Socio-economic Determinants for Maize Smallholder Farmers' Adoption of Purdue Improved Crop Storage in Mbozi District, Tanzania

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Abstract

Post-harvest handling technologies like Purdue Improved Crop Storage (PICS) bags are so effective in reducing post-harvest losses and improve food security. Despite the potential of PICS bags in reducing post-harvest losses, the adoption of PICS bags is still low and a good fraction of Sub-Saharan Africa (SSA) farmers continue to practice their traditional methods. The current study aimed at exploring socio-economic determinants of maize smallholder farmers' adoption of PICS bags in Mbozi District. The data on which the paper is based were collected from four villages of Mbozi District using a mixed research approach. A cross-sectional research design was adopted whereby data were collected at once. Quantitative data were collected using a structured questionnaire with 120 respondents who were selected using simple random sampling. Qualitative data were collected using Focus Group Discussion (FGDs) and Key Informants Interviews (KIIs) and analysed using content analysis. Quantitative data were analysed using the Statistical Packages for Social Science (SPSS), whereby descriptive statistics such as frequency, mean, standard deviation, and percentages were determined. In addition, a binary logistic regression model was used to determine association of some key socio-economic factors and adoption of Purdue Crop Storage (PICS) bags., The results from the logistic regression show that, gender of the household head, education of the household head, maize farming experience of the household head, access of the household to credit, and access of the household head to training on PICS were found to be important predictors of household adoption of PICS ($p < 0.05$). Therefore, the paper recommends that, the Local Government and other stakeholders should train smallholder farmers on PICS and creates awareness in order to help to increase understanding of PICS bags among more maize farmers. There is a need for more advocacy initiatives by stakeholders on subsidizing the costs of PICS bags in order to improve the adoption of PICS bags by farmers.

Keywords: *Purdue Improved Crop Storage, Smallholder Maize Farmers, Adoption.*

1.0 Introduction

Post-harvest losses, due to pests are an enduring problem throughout the developing World. According to FAO (2011), approximately one-third of the food produced for human consumption worldwide is wasted. It is estimated that 54 percent of losses occur during production, post-harvest handling, and storage. According to FAO (2011 cited in Abbas *et al.,* 2014) this post-harvest loss is responsible for economic costs estimated at US $750 billion. As Ambler *et al.,* (2017) observe,, the harvest loss of maize was about 30 percent while the total maize loss was 40 percent. Similarly, Abbas *et al.,* (2014) observe, in worst cases, up to 32 percent of maize-on-cobs could be lost to birds, monkeys, other rodents before harvest, and through qualitative spoilage by mould and fungi which could be extensive in wet conditions. The loss translates to 1.3 billion tons of food per year in a world where over 870 million people go hungry. In Sub-Saharan Africa (SSA), postharvest losses (PHL) for grains alone exceed USD 4 billion. This magnitude of food loss exceeds the value of the total food aid received in the region (SSA), and is equal to the annual value of cereal imports to SSA (World Bank, 2011). Scholars (e.g. Owach *et al*., 2017), establish that postharvest food losses contribute greatly to food, nutrition, and income insecurity in this region. Such losses are estimated to be equivalent to the annual caloric requirement of 48 million people. Studies by FAO suggest that farmers in Tanzania lose up to 40 percent of produce after harvesting. In Tanzania, such food losses have led to frequent food shortages, which are experienced in different parts of the country with small-scale maize farmers representing the most vulnerable populations. This is especially because most of the available storage pests control strategies are unavailable to them due to prohibitive costs (HELVETAS, 2013). One of the highly affected crops is maize, which is an important and among the widely consumed agricultural food crops in the globe. it is considered a vital crop for achieving food and nutritional security for both poor producers and consumers (Jones and Lowenberg-DeBoer, 2014).

In responding to such huge food losses caused by insects, pests, and pathogens, farmers opt to sell their produce shortly after harvest, resulting to the loss of opportunity to earn revenue at peak market prices. Other farmers use traditional storage practices, which cannot guarantee protection against major storage pests of staple food crops such as beans and maize. Other farmers apply synthesis insecticides as storage protectants but adequate protection is often not achieved. Sometimes these insecticides are not available in their localities all the time and knowledge pertaining to proper use of them is questionable. Moreover, the indiscriminate use of insecticides by some farmers is likely to cause the insects develop resistance and bring about environmental and human health disorders (Paul *et al*.2009; Obeng-Ofori 2011; Baributsa *et al*. 2014). Various storage technologies have been developed to reduce post-harvest losses. These include silos, metal canister/drums, cold chain storage containers, woven bags, plastic bags, insect proof containers, Purdue Crop Storage (PICS) bags, and adaptations to traditional storage technologies (CITE 2015). Many of these products have been piloted in small-scale programs to improve lives of smallholder farmers in Africa, Southern Asia, and Central America. The Purdue Crop Storage (PICS) tripple-layer plastic bags were initially introduced by Purdue University in 2007 as a five-year initiative supported by a grant from the Bill and Melinda Gates Foundation in West Africa. This initiative was designed to help farmers access an innovative low-cost and chemical-free cowpea storage technology through Bean/Cowpea Collaborative Research Support Program (CRSP) (Baributsa *et al*. 2014). in another study, in East Africa Abbas *et al.,* (2014) suggested that promoting adoption of the improved storage technologies by farming households would substantially contribute to household food security and income by reducing storage losses. It was highlighted that certain Post-harvest handling technologies (Hermetic technologies) such as metal silos and PICS bags are so effective that if adopted, additional preservation techniques to protect the crops would not needed (Carvalho *et al*.2012; Gitonga *et al*. 2012; Tefera *et al*. 2012).

although there are several studies on the reduction of post-harvest losses, for example, Carvalho *et al*. (2012) focused on the use of modified atmosphere to control sitophiluszeamais and sitophilusoryzae on stored rice; Chisenga (2015) focused on the adoption of conservation agriculture, and Gitonga (2012) focused on the impact of metal silos on households' maize storage. Despite the potential of PICS bags in reducing post-harvest losses, the adoption of PICS bags is still low and post-harvest losses of maize remain significant. Therefore, the study on which this paper is based aimed at assessing the adoption or none-adoption of PICS bags by maize producing households in Mbozi District'. The paper would be useful to policy makers and other stakeholders interested in devising strategies of reducing post-harvest losses among smallholder maize farmers. The socio-economic factors influencing the adoption of PICS are also paramount and must be studied to increase a convincing number of maize farming households into using PICS bags. In this way, poverty alleviation, household food, and income security, access to safe and chemical free staple food could be attained.

The paper is informed by the "Technology Diffusion Theory" which is based on farmers' decision to adopt new technologies (Isham, 2002). The theory postulates that, farmers with more education and bigger land area will have more knowledge on improved farming systems and are more likely to adopt technologies rapidly. According to the diffusion theory, the adoption of technologies is influenced by many factors. For example, access to extension services can influence farmers' adoption of technologies. Therefore, the more contact a farmer has with the extension services, the more the information the farmer will access thus, the higher the possibility of using the technology (Haji, 2003). In addition, farmer's socio-economic characteristics such as age, sex, marital status, household size, and years of farming experience, distance to the market, group membership, and access to credit may influence the adoption of post-harvest technologies (Ali 2012; Elemasho *et al*. 2017; Mukarumbwa *et al*. 2017). According to Adeogun *et al*., (2010), younger farmers are more likely and willing to spend more time to obtain information on improved technologies as opposed to older farmers hence could the former are more likely to adopt new technologies than are the latter.

2.0 Methodology

The study was conducted in Mbozi District, which was selected purposively based on its ranking in maize production in Songwe Region and its potential for maize production (NBS, 2003) and the fact that the district is located in one of the four zones (northern zone, central zone, lake zone and southern highlands zone). This is where PICS bags promotion was conducted in 2015 (Mwijande, 2017). The study adopted a cross-sectional research design whereby data were collected once using a pre-structured questionnaire and checklist of questions. The design was thought as suitable for the current study because it allows the collection of data, which can be used to determine the relationship between variables. The population for the study on which the paper is based comprised all maize farmers in Mbozi District. The sampling unit was a household. Exploratory sequential research strategy was adopted involving the initial phase of qualitative data collection and the analysis, which was followed by a phase of quantitative data collection and the analysis (Cresswell, 2003). The exploratory sequential research strategy was adopted in order to integrate the results from two stages in order to expand the scope and improve the quality of the results. The qualitative phase of data collection involved Focus Group Discussions (FGDs) and Key Informant Interviews (KIIs). Four FGDs with participants knowledgeable in PICS with each FGD having participants ranging from six to eight were conducted. Thirteen KIIs were purposely selected, these include one representative from ADP Mbozi, Unyiha Associated Ltd and G2L Company Limited, PICS consultant, TFA, four Ward Executive Officers (WEO), and four Village Executive Officers (VEO). The selection of KIIs participants was based on age, experience, and position. The aim was to get the oldest members with long experience on maize production and PICS bags in the respective villages.

The quantitative phase of data collection involved multi-stage sampling to select four wards out of 25 wards producing maize in the district. It was important to use the selected sample as shown as it allows the use of multiple sampling techniques within a single study. In order to obtain representative villages, random sampling was employed to select one village from each of the four wards. Thereafter, 120 respondents were randomly selected from four villages (i.e. Isalalo, Zelezeta, Ivwanga, and Isenzanya; for other details see Table 1), making 30 from each village. The sample size of 30 respondents from each village was picked because households in these villages had similar socio-economic characteristics and the sample size of 30 respondents is enough for analysis (Field, 2013). Simple random sampling was used because it provides equal opportunity for every respondent to be selected and the selection was guided by village register.

Table 1: Sample Distribution

Sn	Ward	Village	No. of Respondents
1	Msia	Isalalo	30
2.	Igamba	Zelezeta	30
3.	Mlowo	Ivwanga	30
4.	Nambinzo	Isenzanya	30
		Total	**120**

Qualitative data, which were collected using a checklist of questions, were analysed using content analysis whereby information pieces were organized into different themes and compared based on the study objectives. Quantitative primary data were collected using a structured questionnaire with both open and closed ended questions. The collected quantitative primary data were analysed using the Statistical Package for Social Science (SPSS), whereby descriptive statistics such as frequencies, percentage, mean, and standard deviation were determined. In addition, a binary logistic regression model (as detailed below) was used to determine the association of some socio-economic characteristics and the adoption of PICS by smallholder maize farmers. The logistic regression model was chosen because it accepts a mixture of continuous and categorical independent variables, and for the current case the dependent variable was categorical (o=non-adoption of PICS and 1=adoption of PICS. The likelihood of the adoption of PICS by maize smallholder farmers was predicted using the following binary logistic model:

$Lg(P/1-P) = \beta o + \beta 1\, x1 + \beta 2\, x2 + \beta 3\, x3 + \ldots \beta n\, xn + \varepsilon i$………….. (1) Where P=Maize farmers adoption of PICS bags (1 = adopt 0 = does not adopt) 1-P= Maize farmers none-adoption of PICS bags; $X_1 – X_{10}$ = Explanatory socio-economic predictor variables as shown in table 2.

Table 2: Operationalization of Socio-economic Variables

SN	Explanatory variable	Measurement	Expected Sign	Description	Comment
1	Education level	Continuous	+	Highest level of education that a farmer achieved	The more educated, the better negotiation and information processing capacity
2	Sex	Dummy	+	1; if Male 0; if Female	Male more chance of PICS adoption
3	Age	Continuous	+	Age of the household head	Older household head more chance of adopting PICS
4	Maize farm size	Continuous	+	Size of the farm under maize cultivation (hectares)	Large size increases chances of adopting PICS
5	Household size	Continuous	+	Number of household members	Large household size reflecting availability of more labour force to facilitation production and transportation of crops
6	Household income	Continuous	+	Total household income in TZS	Higher income more chances of adopting PICS
7	Distance from the market	Continuous	-	Distance in km	Less distance increase chances of adopting PICS
8	Maize farming experience	Continuous	+	Years in maize farming	More years in maize farming means more experiences
9	Access to credit	Dummy	-	1=if the farmer has access to credit 0=if no access	Credit access more chance to adopt PICS
10	Access to training on PICS	Dummy	-	1=if the farmer has access to training on PICS 0=if no access	PICS training access more chance to adopt it

3.0 Results and Discussion

3.1 Socio-economic Characteristics of Surveyed Households

Socio-economic characteristics can influence a household's adoption of PICS bags. Socio-economic characteristics that have been taken into account in this paper include, age, sex, education level, maize farming experiences, maize farm size, household size, access to credit, access to training on PICS, household income, and distance from the market. The above characteristics according to literature (see for example, Ayoola *et al*., 2011; and Adamu *et al*., 2012) can influence the adoption of agricultural technologies. The respondents' major socio-economic characteristics are shown in Table 3. The results show that 80 percent of the respondents were Male-Headed Households (MHHs) while 20 percent were Female Headed Household (FHHs). The lower number of FHHs probably is caused by the nature of African societies where most families are headed by males. The higher number of MHHs observed in this study conforms to a previous study by Chirwa *et al*., (2011), who reported that MHHs are more likely to adopt improved technologies.

Table 3: Descriptive of Households' Socio-economic Characteristics (n=120)

Explanatory Variables Deviation	Description	Mean or /%	Std.
Gender	Male	80*	
	Female	20*	
Age	In years	36. 65	10. 796
Education	Years of formal schooling	9. 35	3. 010
			0.499
Maize farming experiences	Years in maize farming	13.79	8.623
Access to credit	Accessed	55*	
	No Access	45*	
Access to training on PICS	Accessed	47*	
	No Access	53*	

The mean years of schooling were 9 years. Education and literacy are important factors in determining the decisions to adopt technologies among farmers. The mean age of the respondents was 36 years, which is considered a productive age. The nature of age is parabolic in nature. On the one hand, older household heads are believed to have accumulated more personal capital and experience and thus are more likely to invest in innovation. On the other hand, younger household heads are more flexible and energetic and hence are more likely to adopt new technologies. In another study, Eswarn *et al*., (1997) reveal that age between 30-36 years is productive age, which is favourable for high production.

The findings show further that 55 percent of the respondents had access to credit. Access to credit is essential in enhancing households' accumulation of capital for investing in new storage technologies such as PICS. The study also found that 47 percent of the respondents had access to training on PICS. Access to training on PICS is necessary in creating awareness on PICS. According to Kimaro *et al.,* (2010), exposing farmers on storage technologies can stimulate the adoption of such technologies.

3.2 Socio-economic Determinants of Maize Smallholder Farmers Adoption of Purdue Improved Crop Storage Technology

Binary logistic regression was used to model the selected variables and socio-economic determinants of the adoption of PICS among maize farmers as presented in Table 4. The results show that, among the ten (10) variables, five variables: sex of the household head, education of the household head, maize-farming experiences of the household head, household access to credit, and household head training on PICS were found to be important predictors of household adoption of PICS ($p < 0.05$). The strongest predictor was sex of the household head ($p = 0.000$).The findings in Table 4 indicate that the Hosmer and Lemeshow test showed a Chi-square statistics of 6.253 ($p = 0.598$). This means that the overall model predicted the outcome well because the Hosmer and Lemeshow test Chi-square was not significant (Field, 2013). In Table 4, the Wald statistic value of gender of the household head which was Wald = 21.420 was the maximum and statistically significant at p ≤ 0.001. In addition, household training on PICS that had a Wald statistic value of 18.647 was the second highest and statistically significant at p ≤ 0.01. The implication of this finding is that as access to training on PICS among household heads increases the likelihood of adopting the technology.

Table 4: Binary Logistic Regression Estimates for the Adoption of PICS Bags (n=120)

Variables	B	S.E.	Wald	Sign	Exp
Age	-0.270	0.113	5.703	0.017	0.763
Gender	8.742	1.889	21.420	**0.000***	6258.115
Education	0.615	0.178	11.863	**0.001***	1.849
Household Size	0.351	0.280	1.576	0.209	1.421
Farm size	-0.702	0.286	5.997	0.014	0.496
Monthly Income	0.000	0.000	2.893	0.089	1.000
Distance to the market	-0.044	0.090	0.236	0.627	0.957
Maize farming Experience	0.775	0.209	13.679	**0.000***	2.170
Access to credit	2.911	0.874	11.088	**0.001***	18.367
Access to Training on PICS bags	3.310	0.767	18.647	**0.000***	27.385
Constant	14.517	0.677	16.478	**0.000***	0.000

Omnibus Tests of Model Coefficients (Chi-square = 150.512; sig. = 0.000); Cox & Snell R Square = 0.591, Hosmer and Lemeshow Test (Chi-square= 9.019) sig. = 0.351); Nagelkerke R Square = 0.791; * and ** indicate levels of significance at 5%.

The logistic results (Table 4) show that gender of the household heads influenced significantly household chances of adopting PICS (p=0.05). The findings indicate further that if MHHs had to adopt PICS, the odds ratio would be 8.742, implying that the household headed by men had 8.743 times chances of adopting PICS as opposed to FHHs. This finding implies that MHHs are more likely to adopt PICS than is the case with FHHs. This finding was in line with a prior expectation that male households are more likely to adopt PICS since they are responsible for making decision on storage. The findings correspond with the findings in a study by Oluoch (2014) and Ayedun (2018) who reported that household headed by males are more likely to adopt crop storage technology as men are more energetic and have the ability of adapting to new storage technologies.

The results (Table 4) show further that access to training on PICS was found to have positive significant influence on the likelihood of a household to adopt PICS (p=0.05). The findings indicate that, the odd ratio for access to training on PICS was 18.647 implying that households with access to training on PICS are 18.647 times more likely to adopt PICS. This is not surprising because training provides them with the opportunity of accessing information, which might enhance the adoption of PICS.

The FGDs participants had this to say:

> *"...Farmers' awareness and readiness on adoption and use of PICS technology is convincing. Although availability of this technology in my village is very limited unless you arrange with an Agricultural officer who has access to information on where you can access…." (*FGDs participants in Isalalo village, 14/08/2018***).***

Similar findings are reported in other studies (e.g., Chisenga, 2015; Odenya and Kebenney, 2008; Okoedo and Onemoleas 2009; Khanna, 2010; Ayedun 2018), which reveal that lack of awareness on the availability of storage technology among households resulted into serious post-harvest losses. Furthermore, training on storage technology was positively associated with the adoption of a particular technology.

The binary logistic regression results (Table 4) revealed further that access to credit exerted a positive and statistically significant effect on the chances of a household to adopt PICS (p=0.05). The findings indicate further that the odds ratio for access to credit was 2.911, implying that households with access to credit were 2.911 more likely to adopt PICS. This might suggest that households with more credits can use credit fund to buy PICS bags. This finding is in line with the observations from some of KIIs participants that:

> "*…Price is not affordable, they do complain about 5000/= @ PICS Bag being very expensive for them and for that matter they can't buy and therefore they cannot use. Those with access to credit are able to afford the price subsidized by their SACCOs…" (KIIs* Participant***).***

These findings concur with the findings reported by FAO (2011), Makingi and Urassa (2017), which indicate that access to credit facilities the adoption of farming technologies.

Education of the household head in Table 4 showed a positive and statistically significant influence on the household chances of adopting PICS bags (p=0.05). The findings revealed further that when education level increased by one year, the odds ratio became 0.615, implying that households with more years of schooling are 0.615 times more likely to adopt PICS bags. An increase in the education means the households have the possibility of acquiring more income for incurring the costs of buying PICS bags. Similar findings are reported by other scholars (e.g. Oluoch, 2014; Chisenga, 2015; Makingi and Urassa, 2017) who reported that increasing literacy helps farmers to acquire more income, understand information, and adopt new storage technology.

The maize farming experience of the household head as shown in Table 4 influenced significantly the household adoption of PICS bags (p=0.05). according to the findings, when the experience of the household head in maize farming increased by one year, the odds ratio increased by 0.775 implying that households with more experience in maize farming are 0.775 more likely to adopt PICS bags. A possible explanation to this could be that households with more experience in maize farming have the opportunity of using different storage facilities. More experience in maize farming also implies that the households are aware of storage technologies, which are effective in reducing post-harvest losses and reduce the inherent risk in using ineffective storage technology.

FGDS shared a similar concern that:

> "…*Our experience in using other maize storage technology shows that PICS bags are more effective as it has proven that insects have no chance of making their way into the bags as they die of oxygen deprivation after three to five days. I can confidently say that these bags were intended for smallholder farmers. It makes my household lives both efficient and flexible as I can store our produce in the bags at any time and be assured that our product will last. When I need to feed my family or sell it, it is readily available and results in a decent amount of income. ...." (*FGDs participants in Zelezeta village, 12/08/2018 ***).***

The above extract implies that smallholder farmers are confident with PICS bags. As reported by scholars (e.g., Ayandiji *et al*., 2011; Aidoo *et al*. 2014; Malira and Kandiwa, 2015) farmers with more experiences on PICS tend to adopt PICS bags since they understand better devastating effects of insects on stored grains.

4.0 Conclusions and Recommendations

Based on the empirical findings presented in this study, it can be concluded that: gender of the household head, education level of the household head, maize farming experiences, access to credit, and household head access to training on PICS are the socio-economic characteristics, which were associated significantly with a household's adoption of PICS bags.

It is therefore recommended that awareness creation would be beneficial in promoting PICS, as it would help to increase more maize farmers understanding of PICS bags. It is also recommended further that more training needs to be provided to maize farmers to improve their technical expertise on PICS bags, especially considering that a high proportion of farmers are not using PICS bags due to ignorance and lack of technical knowledge. Likewise, there is a need for more advocacy initiatives on subsidizing the costs of PICS bags by stakeholders in order to improve the adoption of PICS bags by farmers. This is especially so because the costs associated with adopting PICS bags was a major challenge identified by the farmers

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