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ADOPTION OF IMPROVED STORAGE TECHNOLOGY FOR REDUCTION OF POST-HARVEST LOSSES AMONG SMALLHOLDER CEREAL CROP FARMERS: LESSONS FROM MVOMERO DISTRICT, TANZANIA.

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Abstract: The post-harvest losses as the decrease in quantity or quality of food along the food supply chain is a critical phenomena for farmers in Tanzania. The reduction of post-harvest losses has been identified as one of the key pathways to food security. Despite the policy prioritisation and interventions in reducing post-harvest losses, the adoption of improved post-harvest storage technology for cereal crops remains scant to most farmers. This paper examined factors for adopting improved storage technology of cereal crops among smallholder farmers in Mvomero District, taking Lubungo village as a case. A sample of 262 participants was used. The study used a cross-sectional design that blended qualitative and quantitative methods. Data were collected from primary and secondary sources. The logistic binary regression model was used to analyze quantitative data. Findings from the study indicated that following the interventions through the Grain Post-Harvest Loss Prevention (GPLP) project introduced in the Mvomero District, about 70% of the total sampled farmers adopted the improved cereal crops storage technology. Besides, the education level, farm size, income level, knowledge, and age of respondents significantly contributed to the adoption of improved cereal crop storage technology in the study area.

Keywords: *Adoption, improved storage technologies, metal silos, hermetic bags*

1.0 Introduction

The data on post-harvest losses of agricultural produce indicates that about one-third of the food produced in the world per year for human consumption is lost or wasted. Furthermore, it is demonstrated that food losses and waste total approximately $680 billion in industrialized countries and around $310 billion in developing countries. The industrialized and developing countries are wasting approximately comparable amounts of food (670 and 630 million tons, respectively (Sawicka, 2020). The reduction of post-harvest losses has been identified as a critical pathway to food security around the globe. Despite policy prioritisation in reducing post-harvest losses in various nations, knowledge about the improved post-harvest storage technology for cereal crops remains scant to most smallholder farmers (Klara *et al*., 2021). Post-harvest losses as the decrease in quantity or quality of food along the supply chain are critical to most farmers (FAO, 2019).

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According to the High-Level Panel of Experts (HLPE) on food security, around one-third of all food produced is lost along the food chain from the first stage of the chain production to the last stage of consumption. Generally, the global quantitative food losses and wastes during the year are around 30% for cereal crops. In similar vain, the East African Community makes huge post-harvest losses in food products annually in the range of 30% in cereals (Bazivamo, (2022). This is primarily attributed to smallholder farmers' traditional post-harvest storage system. This loss is defined as waste for farmers and other value chain actors, resulting in food insecurity and high price for the final consumers. For cereal crops, the post-harvest loss is due to poor harvest scheduling and timing, poor harvest practices, improper handling of produce, shortage of appropriate storage technologies at the micro-level, poor coordination long chain at the mid-level, and policy issues at the macro-level (Vishweshwaraiah *et al*., 2014).

Adopting improved post-harvest storage technology for cereal crops remains one of the most problematic issues throughout the post-harvest chain (Boxall, 2002; Golob, 2002). The traditional cereal crop storage technologies are the primary storage techniques utilized by smallholder farmers in Tanzania. The dominant types of traditional storage technologies include: on-field, open storage, jute bags, polyethylene or polypropylene bags, raised platforms, conical structures with thatched roofs, and giant woven baskets (FAO, 2004; Addo *et al*., 2002). Also, smallholder farmers store bags in their private rooms or heaped on floors, and if cereal crops are moved during the storage season, it is very commonly threshed and bagged (Addo *et al*., 2002).

According to Tanzania Agricultural Policy (2013), many technological innovations, including post-harvest technologies, have not yet been adopted by most smallholder farmers in Tanzania. This is mainly due to smallholder farmers' inadequate delivery systems or low adoption. According to National Post-Harvest Management Strategy (NPHMS) (2019-2029), different studies demonstrate that farmers in Tanzania lose up to 40 percent of the harvest through post-harvest losses depending on the crop and geographical location area. The government has put in place some strategies and interventions to reduce yield and post-harvest losses. The notable strategy is the National Post-Harvest Management Strategy (NPHMS) of 2019-2029. Although the government has done much through various policies, strategies, and programs, challenges remain in addressing post-harvest losses caused by traditional post-harvest technologies used by smallholder farmers in the country.

Also, the '*heltevas'* Tanzania, as part of a network of independent development organisations introduced the Grain Post-harvest Loss Prevention (GPLP) project in 2016 in Mvomero District in Morogoro, Tanzania. The project's overall objective was to promote the adoption of improved post-harvest storage technology for cereal crops among smallholder farmers. The project benefited more than 15,000 smallholder farmers who

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were introduced to metal silos and improved hermetic grain storage technologies for smallholder farmers since 2016 (FAO, 2018). Despite the identified interventions, the Mvomero District Council Agricultural Progressive report of 2019 shows that more than one-third of smallholder farmers continued to practice and use traditional post-harvest storage technologies. As a result, farmers lose 20 to 40% of cereal crops per season during and after harvesting. Therefore, this study examined factors for a shift from the traditional storage system to improved post-harvest storage technology for cereal crops among smallholder farmers in Mvomero District.

Theoretically, adoption depends much on the diffusion of innovation to respective societies. That is, diffusion is the process by which an innovation is communicated through specific channels over time among the members of a social system (Rogers, 1962). It is assumed that in the adoption of innovation through diffusion, individuals progress through 5 stages: knowledge, persuasion, decision, implementation, and confirmation. If the invention is adopted, it spreads via various communication channels. During communication, the idea is rarely evaluated from a scientific standpoint; rather, subjective perceptions of the innovation influence diffusion. The process occurs over time. Finally, social systems determine diffusion, norms on diffusion, roles of opinion leaders and change agents, types of innovation decisions, and innovation consequences. Moreover, innovation diffusion depends on key parameters: the innovation itself, communication channel, time, and social system (Rogers, 1962).

2.0 Methodology

2.1 Study design and data collection

The study was conducted at Lubungo Village in Mvomero District. The village was purposively selected from among 30 villages for two main reasons. Firstly, the village is one of the district's leading cereal crop producers. Secondly, the village has the highest rate of adoption by 75% of improved post-harvest storage technologies such as hermetic bags and metal silos. Both probability and non-probability sampling techniques were used in the study. In probability sampling, clustered sampling technique was employed to cluster two groups to represent the sampled population that included adopters and no adopters of improved post-harvest storage technologies from which primary data was collected. This helped to avoid subjectivity and personal biases. The two clusters used simple random sampling to select respondents based on their characteristics of adopters and non-adopters and other variables related to the issue under study.

The target population for this study was smallholder farmers from the selected village. The unit of analysis constituted an individual smallholder farmer, preferably a head of household. A sample frame for this study constituted a total of 2,381 smallholder farmers. A sample of 256 farmers was drawn using the Cochran (1977) sample size formula. However, during the survey, the study reached 262 farmers.

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The study adopted a cross-sectional design that blended qualitative and quantitative (mixed) methods. Data for this study were collected from both primary and secondary sources. Preliminary data was collected from the cereal crop farmers through interviews, observation, and focus group discussion using questionnaires as well as a checklist. Secondary data was obtained through a review of relevant documentary sources. Qualitative and quantitative data were marshaled in order to provide a comprehensive analysis of the study problem. In this design, the two types of data were collected and then integrated in the interpretation of the overall results (Creswell, 2003).

2.2 Data analysis

Descriptive and inferential statistics were used to analyse quantitative data whereby frequency and percentage and binary multiple regression were employed, respectively. Prior to regression analysis, the multi-collinearity test was run to measure the correlation between variables. The Logit regression model in equation (1) was employed to examine factors influencing the adoption of post-harvest storage technologies for cereal crops.

$$\ln\left(\frac{P_i}{1-P_i}\right) = \alpha + X_i\beta \quad \text{...} \quad (1)$$

Whereby P_i is the estimated probability for adopting storage technologies; **α** regression constant, β is a vector for estimated regression coefficients, and X_i's a vector for explanatory variables. Pi=Dependent variable and P is the estimated probability.

By rearranging (i), the estimated probability of default P(Y=1) is given by

$$P(Y=1/x) = \frac{1}{1+^{-(\alpha+\beta_1X+\beta_2X+\beta_3X+\beta_4X+\beta_5X_5+\ldots + \beta_iX_i)}} \quad \text{..............................} \quad (2)$$

Where; α, β_1, β_2, β_3, β_4, β_5...... β_i are the coefficients to be estimated, and e is the error term.

Qualitative data were analysed through a thematic analysis whereby themes of interviews and observational field notes were analysed by identifying the main themes, assigning codes to the main themes, classifying responses under the main themes, and integrating themes and responses into the text.

3.0 Results and Discussion

3.1Characteristics of Respondents

This section describes the characteristics of respondents in the study area. The major demographic parameters examined in the inquiry were: the age of respondents, marital status, education level, sex, and household size (Table1).

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Table 1: Characteristics of the respondents (n = 262)

Variable	Frequency	Percentage
Age		
18-35 years	81	30.9
36-55 years	151	57.6
56+ years	30	11.5
Sex		
Males	170	64.9
Females	92	35.1
Marital status		
Single	22	8.4
Married	203	77.5
Divorced	18	6.9
Widow	19	7.3
Level of education		
Primary	163	62.2
Secondary	49	18.7
Degree	13	5.0
No formal education	37	14.1
Household size		
2-6	211	80.5
7-10	48	18.3
11+	3	1.1

The results in Table 1 indicate that most respondents (57.6%) were aged between 36-55 years, (30.9%) were aged between 18-35, and 11.5% were 56 years and above. Very few respondents (11.5%) were aged between 56 years and above. This implied that the most active age group engaged in cereal crop farming as the dominant economic activities ranged between18-55 years which also could be a good predictor for adopting improved storage technology.

Moreover, findings on the sex of the respondents revealed that out of the sampled respondents interviewed, 64.9% were male, and 35.1% were female. This indicates that male respondents were almost twice as compared as their female counterparts. On marital status, results showed that more than half (77.5%) of the respondents involved in the study were married, 8.4% single, 7.3% widows, and 6.9% divorced. The education level of respondents varied by 62.2% of the respondents attended primary education, 18.7% secondary education, 14.1% did not participate in school. This implies that the literacy level in the study area was slightly high to the extent that it could influence the awareness creation processes that the WOPATA project was creating. On the household size, results indicated that the majority of the respondents, 80.5% had a family size ranging between 2 and 6 members, 18.3% had a family size ranging from 7-10 members, and a few 1.1% had a family size above 11 members.

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3.2 Factors for Adoption of Improved Storage Technologies

This study examined factors for the adoption of improved post-harvest storage technology among smallholder farmers in the study area. The major variables used in the inquiry were: the adoption level, education level, farm size, demographic variables (sex, age, gender, and household size), income level, access to credits, awareness, knowledge, and skills; and local environment. The results from the Double-hurdle model were used to show the decision to adopt the improved storage technology and the extent of farmers' adoption.

Before regression analysis, a multi-collinearity test was conducted by running a correlation matrix whereby those variables with high correlation (>0.6) were combined, and some of the farm size and household income were dropped out. Based on Table 2 for model summary and variables in the equation indicated that variables included in the model were a good predictor of factors for the adoption of improved storage technology (Nagelkerke R^2= 0.58). The findings show that the model fits to explain the change in the dependent variable as a result of the change in the independent variable.

Table 2: The Statistical Test of the Double-Hurdle Model

Test statistic	Probit, D	Truncated Regression, Y(Y>0)
Wald χ^2	59.3	51.7
Prob > χ^2	0.001***	0.00*
LOG-L	-98	0.56
AIC	0.53	0.06
Number of obs (N)	262	79

Source: Field Survey, 2020.

X^2-Test Double Hurdle versus Tobit: Γ = 44.7 > $\chi^2(16)$ = 32.3, *, ** *and *** refers statistically significant at 10%, 5% and 1% respectively; k = number of parameters*

Nagelkerke R Square= 0.58, **NS**= Not significant, *****= significant, **p**= 0.05

The variables took a value of 1 if the farmer adopted improved storage technology and 0 if it was otherwise. In this regard, about 70.2% of the total sampled smallholders' farmers reported adopting improved cereal crops storage technology during the study. Moreover, the number of cereal crops stored by using improved storage technology by the farmers was used as a further dependent variable in the second stage of truncated regression. Generally, there was a good and positive likelihood of adoption of improved cereal storage technology.

The analysis involved two major steps; the first involved testing the Tobit model versus the substitute of a probit with truncated regression, as indicated in Table 2. The results of the formal test, between the Tobit and the two-step modeling, showed crushing proof of the fitness of the selected model for the analysis. The log-likelihood values from L.R. test results propose the choice of not using the Tobit model for analysis. That is, the test statistic Γ=44.68 exceeds the critical value of the χ^2 distribution. The model's selection also consists of using Akaike's Information Criterion (AIC), whereby the model with the

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lowest value was selected. Therefore, this stage revealed that the decision to use the double hurdle model for the analysis was suitable to explain how a special process governs decisions.

3.2.1 Adoption level

Results from the study presented in the Double-hurdle model (Table 3) show that the decision of farmers to adopt the improved storage technology for the model summary and variables in the equation indicated that variables included in the model were good predictors for factors for the adoption (Nagelkerke R^2= 0.58). Therefore, the findings showed that the model was fit to explain the change in the dependent variable as a result of the change in the independent variable. Besides, before the regression analysis, a multi-collinearity test was done by running a correlation matrix whereby those variables with high correlation (>0.6) were combined.

Table 3: The Statistical Test of the Double-Hurdle Model

Test statistic	Probit, D	Truncated Regression, Y(Y>0)
Wald χ^2	59.3	51.7
Prob > χ^2	0.001***	0.00*
LOG-L	-98	0.56
AIC	0.53	0.06
Number of observations (N)	262	79

Source: Field Survey, 2020.

X^2-Test Double Hurdle versus Tobit: Γ = 44.7 > $\chi^2(16)$ = 32.3, *, ** *and* *** *refers statistically significant at 10%, 5% and 1% respectively; k = number of parameters*

Nagelkerke R Square= 0.58, **NS**= Not significant, *****= significant, **p**= 0.05

A variable took a value of 1 if the farmer adopted and 0 if it was otherwise. About 70.2% of the total sampled farmers reported adopting improved cereal crop storage technology during the study. The number of cereal crops stored using improved storage technology by farmers was used as a further dependent variable in the second stage of truncated regression. Generally, there was a good and positive likelihood of adoption. Moreover, the analysis was done by considering two steps; the first involved testing the Binary model versus the substitute of the probit, together with truncated regression, as indicated in Table 4.

Results of the formal test between the binary and the two-step modeling have shown crushing proof of the fitness of the selected model for the analysis. The log-likelihood values from L.R. test results propose the choice of not using the Binary model for the analysis.

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3.2.2 Socio-demographic factors

Results on the association between socio-demographic factors and the adoption of improved post-harvest storage technology for cereal crops among smallholder farmers are indicated in Table 4. The dominant demographic factors examined were sex, age, and gender. Regarding sex, the findings showed that male smallholder farmers were likelier to adopt as early adopters in the first stage of the double-hurdle model than females.

Table 4: Estimated Coefficient of Adoption of Improved Cereal Crops Storage Technology from Double Hurdle Model

Variables	Binary		Truncated Regression	
	Coefficient	RobStd. Err	Coefficient	RobStd. Err
Gender	0.27	0.11	0.02	0.22
Age	0.016	0.018*	-0.022	0.013*
Family size	0.024	0.014	0.004	0.011
Level of Income	0.26	0.08***	0.04	0.11
Level of education	0.006	0.030	0.002	0.023
Awareness	0.15	0.24	0.04	0.17
Knowledge and Skills	0.24	0.000	0.02	0.000
Credit	0.41	0.15	0.03	0.19
Cost of the technology	-0.28	0.09***	-0.41	0.16***
Year of Adoption	0.27	0.014**	0.012	0.005***
Constant	1.135	0.315		
Number of obs	262			
Pseudo R	0.0018			8.05***
L.R. chi2	34.65			

, ** and * refers statistically significant at 10%, 5% & 1% respectively.*

Besides, results also revealed that male farmers had a 27% probability of adopting than their female counterparts. On the contrary, the gender of the head of household had no effect (not significant at 5%) on the second stage of the analysis, which measured the extent of adoption. On the base of the age of the farmers, findings showed that age had an outstanding U-shaped effect on the level of adoption. Although age was disqualified at the first stage in the double hurdle adoption model, it had no significant effect on the possibility of adoption level. This implies that among the selected demographic factors involved in the inquiry, sex and age were positively related to adopting improved post-harvest storage technology. In contrast, the age of the respondent was negatively associated with the adoption.

3.2.3 Knowledge and Skills

Principally, the innovation-decision process starts with the knowledge stage. In this step, an individual learns about the existence of innovation and seeks information about the innovation by questioning "what?" "how?" and "why?" are the critical queries in the knowledge phase. During this phase, the individual attempts to determine "what the innovation is, how and why it works." In examining respondents' knowledge and skills,

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there was a positive coefficient of both knowledge and skills in the adoption of improved storage technology of cereal crops among smallholder farmers. The study's results indicated a direct association between the knowledge of farmers and adoption level; farmers with knowledge and skills had a high possibility of adopting the improved storage technologies compared to those who didn't. The positive effect of knowledge and skills suggests the utilization of the technology by 24% and 15%, respectively. This also meant that, in the second stage of the hurdle test, these two variables had a significant effect at 5% on the level of adoption. On the other hand, the level of education among farmers had a significant contribution to the adoption with a positive effect on the probability at a coefficient value of 0.006. Adoption of improved post-harvest cereal crops storage technologies was mainly associated with knowledge and skills farmers possess; out of 262 sampled respondents (cereal crop farmers) interviewed, 70.22% were adopters of the improved storage technologies compared to 29.78% who were non–adopters. This implies that farmers' education level had effects on the level of adoption of technology, increased literacy among farmers helped to acquire and understand information that influenced the adoption of new methods in a rapidly changing environment. Besides, education helps improve attitudes, beliefs, and habits, thus leading to a greater willingness to accept risks and adopt new innovations. Farmer's education level increases access to external sources of information or enhances the ability to acquire knowledge through experience with new adoption.

3.2.4 Income level and affordability based on the cost of technology

Under this variable, the study examined whether farmers' income and affordability influence the adoption of improved post-harvest technology based on the cost of respective technology opted by respective farmers. The study findings on income level indicated that there was a positive coefficient of the extent of income within the adoption equation, which supports the speculation that farmers who had higher levels of income of one shilling resulted in an additional shilling 0.26 in income and thus, were much more likely to adopt improved storage technologies. This implies that the positive impact of the extent of income variation indicated the utilization of current innovations, training, and awareness and increased the chance of adoption almost by 26%. Moreover, farmers are always considering storage as a complementary activity to the whole process of the production stages. Therefore, adoption and income level provided a synergistic average profit variation of TZs 20,000 compared to traditional storage farmers.

Besides, data on affordability based on the technology showed a significant effect at 10%. The cost of buying the storage technology significantly impacted the extent of the adoption of the technology among farmers. There was a decrease in the likelihood of adoption of the improved post-harvest storage technology for cereal crops among smallholder farmers for farmers without affordability of buying the technology by 28%, while the perception of

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adoption, farmers with the cost of the technology were associated with a reduction of the adoption proportion of the improved cereal crop storage technologies by 41%. This implies that smallholder farmers in the study areas were rational decision-makers in adopting the improved technologies based on certain features, which helped them to reduce cereal losses. Thus, an ideal system for smallholder farmers that must be considered in storage technologies to be hermetically sealable, mechanically durable, flexibility, and cost-effective compared to conventional storage options such as larger grain borer seems to be well adopted by farmers as a result of the intervention at a lower level. Such a storage system appears to help farmers reduce grain storage losses, maintain grain quality, and reduce food insecurity for smallholder farmers in the study area.

4.0 Conclusion and Recommendations

Conclusively, the study results indicated that many farmers adopted improved cereal crop storage technology with varied factors pushing them. On demographic factors, there was a positive association between socio-demographic factors and the adoption of improved post-harvest storage technology for cereal crops among smallholder farmers. Regarding sex, the findings indicated that male smallholder farmers were likely to adopt as early adopters in the first stage of the double-hurdle model compared to their female counterparts. On the contrary, age and gender had no significant effect on the latter adoption level. On the other hand, knowledge of farmers had effects on the level of adoption of technology among farmers, whereby increased literacy among farmers helped them to acquire and understand information that influenced the adoption of new methods in a rapidly changing environment. Besides, education helped in raising awareness that improved attitudes, beliefs, and habits, thus leading to a greater willingness to accept risks and adopt new innovations. Moreover, the study findings on income level indicated that there was a positive coefficient of the extent of income within the adoption equation, which supports the speculation that farmers who had higher levels of income of one shilling resulted in an additional shilling 0.26 in income, thus, were much more likely to adopt improved storage technologies. This implied that farmers' income and affordability positively influence the adoption of improved post-harvest technology based on the cost of the respective technology opted by an individual farmer.

Generally, the findings from the study raise diverse recommendations since it has been found that there was a positive coefficient of both knowledge and skills in the adoption of improved storage technology of cereal crops among smallholder farmers. There was a direct association between farmers' knowledge and adoption level; farmers with knowledge and skills had a high possibility of adopting the improved storage technologies compared to those without understanding. These findings call for the need of the Tanzania government, through the ministry of Agriculture Livestock and Fisheries, to disseminate knowledge on the use of the improved post-harvest technology to smallholder farmers at

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the local level. Acquisition of appropriate knowledge shall trigger rational decisions among farmers on adopting the right technology to store cereal crops. Additionally, since some farmers failed to adopt the improved cereal crops storage technology due to the cost of the respective technology, the government should reduce the importation taxes for the agricultural inputs associated with the improved storage technology.

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