Typology and Adoption level of Improved Post-harvest Storage Technology for Cereal Crops among Smallholder Farmers in Mvomero District, Tanzania

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Ikisiri

Pamoja na jitihada za serikali za kuboresha matumizi ya teknolojia bora za kuhifadhi nafaka baada ya mavuno kwa wakulima wadogo nchini, ufikiaji na matumizi ya teknolojia hizo ni tatizo katika mnyororo wa thamani wa mazao ya nafaka. Katika kuunga mkono jitihada za serikali, shirika la 'heltevas' lenye makao makuu yake nchini Uswisi, Ujerumani na Marekani katika mwaka 2016 lilianzisha mradi wa kuzuia upotevu wa mazao ya nafaka baada ya kuvuna katika wilaya ya Mvomero kwa lengo la kuhamasisha wakulima wadogo kutumia teknolojia bora za kuhifadhi mazao ya nafaka baada ya mavuno. Utafiti huu ulifanya tathmini ya aina ya teknolojia bora za uhifadhi zilizotolewa kwa wakulima na kiwango cha matumizi ya teknolojia hizo. Sampuli ya watu 262 walihojiwa. Utafiti huu umetumia njia ya kuhoji watu maramoja kwa wakati mmoja ikichanganya mbinu za takwimu na maelezo. Takwimu zilikusanywa kutoka chanzo cha awali na upili. Mbinu za kimahesabu na za maelezo zilitumika kuchakata takwimu. Matokeo ya utafiti huu yanaonesha kuwa mradi ulifanikiwa kutoa elimu na teknolojia bora ya kuhifadhi mazao kwa wakulima wadogo, na kuwezesha kwa kiwango kikubwa kubadilisha tabia za wakulima juu ya uhifadhi wa mazao ya nafaka. Pia kwa kiwango kikubwa wakulima wanatumia teknolojia bora za kuhifadhi mazao ya nafaka baada ya mavuno.

Abstract:

Despite government interventions on promoting improved post-harvest storage technology among smallholder farmers in the country, the access and adoption of the technologies remain one of the most problematic issues throughout the post-harvest chain resulting in post-harvest losses. In complementing government effort, the 'heltevas' organisation in 2016 introduced the Grain Post-harvest Loss Prevention (GPLP) project in the Mvomero district to promote the adoption of improved post-harvest storage technology. This paper, therefore, examined the typology and adoption level of post-harvest storage technology for cereal crops among smallholder farmers taking the Mvomero district as a case. A sample of 262 participants was used. The study used a cross-sectional design. Data were collected from primary and secondary sources. Descriptive statistics and regression analysis were used to analyze quantitative data, where a multi-collinearity test was employed to measure the correlation between variables. Findings from the study indicated that the GPLP project disseminated knowledge on improved post-harvest storage technologies, resulting in farmers' persuasion that influenced the decision to adopt and implement the diffused technologies. Diverse types of enhanced post-harvest storage technology innovations were disseminated to farmers which include;Perdue Improved Crop Storage (PICS), metal silos, Agro Z, and super grain. To a large extent, farmers adopted the diffuse technologies.

Keywords: Typology, Adoption, Improved post-harvest storage, Cereal crops, Smallholder farmers

1.0 Introduction

The reduction of post-harvest losses has been identified as a key pathway to global food security. However, despite policy prioritisation in reducing post-harvest losses, knowledge about the improved post-harvest storage technology for cereal crops remains scant to most farmers (Klara, Verena, and Froukje, 2021). Post-harvest losses as the decrease in quantity or quality of food along the food supply chain are critical to most farmers (FAO, 2019). According to the High-Level Panel of Experts (HLPE) on food and security, globally, around one-third of all food produced is lost along the food chain from the first stage of production to the last stage of consumption and is largely attributed to the traditional post-harvest storage system practised by smallholder farmers. This loss is defined as waste for farmers and other value chain actors and results in a high price for the final consumers. This also may lead to food insecurity by making food less accessible to vulnerable groups. The cereal crop loss is due to the poor harvest scheduling and timing, poor harvest practices, careless handling of produce, lack 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).

Theoretically, adoption depends much on the diffusion of innovation to respective societies. That is, diffusion is how innovation is communicated through specific channels over time among the members of a social system (Rogers, 1962). It is assumed that in adopting innovation through diffusion, individual's 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, diffusion of innovation depends on key diffusion parameters, that is, innovation itself, communication channel, time, and social system (*ibid*).

Adoption of improved post-harvest storage technology for cereal crops remains one of the most problematic issues throughout the post-harvest chain; particularly in the storage stage, devastating pests such as the large Grain Borer can cause up to 30% dry-weight-losses in six months of storage (Boxall, 2002; Golob, 2002). The traditional cereal crop storage technologies are major 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 as shown in clay structures, and giant woven baskets (FAO, 2004; Addo, Birkenshaw, and Hodges, 2002). Farmers may also store bags in their personal rooms or simply heaped them on floors, and if cereal crops are moved during the storage season, however, it is very commonly threshed and bagged (Addo, Birkenshaw, and Hodges, 2002).

According to Tanzania Agricultural Policy (2013), many technological innovations, including post-harvest technologies, are not yet been adopted by the majority of smallholder farmers in Tanzania. This is because they are unknown to smallholder farmers, or there are inadequate effective delivery systems in place. Besides, FAO (2010) and the Ministry of Agriculture (2011) affirm that less adoption of improved storage systems is the reason for low agricultural supply in Tanzania due to grain loss. This has resulted in low income and poor standards of living for smallholder farmers, especially in rural areas. According to National Post-Harvest Management Strategy (NPHMS) (2019-2029), results from different research studies FAO conducted demonstrate that farmers in Tanzania lose up to 40 per cent of the harvest through post-harvest losses depending on the crop and geographical area.

The government has formulated relevant policies, strategies, and programmes. The most applicable public policies to crop post-harvest losses are the National Agriculture Policy (2013) and Agriculture Marketing Policy (2008) and National Post-Harvest Management Strategy (NPHMS) (2019-2029) which all acknowledge that post-harvest losses are largely caused by the shortage of relevant technologies as a challenge in achieving food security in Tanzania. Although the government, through various policies, strategies, and programmes has done much, challenges still remain in addressing post-harvest losses caused by traditional post-harvest technologies used by smallholder farmers in the country.

In spite of all of the identified interventions, the Mvomero District Council agricultural progressive reports (2019) indicate that the trend of the total production of cereal crops produced in 2016, 2017, 2018, and 2019 are: 192,333 tons, 321,712 tons, 268,548 tons, and 285,681 tons respectively. However, the council experienced a post-harvest loss of 10 % during the storage of cereal crops. Besides, the post-harvest loss is experienced due to the fact that one-third of smallholder cereal crop farmers continue to practice and use traditional methods of post-harvest storage technology. Moreover, farmers' traditional on-farm and storage technology include fireplaces, local cribs, roofs, woven granaries, underground pits, and wooden platforms. Farmers reported a 30-35 % loss during and after harvesting. According to council progressive agricultural quarterly reports, the average total post-harvest loss reported by District Agriculture Office is about 20-40% per season.

In complementing government effort, the '*heltevas'* Tanzania as part of a network of independent development organisations with head offices in Switzerland, Germany, and the United States of America, in 2016 introduced Grain Post-harvest Loss Prevention (GPLP) project in the Mvomero district. 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. Concerning improved post-harvest technology, the project component included: reducing high post-harvest losses, eradicating insufficient storage and processing capacity, promoting entrepreneurship capacity, promoting good market, and improving market linkages. To reduce post-harvest losses and inadequate improved storage technologies, the projects introduced improved hermetic grain storage technologies (Metal silo and Hermetic bags) to smallholder farmers in 2016 (FAO, 2018). This inquiry, therefore, examined the typology and adoption level of improved post-harvest storage technology for cereal crops among smallholder farmers by taking Mvomero District as a case.

Understanding the typology and adoption level of improved post-harvest storage technology for cereal crops among smallholder farmers is a prerequisite aspect in promoting improved storage technologies to combat food losses and achieve food security in Tanzania. Additionally, it is significant to the policymakers and government in general. The study provides more information on the typology and adoption level of the improved post-harvest storage technology for cereal crops farmers prefer and their reasons for preferences. Besides, information on the adoption level provides more insight to the decision-makers on scaling up strategies for wider use of improved post-harvest storage technology among farmers. Other stakeholders like non-government organizations engaging in agricultural interventions of the post will use the information from this study to improve their ways of equipping farmers with information for reducing post-harvest losses on cereal crops. Furthermore, this study will provide a platform for other researchers and academicians to further studies on this subject based on findings and recommendations.

2.0 Methodology

The study was conducted at the Lubungo village in the Mvomero district. The village was purposively selected as a case from among 30 villages based on two reasons: the village is one of the leading producers of cereal crops in the district. It is leading among other villages within the project area with a high rate of 75 % of adoption 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 a sampled population that included adapters and no adopters of improved post-harvest storage technologies from which primary data was collected. This helped to avoid subjectivity and personal biases. From the two clusters, simple random sampling was used to select respondents from the two different cluster groups of farmers based on their characteristics of adopters and non-adopters and variables related to the issue under study.

The target population for this study was the community members from the selected village in which an individual smallholder farmer, preferably heads of household, constituted the unit of analysis. A sample frame for this study comprised a total of 2,381 population of both adopters and non-adopter smallholder farmers, who included a list of the entire population from which the sample size was drawn. A sample of 262 participants was used; 256 were respondents from heads of households, and 6 were crucial informants selected purposively with their degree of importance, knowledge, and influence in the study area. Hence by using the sample size estimation formulae with a finite population from Cochran 1977, the following was sample size estimation used.

$$n = \frac{Z^2 * p * q * N}{e^2 \, (N-1) + (Z^2 * p * q)}$$

Whereby;

N = Total number of farmers, e = Standard (allowable) error 0.0579, since the estimate should be within 2% of true value, sample proportion p = 0.5 with q = 1-p= 0.5, n = sample size, z = normalized number at a given interval (CI) and 1= constant. Taking N = 2,381, Z = 1.96 at 95% CI, results are as follows:

$$n = \frac{(1.96^2 x 0.5 x 0.5 x 2381)}{(0.0579^2 x 2380) + (1.96^2 x 0.5 x 0.5)}$$

n = 256 + 6 Key informants =262 participants.

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 were collected from the cereal crop farmers who were key respondents during a field survey. Secondary data were obtained through a review of relevant documentary sources from the archives of various organizations, including the Ministry of Agriculture Mvomero District Council office. Qualitative and quantitative data were marshalled in order to provide a comprehensive analysis of the study problem. In this design, both forms of data were collected and then integrated into interpreting the overall results (Creswell, 2003). Primary data were collected through interviews, observation, and focus group discussion using questionnaires as well as a checklist. Secondary data were collected through the documentary review method.

The collected data were edited to detect errors and omissions before being classified and coded to enable them for analysis. Regression analysis was used to analyse quantitative data, where a multi-collinearity test was run to measure the correlation between variables. More specifically, the binary multiple regression analysis was employed to examine factors influencing the adoption of strategies for post-harvest storage technologies of cereal crops using the following statistical Logit regression model:

$$\ln\left(\frac{P_i}{1-P_i}\right) = \alpha + \beta_1 x_1 + \beta_2 x_2 + ... + \beta_p x_p$$

Such that:-

$$\ln\left(\frac{P_i}{1-P_i}\right) = P(Y_i = 1/X) = \alpha + \beta_i x_i \text{..} \quad \text{(i)}$$

Where P_i is the estimated probability for the adoption of storage technologies; **α** regression constant, β_i is a vector for estimated regression coefficients, and X_i's a vector for explanatory variables, which are x_1=sex of ……., x_2=family size, x_3=income level, x_4=education level, x_5=awareness, x_6=knowledge and skills, x_7=credit, x_8=cost of technology, and x_9=year of adoption. Y_i=Dependent variable = adoption of storage technologies.

Besides, descriptive statistics were used where numbers assigned to variables were used to summarize and describe data, frequencies, and percentages and mean were the main types of descriptive statistics used in verifying the relationship between variables. The qualitative data were analysed through thematic (content) analysis. The themes/contents 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 articles and responses into the text.

3.0 Results and Discussion

3.1 Characteristics of Respondents

This section offers a description of the characteristics of respondents in the study area. The primary demographic parameters examined in the inquiry were: the age of respondents, marital status, education level, sex, and household size.

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

Variable	Frequency (n = 262)	Percentage (n %)	All n= 262, N %
Age			
18-35 years	81	30.9	81 (3.4)
36-55 years	151	57.6	151 (6.3)
56+ years	30	11.5	30 (1.2)
Sex			
Males	170	64.9	170 (7.1)
Females	92	35.1	92 (3.8)
Marital status			
Single	22	8.4	22 (0.9)
Married	203	77.5	203 (8.5)
Divorced	18	6.9	18 (0.7)
Widow	19	7.3	19 (0.7)
Level of education			
Primary	163	62.2	163 (6.8)
Secondary	49	18.7	49 (2)
Degree	13	5.0	13 (0.5)
No formal education	37	14.1	37 (1.5)
Household size			
2-6	211	80.5	211 (8.8)
7-10	48	18.3	48 (2)
11+	3	1.1	3 (0.1)

The results in Table 1 indicate that the majority of respondents (57.6%) were aged between 36-55 years, (30.9%) were aged between 18-35, and 11.5% had 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 could also 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 males, and 35.1% were females. This indicates that male respondents were almost twice as compared to 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, and a few 5.0% had college and university education. 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.

3.2. Farmer's Awareness of the Types of Improved Post-harvest Storage Technologies

Awareness provides the knowledge of the innovation's existence to farmers. The knowledge supplied to farmers can motivate the individual to learn more about the innovation and eventually adopt it. Besides, the innovation-decision process starts with the knowledge that raises farmers' awareness of the types of improved post-harvest storage technologies. Awareness plays a vital role in the adoption of the induced storage technology for cereal crops storage during the post-harvest period. Education disseminated to farmers is positively associated with households (farmers) adoption decision behaviours. Education that results in awareness is dominant in determining diffusion, acceptability, and use of the induced technology. As stated earlier in this paper, in complementing government efforts, the '*heltevas'* organisation 2016 introduced the Grain Post-harvest Loss Prevention (GPLP) project in the Mvomero district. 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. Farmers were provided with training on improved technology to increase their knowledge and skills, which could influence awareness and confidence in using them and leave their traditional ways, which they used for many years. The training was provided using different channels, including house visits to farmers and demonstrations. Basically, the assumption was that farmers who have been trained have a greater possibility of choosing improved storage technologies than those who have no training; without training, most of them will prefer the traditional technique because they are conversant with it. In examining farmers' awareness of the typology of types of improved post-harvest storage technologies introduced in the study area, respondents were asked to identify the major types of improved post-harvest storage technologies available in their area.

Findings on farmers' awareness of improved post-harvest storage technology from the study area as presented in Table 1 indicate that most farmers 60%identified the Perdue Improved Crop Storage (PICS), 19.56% identified metal silos, 1.74% identified Agro Z, and 18.70% identified super grain. This implies that the diffusion of innovation of improved post-harvest storage technology from the '*heltevas'* organisation in the study area was communicated through proper channels among members of a social system. Also, participants created and shared information to reach a mutual understanding of the diffused technologies. Given the improved storage technologies introduced to farmers, PICS technology was highly identified by farmers compared to other enhanced post-harvest technologies of identified metal silos, AgroZ, and super grain.

Table 2: Types of improved post-harvest storage technologies adopted by farmers

Storage technologies	Frequency	Percent
Metal silos	45	19.56
Perdue Improved Crop Storage (PICS)	138	60.00
AgroZ	4	1.74
Super grain	43	18.70
Total	**230**	**100**

Besides, the communication process in which participants created and shared information influenced farmers to reach a mutual understanding that gives conditions that increase the likelihood that members of a given culture will adopt a new idea, product, or practice. Similarly, the diffusion of innovation theory predicts that media and interpersonal contacts provide information and influence opinion and judgment.

Plate 1: A farmer from the study area holding PICS bags and cereal crops stored within it

Plate 2: Metal silos adopted by farmers observed in the study area

3.3 Characteristics of improved post-harvest storage technologies

Smallholder farmers are rational to adopt the improved storage technologies based on certain features which helped them to reduce cereal losses. Thus, the ideal has considered storage technologies to be hermetically sealable, mechanically durable, flexibility, and cost-effective when compared to orthodox storage options such as larger grain borer. Findings on characteristics of improved post-harvest storage technologies based on farmers' preferences indicated that smallholder farmers considered the improved post-harvest technology to be affordability by 92%, hermetic by 53.8%, easy inspection by 28.6%, flexibility by 35.1%, durability by 29.8%, easy handling by 24.4%. This implies that smallholder farmers were the rationale for adopting the improved post-harvest storage technologies based on certain features, which helped reduce cereal losses. Affordability in terms of the price of the enhanced storage technology was essentially a major characteristic mentioned by most the farmers, followed by a hermetic, easy inspection, flexibility, durability, and easy handling.

In this case, it has been noted that, among other characteristics, the cost of improved storage technologies was a significant factor in allowing the uses of the improved storage technologies to store grain. Smallholder farmers would manage to make choices because of the cost of such technologies. Thus, the ideal system for smallholder farmers must consider storage technologies to be hermetically sealable, mechanically durable, flexible, and cost-effective compared to conventional storage options such as larger grain borers.

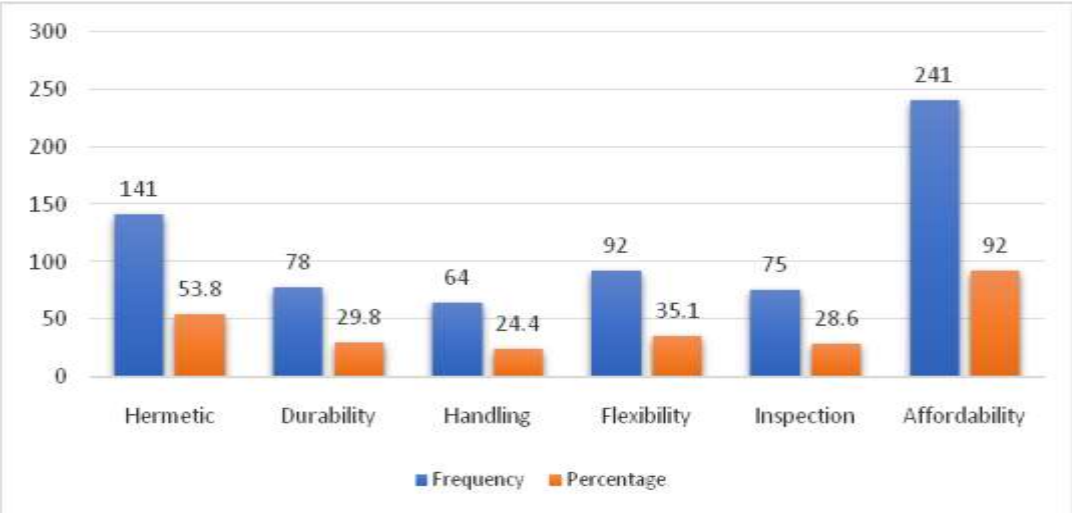

Figure 1: Characteristics of improved post-harvest storage technologies

3.4 Level of adoption of the improved post-harvest storage technologies

The level of adoption was examined to determine the number of farmers using improved post-harvest technologies compared to farmers using the traditional methods (the individual farmer chooses to adopt or reject the innovation) after interventions from the '*heltevas'* organisation. Theoretically, it was assumed that based on the knowledge of the improved post-harvest storage technologies provided by the '*heltevas'* organisation could result in farmers' persuasion that influences the decision on adoption and implementation of the diffused technologies that is full use of an innovation as the best course of action available to farmers.

Results from the study, as presented in Figure 2, indicated that out of the total of 262 sampled cereal crop farmers interviewed, the level of adoption was 184 (70 %) adopted improved post-harvest technologies compared to 78 (30%) non–adopters who were still using the traditional storage technologies of the wooden platform, local crib, sacks, and pesticides.

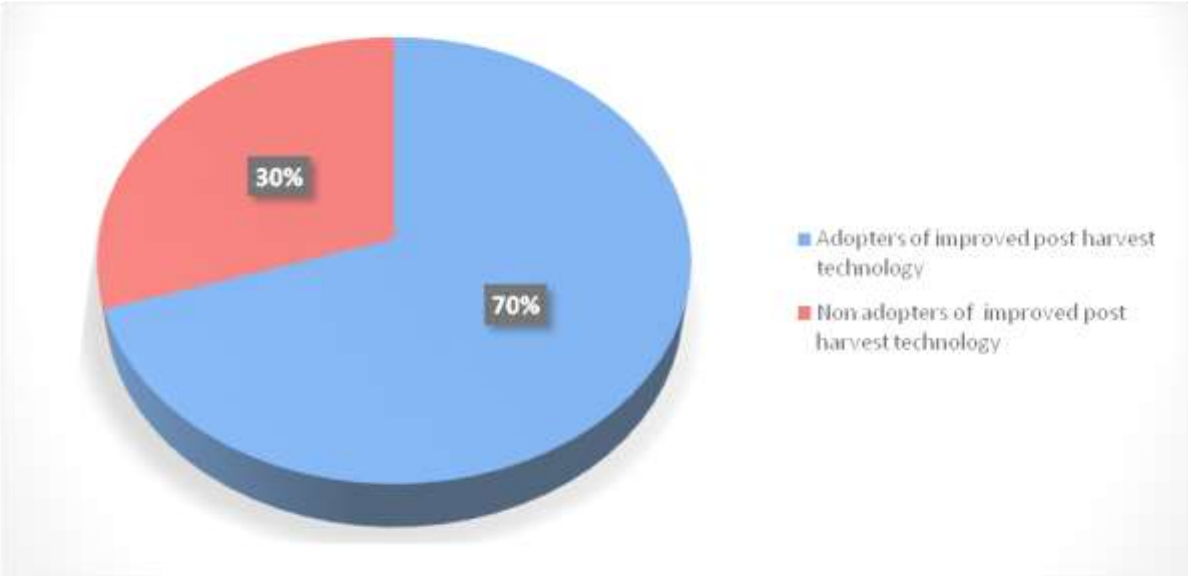

Figure 2: Level of adoption of the improved storage technologies

Moreover, results from the study as presented in the Double-hurdle model (Table 3) shows 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). Findings, therefore, 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. A variable took a value of 1 if the farmer adopted and 0 if it was otherwise. About 70% of the sampled farmers were reported to adopt 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 the adoption.

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

X^2-Test Double Hurdle versus Tobit: $\Gamma = 44.7 > \chi^2(16) = 32.3$, *, ** *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

Moreover, the analysis was done by considering two steps; the first one involved the testing of 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-s modelling have shown the crushing proof of the fitness of the selected model for the analysis. The log-likelihood values from LR test results propose the choice of not using the Binary model for the analysis.

Table 4: Estimated coefficient of adoption of improved cereal crops storage technology from the 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***
LR chi2	34.65			

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

3.5 Types of Traditional Storage Technologies Used by Non-adopters

Generally, the farmer's persuasion following the knowledge of the improved post-harvest storage technologies influences the innovation decision process among individual farmers. Findings from the study indicate that despite the interventions of inducing the improved post-harvest storage technologies introduced by the '*heltevas'* organisation in the study area, some (30%) of individual farmers still had a negative attitude toward the innovation resulting in an unfavourable attitude toward the innovations. Non-adopters used diverse traditional technologies for post-harvest grain storage, whereby 34.4% used wooden platforms, 1.9% used local cribs, and 63.7% used sacks and pesticides (Table 5). This implies that sacks and pesticides are traditional storage technology for cereal crops that farmers widely used compared to the wooden platform and local crib. Plates 3 and 4 show below the standard storage technology of wooden platforms and local cribs.

Table 5: Types of traditional post-harvest storage technologies

Storage technologies	Frequency	Percent
Wooden platform	90	34.4
Sacks and pesticides	167	63.7
Local crib	5	1.9
Total	**262**	**100**

Plate 1: Wooden platform traditional storage technology observed in the study area

Plate 2: Local crib traditional storage technology observed in the study area

The study also found that more farmers' preference for traditional storage technology was based on the low price of local materials used makes the low price of conventional storage technology. For example, sacks and pesticides were available in the nearby local market at an average price of 1000 TZs. Furthermore, farmers' participation in an extension programme on these storage technologies has an essential effect on the probability that positive perceptions of the quality of effectiveness against insects are provided by the improved traditional wooded granary, sacks, local cribs, and sofa grain.

4. Conclusion

Generally, the results from the study indicated that the interventions made by the '*heltevas'* organisation in the study area through promoting the adoption of improved post-harvest storage technology for cereal crops among smallholder farmers resulted in diverse types of innovations of improved post-harvest storage technology disseminated to farmers that were: the Perdue Improved Crop Storage (PICS), metal silos, Agro Z and super grain. Based on the knowledge of the improved post-harvest storage technologies provided by the organisation resulted in farmers' persuasion that influenced the decision on adoption and implementation of the diffused technologies that, is full use of an innovation as the best course of action available to farmers by 70%. While the Tanzania Agricultural Policy (2013) declares that many technological innovations, including post-harvest technologies, are not yet been adopted by the majority of smallholder farmers in Tanzania; and Agriculture Marketing Policy (2008) and National Post-Harvest Management Strategy (NPHMS) (2019-2029) acknowledge post-harvest losses largely caused by the shortage of relevant technologies as a challenge in achieving food security in Tanzania. In the study area, smallholder farmers were rational adaptors of the improved post-harvest storage technologies based on specific features that helped reduce cereal losses. Adopting a particular type of improved post-harvest storage technologies was based on farmers' preference for technology characteristics disseminated to them. Smallholder farmers considered the improved post-harvest technology affordable, hermetic, easy inspection, flexible in use, durable, and easy to handle.

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