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Socioeconomic determinants of hybrid maize adoption in Kenya

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Kenya has increasingly relied on modern agricultural technology to increase productivity since land extensification is no longer a feasible option to satisfy national food demands. Hybrid maize varieties have been one of the more successful technologies developed, responsible for dramatic yield increases in the developed world since World War II and more recently as an integral part of the Green Revolution. The purpose of this paper is to investigate the factors that affect the adoption of hybrid maize varieties in Kenya. A household survey was conducted to collect data on demographic and socioeconomic factors, as well as to elicit farmers' perceptions of the agronomic and consumption benefits of hybrid maize compared to open pollinated varieties. Using econometric (discrete choice) models, results showed that farmers' perceive that hybrid maize provides significant benefits in obtaining higher yields, but are less effective protecting against drought. Several other demographic and socioeconomic variables also had positive effects on hybrid maize adoption including access to modern farm equipment, distance to market, age, gender, education level and occupation of the household head. As Kenya and other African countries look to biotechnology as a means to increase productivity, the seed industry will need to continue finding ways to develop genetically modified maize to improve drought protection.

Key words: Hybrid maize, adoption, open pollinated variety, farmer's preference, Kenya.

INTRODUCTION

Maize is the most important staple food in Kenya, accounting for 65% of total staple food caloric intake and 36% of total food caloric intake (Ariga et al., 2010). However, domestic maize production is not keeping pace with the growth in national demand for maize. Imported maize has been increasingly filling the gaps left by insufficient domestic production, approaching an average of one million metric tonnes in an average year.

Land extensification and advanced agricultural technologies are two main paths to increase crop yields. With the supply of arable soil suitable for maize production exhausted by population pressure, Kenya will increasingly rely on modern agricultural technology to increase productivity since land extensification is no longer a feasible option to satisfy national food demands.

One of the most important methods to enhance maize

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productivity is to use improved maize varieties. In 1908, George H. Shull published a paper “The composition of a field of maize”, considered as the beginning of the exploitation of hybrid in maize breeding. By crossing inbred lines, hybrid maize varieties provide more stable and higher yield than randomly mated varieties, which are the open-pollinated varieties (OPV) (Crow, 1998). Transitioning from OPV to hybrid maize, however, requires a fundamental shift in farming. Producers become reliant on external seed sources and technological support. Agronomic conditions need to be properly maintained, which typically requires modern farming techniques compared to the traditional practices used on OPV. In the U.S., when hybrid maize became commercially available, some farmers were reluctant to adopt them initially. Demonstration plantings and field observations proved the worth of the hybrids. The demand for hybrid seed in 1935 in the Corn Belt exceeded production, and the hybrid seed industry developed rapidly (USDA, 1962) and has remained an integral part of the U.S. maize industry and its’ far reaching success in increasing maize yields.

In Kenya, and throughout the developing world, extending the use of hybrid maize varieties has been further challenged by a cultural attachment to OPV forged through generations of growing OPV varieties. The taste, color, texture and other consumption preferences are unique to local OPV and studies have documented the greater implicit value that households attach to OPV compared to hybrids. Such intrinsic value continues to make Kenyan farmers more reluctant to adopt improved maize varieties.

To increase hybrid maize adoption and its sustained use, it is critical to comprehend the factors determining adoption choice. Adoption studies investigate seek to identify factors significantly linked to the use and diffusion of new technology such as hybrid maize varieties and over the past few decades have become legion in the development literature (Kebede et al., 1990; Adesina and Zinnah, 1993; Adesina and Baidu-Forson, 1995; Chilot, 1996; Ouma et al., 2002; Doss 2003, 2006; Mignouna et al., 2010; Smale and Olwande, 2014). Although a variety of factors have been identified explaining patterns of initial adoption, long term use, and re-adoption of hybrid maize varieties, because of cultural, agronomic, natural resources, political, and socioeconomic differences, it is difficult to generalize those factors affecting significantly the adoption of new crop varieties, either within or between countries (Ouma et al., 2002; Wekesa et al., 2003; Mignouna et al., 2010; Smale and Olwande, 2014).

Findings from several adoption studies in Kenya highlight the transient nature of hybrid maize use and diffusion. In the Embu district of Kenya, Ouma et al. (2002) found that gender is the most influential factor determining hybrid maize use, given that men have a 55% higher probability than women of adopting improved maize varieties,. In addition to gender, access to labor, availability and application of organic fertilizers (manure), and on-site extension visits also have positive influence on the adoption of hybrid maize in Embu. However, other factors including access to credit use, education, age of household head, and farm size have no significant influence on decision-making.

Wekesa et al. (2003), in the coastal lowlands of Kenya, identified a rather different set of factors linked to hybrid maize adoption that suggest that producers place a large emphasis on the economic performance of hybrid maize. Liquidity- the availability of cash and short-term credit to purchase production inputs- was the most important factor for adoption of new maize production technologies. Household income (and presumably wealth) had a negative effect on adoption, as households with substantial sources of off-farm income were less likely to adopt new maize varieties than households engaged only in agriculture. Moreover, the higher cost of the hybrid maize varieties had a negative effect on its adoption, with farmers in coastal lowlands often opting to grow open pollinated varieties due to their lower cost. The poorly developed seed markets also had a negative effect on hybrid maize adoption, including limited hybrid seed supplies, the high cost of hybrid maize seeds, and the lack of extension and training needed required to successfully produce hybrid maize. A handful of other factors had a positive effect on hybrid maize adoption, including increased productivity (higher yields, larger cob sizes, more cobs per maize plant) and better grain filling than OPV maize.

A recent study made by Mignouna et al. (2010) on the adoption of *Imazapyr*-resistant maize (IRM), an improved maize variety that has strong resistance to *Striga* infestation in western Kenya, indicated that that age of the household head had a positive influence on IRM adoption. Mignouna et al. (2010) results run counter to most previous research on the adoption of not only hybrid maize, but of new agricultural technology in general (fertilizer, irrigation, animal traction, etc). The case of IRM stands out since older farmers have accumulated experiences from decades of maize cultivation, particularly *Striga* infestation, which made a significant difference between past technologies used for its control and the IRM variety. Farmers with more formal schooling were found to be more technically efficient than less formally schooled producers, indicating that farmers with more formal education respond willingly to the new technology and produce closer to the frontier of production possibilities.

Smale and Olwande (2014) investigated the long-run change in hybrid maize adoption on smallholder farms on Kenya given the substantial number of producers that grew hybrid maize for several years before returning back to OPV. Using the Tobit model it was detected that the gender of the household head had a significant effect on hybrid maize adoption. Female headship reduced the extent of hybrid seed use significantly compared to similar households led by a male patriarch. Unlike previous studies, neither education level of the household head nor labor size (family size) appears to influence the amount of hybrid seed planted among smallholder maize growers. Farm size (acreage) has a positive and significant relationship on the extent of hybrid maize seed demand, but its magnitude (explanatory power) was not large due to most of the households pursuing other production activities. Household wealth also had a highly significant effect on hybrid adoption.

Recent research by Schroeder et al. (2013) confirms findings from several previous adoption studies. The low hybrid maize adoption rates observed in their survey was explained by the lack of information and poor infrastructure found in the study area. There was an overall lack of awareness of newly released hybrid varieties, a lack of hybrid varieties adapted to the rather harsh agroecological conditions local marginal areas, a lack of confidence in the quality of some hybrid maize seeds, poor access to shop, low profitability due to high seed cost and high transportation costs, inadequate access to credit, and a generally low literacy level among heads of household.

Similar results have been found in other parts of Africa. Improved maize varieties adoption research in Southwest Nigeria found that age of the farmers had a negative effect on the adoption of improved maize varieties, whereas positive effects were identified for household size and education (Lawal et al., 2004). The negative effect of age on hybrid adoption is the more typical result as younger farmers appear more capable and willing to change and adopt technology innovations than older ones. Household size and education had a positive, significant effect on improved maize varieties adoption. The positive effect of household size and adoption were explained as larger households having a larger number of working members and will be more capable to withstand the increased level of risk and unintended consequences that are typically associated with the adopting technology innovations. Similarly, education provides an individual with a border formal intellectual horizon and can often enable farmers to better evaluate new information when deciding on the adoption of improved crop varieties.

The overall objective of this study is to determine the factors that significantly affect the adoption of improved maize varieties in Kenya. Specific objectives of this research are to: (1) Identify the preferences that Kenya maize producers have when selecting maize varieties; (2) Identify the preference differences between OPV maize adopters and hybrid maize adopters; (3) Quantify the valuations of maize characteristics across all farmers; estimate the weights of factors that influence the hybrid maize adoption; and (4) Identify factors that have a significant effect explaining the adoption and use of hybrid maize versus OPV maize.

The research presented in this paper is expected to contribute to the development of literature by providing a contemporary perspective on the status of hybrid use and choice among smallholder farmers. Although the study site is in Kenya, findings are expected to be of broader interest throughout East Africa and sub-Saharan Africa. Findings from this study will also be of interest to the Kenyan agribusiness community. Hybrid seed companies will have an updated adoption profile to assist in future breeding efforts to satisfy the needs and wants of Kenyan maize producers. Input providers can identify bottlenecks and other constraints found from the household interviews.

Maize in Kenya

Maize was first introduced in Kenya by Arab traders, and appeared in exhibitions at the first Agricultural Show in Nairobi in 1902 (Karanja, 1990). By 1903, maize covered about 20% of the total food crop area in Kenya (Meinertzhagen, 1957). In the early years, even though the crop was widely adopted by African farmers, commercial market outlets were weak, relegating maize to a subsistence crop. The first opportunity for Kenya farmers to increase maize production beyond subsistence levels came in 1942, when the colonial government enacted an increased production of crops by ordinance. This ordinance mobilized the farmers to increase production of all food crops, particularly maize, to feed troops and personnel during the Second World War (Karanja, 1996). In the aftermath of World War II, maize became more popular in Trans-Nzoia district; half of the large-scale farms in that area had begun to grew maize by 1964, the year first conventional hybrids were commercially released (Gerhart, 1975).The first hybrid maize seed H611, was commercially released in 1964 (Karanja, 1990). Between 1964 and 1990, a total of 18 hybrid maize varieties were released (Johnson, 1980; Karanja, 1996). Studies from CIMMYT (International Maize and Wheat Improvement Center) indicated that, based on seed sales, an estimated 62% of maize area was planted to hybrids in 1990 and 1996, and reach 68% by 2006 (Hassan et al., 2001; Langyintuo et al., 2008; López-Pereira and Morris, 1994). Now, most improved maize seed grown by farmers in Kenya is hybrid maize, as compared to a small amount of open pollinated varieties (OPV) maize.

Kenya’s national maize production has doubled over the past fifty years (1963-2012), from around 1.5 million metric tons to slightly over 3.0 million metric tons (Figure 1). Those substantial gains in maize production and efforts to increase per-capita maize consumption were eroded by an even larger increase in Kenya’s population, which more than doubled during that same time period (1963-2012) increased more than fivefold from 8.91 million in 1963 to 42.5 million in 2012 (World Bank 2016), Kenya’s rapid population growth reduced per-capita maize production and stimulated staple food imports,

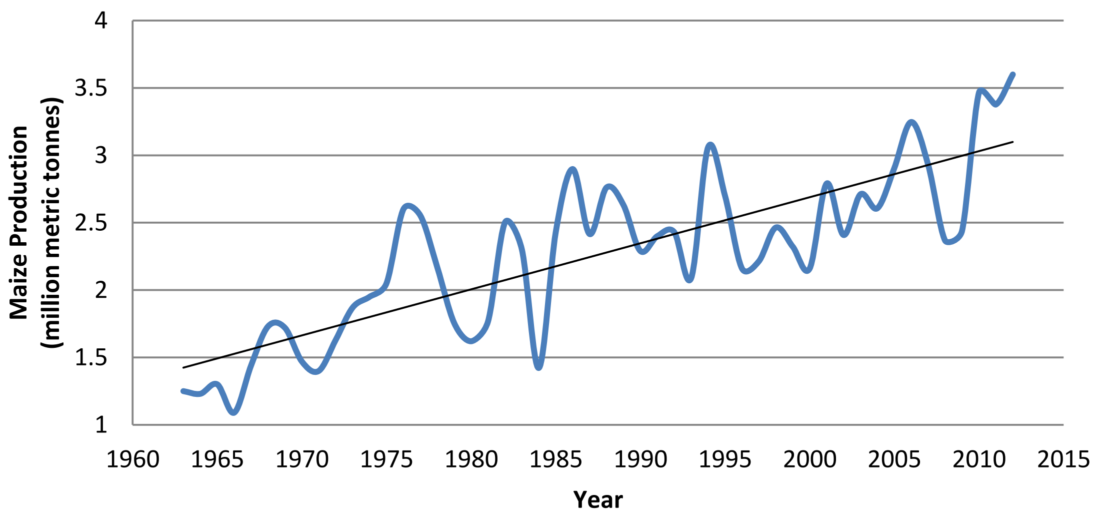

Figure 1. Maize production in Kenya for the last 50 years (1963~2012) (Source: FAO).

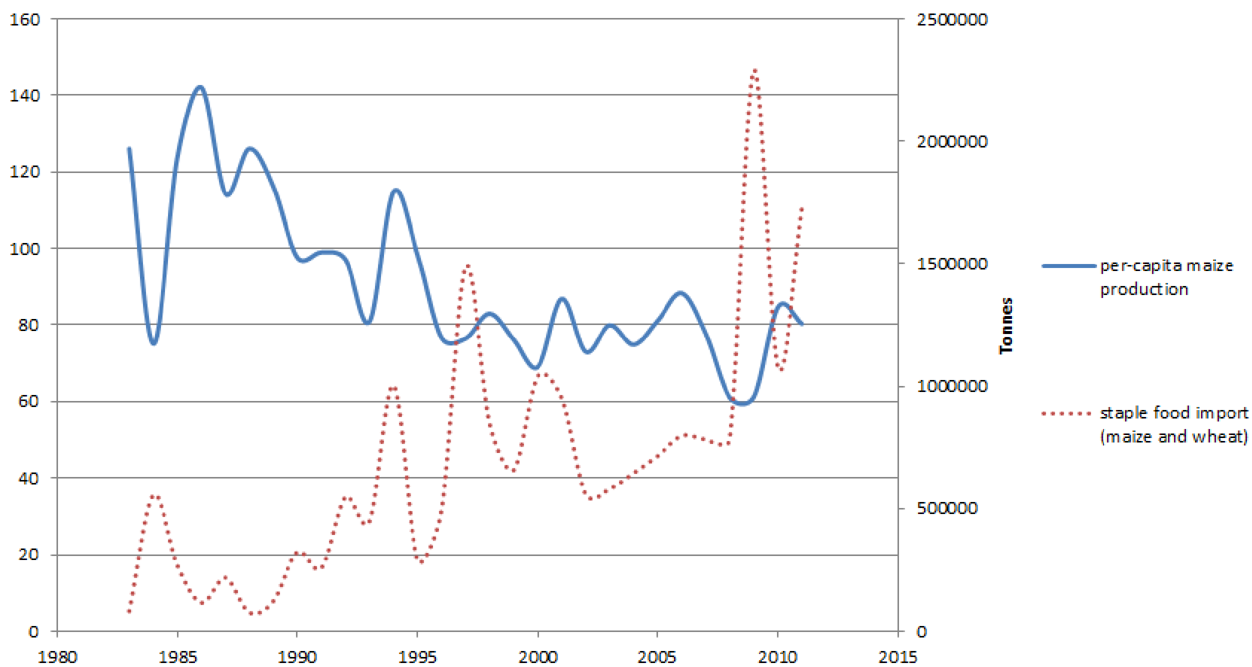

Figure 2. Per-capita maize production and staple food import for last 30 years (1983~2012) (Source: FAO and World Bank).

particularly over the past three decades (1983-2012) when maize productivity began to stagnate (Figure 2). It is hence necessary to revitalize agricultural productivity to satisfy the staple food needs of Kenya's growing population.

METHODS

Three steps were needed in order to determine which factors affect the adoption of improved maize varieties in Kenya. In the first step, a field survey instrument was developed and primary data was collected from on-farm site visits. In the second step, an empirical model was constructed using statistically rigorous econometric models. In the third step, significant variables were identified from the model results using statistical testing and compared to prior expectations and results from similar adoption studies.

Data

The surveys were conducted in eight different districts in Kenya across Kenya's two primary maize producing provinces, The Rift

Figure 3. Sample regions in Kenya.

Valley and Eastern (Figure 3). The Rift Valley Province surveys were obtained from the Trans Nzoiat, Kwanza, Wareng, and Eldoret districts, and the Eastern Province included the Yatta, Machakos, Maara, and Uasin Gishu. A total of 444 farmers were randomly selected based on each region's population density. This resulted in 199 farm surveys from the Eastern province and 245 farm surveys from the Rift Valley province.

A field survey questionnaire was developed to elicit maize farmers' preferences for hybrid maize versus OPV and to collect other data hypothesized as potentially linked to hybrid maize adoption. Four main parts were included in the field survey: (1) Socioeconomic status for head of household; (2) agronomic and production attributes of the farm; (3) farmers' preferences for hybrid versus OPV maize varieties; and (4) miscellaneous variables (extension, distance to roads, etc). Field survey questions are listed in Table 1.

Empirical model

Many studies of new technology adoption have used a logit model to identify adoption patterns and trends among a sample of producers (Schmidt and Strauss, 1975; Garcia et al., 1983; Kebede et al., 1989; Gabriel and Rosenthal, 1989; Yahanse et al., 1990; Polson and Spencer, 1991; Salalsya et al., 1996). The logit model can assess various factors that affect adoption of a given technology while providing predicted probabilities of new technology adoption. For example, the logit model can be used to

Table 1. Variable used in producer survey questionaire.

Variable	Definition	Response levels
Household head		
Age	Age of the household head.	Years
Gender	Gender of the household head.	Male = 1; Female = 0
Education	Education level of the household head.	No schooling = 0; Primary = 1; Secondary = 2; College = 3; University = 4
Occupation	Primary occupation of the household head.	Farmer = 1; Other = 0
Farm		
Household size	Number of persons in the household.	Integer number
Farm acreage	Total acreage of farm.	Acres
Preferences		
Early maturity	How early does the hybrid varieties mature compared to OPV?	Much earlier = -2; Earlier = -1; Same = 0; Later = 1; Much later = 2
Drought escape	How much drought escape does hybrid maize provide in below normal rainfall compared to OPV maize?	
Drought tolerance	How much drought tolerance does hybrid maize provide in years of below normal rainfall compared to OPV maize?	
Pest resistance	How resistant to pests is hybrid maize compared to OPV maize?	
Disease resistance	How resistant is hybrid maize to diseases compared to OPV maize?	Much worse = -2; Worse = -1; Same = 0
Yield potential	How well does the hybrid maize yield compared to OPV maize?	Better = 1; Much better = 2
Taste of green maize	How is the taste of green maize of hybrid maize compared to OPV maize?	
Taste of dry maize	How is the taste of dry maize of hybrid variety compared to OPV maize?	
Texture	How is the texture of maize of hybrid variety compared to OPV maize?	
Other		
Market distance	Distance to the nearest market.	Kilometers
Extension visits	Times extension officer visits in a typical year.	Integer number
Credit	Whether or not credit is used to purchase hybrid maize seed	Yes = 1; No = 0
Drought effect	Whether or not drought adversely affected maize crop	Yes = 1; No = 0
Preparation technique	Energy source for land preparation.	Human = 1; Oxen = 2; Machinery = 3

Kenyan farmers use both the metric and the English system.

indicate how the likelihood (probability) of a family adopting a particular technology changes according to the age of household head, keeping all other factors constant in the model. Profiles based on the likelihood of adoption provide a more realistic and useful metric since it generates information about the relative importance of each factor influencing adoption. Traditional econometric approaches test for statistical significance of individual factors but cannot readily assess their relative importance.

Logit model with binary response

Even though the binary response logit model has some limitations when applied to this type of research, it provides an initial basis for comparing among more elaborate discrete choice models considered as follows.

Liner Regression Model (LRM):

$$Y_i = \alpha + \sum_{i=1}^{k} \beta X_i + \varepsilon_i, \qquad \varepsilon_i \sim N(0, \sigma^2). \qquad (1)$$

Instead of modeling the linear relationship between the original dependent variable Y_i and the independent variables X_i, a discrete choice model analyzes the probability of a discrete event occurring, noted as Y_i=1, which can be explained by independent variables, X_i. Discrete choice models estimate a specific class of functions, probability functions, so that probabilities of the discrete values can be obtained. Many probability functions exist. One of the more suitable functions of this type is the logistic function, which assumes in particular that:

$$\pi_i = P(Y_i = 1|X_i) = F_{logit}\left(\alpha + \sum_{i=1}^{k} \beta X_i\right) = \frac{\exp\left(\alpha + \sum_{i=1}^{k} \beta X_i\right)}{1+\exp\left(\alpha + \sum_{i=1}^{k} \beta X_i\right)} \quad (2)$$

Where π_i represents the probability the Y_i=1 at a household *i*, P represents the probability that Y_i=1 given the vector of household adopt hybrid varieties, F_{logit} is the cumulative standard logistic distribution function, and β are the parameters from LRM. Hence, the probability that a household *does not* adopt hybrid maize can be expressed as:

$$1 - \pi_i = P(Y_i = 0|X_i) = \frac{1}{1+exp(\alpha+\sum_{i=1}^{k} \beta X_i)} \quad (3)$$

From Equations 2 and 3, the following is obtained:

$$Ln(\frac{\pi_i}{1-\pi_i}) = \alpha + \sum_{i=1}^{k} \beta X_i \quad (4)$$

Where the ratio $\frac{\pi_i}{1-\pi_i}$ is that Y=1, which corresponds to the ratio of the predictor in this linear logit response function.

Logit model with ordinal response

Due to the high expected adoption rate for hybrid maize varieties (>80%) in the study area the probability for $Y_i = 1$ is much higher than $Y_i = 0$ in the binary response logit model. It is thus more practical to assume farmers' adoption behavior has more than two levels. Under these more general conditions the polytomous logit model is more suitable than binary logit model since its structure can contain more than two discrete levels (Kutner et al., 2008). Farmers were separated into three groups based on their maize variety adoption behavior:

$$Y_i = \begin{cases} 1 & if\ household\ only\ adopted\ OPV\ variety\ (j = 1) \\ 2 & if\ household\ partly\ adopted\ hybrid\ variety\ (j = 2) \\ 3 & if\ the\ household\ only\ adopted\ hybrid\ variety\ (j = 3) \end{cases}$$

A polytomous logit model has two forms: An ordinal response model and a nominal response model. In the research, farmers' adoption response is from no hybrid maize at all to partly adopt hybrid maize, then to fully adopt hybrid maize. Therefore is an order among those response levels. If dependent variables are ordered rather than arbitrary, then the ordinal logit model should be used (Kutner et al., 2008). Which means the cumulative probability P (Y ≤ j) will instead the specific category probabilities P (Y = j) in the logit model. Then the proportional odds model was adopted:

$$P(Y_i \le j|X_i) = \frac{exp\left(\alpha_j+\sum_{i=1}^{k} \beta X_i\right)}{1+exp(\alpha_j+\sum_{i=1}^{k} \beta X_i)} \quad (5)$$

According to Green (2002) and Kutner et al. (2008), one of the assumptions underlying ordinal logit regression is that the relationship between each pair of response categories is the same. In other words, ordinal logit regression assumes that the coefficients that describe the relationship between, in this case, group 2 (partly grew hybrid maize) versus group 1 (only grew OPV maize) of the response variables are the same as group 3 (only grew hybrid maize) versus group 2. The ordinal logit function for adoption level j can be expressed as:

$$Ln(\frac{P(Y_i \le j|X_i)}{1-P(Y_i \le j|X_i)}) = \alpha_j + \sum_{i=1}^{k} \beta X_i \quad (6)$$

The final logit regression model format as follows:

$$Ln\left(\frac{\pi_i}{1-\pi_i}\right) = \alpha_j + \sum X_i + \varepsilon \quad (7)$$

Where, $\pi_i = P(Y_i \le j|X_i)$, the probability one household *i* response to adoption level j or lower; α_j = intercepts; X_i = independent variables (shows in the end of this chapter); ε = error term.

Parameter explanation for logit model

As discussed previously, the predictor of logit model is a natural logarithm for the ratio of odds that one event occurs ($\widehat{odds}1$), as a result, the interpretation of the estimated coefficient b_i would be the exponential odds ratio. For example, consider the value of the fitted logit response function for X= x' :

$$Ln(\widehat{odds}1) = \alpha + bx' \quad (8)$$

And for X = x' + 1:

$$Ln(\widehat{odds}2) = \alpha + b(x' + 1) \quad (9)$$

Therefore,

$$Ln(\widehat{odds}2) - Ln(\widehat{odds}1) = Ln\left(\frac{\widehat{odds}2}{\widehat{odds}1}\right) = b \quad (10)$$

Hence, the estimate odds ratio can be exhibited as:

$$\widehat{OR} = \frac{\widehat{odds}2}{\widehat{odds}1} = \exp(b) \quad (11)$$

Variable description

This variable that were included in the survey as well as their expected effect according to economic theory was discussed here. The survey variables were selected based on those included in previous research, as well as several new variables related to agronomic constraints (disease, pest, weather, etc) that have taken on new meaning with the emergence of genetically modified crops.

Demographic and socioeconomic variables

The age and gender of the household head (Age and Gender variables) were included in the survey and econometric model since the household head is the primary decision maker and previous research has identified age and gender as having a significant effect on variety choices (Table 2) (Smale et al., 2001; Stella et al., 2001; Ouma et al., 2002). The expected sign for age and gender variables is, however, difficult to predict *a priori*. Literature has found both positive and negative effects of age (Smale et al., 2001; Ouma et al., 2002).

The Education variable quantifies the education of the household head, the presumed decision maker. Education can be quantified in many different forms. In this research, only formal schooling is counted towards education; knowledge gained through actual farming is proxied by other variables such as age and access to agricultural extension. Formal education provides access to literacy, which has played a significant role in the adoption of agricultural technology (Doss, 2003; Lawal et al., 2004). Education often improves producers' ability to comprehend and internalize the innovations and subsequent impact of new technology on household welfare. Hence, the expected sign for this variable is

Table 2. List of independent variables and expected signs used in the econometric model.

	Variable	Expected sign
X_1	WP (weighted preference for maize varieties)	+
X_2	Age_middle $= \begin{cases} 1 & \text{for age household head over 40} \\ 0 & \text{otherwise} \end{cases}$	±
X_3	Age_older $= \begin{cases} 1 & \text{for age household head over 55} \\ 0 & \text{otherwise} \end{cases}$	±
X_4	Gender $= \begin{cases} 1 & \text{for male} \\ 0 & \text{for female} \end{cases}$	±
X_5	Edu_1 $= \begin{cases} 1 & \text{for education level of household head higher than primary} \\ 0 & \text{otherwise} \end{cases}$	+
X_6	Edu_2 $= \begin{cases} 1 & \text{for education level of household head higher than secondary} \\ 0 & \text{otherwise} \end{cases}$	+
X_7	Edu_3 $= \begin{cases} 1 & \text{for education level of household head higher than college} \\ 0 & \text{otherwise} \end{cases}$	+
X_8	Household size	+
X_9	Occupation	+
X_{10}	Farm acreage	+
X_{11}	Credit	+
X_{12}	Market distance	-
X_{13}	Extension visits	+
X_{14}	Drought effect	-
X_{15}	Preparation technique	+

positive. The relationship between education and choice may not be linear, that is, the effect of each level of education is not expected to be the same. For instance, the difference between three years of education in primary school is expected to have a lower effect on the likelihood of adopting improved technologies compared to three years of post-graduate work (Greene, 2002). To include the non-linear effects of higher levels of education, the education variable was placed in a category format so that each category would have an independent effect on variety choice, that is, act as a dummy variable.

The variable “Occupation” is included in the model to determine whether off-farm employment or other income sources for the household head has a significant effect on variety choice. If the household head has an occupation other than farming, their motivation to adopt hybrid variety may decrease. The expected sign for farming as primary occupation of the household head is hence positive (Kebede. et al., 1990; Smale et al., 2001; Wekesa et al., 2003).

The “Household size” variable is a measure of household labor availability for farming. Labor is an essential input for agricultural production. One feature of agricultural production is the uneven demand for labor, since conditions such as seasonal events, natural hazards, pest infestations, and crop variety may change the demand for labor. Farmers may choose not to adopt varieties that would require more intensive management practices and hence additional labor than the household can supply (Doss, 2003). A larger “household size” provides greater potential for labor supply, so its expected sign is positive.

The “farm acreage” and “preparation source” variables are proxy measures of the resource endowment and wealth of the household. Wealth can affect adoption decisions for several reasons, primarily because wealthy households have greater access to resources, more capacity to adopt a new variety, and greater ability to absorb financial risk. Larger farms have greater ability to absorb production risk. The expected sign for both “farm acreage” and “preparation source” are positive (Kebede et al., 1990; Smale and Olwander, 2012).

The “Credit” variable was included since adopting new technology such as hybrid varieties requires pre-planting expenditures that many households struggle to self-finance. This variable is difficult to measure correctly since it is difficult to distinguish farmers who choose not to use credit and the farmers who are not able to access credit. According to previous research, credit use usually has a significant positive effect on improved variety adoption (Smale et al., 2001; Wekesa et al., 2003).

The “Market distance” is included as a proxy measure of market access. Since the market is the place to purchase inputs and sell outputs, households with more convenient and less costly access to a market would have a greater potential level of adoption, holding constant all other factors. Hence, the expected sign for “Market distance” is negative (Salasya et al., 1998).

The “Extension visits” variable is a proxy-measure of access to information on new agricultural technologies. Extension service has been considered an important means of technology dissemination in agriculture, particularly in remote areas where communication is difficult. Farmers will likely not adopt new crop variety unless they are familiar with how the new technologies perform and how are produced. Theoretically, the number of extension officer visits should have a positive effect on new variety adoption, so the expected sign is positive (Salasya et al., 1998; Smale et al., 2001; Ouma et al., 2002; Ouma et al., 2006).

The two drought effect variables (“Drought escape” and “Drought tolerance”) can be considered as proxy measures for producers concerns for drought and the stress that high heat and low soil moisture place on plant development. Adequate rainfall is a necessary factor for successful agricultural development since it enables higher productivity crops such as maize, so it was assumed that drought has more effect in the drier and less developed Eastern. The expected sign for the drought effect variables also depends on whether farmers perceive the hybrid maize variety as providing greater protection against drought than OPV. Hence, producers in the drier Eastern Province would have a positive sign if hybrids are drought tolerant, whereas Rift Valley producers would likely have the opposite sign since drought tolerant varieties are typically underperform in normal to above average rainfall conditions.

Preferences

The household surveys asked producers for their stated preferences comparing hybrid maize to OPV. Varietal preferences were measured in nine categories: Drought escape, drought tolerance, pest resistance, disease resistance, early maturity, yield potential, taste of green maize, taste of dry maize, and texture. Responses to each of the nine categories indicate how producers evaluate hybrid maize performance relative to OPV maize production and consumption attributes. As shown in Table 1, varietal preferences were partitioned into 5 levels, that is, Likert scales, from -2 to +2. If the value is positive, the farmer indicated that hybrid maize has better performance for this category, while a negative number indicates the farmer considered that OPV maize has better performance than hybrid maize.

An aggregate variable for producers' stated preferences was derived from the nine preference variables. Weights for each of the variables were used to develop a single overall aggregate measure of producers' stated preference for hybrid varieties. Attaching weights to each of the preference variables is necessary since farmers have individual attitudes on the importance of each maize characteristic. For example, some farmers may attach great importance to yield performance while others may place greater emphasis on taste when making decisions. Without weights, the nine maize characteristics would have been equally weighted across all farmers, an unrealistic assumption.

Weights for each of the nine characteristics were obtained from the producers during the survey. Producers ranked the importance of the characteristics using an ordinal ranking from 1 to 9. Producers were instructed to follow an ordinal ranking criteria among the nine categories, that is, number 1 indicates the most important (highest weighted) category and number 9 the least important (lowest weighted) category. Producers often placed multiple characteristics in the same level resulting in substantial number of "ties". There were also numerous instances where producers had no response to one or more of the variables. These three producers well document the two data collection issues that arose during the surveys, namely instances of "ties" among categories and categories for which producers did not respond.
In order to keep consistency, the ordinal rankings were adjusted according to the following pair of assumptions:

1. "Tie" ranking indicates that the two (or more) characteristics have the same weight for this farmer;
2. "N/A" and the blank response means the farmer would not consider this characteristic at all when they adopt maize varieties, thus they were considered as "0".

There is an alternative method to make the assumption 2: Consider the blank responses as the least important category for that farmer, which means fill the "N/A" responses with the largest ranking number plus one. The weights will be different, but analysis of this alternative indicated that the ranking and the logit model results were consistent with one another so the less cumbersome method, assuming zero weight, was chosen.
Based on the assumptions, generalizing the weight across all farmers requires the following three steps:

Step 1: Replace the "N/A" or "0" responses with positive infinity (a large positive number) to approximate a zero weight on the ordinal ranking. A new set of rankings is obtained that does not contain any missing/undefined attributes (Table 3).
Step 2: Generalize the ranking numbers. The formula for generalizing the ranking numbers is specified as:

$$\beta_{ij} = \frac{X_{ij}^{'}}{\sum X_{ij}} \quad (12)$$

Where: β_{ij} = generalized ranking number for household i response to characteristic j; $X_{ij}^{'}$ = ranking number for household i response to characteristic j from modified data. X_{ij} = ranking number for household i response to characteristic j from original data.
Step 3: Generalize the weight. The formula for generalizing the weights is specified as:

$$W_{ij} = \frac{\exp(-\beta_{ij} X_{ij}^{'})}{\sum \exp(-\beta_{ij} X_{ij}^{'})} \quad (13)$$

Where: W_{ij} = generalized weight for household i response to maize characteristic j; β_{ij} = generalized ranking number for household i response to maize characteristic j; $X_{ij}^{'}$ = ranking number for household i response to maize characteristic j from modified data.
Finally, the new variable weighted preference was formed:

$$WP_i = \sum W_{ij} P_{ij} \quad (14)$$

Where: WP_i = weighted preference for household i; W_{ij} = weight for household i response to maize characteristic j; P_{ij} = maize characteristic j for household i.

RESULTS AND DISSCUSSION

Summary statistics of data

Based on the different combinations of maize varieties grown on the surveyed farms, households were divided into three groups, corresponding to producers who grew: Only OPV maize, both OPV and hybrid maize, and only hybrid maize (Table 3). The average age of household head in the sample is 48.95 (Table 3). The mean value of the binary variable gender was 86%, meaning that 86% of the households were headed by males (Table 3). Hybrid maize adopters had on average a higher level of education, 1.6, compared to the OPV-only farmers, whose level averaged 1.29 (Table 3). Even though hybrid maize adopters had a higher level of education, the average education levels for all the three groups was 1.56, about midway between primary and secondary school (Table 3). Over half of the household heads had an occupation of farming, with an average of 59% across all three groups (Table 3). There was an increasing trend for the gender variable across the three groups, from 0.73 in the OPV-only group to 0.91 in the hybrid-only group (Table 3).

Household size was largest for the hybrid-only group, 6.29 persons, but there was no significant difference when compared to the other groups (Table 3). Producers who grew both varieties of maize had an average household size of 5.79 persons and the OPV-only group had an average size of 5.28 persons (Table 3).

The mean acreage for each group is 2.04 acres for OPV-only, 4.73 acres for both, and 6.20 acres for hybrid-only. Similarly, land preparation technique value was significantly larger for hybrid-only households (2.39) than

Table 3. Demographic and socioeconomic variables for different adoption groups.

Groups	OPV-only (Obs 41)		Grow-both (Obs 114)		Hybrid-only (Obs 289)		Total (Obs 444)		t-test for significant difference(P value)		
Variables	**Mean**	**Std Dev**	**Mean**	**Std Dev**	**Mean**	**Std Dev**	**Mean**	**Std Dev**	**OPV-onlyversus Grow-both**	**OPV-only versus Hybrid-only**	**Grow-bothversus Hybrid-only**
Household head:											
Age	48.83	14.92	52.05	12.01	47.73	15.05	48.95	14.41	0.171	0.663	0.007
Gender	0.73	0.45	0.8	0.4	0.91	0.28	0.86	0.34	0.451	0.001	0.001
Education	1.29	0.64	1.53	0.77	1.6	0.85	1.56	0.82	0.086	0.024	0.404
Occupation	0.51	0.51	0.64	0.48	0.59	0.49	0.59	0.49	0.152	0.358	0.337
Farm:											
Household size	5.28	1.77	5.79	2.63	6.29	3.03	6.07	2.85	0.253	0.039	0.122
Farm acreage	2.04	1.78	4.73	10.25	6.2	12.06	5.44	11.1	0.103	0.028	0.251
Other:											
Credit	0	0	0.08	0.27	0.02	0.14	0.03	0.18	0.064	0.353	0.005
Market distance	4.82	4.64	4.28	4.78	6.8	8.56	5.97	7.52	0.534	0.148	0.003
Extension visits	5.2	9.5	5.67	10.39	2.99	7.07	3.87	8.33	0.802	0.077	0.003
Drought effect	0.95	0.22	0.9	0.3	0.57	0.5	0.69	0.46	0.282	<0.001	<0.001
Preparation technique	1.5	0.6	1.76	0.61	2.39	0.79	2.15	0.8	0.009	<0.001	<0.001

for households that grow-both and for OPV-only households (Table 3).

The data shows that very few households use credit, with an average of 3% across all groups (Table 3). The OPV-only group, as expected, did not use any credit (Table 3). On average, OPV-only and grow-both group are closer to market than the hybrid-only group (Table 3). The survey also shows that mean number of extension visits for the hybrid-only group (2.39) is much lower than for the Grow-both (5.67) and OPV-only (5.2) groups (Table 3). The negative influence for drought is much lower for the hybrid-only group (57%) than the other two groups, with the greatest concern among OPV-only (95%). The mean value of land preparation technique for grow hybrid maize group is 2.36, which indicates a majority of families using oxen for land preparation and a smaller proportion using machinery. The mean values for OPV-only and grow-both household are 1.50 and 1.76, with 0.60 and 0.61 standard deviations respectively, indicating that most families in those two groups use oxen and human for land preparation.

Hybrid variety performance

Hybrid varieties performed better, according to producers' subjective evaluation, in all of the categories except "Drought escape" (Table 4). Substantially greater performance was found in both the overall sample, as well as within each of the three producer groups. Moreover, there is a noticeable increasing trend across the three groups (going from left to right in Table 4) in nearly all (seven out of nine) of the categories, which confirms prior expectations that hybrid-only farmers believe hybrids perform much better than OPV (Table 4). In the subcategory preferences, the larger the absolute value, the larger the gap the household believed existed between hybrids and OPV (Table 4). The most significant gap is "yield potential" (1.48), the second largest is found within the "texture", while the smallest gap is within the "drought escape" variable (-0.10).

Weighted preference (WP) was calculated using Equation 14. After weighting, the preference is transformed into a continuous variable with a range from -2 to 2. The average WP for total sample is 0.87, which means in general, maize

Table 4. Subcategories preferences and weighted preference for different adoption groups.

Groups	OPV-only(Obs 41)		Grow-both(Obs 114)		Hybrid-only(Obs 289)		Total(Obs 444)	
Preferences	**Mean**	**Std Dev**	**Mean**	**Std Dev**	**Mean**	**Std Dev**	**Mean**	**Std Dev**
Drought escape	-0.07	1.08	-0.26	1.10	-0.04	1.19	-0.10	1.16
Drought tolerance	0.02	1.17	0.13	1.21	0.49	1.09	0.35	1.14
Pest resistance	0.05	0.96	0.26	1.01	0.70	0.92	0.53	0.98
Disease resistance	0.12	0.98	0.30	1.03	0.70	0.94	0.54	0.99
Early maturity	-0.02	1.23	0.40	1.05	0.48	1.09	0.41	1.10
Yield potential	0.95	0.94	1.36	0.76	1.61	0.54	1.48	0.68
Taste of green maize	0.22	0.97	0.11	1.12	0.69	1.06	0.50	1.10
Taste of dry maize	0.15	1.09	0.18	1.16	0.74	1.09	0.54	1.14
Texture	0.79	0.70	0.79	0.70	1.05	0.75	0.96	0.74
Weighted preference	0.32	0.63	0.61	0.67	1.05	0.57	0.87	0.66

Preferences were partitioned into 5 levels from -2 to 2. If the value is positive, a farmer indicated that hybrid maize has better performance for a subcategory.

Table 5. Generalized weights (average) and ranking for different groups households.

Groups	OPV-only(Obs 41)		Grow-both(Obs 114)		Hybrid-only(Obs 289)		Total(Obs 444)	
Characteristics	**Weight (%)**	**Ranking**	**Weight (%)**	**Ranking**	**Weight (%)**	**Ranking**	**Weight (%)**	**Ranking**
Yield potential	25.13	1	32.28	1	44.64	1	39.66	1
Early maturity	14.82	4	16.36	3	13.52	2	14.37	2
Drought escape	14.93	3	14.02	4	9.44	5	11.33	3
Drought resistance	17.86	2	16.63	2	7.27	6	10.66	4
Disease resistance	7.66	5	7.09	5	12.10	3	10.40	5
Pest resistance	7.06	6	6.76	6	10.21	4	9.03	6
Taste of green maize	5.76	7	3.14	7	1.49	7	2.31	7
Taste of dry maize	4.03	8	2.28	8	0.77	8	1.46	8
Texture	2.75	9	1.42	9	0.54	9	0.97	9

producing households consider hybrid maize performs slightly better than OPV maize (Table 4). The greater performance of hybrids is more apparent when compared across the three groups. The hybrid-only group has the most favorable preference of hybrids, with a weighted preference of 1.05, which is 40% larger than producers who grow-both OPV and hybrids, 0.61, and the OPV-only group, whose WP was 0.32 (Table 4).

Yield potential accounts for the largest weight for all three producer groups (Table 5). The importance of yield potential is most apparent within the hybrid-only group, where it accounts for almost 45% of the total weight (Table 5). The average weights for early maturity, drought escape, drought resistance, disease resistance and pest resistance are almost identical (a range from 9 to 14%). The least important characteristics of maize were those related to consumption: Taste of green maize, taste of dry maize, and the texture of the maize when made into *ugali*, a corn meal with the consistency of mashed potatoes that is the staple dish of Kenya. The ranking of these three consumption related characteristics is consistent across all three groups (Table 5). The lack of importance of maize as a consumption good is particularly noteworthy. The survey results indicate that households place more value on growing a maize variety with stronger agronomic performance rather than for its role as a staple food. This result suggest that rural households are more market oriented than in the past, perhaps signaling a long-term shift towards more commercialization in the maize sector. Moreover, the OPV-only group places a larger weight on the last three characteristics (11.54% total) than the Grow-both group (6.84% total) and hybrid-only group (2.8% total).

Model results

Maximum likelihood estimation results for the ordinal logit model were obtained using the SAS PROC Model statement. The logit model provides a modestly good fit to the data with a log likelihood value of -280 and nine out of seventeen variables statistically significant (P<0.05).

Table 6. The result of the model for factors affecting choosing maize varieties.

Variable	Coefficients	Standard Error	Pr > |z|	Odds ratio
Weighted preference	1.051	0.192	0.000***	2.859
Preparation technique	0.729	0.172	0.000***	2.073
Drought effect	-1.148	0.368	0.002***	0.317
Occupation	0.430	0.252	0.088*	1.538
Market distance	0.057	0.024	0.020**	1.058
Gender	0.650	0.324	0.045**	1.915
Age_middle	-0.553	0.312	0.076*	0.575
Age_older	0.352	0.280	0.208	
Edu_1	-0.475	0.489	0.332	
Edu_2	-0.040	0.260	0.879	
Edu_3	0.776	0.448	0.084*	2.172
Household size	0.041	0.045	0.364	
Farm acreage	0.026	0.020	0.199	
Credit	-0.306	0.566	0.589	
Extension visits	-0.010	0.013	0.421	
Intercept 2	-1.494	0.753	0.047*	
Intercept 1	0.666	0.747	0.373	
Log Likelihood	-280			
Obs	432			

This model is based on Ordinal logit model regression with dependent variable; * significant at the 10% level, ** significant at the 5% level, *** significant at the 1% level. 12 observations were deleted due to missing values or exceptional survey response.

The odds ratio change is not as straight forward to interpret as the probability change, which is given by the coefficients estimated in linear probability model. However, according to Maddala (1983), dividing the logit coefficients by 4 gives an approximation of the linear probability coefficients.

The weighted preference (WP) is one of the most significant and influential variables in the model (Table 6). According to Maddala (1983), the WP coefficient of 1.051 indicates that, holding other conditions constant, a one-unit increase in WP increases, the probability for one household to reach a higher adoption level (that is, OPV-only to grow-both, or grow-both to hybrid-only) will increase by 26% (Table 6). The WP variable is a combination of nine preferences about maize characteristics and their associated weights. The weight of maize performance characteristics indicated that yield potential account for almost 40% of the total weight (Table 5), and yield potential is the most outstanding performance characteristic for hybrid varieties compared to OPV (Table 4). The results suggest, hence, that yield potential is highly influential in the maize variety selection process.

Land preparation technique is one of the two most significant variables (*P*<0.0001), along with WP, in the Logit model (Table 6). Significance of the land preparation variable implies that households who use oxen or tractor to prepare the farmland, rather than by manual means (hand-n-hoe), have a higher probability of adopting a hybrid. Since land preparation is a proxy to family wealth and resource holdings, the significance of land preparation also implies that richer households have a greater probability to have adopted hybrid maize varieties. The positive effect of wealth on hybrid adoption is consistent with the findings from Smale and Olwande (2014).

Drought effect was significant in the model (*P*<0.01; Table 6) with a negative effect on hybrid maize adoption. Climate has a significant impact on Kenyan maize production, which explains why hybrid maize adoption rate is lower in the area where drought is more prevalent. Household survey data shows found that hybrid maize adoption rate is 99% in Rift Valley Province and 80% in Eastern Province. These results suggest, therefore, that existing hybrid maize varieties marketed in the drought-prone areas have no significant yield advantage, compared to OPV maize, in drought prone years. With improved breeding for drought resistance, and holding all else constant in the model, hybrid maize adoption rate would be expected to increase. The statistical data confirmed this implication. The total sample mean value for drought tolerance is 0.35 and for drought escape is -0.1 (Table 4). This indicated on average, farmers considered current hybrid maize varieties performed slightly better than OPV on drought tolerance but perform worse by a substantially greater amount on drought escape.

Market distance is the only significant variable in the model whose effect (sign on the coefficient) was contrary to prior expectations (Table 6). The relationship between market distance and hybrid maize adoption is expected to be negative because closer market proximity should reduce cost and enable greater access to market information. The estimated coefficient of the Market distance variable is 0.056 can be explained as indicating that a one-mile increase in distance to market increases the probability of reaching a higher level of adoption by approximately 1.4% (Table 6). The most reasonable explanation for this unexpected result is that the smaller, less affluent farms are located closer to towns where markets are located while the relatively wealthier farms adopting hybrid live further away from the towns in more quasi-suburban settings. Producers close to markets are also more likely to specialize in higher valued crops such as fruits and vegetables, while producers farther away from markets would be more likely to grow lower-valued crops such as maize. Those conditions would create a positive effect for Market distance though opposite to prior expectations.

The gender variable's significant positive sign in the ordinal logit model ($p<0.05$; Table 6) means that male-headed households were more willing to adopt hybrid maize. This confirmed the conclusions made by Ouma et al. (2002), Smale and Olwande (2014). Female maize farmers are likely to be more concerned with satisfying household consumption needs than male counterparts who would be more likely engaged in commercial farming.

The dummy variable "age_middle" was significant ($p<0.1$; Table 6) and negatively related with hybrid maize adoption response in the ordinal model, indicating that middle-age household heads were more reluctant to adopt hybrid maize. However, due to the low confidence level and insignificance of the variable "age_older", it is not safe to draw the conclusion that age always has a significant influence on maize varieties adoption. In fact, the influences of age were mixed in former studies. For example, it was significantly positive in the research of *Imazapyr*-resistant maize adoption in Kenya (Mignouna et al., 2010), and was significantly negative in the Southwest Nigeria study (Lawal et al., 2004), in some other cases, it was not significant at all (Ouma et al., 2002; Ouma et al., 2006).

From the results, household education level for primary (Edu_1) and secondary (Edu_2) are not significant, but college and higher education (Edu_3) level was significant ($P<0.1$) and had a positive effect in the model (Table 6). More formally educated farmers have developed a greater preference for hybrid seed and likely have greater access to purchased seed and are more likely to maintain the improved agronomic conditions required for improved seed. This result concurs with a research on adoption of maize production technologies in the coastal lowlands of Kenya which also found formal education had a positive effect on hybrid adoption (Wekesa et al., 2003).

The Occupation variable is significant in the model ($P<0.01$; Table 6). According to this result, if the primary occupation of the household head is farming, the household is more likely to adopt hybrid maize. One possible explanation is that farm households could have a greater willingness and feel more confident to adopt a new technology such as hybrid maize than households where farming occupies at best a secondary role in securing household welfare. Ordinarily, if the household head has a profession other than agriculture, then household has off-farm income. Therefore, the significantly positive sign for the Occupation variable can also explain that the odds for hybrid adoption will decrease if the households have off -farm income. This result confirmed the finding from Wekesa et al. (2003).

The variables household size, farm acreage, credit and extension visits were not statistical significant at any of the levels considered in this paper ($P>0.10$). However, a major benefit in logit modelling is that the model determines the relative importance of the independent variables to explain the dependent variable, whether the independent variables are significant or not (Ueckermann et al., 2008). Household size measures labor availability. Non-significant association indicates that labor adequacy is no longer a strong influence on improved seed adoption, a result that differs from former findings (Kebede et al., 1990; Ouma et al., 2002). Credit use was found to have great positive influence on new technology adoption in former research (Smale et al., 2001; Wekesa et al., 2003), but in this paper, credit use is not significant. On one hand, the sample size is comparably small: Among the 444 respondents, only 15 households claim to have used credit before. On the other hand, the distinction between credit used and credit accessibility is difficult to observe (Doss, 2003). The limited credit uses implies that access to credit may be a major constraint for households with low income to adopt hybrid varieties. The effect of extension visits is insignificant. This variable may have been affected by transportation, regional population density, and current adoption rate. Given that the mean extension visit time shown in Table 3 is 5.20 for OPV-only households, 5.67 for grow-both households and 2.99 for hybrid-only households, this may indicated that extension officers have little impact on hybrid maize adoption in recent years, and extension officers have low motivation to visit high adoption rate households.

Conclusions

In Africa, hybrid maize varieties will continue to play an important role in securing food needs for growing populations that are becoming affluent and demanding more food products. Hybrids are also expected to play an important role in the 21st century as Africa transforms its agriculture from the traditional land abundant agricultural paradigm to a new paradigm science-based under conditions of shrinking land and labor supply. The role of biotechnology will likely be significant and hybrids will be important players. Since developing Genetically Modified (GM) products is costly, with large fixed costs, the seed industry will likely need to make careful choices on which varieties to use as the platform GM plants. Hence, research such as presented in this paper provides valuable information for the industry as it begins planning for the GM product lines. Results from this paper suggest that the seed industry needs to continue monitoring household preferences for maize varieties across a broad spectrum of attributes. While technical merits of higher yields maintain a dominant role in hybrid maize popularity, it occupies less than half of the importance attached to hybrid maize performance. Attributes that could potentially be addressed through plant biotechnology breakthrough such as early maturity, drought escape, plant protection, and taste qualities occupy nearly equal shares. Such new developments will be are necessary since according to model results since OPV maize was found to perform better than hybrid maize in drought escape and taste. Therefore, maintaining and improving yield potential, and improving taste of green maize are the key for future maize variety development. Socioeconomic conditions were also found to have a significant effect on hybrid maize adoption. Farm households with presumably lower income and wealth, that is, those with less education, had a lower likelihood of adopting hybrid maize. Promoting the use of hybrid maize will hence require increased efforts to extend hybrid maize to households with less knowledge and trust of new technology. Similarly, given the near complete lack of credit in the study area, reducing the input costs and implementing credit contracts would likely vastly contribute to the future adoption of new maize varieties.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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