past years were more likely to adopt new maize varieties.

Less than 20% of famers used improved maize varieties during all five years. Thus, we should think of ways to increase attention. Sixty percent did not use them at all, and 21% used them for one or more years and then discontinued. The study also found a positive correlation between access to improved seeds, production per hectare, and increase in area allocated to new maize varieties. In addition, farmers who were members of a farming association increased their area under maize cultivation. In contrast, farmers with high risk perception of drought have decreased their area allocated to new maize varieties compared to those with low drought risk perception.

The results on the low adoption rate of improved maize varieties in this part of Kenya found in this study are similar to the results found by Bett et al. (2006) and Muhammad et al. (2010). A study by Bett et al. (2006) revealed that the adoption of improved maize varieties has been very low in arid and semi-arid land of eastern Kenya despite the high number of improved varieties released in that part of the country. In addition, Muhammad et al. (2010) found that despite the efforts dedicated to the promotion of high yielding varieties over the last four decades, the adoption of improved maize has been very low in the eastern province of Kenya.

The low rate of adoption of improved maize varieties in this part of Kenya can be attributed to poverty, poor infrastructure and markets, low selling prices, and liquidity constraints. Households do not have access to credit due to lack of collateral, lack of credit facilities in the vicinities, distance to the source of credit, and lack of knowledge about sources of credits (Muhammad et al., 2010).

In order for government, NGOs and other development organizations to help rural households in this part of the eastern province of Kenya, it is important to invest more in roads to facilitate farmers' access to markets and reduce transportation costs. In addition, government and development organizations have to develop plans, strategies and mechanisms to help households access to inputs and outputs markets, reduce the interference of middlemen, and get access to agricultural credits in order to stimulate the adoption of improved seeds.

Although the results from this study cannot be generalized to Kenya or to the entire African continent, the high percentage of farmers who did not adopt the new maize varieties and those who discontinued using them in subsequent years must be a concern for researchers and all parties involved in the promotion and the diffusion of new agricultural technologies in this part of Kenya in particular and the Sub-Saharan Africa in general. Future studies and research can investigate the adoption in other parts of the continent where new farming technologies in general and high yielding crop varieties have been introduced. However, the adoption rate and the agricultural productivity are still very low.

Finally, besides exploring the risk and liquidity constraints as causes, more studies should focus on the determinants of non-adoption of new farming technologies and reasons why some farmers have discontinued using them. If liquidity constraint is the major problem as mentioned in several studies on technology adoption in Sub-Saharan Africa, governments, donors, researchers and other development agencies may need to devise new plans and strategies, based on the socio-economic realities of Sub-Saharan African countries, in order to implement and restore the financial markets in rural areas.

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