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Factors affecting the adoption of agricultural innovations on underutilized cereals: The case of finger millet among smallholder farmers in Kenya

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Agricultural innovation adoption is fundamental in increasing incomes and food output in developing countries. However, the factors that influence farmers' decisions to adopt innovations in underutilized crops are not well-documented. Underutilized crops like finger millet have been an alternative form of sustenance for resource-poor farmers especially in arid and semi-arid areas in Kenya. They are more nutritive and resilient to environmental extremes and harsh weather conditions than common crops like maize. The study presented sought to investigate factors that facilitate or impede the probability and level of use of different innovations (improved varieties, conservation tillage, integrated pest and weed management, and group marketing) on the production and marketing of these crops. A multi-stage sampling technique was used to survey 384 finger millet producers in Elgeyo-Marakwet County, Kenya. The study employed a multivariate probit to model simultaneously the interdependent adoption decisions of finger millet farmers and an ordered probit to determine the level of adoption. The results reveal that plot size, off/non-farm income, household credit, and extension contact positively influence the decision to adopt and the level of adoption. Technical training positively affects the level of adoption but negatively influences the probability of adopting some innovations. Awareness of these factors could allow the development of strategies, policies, and plans to increase the uptake and sustenance of agricultural innovations on the production and marketing of finger millet and could, consequently, contribute to the food security and incomes of finger millet farmers through enhanced productivity and marketing of the crop.

Key words: Agricultural innovations, adoption, underutilized cereals, smallholders, Kenya.

INTRODUCTION

The adoption of agricultural innovations is crucial to increase incomes and food output in developing countries

to meet the needs of the continuing growing population (Pingali, 2012).

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Following the dawn of the green revolution, strenuous efforts to increase the adoption of agricultural innovations, such as improved varieties for wheat, rice, and maize, chemicals, machinery, and irrigation among producers resulted in a significant increment in incomes and global food output (Adhikari et al., 2018) especially in the global North as well as in emerging economies in Asia (Toenniessen, et al., 2008). However, in practice, the approach also brought environmental issues, health and social problems, monoculture, and the growth of unsustainable farming systems (Yapa, 1993; Dawson et al., 2016). The successes and limitations of this approach have been subject to debates for several years, calling for more sustainable methods to increase food output and incomes. In this context, diversification toward underutilized crops and the adoption of environmentally sustainable practices has gained more attention, especially in developing regions like Sub-Saharan Africa (Mabhaudhi et al., 2016).

A major part of agricultural innovation research focuses on widely consumed and traded cereal crops such as rice, wheat, and maize (Ejeta, 2010; Godfray et al., 2010; Pingali, 2012; Gutti et al., 2018), while cereal crops important to African smallholders, commonly known as underutilized or orphan crops such as millet and sorghum, receive less attention (Tadele, 2014). Underutilized crops – like other crops – are classified into cereal crops such as millet and sorghum, legumes, root, and fruit crops (Tadele, 2009, 2014) and usually describe varieties that have long received little attention from farmers, consumers, scientists, and policy makers (Padulosi et al., 2013). Their cultivation used to be widespread in the past but was widely abandoned in favour of other – modern – crops today (Padulosi et al., 2002). Further, they are mostly not traded to a significant extent and, if so, only with a limited geographical reach (Naylor et al., 2004). In recent years, a strand of literature and strategies has emerged that promote particularly underutilized cereal crops including finger millet. It is argued that these could make an important contribution to food and nutritional security as well as to income generation to resource-poor farmers living in low productivity areas like the semi-arid climates of Sub-Saharan Africa for several reasons (Padulosi et al., 2013). These cereals are known to be more nutritious particularly in terms of increasing the supply of micronutrients (Tadele, 2014). Besides, they tend to be more resilient to poor or unpredictable agro-ecological conditions than commonly produced cereals such as maize, wheat, and rice (Tadele and Assefa, 2012). Despite their low adoption, underutilized crops therefore carry the potential to alleviate some of the most pressing issues in terms of food production in demanding agro-climatic conditions.

Nevertheless, underutilized crops are also attached to major bottlenecks: low yields and high labour requirements compared to other crops limit their productivity and

marketing (Naylor et al., 2004). For instance, in Kenya huge gap exists between the yield of millet and major cereal crops like maize, wheat and rice (Table 1). Environmental factors, such as pest, diseases, and weeds, contribute to a large loss in yield and, consequently, limited or no marketable surplus (Pingali, 2012). The feasibility of growing underutilized crops is, therefore, strongly bound to how they are produced and marketed. Acknowledging the niche potential and the importance of innovative measures in production, there is a significant rise in promoting the introduction and adoption of innovations in these crops (Walker and Alwang, 2015). For instance, locally administered organizations such as the International Research Crops Institute for the Arid and Semi-Arid Tropics (ICRISAT) established programs that involve farmers to develop improved varieties and increase sustainable agricultural practices for traditional crops including millets (Goron and Raizada, 2015). The promotion and adoption of innovations on these crops therefore are witnessed in most parts of unfavourable environments of Sub-Saharan Africa (Pingali, 2017).

In Kenya, numerous donor-funded organizations are fostering the development, dissemination, and adoption of various innovations in finger millet and other underutilized crops with the aim of diversifying household nutrition and incomes especially in semi-arid areas. For instance, the International Research Crops Institute for the Arid and Semi-Arid Tropics (ICRISAT) and the Kenya Agricultural Livestock Research Organization (KALRO) in collaboration with Egerton University as well as seven selected counties in arid and semi-arid areas in Kenya are currently promoting innovations on finger millet and other underutilized crops. These research organizations released seed varieties which have been proven on field trials and on-stations to be more productive and resistant to striga weeds and blast diseases compared to the local varieties (Oduori, 2005; Mgonja et al., 2013). Farmers are also encouraged to employ low-cost and environmentally friendly practices, including integrated pest and weed management and conservation tillage to control finger millet diseases and weeds as well as conserving water and soil. This is because most finger millet farmers are resource-constrained and live in marginal areas (Mgonja et al., 2013). Further, since most finger millet farmers engage in subsistence production, these organizations are linking farmers to the market through the formation of finger millet collective marketing groups (aggregation centres) to promote economies of scale and sufficient market power amongst smallholders. The aim of these initiatives is to increase household nutrition through the diversification of diets and household incomes from marketable surplus in a sustainable manner for resilience and inclusive agricultural growth. This could be made possible through the adoption of these innovations by smallholder farmers.

In the agricultural sector, uniform adoption of

agricultural innovations among smallholder farmers, however, is not common because of many factors (Awazi and Tchamba, 2018). Several studies (Langyintuo and Mekuria, 2005; Akudugu et al., 2012; Loevinsohn et al., 2013; Wairimu et al., 2016) agreed that the adoption of agricultural innovations depends on a range of farmer, farm, and institutional as well as innovational characteristics but studies addressing adoption problems affecting underutilized cereals are still scarce. A better understanding of the factors that affect farmers' adoption decisions on underutilized cereals like finger millet is necessary to design promising strategies to stimulate the adoption of these innovations.

Agricultural innovation adoption among smallholder farmers has received significant attention in the last decades. The terms "technology" and "innovation" are often used interchangeably in various strands of literature. For this article, however, the two are different. We agree with Rogers (2004) in defining innovation as an idea, practice, or knowledge that is new to a decision maker or the user, irrespective of whether it is new to other individuals or the country or the world. Agricultural innovation is a broad term which encompasses technical elements, such as improved varieties and sustainable agricultural practices, as well as organizational elements, such as collective action or farmer organizations, or institutional innovations which may be new operational instruments in the form of social norms, or operating procedures which facilitate effectiveness in processes (Triomphe et al., 2013; Makini et al., 2016).

Several studies (Olwande et al., 2009; Ogada et al., 2010; Mignouna et al., 2011; Ogada et al., 2014;) addressing factors that influence farmers' decisions to adopt or use new innovations are skewed toward widely consumed cereal crops especially maize. In contrast, little information exists on the factors influencing farmers' adoption decisions on various underutilized crops like finger millet innovations. The few existing studies have mainly focused on the adoption of technical innovations including hybrid varieties and the use of chemical fertilizer in finger millet production (Gitu, et al., 2014; Handschuch and Wollni, 2016). Most promoted innovations among smallholder finger millet farmers, however, are market-related and resource-conserving innovations aimed at increasing productivity in a sustainable manner as well as improving access to markets. There is no empirical evidence on the adoption of organizational innovations, such as group marketing and sustainable practices including conservation tillage and integrated pest and weed management, on finger millet. This study, therefore, aims at investigating factors that influence the farmers' decisions to use these innovations and the level of use. The objective is to fill this knowledge gap and to generate information to be used by researchers, extension officers, and development organizations in the finger millet production and marketing as well as other cases of underutilized

crop production. Most of the market-related innovations combine aspects of technical innovation with organizational or institutional ones (Triomphe et al., 2013). The current study, thus, combines technical innovations such as improved finger millet varieties, conservation tillage, and integrated pest and weed management with organizational innovations like group marketing. Well, it can be generally discussed in how far fostering these innovations on underutilized crops might lead to unintended negative effects this paper focuses mainly on the factors which affect adoption of these innovations.

THEORETICAL FRAMEWORK

Smallholder households in Kenya and other developing countries produce and market agricultural products under uncertainty and imperfect market structures. Hence, finger millet farmers would invest in a given innovation if the expected utility of adoption U_k is higher than expected utility U_o without adoption (Borges et al., 2015).

That is when $U_k > U_o$. Although the utility of farmers is not directly observed, the relationship between the expected utility and innovation adoption is postulated to be a function of the characteristics observed and a random disturbance term that arises from unobserved factors. The strand of literature on adoption group these observed factors into various categories: farmer characteristics, farm-specific factors, and institutional and innovational factors (Langyintuo and Mekuria, 2005; Saka and Lawal, 2009; Chuchird et al., 2017).

However, increasing finger millet productivity demands the multiple adoption of these agricultural innovations including improved varieties of finger millet, conservation tillage, integrated pest and weed management, and group marketing to achieve higher yields and promote the sustainability of the smallholder farming systems as well as transform subsistence farming to market-oriented agriculture. This implies that the adoption decisions of finger millet farmers are basically multidimensional. In this case, there is a high chance that the adoption of one finger millet innovation can alter the likelihood of adopting another, resulting in potential interdependence between unobserved factors as well as the adoption of different practices. The source of interdependence could be complementarity (positive) and substitutability (negative) (Wainaina et al., 2016). This study, therefore, hypothesized that the adoption decisions of finger millet farmers on improved finger millet varieties (IV), conservation tillage (CT), integrated pest and weed management (IPW), and group marketing (GM) are interdependent. The decision also depends on the expected utility of the innovation measured by observed factors such as farmer (age, education, household size, and gender), farm (plot size and off/non-farm income),

and institutional factors (access to information, access to credit, and access to infrastructure such road or market) (Loevinsohn et al., 2013).

EMPIRICAL ESTIMATION

Multivariate probit

A multivariate probit model (MVP) and an ordered probit model were used to determine the probability and the level of adoption of agricultural innovations by finger millet farmers. The MVP simultaneously models the influence of explanatory factors on each of the four innovations, allowing potential correlations of unobserved factors among the adoption decisions. Correlation may result from innovational complementarity or substitutability. MVP is a model which has been used by several studies to assess adoption decisions of multiple technologies (Teklewold et al., 2013; Wainaina, et al., 2016). It is an extension of the probit model (Greene and Hensher, 2010) and is used to analyse several correlated binary outcomes jointly (Temesgen et al., 2017). The model is specified as follows;

$$Y_{ij}^* = x_{ij} \beta_j + u_{ij}, \quad j=1, \dots, 4 \tag{1}$$

Where $j=1, \dots, 4$ denotes the innovational binary choices available, namely: improved varieties, conservation tillage, integrated pest and weed management, and group marketing.

In Equation 1, the assumption is that a rational i^{th} farmer $i = 1, \dots, n$ has a latent variable, Y_{ij}^* , which captures the unobserved preferences or demand associated with the j^{th} choice of agricultural innovations. This latent variable is assumed to be a linear combination of observed characteristics x_{ij} that is the farmer, farm and institutional characteristics affecting the adoption of j^{th} innovation, as well as unobserved characteristics captured by the stochastic error term u_{ij} . The vector of parameters to be estimated is denoted by β_j . Given the latent nature of Y_{ij}^* , the estimations are based on observable binary discrete variables Y_{ij} , which indicate whether a farmer adopts an innovation or not.

Using the indicator function, the unobserved preferences in Equation 1 translate into the observed binary outcome equation for each choice as follows:

$$Y_{ij} = \begin{cases} 1 & \text{if } Y_{ij}^* > 0 \\ 0 & \text{otherwise} \end{cases} \tag{2}$$

Since adoption of several innovations is possible, error terms in Equation 1 jointly follow a multivariate normal distribution, with zero conditional mean and variance

normalized to unity, where $u_{ij} \sim \text{MVN}(0, \Sigma)$ and the covariance matrix Σ is given by:

$$\begin{pmatrix} u_{1i} \\ u_{2i} \\ u_{3i} \\ u_{4i} \end{pmatrix} \sim \begin{bmatrix} 1 & \rho_{12} & \rho_{13} & \rho_{14} \\ \rho_{21} & 1 & \rho_{23} & \rho_{24} \\ \rho_{31} & \rho_{32} & 1 & \rho_{34} \\ \rho_{41} & \rho_{42} & \rho_{43} & 1 \end{bmatrix} \tag{3}$$

This assumption means that Equation 3 gives an MVP model that jointly represents decisions to adopt an innovation. This specification with non-zero off-diagonal elements allows for correlation across the error terms of several latent equations, which represent unobserved characteristics that affect the choice of alternative agricultural innovations. Numerous studies (Wainaina et al., 2016; Temesgen et al., 2017) have employed Geweke–Hajivassiliou–Keane (GHK) to compute the maximum likelihood function based on multivariate normal probability distribution. The GHK simulator is primarily based on multivariate normal distribution function that can be expressed as the product of sequentially conditioned univariate normal distribution functions, which can be accurately evaluated (Cappellari and Jenkins, 2003). The current study therefore, used the GHK simulator to estimate the equations using maximum likelihood method.

Ordered probit model

The level of use of agricultural innovations in production and marketing of finger millet was estimated using ordered probit model. Finger millet farmers may adopt one or multiple innovations to increase productivity and marketing. Multivariate probit only predicts the factors that influence the adoption decision, hence not distinguishing between those farmers who used one innovation and those who used multiple innovations in different combinations. Consequently, it is difficult to determine the cut-off points between users and non-users of agricultural innovations and the associated factors (Maguza-Tembo et al., 2017). Therefore, an additional model (ordered probit model) to assess the level of adoption and the factors influencing innovations was employed. Following Teklewold et al. (2013), the dependent variable for the level of adoption is based on the number of innovations adopted. This measure is ordinal and as a result ordered probit and poison regression model can be employed (Maguza-Tembo et al., 2017). However, the biggest shortcoming of poison regression model assumes all the innovations to have equal chances of being adopted (Boz, 2014). In the current study, the probability of adopting the first

innovation could differ from the probability of adopting the second or third, given that adopting the second or more innovations may depend on the probability of adopting the first innovation. The number of innovations used by finger millet farmers is an ordinal variable and, thus, we use an ordered probit model in the estimation.

The adoption decision is based on an expected utility framework. The farmer decides to adopt additional innovation if the utility derived from adopting it is higher than not adopting it. Since the utility level of a farmer is not observed (Y_i^*), the observed level of adopted innovations (Y_i) is related to the latent variable (Y_i^*), as presented in the following equations:

$$Y_i^* = X_i\beta + u_i \quad (i = 1, 2 \dots n) \quad (4)$$

$$Y_1 = 0 \text{ if } Y_i^* < \delta_1 \quad (5)$$

$$Y_2 = 1 \text{ if } \delta_1 \leq Y_i^* < \delta_2 \quad (6)$$

$$Y_3 = 2 \text{ if } \delta_2 \leq Y_i^* < \delta_3 \quad (7)$$

$$Y_4 = 3 \text{ if } \delta_3 \leq Y_i^* < \delta_4 \quad (8)$$

$$Y_5 = 4 \text{ if } \delta_4 \leq Y_i^* \quad (9)$$

where u_i are the residual error terms and $\delta_1 < \delta_2 < \delta_3 < \delta_4$ are threshold parameters that are empirically estimated using β .

METHODOLOGY

Study area, sampling, and data collection

The study was carried out in Elgeyo-Marakwet County in December 2016. The case study site was chosen due to the various initiatives in the area targeting the improvement of livelihoods using traditional, underutilized crops and owing to its socio-economic conditions since 57% of people live below the poverty line (CIDP, 2013-2017). In Elgeyo-Marakwet, finger millet together with sorghum used to be the most important cereal crops until the introduction of maize (Östberg, 2015). The production and consumption of these crops declined due to the shift toward maize production among smallholder farmers and recent widespread neglect by researchers and policy makers. For this work, we draw from a survey with 384 finger millet smallholder farmers based on multi-stage sampling. The first stage involved purposive selection of the county. Purposive selection further served to select two sub-counties and two wards from each sub-county to be included in the analysis owing to the intensity of finger millet production. Finally, smallholder finger millet farmers were randomly sampled from the four wards. The determination of the sample size followed proportionate to size sampling methodology as specified by Anderson et al. (2016). Sets of structured and semi-structured questionnaires, organized into five sections were used to collect

data. The first section was dedicated to obtaining information on the socio-economic and demographic characteristics of the survey respondent like age, education, gender, and the number of members in the household as well as household assets. The second and third sections were devoted to understanding the farm attributes and the production and marketing of crops by the farmer. The fourth section was mainly to obtain information on the institutional and organizational characteristics of the farmer, followed by the last section committed to identifying various innovations used by finger millet farmers. Data were analysed using STATA version 14.2 software. Both descriptive and inferential statistics describe the statistical apparatus to analyse the data.

RESULTS AND DISCUSSION

Descriptive statistics

Finger millet improved varieties

The results of the current study indicated that about 40% of the sampled finger millet farmers in the 2015/2016 cropping season used improved finger millet varieties. The sources of finger millet seeds were their own recycled seeds from previous growing seasons (stock), local markets, the government extension program, research organizations (ICRISAT, KALRO and Egerton University), and private seed suppliers. From these sources, own recycled seeds from previous growing seasons and local markets shared the greater amount of finger millet seeds planted by the sample farmers.

Conservation tillage

Conservation tillage was one of the important innovations used by finger millet farmers (52%) to enhance the productivity and conservation of the resource. Most of the finger millet smallholders attested that they leave most of the soil surface covered with crop residue at planting time; some of the smallholder finger millet farmers also till planting rows and later carry out mechanical weeding or hand-pull weeds. The users of conservation tillage obtained the idea from Egerton University, ICRISAT, and other research institutions, 35% got the information from government extension officers and approximately 10% of the farmers learned from other fellow farmers.

Integrated pest and weed management practices (IPMW)

Results indicated that about 64% of the sampled farmers used integrated pest and weed management practices (IPMW) to control pests in the 2015/2016 cropping season. In this regard, IPMW methods included the hand-pulling of weeds and burning before flowering (51%), the

Table 1. Yield of selected cereals crops in Kenya (2016).

Crop	Yield in ton/ha
Maize	1.42
Wheat	1.45
Rice	4.03
Millet	0.61
Sorghum	0.63

Source: FAOSTAT statistical division.

use of traps and baits (42%), early planting (15%), the use of other plants (cow pea, pigeon pea and groundnuts) to trap and destroy pests and diseases and control some weeds (27%), and crop rotation (31%). Most of these practices were used in combinations of two or a maximum of three.

Group marketing

The study found out that only 28% of finger millet farmers had embraced group marketing as a means for accessing a market for their produce. Members of the group aggregate their output and look for one buyer to increase their economies of scale and bargaining power. Most of the farmers interviewed indicated they received advice on a new way of marketing finger millet output from Egerton University and county government extension officers.

Description of farmer, farm and institutional characteristics

As shown in Table 1, out of the 384 households interviewed, about 87% were headed by males, while the remaining 13% were headed by females. The proportion of household heads in the sample is much lower compared to the national level (that is, one third of the total rural household heads is female). The average age of the sample household head was found to be 42 years. On average, a household head had approximately 8 years of formal education. The average area cultivated for finger millet production during the 2015/2016 cropping season was 0.6 acres, which accounts for about 30% of the average total cultivated land size and 40% under cereal crops, respectively. The dominant cereal crop in the study areas is maize. It covers 36% of the average total crop area and 50% of the area under cereal crops, respectively. The results of the current study indicated that about 38% of the farmers interacted with extension officers approximately twice during the cropping period. As displayed in Table 1 about 28% of finger millet farmers had received technical training on finger millet from the research and learning institution on the technical aspects of various innovations. During the

reference cropping season, only 13.8% of the sample farmers had received a cash credit for finger millet production from credit institutions. The walking distance measured in minutes from the farmers' residence to the nearby market was found to be about 50 minutes on average.

Adoption decisions and level of adoption

Multivariate probit results

Tables 2 and 3 present the maximum likelihood estimation results of our multivariate probit model on the factors influencing the decision of smallholder farmers to use innovations in finger millet production and marketing.

The likelihood ratio test ($X^2(6) = 19$, Prob < 0.000) of the independence of the residual terms is strongly rejected at a one percent level of significance, implying that the multiple use of innovations is not mutually independent. They are interdependent and, consequently, support the use of MVP modelling. Table 3 shows the correlation between the error terms of the innovations. The correlation coefficients were statistically different from zero in three of the six pair cases and all the three cases were positive, indicating complementarity among the innovations studied.

Gender of the household head

Keeping other variables in the model constant, the gender of the household head had a negative and significant influence on the likelihood of using conservation tillage at a 1% level of significance. The negative effect implied that female-headed households were more likely to adopt conservation tillage compared to their male counterparts. This is of interest because in most African countries, men leave many of the finger millet management practices to women including land preparation, seeding/transplanting, harvesting, and threshing (Thilakarathna and Raizada, 2015). Hence, females are more likely to adopt conservation tillage because it is frequently cited as having labor-saving properties.

Table 2. Agricultural innovations and explanatory variables.

Variables	Description	Mean	Std
Innovations(Dependent variables)			
Improved variety (IV)	use of the innovation 1=yes and 0 otherwise	0.409	0.492
Conservation tillage (CT)	use of the innovation 1=yes and 0 otherwise	0.518	0.5
Integrated pest management (IPW)	use of the innovation 1=yes and 0 otherwise	0.638	0.481
Group marketing (GM)	use of the innovation 1=yes and 0 otherwise	0.281	0.45
Explanatory variables			
Gender	1=if sex of the head is male	0.865	0.343
Education	Years of schooling of household head	8.81	3.851
Age	Age of the household head in years	42.383	12.168
Household size	Family size number of household members living together for the past six months	5.297	2.108
Plot size	Size of the plot allocated to finger millet in acres	0.601	0.44
Off/non-farm income	Kenya Shillings	37324.48	88389.8
Household credit	Received credit for the crop 1=Yes and 0=No	0.138	0.345
Extension	Received extension services 1=Yes and 0=No	0.300	0.458
Extension contact	Number of contacts with extension officer per year	1.770	1.126
Technical training	Received technical training 1=Yes and 0=No	0.276	0.448
Distance to the nearest market	Distance to the nearest market in walking minutes	50.208	48.221

Source: Survey data (2016).

Table 3. Estimated covariance matrix of the regression equations between innovations using multivariate probit model.

	ρ^{IV}	ρ^{IPW}	ρ^{CT}	ρ^{GM}
ρ^{IV}	1			
ρ^{IPW}	0.188 (0.092)**	1		
ρ^{CT}	-0.023 (0.089)	0.227 (0.087)***	1	
ρ^{GM}	0.059 (0.095)	0.162 (0.093)	0.250 (0.086)***	1

Likelihood ratio test of P (IPW) (IV) = P (CT) (IV) = P (GM) (IV) = P(CT) (IPW) = P (GM) (IPW) = P (GM) (CT) = 0: $X^2(6) = 19.704$
 Prob > $X^2 = 0.0031$.

*, **, and *** indicate statistical significance at 10, 5, and 1% level of significance.

Source: Survey data (2016).

The findings concur with those of other studies (Chalermphol et al., 2015; Asfaw and Neka, 2017; Wossen et al., 2017).

Age of the household head

Young household heads had a higher tendency toward adopting integrated pest and weed management at a 10% level of significance. This implies that younger finger millet farmers were 46% likely to adopt integrated pest and weed management than older farmers. Younger farmers are often better educated and tend to be more aware of the benefits of new innovations. This relationship between age and innovativeness is similarly

observed by Ghimire and Kafle (2014) who also reported a negative relationship between age and the use of integrated pest management.

Education of the household head

Consistent with the work of Bruce (2015) on innovation adoption, the education of the household head had a positive and significant impact on the adoption of conservation tillage and integrated pest and weed management at a ten and 5% level of significance, respectively. Educated farmers are believed to have a higher ability to obtain, interpret, and respond to new information about technologies than their peers with little

or no education (Namara et al., 2014). More educated farmers are, furthermore, more likely to access information and advice from extension workers which influence their adoption and use of these innovations.

Size of the farming household

The size of the farming household had a positive and significant influence on adoption of finger millet improved varieties, which was statistically significant at 1% level. That is, an increase in the size of the household increased the probability of adopting improved varieties of finger millet by 10.2% when other factors are held constant. This could be explained by the fact that an increase in the size of the household implies an increased demand for food. To meet the demand, the household seeks better finger millet varieties that will increase the output. The results also reveal that the size of the farming households negatively influenced the adoption of conservation tillage and group marketing which were statistically significant at five and 10%, respectively. That is, holding all factors constant, an increase in the size of the household decreased the use of conservation tillage and group marketing by 9.7 and 7.3%, respectively. These findings suggest that small households are more likely to adopt conservation tillage and group marketing as compared to larger households. Conservation tillage is labour- and resource-saving technology that small households with less family labour could be more inclined to adopt unlike larger households (Rockström et al., 2009). Large households are less likely to join group marketing because there is high demand for food and may have no or less surplus for the market, since most farmers in the study area attested that they produced finger millet mainly for subsistence.

Land size allocated to finger millet

The results also show that the plot size positively influenced finger millet farmers to join group marketing at 1% level. That is, an increase in plot size under finger millet would increase the probability of adopting group marketing at 82%, other factors held constant. This can be explained by the fact that large area of agricultural land provides opportunity for surplus production hence, farmers joined group marketing to linked them to markets to absorb their surplus production at lower marketing cost.

Off-/non-farm income

The findings further reveal that the presence of off-farm income positively influenced the adoption of integrated pest management which was statistically significant

($p < 0.01$). That is holding other factors constant, a unit increase in off-farm income would increase the likelihood of adopting integrated pest and weed management at 9%. This is consistent with the findings of Muriithi et al. (2016) where extra income earned from non-agro-based activities positively influenced the adoption of integrated pest management technology. However, the results contradict the findings by Asfaw and Neka (2017) where off-farm income had a negative effect on the adoption of soil and water conservation technologies

Extension services

The findings also show that access to extension services positively and significantly influences the adoption of all the four innovations, namely, improved variety, conservation tillage, integrated pest and weed management, and group marketing. The results support the apparent tendency that farmers accessing extension services increases their likelihood of adopting various technologies. Farmers have a higher likelihood of changing their farming and marketing styles if they are more informed, as is the case with extension services that disseminate agricultural information. Therefore, the more access to information farmers have, the more likely they are to adopt and embrace innovations in the production and marketing of finger millet. The findings are consistent with Muriithi et al. (2016)'s results, where access to extension services had a positive impact on the adoption of integrated pest management practices in the suppression of mango-infesting fruit flies.

Technical training

The technical training of farmers on the usage of innovations in finger millet had a positive impact on integrated pest and weed management. This implies that farmers who had technical training had a higher chance of adopting the IPWM innovations for farming finger millet as opposed to their counterparts who had no training. This is anticipated since training impacts knowledge and gives an opportunity for farmers to learn how to best use innovations. The results are similar with (Pierpaoli et al., 2013) findings. The results of the current study also concur with those of Jayasooriya and Aheeyar (2016) where the knowledge of farmers of integrated pest management had a great influence on the use of the practices, indicating the possibility of increasing adoption through awareness and training. However, technical training had a negative and significant impact on improved seed varieties at a 10% level of significance. The findings though not expected were consistent with the findings of Murage et al. (2015) where the type of information accessed during training had a negative impact on the adoption of innovations. Technical training

Table 4. Multivariate probit model results on factors influencing adoption decision.

Variables	Improved variety		Conservation tillage		IPWM		Group marketing	
	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE
Gender	-0.020	0.214	-0.598***	0.209	0.238	0.210	-0.174	0.216
Education	0.014	0.021	0.039*	0.021	0.043**	0.022	0.023	0.021
Age	-0.009	0.005	0.002	0.006	-0.012*	0.007	0.023	0.006
Household size	0.100***	0.037	-0.097**	0.038	-0.257	0.038	-0.073*	0.039
Plot size	0.277	0.175	0.086	0.163	0.257	0.166	0.825***	0.175
Off/Non-farm income	0.020	0.014	0.009	0.014	0.090***	0.015	0.008	0.014
Household credit	0.881***	0.213	0.427**	0.215	0.332	0.228	-0.136	0.209
Extension contact	0.451***	0.091	0.600***	0.096	0.167*	0.088	0.204***	0.076
Technical training	-0.441***	0.192	0.237	0.175	0.92***	0.218	0.124	0.173
Distance to market	-0.001	0.002	-0.001	0.002	-0.001	0.002	0.004**	0.002
Constant	-0.870***	0.326	0.359	0.307	0.428	0.322	-0.916***	0.320
Number of observations		384						
Log likelihood		-816.375						
Wald chi2(44)		263.64***						

*, **, and *** indicate statistical significance at 10, 5, and 1 percent level of significance.

Source: Survey data (2016)

on an innovation may result in shifting resources in its favour, leading to high adoption and consequently less attention may be given to other innovations.

Access to credit

The findings show that access to credit positively and significantly influences the use of improved variety and conservation tillage at a 1% level of significance. That is, farmers who access credit have a higher likelihood of adopting the technologies than those who do not access credit. Most technologies require financing with a significant amount of money. If the farmers cannot self-finance their farming, access to credit fills the gap to enabled increased production. That is, farmers who have more access to money can purchase improved seeds for finger millet and they can also pay for the time taken to practice row planting as opposed to broadcasting and other conservation tillage practices. Thus, access to credit increases the chances of farmers adopting technological innovations in the production and marketing of finger millet. The current findings concur with past findings of (Wossen et al., 2017).

Distance to the market

The walking distance to the market also significantly and positively influences the adoption of group marketing at 1%. That is, for a unit increase in distance to the market,

the chances of a farmer adopting group marketing increases by 0.37%. Distance to the market is a proxy for infrastructure and time spent by farmers traveling which results in higher marketing costs. Therefore, the greater the distance, the more willing the farmers are to reduce costs and join a marketing group to share transport and other marketing costs. Mottaleb et al. (2016) also found that the distance positively influenced the adoption of agricultural technology.

Ordered probit results

The chi-square statistics of the ordered probit is 154.42 and is statistically significant at a 1% level of significance. For the interpretation of the ordered probit, the study used marginal effects after estimation of the ordered probit model. Marginal effects are presented in Table 4. The results reveal that if any household were taken at random, there would be an 8% likelihood that they had adopted none of the innovations with a 92% likelihood of adopting at least one innovation in finger millet production. Among the eleven explanatory variables entered into the model, only five were statistically significant at a 1% level. The significant variables were plot size, off/non-farm income, extension contact, household credit, and technical training.

Holding all other factors constant, an increase in the area allocated to finger millet production increases the probability of adopting two, three, or four innovations by 31, 10.5 and 5.8%, respectively, and reduces the

Table 5. Ordered probit results with marginal effects on factors influencing the level of adoption.

Variables	Ordered probit		Marginal effects				
	Coeff.	SE	Prob(Y=0 X)	Prob(Y=1 X)	Prob(Y=2 X)	Prob(Y=3 X)	Prob(Y=4 X)
			dy/dx	dy/dx	dy/dx	dy/dx	dy/dx
Gender	-0.204	0.163	0.029	0.045	-0.007	-0.041	-0.026
Education	0.011	0.015	-0.002	-0.003	0.001	0.002	0.001
Plot size	0.517***	0.129	-0.082***	-0.113***	0.031**	0.105***	0.058***
Age	0.001	0.186	0.004	0.005	-0.001	-0.005	-0.003
Household size	-0.035	0.028	0.006	0.008	-0.002	-0.007	-0.004
Off farm income	0.044***	0.106	-0.007	-0.009	0.002**	0.009***	0.004***
Household credit	0.605***	0.162	-0.072***	-0.134***	-0.009	0.119***	0.095***
Extension contacts	0.468***	0.064	-0.075***	-0.102***	0.028***	0.095***	0.053***
Technical training	0.315***	0.135	-0.046***	-0.069***	0.011	0.065***	0.040***
Distance to the Market	0.001	0.001	0.002	-0.001	0.000	0.000	0.001
δ_1	-0.545	0.231					
δ_2	0.420	0.228					
δ_3	1.422	0.234					
δ_4	2.335	0.250					
Observation	384						
Wald chi2(10)	154.42						
Prob>chi2	0						
Log Likelihood	-512.143						
Pseudo R2	0.13						

*, ** and *** indicate statistical significance at 10,5 and 1 percent level of significance.
 Source: Survey data (2016).

probability of adopting one or none by 11.3 and 8%, respectively. Increasing the amount of land allocated to finger millet production can reveal the farmer's preference for the crop and, consequently, the adoption of more innovations to maximize output returns. For finger millet farmers employing off-farm activities, the probability of adopting two and more innovations, thus, increases. These results are reasonable since farmers who have diversified their income-generating activities are generally more capable of facilitating the adoption of more innovations than their counterparts.

Given the nature of the agricultural innovation, contact with extension services is critical for the diffusion of information on innovations. For every additional contact of finger millet farmers with extension officers, the probability of using more than two innovations increases by 2.8%. These findings are consistent with Teklewold et al. (2013) where access to extension services affected the number of technologies adopted by farmers. Similarly, access to credit increases the likelihood of adopting three or more finger millet innovations. This can be explained by the fact that credit is an incentive to increase the production of finger millet and enables investment in inputs. Moreover, access to credit implies the ability of the farmer to finance the adoption of any innovation that would require an extra investment (Table

5). Technical training on innovations had a positive effect on the number of innovations adopted. Households that received some technical training on innovations were more likely to adopt more than three innovations than those that did not. This is anticipated to be the case since farmers are interested in adopting innovations that they possess a working knowledge. That is, if farmers know how a certain innovation works, the more they are likely to make use of it.

CONCLUSION AND RECOMMENDATIONS

This paper investigated the factors that influence finger millet adoption and level of adoption of different agricultural innovations in Elgeyo-Marakwet County. Innovations considered in the study included: improved seed varieties, conservation tillage, and integrated pest and weed management as well as group marketing. Some of the innovations exhibit complementarity, indicating interdependence. Household and farm characteristics as well as institutional conditions were the factors examined as to whether they influence the use of these innovations.

The results revealed that households with young household heads were more likely to adopt integrated

pest and weed management. Moreover, the education of the household head had a positive and significant impact on the adoption of conservation tillage. The findings further highlight the high importance of extension services: consulting with extension officers positively and significantly influences the adoption of all the innovations considered in the study. Access to credit positively and significantly influences the use of improved seed varieties and conservation tillage. Although, the technical training of farmers on the adoption of innovations in the production of finger millet had a positive impact on integrated pest and weed management, it had negative effects on the adoption of improved seed varieties. The ordered probit results confirmed that the level of adoption of agricultural innovations was strongly related to farm and institutional factors. Those households who had allocated more land to finger millet, farmers with extra income from non-farm activities and who had better access to credit and extension services were likely to use more than two innovations.

Based on the findings, strategies aiming to promote innovation adoption for finger millet could place more emphasis on strengthening the existing agricultural extension service provision to improve the uptake of these innovations. Relevant stakeholders could invest in extension services to sensitize finger millet farmers to new innovations, as these have the potential to increase the adoption rate and, consequently, might increase farmers' productivity and incomes. Moreover, farmers could be trained on the technical aspect of these innovations as well as their associated benefits. Strides also need to be made in improving smallholders' financial capability to access credit and empowering farmers' institutions that can provide credit services at an affordable cost. While this study presents evidence on factors that influence the uptake of innovations in production and marketing of finger millet, it is confined to information provided by finger millet farmers at household level. We suggest that future studies could also obtain data from other key players within the production and marketing of these underutilized cereal crops (e.g. extension staff). This will help to better understand issues such as the kind of policies and market environments that can facilitate farmers' adoption decisions.

Further, this study used cross-sectional data collected from randomly sampled farmers to provide representative information needed in the development of underutilized cereal crops. Our study identified key farmer, farm and institutional characteristics that could be targeted for improvement to accelerate the adoption rate of these innovations. However, our data did not permit analysis of the dynamics of innovation adoption decisions. We recommend that future studies could employ panel data to capture dynamic elements that influence adoption choices amongst underutilized cereal farmers.

Lastly, this study explicitly focusses on the factors of adoption without addressing the implications of such

adoptions. Although mainly for more common crops, the discussion and debate about the different innovation types has taken place in other parts of academic literature and we welcome further research on the impacts of different innovations particularly for underutilized cereal crops.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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