International Journal of Scientific Research Updates

Journal homepage: https://orionjournals.com/ijsru/

ISSN: 2783-0160 (Online)

ORION SCHOLAR JOURNALS

(RESEARCH ARTICLE)

Factors that influence smallholder farmers' decisions to employ hermetic bag technology for maize grain storage in Kilosa District, Tanzania

Evelius Vedasto Rwebangira [1, *], Valerian Cosmas Silayo [2] and Geoffrey Christopher Mrema [2]

[1] *Department of National Food Security, Ministry of Agriculture, Tanzania.*
[2] *Department of Food Science and Agro-Processing, School of Engineering and Technology, Sokoine University of Agriculture Tanzania.*

International Journal of Scientific Research Updates, 2022, 04(01), 346–355

Publication history: Received on 16 August 2022; revised on 24 September 2022; accepted on 26 September 2022

Article DOI: https://doi.org/10.53430/ijsru.2022.4.1.0141

Abstract

The huge maize grain losses caused by a lack of improved storage methods have a negative impact on the livelihoods of smallholder farmers and national food security. Despite the effectiveness of hermetic bags against pest insects and fungal growth; and aflatoxins accumulation, the technology is not widely used by smallholder farmers. The survey study was conducted to evaluate the factors that influence the adoption of hermetic bag technology among smallholder farmers in Kilosa district. A total of 180 respondents were purposively selected based on their ability to store maize produce for six months. The data was collected using a smartphone android and responses recorded by open data kit (ODK). The data was analyzed using descriptive statistics and a binary logistic regression model in SPSS software. The descriptive results indicated that overall existing maize storage options among smallholder farmers included interwoven polypropylene bags 43.5%, hermetic bags 17.8% and synthetic chemicals and metal silos account for 38% of respondents. The model results indicated that price, access, awareness, farmer's experience and training factors had a positive and significant impact on the use of hermetic bags. The price variable significantly and negatively influenced the use of hermetic bags at a P<0.01 level of significance. Other independent variables such as awareness, training, access and farmers experience were positively significant at P<0.05 level of significant. The government and other actors could promote and disseminate hermetic storage bag technology as a sustainable approach of lowering grain storage losses while taking identified factors into account.

Keywords: Hermetic bag technology; Logistic regression model; Adoption of hermetic bags; Post-harvest storage losses

1. Introduction

Maize (*Zea mays L.*) is a major staple food crop that offers food security and income to households [1]. In most sub-Saharan African (SSA) countries, the maize crop is largely grown by smallholder farmers in small-sized farms. In Tanzania maize is produced by approximately 3.5 million households with a farm size ranging between 1.0 and 1.30 hectares [2].The maize grain accounts for more than 20% of the calories consumed by nearly 4.0 billion people in the world's developing countries [3, 4]. Although maize is required throughout the year, its production in these countries is very seasonal. Thus requires farmers to preserve their maize grains in effective manner so as to increase food security and profit from sales of their surplus. However, post-harvest storage losses of maize grain, caused by lack of improved storage technologies, have been identified as a threat to progress of maize sub sector in the country [5]. In Africa post-harvest loss of cereal grains including maize is worth more than USD 2.0 billion [6]. The estimated magnitude of maize post-harvest losses in SSA is around 20%, while Tanzania it is closer to 18% of the total production [7]. Insect pests have been revealed as a primary cause of huge maize grains losses during storage. Larger grain borers (LGB) (*Sitophilus*

* Corresponding author: Evelius Vedasto Rwebangira
Department of National Food Security, Ministry of Agriculture, Tanzania.

Truncatus) and maize weevils (*Sitophilus Zeamais*) has been reported as high grain damaging storage insect pests. LGB reported to induce weight losses of up to 40% during three to six months of maize storage using conventional storage method [8]. On the other hand, maize weevils are a widely distributed species that seriously cause a significant weight loss of stored maize grain. Weevils can cause grain loss of more than 30% of the stored maize grain after six months of storage [9]. Majority of the small-holder farmers in rural communities rely on conventional storage techniques such as synthetic chemicals and botanicals as the means of controlling maize storage insects [10]. However, these techniques are ineffective in suppressing infestation these insects. Additionally, these storage options have been claimed to be costly and dangerous to consumers and the environment [11]. Alternatively, farmers prefer to sell their product at a low price immediately after harvest and then buy it again at a high price to avoid losses.

Besides, hermetic bag technology is the most durable technique, ensuring safe grain storage owing to its effectiveness and absence of pesticide uses [4]. Moreover, appropriate application of these hermetic bags guarantees loss reduction of stored grain, thus enhances the farmer's livelihood [12]. Hermetic bags works by preventing outside air and water from entering the stored food grain [13, 14]. In addition to that, hermetic bag technology has been cited that retard the growth and development of insect pest and other grain storage deterioration factors [15]. Unlike other common technologies, hermetic bags have been shown in numerous studies to be effective grain storage alternative against fungal growth and aflatoxin accumulation [15]. Despite the effectiveness of these hermetic bags, their adoption among smallholder farmers remains low.

Several studies have been conducted around the world to investigate the factors influencing small-holder farmers' decisions to use improved post-harvest storage technology [16,76,17]. A recent study in the East African region examined the factors influencing smallholder farmers to employ post-harvest storage technologies, conducted under Rwanda condition [19]. However, few studies regarding identification of the factors influencing the adoption of hermetic bag technology are available at the national level [20]. The current study sought to identify the factors influencing farmers' decisions to use hermetic bag technology in the study area. The significant explanatory variables established under this study would provide rationale for the government and non-governmental organizations to intervene by promoting the use of hermetic bag technology so as to minimize maize storage losses.

2. Material and methods

2.1. Descriptions of Study Area

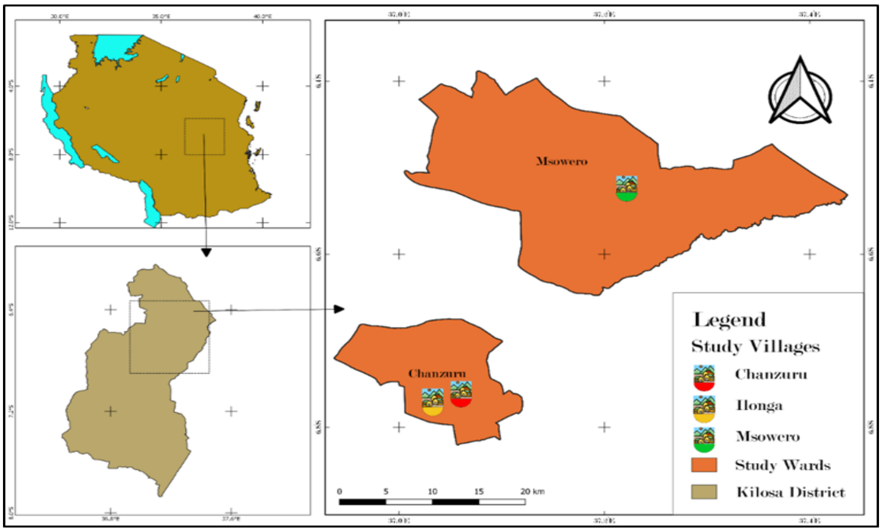

Figure 1 The map of the study area Kilosa district in Morogoro region

The study was carried out in Kilosa District located in the western area of Morogoro region in Tanzania (Figure 1). It is around 300 kilometers west of Dar es Salaam bounded on the west by Dodoma region, on the north by Arusha and Tanga regions, and on the east and south-east by Mvomero and Morogoro rural districts. Kilosa is also bordered by Iringa region and Kilombero district border the area no the south [21]. Agriculture is the main economic activity, and maize is one of the most cultivated food and cash crops in the district. The study area is located between 221700 E to 324900 E and 9127000 N to 9333900 N, with elevations ranging from 550 to 1100 m above sea level. The area has two rainy seasons, with early rains from November to January and heavy rains from March to June; yearly rainfall averages 800 mm; and temperatures range from 18°C in the highlands to 30°C in the lowlands [22].

2.2. Sampling Criteria

A total of 180 respondents were purposively selected from three villages, with 60 respondents from each village. The number of selected respondents was regarded as enough for the analysis, but also due to the study's restricted resources. The selection criteria were local maize farmers and the ability to store maize for at least six months after harvest. This formula was applied to get the representative size.

$$n = \frac{N}{1+N(e^2)} \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where *'n'* is the sample of households, *'N'* is the total size of households, *'e'* is the level of precision 5% [23].

2.3. Data Collection and Analysis

Android smartphone was used to gather data, while Open Data Kit (ODK) was used to record responses. Data collected included respondents' socioeconomic characteristics; access and price of hermetic bags, farmers experience, training and awareness on hermetic bags; the existing maize storage options, total annual income generated from stored grain and land size. Data analysis was carried out using descriptive statistics, inferential statistics and binary logistic regression model through SPSS 26.0.

2.4. Binary Logistic Regression Model

The logistic regression model is widely employed in the technology adoption studies involving variables with dichotomous nature. [24]. On the other hand, the estimate process for the logit model is simpler than that for the probit model [25]. The binary logistic regression model was used to investigate the decision behavior of sampled households since the dependent variable has dichotomous criteria. The dependent variable represented adopters of hermetic bag technology, whilst ten potential independent variables were investigated and examined for their influence on farmers' adoption of hermetic bag technology.

Table 1 Definition of the Variables

Variables	**Type of variable**	**Description of the variables**
Age	Continuous	Age of the respondent in years
Sex	Discrete	Sex: male = 1, female = 0
Education	Discrete	Educational level: educated= 1, not educated = 0
Training	Discrete	Farmers received training on maize storage in hermetic bags: yes = 1, no= 0
Access of hermetic bags	Discrete	Farmers access to hermetic bags: yes = 1, no= 0
Price of hermetic bags	Discrete	Cost of hermetic bags by farmer's view: low= 1, medium = 2, high = 3
Annual income	Continuous	Farmers annual income in TZS
Awareness on hermetic bags	Discrete	Farmers' awareness on hermetic bag storage: yes = 1, no = 0
Farming experience	Continuous	Farmers' years of experience in maize storage
Land size	Continuous	Land size under cultivated in hectare

The logistic regression model employed the following explanatory variables education level, age, sex, farm size, farming experience, training, price and access of hermetic bags, annual income and awareness (Table 1). Therefore probability of farmers decision to adopt hermetic bag technology can be described as [26]:

$$P\left(Yi = \frac{1}{X_i}\right) = P_i = \frac{1}{1+e^{-(\sigma_0+\sigma_1 x_1+\sigma_2 x_2+\cdots+\sigma_m x_m)}} \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

In the above equation, $\sigma_0 + \sigma_1 x_1 + \sigma_2 x_2$ are the input values and P_i is the output value (or the probability of being a case), with σ_0 as the intercept from the linear regression equation and $\sigma_1 x_1$ the regression coefficient multiplied by some value of the predictor (x).

Since $Z_i = \sigma_0 + \sigma_1 x_1 + \sigma_2 x_2 + \cdots . + \sigma_m x_m$ the above formula can be rewritten as shown for easy understanding:

$$P_i = \frac{1}{1+e^{-Z_i}} = \frac{e^{Z_i}}{1+e^{-Z_i}} \text{.......................} (3)$$

Where
σ_0 is the constant term;
σ_1 the coefficients to be estimated,
e_i the error terms.

The above formula indicates that, as the value of Z_i ranges from negative infinitive to positive infinitive P_i is the adoption probability (outcome) of the i[th] dependent variable (adoption of hermetic bag technology), the (1- P_i) is the probability of the household not to adopt the technology, $x_{1,i}$, $x_{2,i}$, $x_{3,i}$, $x_{n,i}$ are the tested farmer characteristics for P_i ranging from the first ($x_{1,i}$) to the n[th] variable, and *e* the error term. This can be represented as follows [6]:

$$\frac{P_i}{1-P_i} = \frac{1}{1+e^{Z_i}} \text{.............................} \quad (4)$$

Now, the most important element in the logistic regression, i.e., odds ratio, can be obtained from equations (3) and (4) which is represented as Pi/1 – Pi as shown in the following expression:

$$\frac{P_i}{1-P_i} = \frac{1+e^{Z_i}}{1+e^{-Z_i}} = e^{Z_i} \text{.........................} \quad (5)$$

The odds ratio in logistic model shows the extent or degree of favoring the household's decision to use hermetic maize storage bags technology. When we take the natural logarithm of equation (5), we can obtain the following formula for logit model which is mostly represented as

$$Li: ln = \ln\left(\frac{P_i}{1-P_i}\right) = Z_i = \sigma_0 + \sigma_1 x_1 + \sigma_2 x_2 + \cdots . + \sigma_m x_m \text{..................} \quad (6)$$

Then, if the disturbance term U_i is taken in to account, the logit model becomes

$$Z_i = \sigma_0 + \sum_{i=1}^{m} \sigma_i X_i + U_i \text{............................} \quad (7)$$

Before running the binary logistic regression model, multicollinearity among the explanatory variables was checked. Accordingly continuous variables variance inflating factor and condition index and discrete variables coefficient of contingency were employed to check the collinearity effects among the variables [18, 26]

3. Results

3.1. Characteristics of the Respondents

Socioeconomic characteristics of the interviewed respondents with categorical and continuous variables analyzed by descriptive statistics are summarized in tables 2 and 3. The results indicated that about 75.6% of the respondents are married and that the rest are single and divorced. Approximately 70.6% of adopters and 85.2% of non-adopters were married (Table 3). Rural community farmers in the majority of developing nations rely heavily on human labor for a variety of farm tasks. They marry young and raise children who subsequently work on these farms [6]. On the other hand, survey result indicated that, among the total sampled households, 41.1% were male and 58.9% of them were female. Around 55.5% of the adopters were male and 86.9% of the non-adopters were female. The chi-square test demonstrated to be significant at the 0.01 and 0.05 probability levels for the distribution of sex and marital status between the two groups, respectively. However, the results of this study contradict the previous research that found no correlation between sex and the likelihood of technology adoption [27]. A dependent variable for the respondents' sex was added to account for sex differences in hermetic bag technology adoption decisions. The capacity of farmers to access, comprehend, and implement knowledge pertaining to the use of enhanced post-harvest storage technologies, notably hermetic bags, is projected to rise in line with their level of education [28]. The survey results indicated that, majority of the respondents can read and write. Around 51.7% of the adopters were educated respondents and 82% of the non-adopters were not educated. Unlike illiterate farmers, educated farmers are more likely to learn about new technology through reading newspapers and leaflets. The chi-square test result revealed a substantial difference in the distribution of non-educated and educated respondents between the two groups. Table 3 also shows that the average age of the respondent farmers were 48.8 years and a standard deviation of 15.287. The average age of the respondents shows the availability of enough manpower to rise maize production in the study area. The mean age of the adopters and non-adopters of the hermetic bags was 43.02 and 51.77 years with standard deviation of 12.288 and 15.859 respectively. Contrary to the believe that the younger farmers are faster in adopting a new agricultural technology compared to aged farmers. It is assumed that elderly farmers have gained knowledge and experience over time and are better equipped to analyze technical information than the younger farmers [27]. The mean difference in age and farming experience was significant at the 1% level of probability, according to the t-test results.

Table 2 Descriptive Analysis of Continuous Variables in Adoption of Hermetic Bag Technology

Adoption of Hermetic Bag Technology							
	Adopters		Non-Adopters		Total (n =180)		
Variables	**Mean**	**Std. deviation**	**Mean**	**Std. deviation**	**Mean**	**Std. deviation**	**t-value**
Age	43.02	12.288	51.77	15.859	48.81	15.287	3.77***
Farming Experience	3.25	0.789	1.80	0.777	2.29	1.038	-11.776***

*** and ** are significant at P < 0.01 and P < 0.05 respectively

In sub-Saharan Africa, the vast majority of people live in rural regions and depend heavily on agriculture for their livelihood. The family size has high influences on the quantity of produced food grain. The family size of the respondent's farmers ranged between four to seven members (Table 2). The increase in family size necessitates robust storage options that ensure the availability of enough and safe food throughout the year. The requirement for improved and more effective grain storage technologies increases with agricultural production levels. However, according to the statistical analysis, there is no significant difference in land size between adopters and non-adopters.

Table 3 Descriptive Analysis of Categorical Variables in Adoption of Hermetic Bag Technology

Adoption of Hermetic Bag Technology								
		Adopters		Non-Adopters		Total (n =180)		
Variables	**Categories**	**Number**	**%**	**Number**	**%**	**Number**	**%**	**χ^2 test**
Sex	Male	66	55.5	8	13.1	74	41.1	29.872***
	Female	53	44.5	53	86.9	106	58.9	
Marital status	Single	31	26.1	6	9.8	37	20.6	6.556**
	Married	84	70.6	52	85.2	136	75.6	
	Divorced	4	3.4	3	4.9	7	3.9	
Educational level	Educated	82	68.9	11	18	93	51.7	41.798***
	Not Educated	37	31.1	50	82	87	48.3	
Land size (ha)	<=1.51	50	42	27	44.3	77	42.8	0.083
	>1.51	69	58	34	55.7	103	57.2	
Household size	0-3	60	50.4	18	29.5	78	43.3	7.404**
	4-7	55	46.2	41	67.2	96	53.3	
	8-11	4	3.4	2	3.3	6	3.3	

*** and ** significant at P < 0.01 and P<0.05 respectively

Furthermore, the survey found that each maize grower used at least one maize storage technology. The vast majority of the respondents (43.5%) store their maize grain in interwoven polypropylene bags, whereas 17.8% of the respondents use hermetic bag technology. However, interwoven bags are connected to significant maize grain storage losses. Farmers, on the other hand, use other storage methods like pesticides and metal silos, which accounted for 38.7% of all existing storage options in the study area (Figure 2).

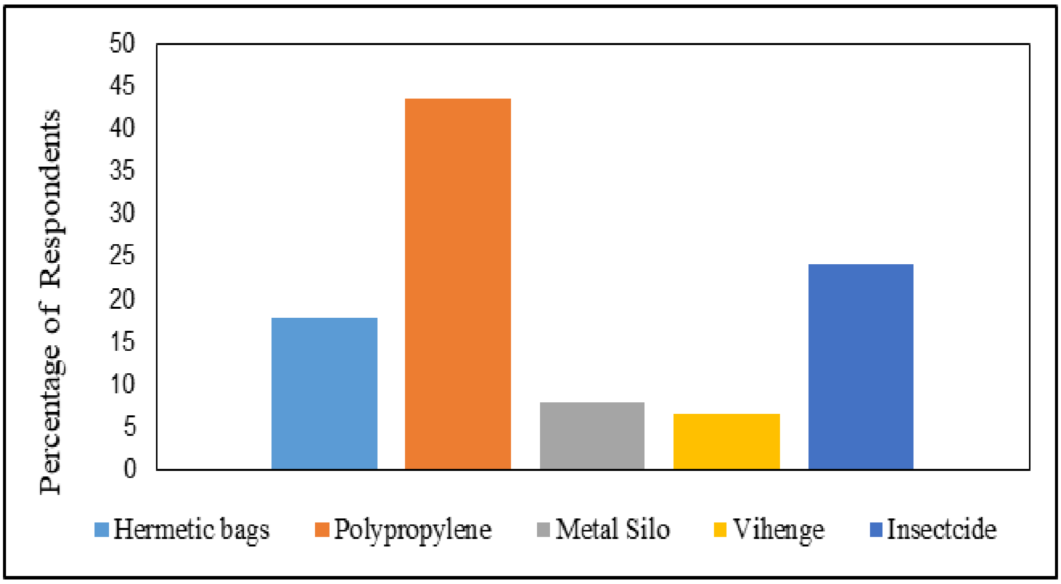

Figure 2 The existing maize grain storage options in the study area

In addition to that, awareness is the unique and fundamental predictor variable that could greatly propel the technology adoption among farmers. According to ***Error! Reference source not found.***, approximately 85.2% of adopters were aware of hermetic bag technology, while 67.7% of non-adopters were unaware of its use.

Table 4 Description of Farmers' Awareness

		Adopters		Non-Adopters		Total	
Variable	**Category**	**Count**	**%**	**Count**	**%**	**Count**	**%**
Awareness	Aware	52	85.2	42	35.3	94	52.2
	Not aware	9	14.8	77	64.7	86	48.8

3.2. Adoption of Hermetic Bags

The model was assessed for its goodness of fit by examining how well the model classifies the observed data or by examination of how likely the sample results are, given the estimates of model variables. The result indicates that the variables included in the model taken together were significantly different from zero at less than 1% level of significance. The chi-square value ($\chi2=195.467$) additionally reveals the accuracy of the model fit. Maximum likelihood was used to estimate the parameters of the variables that are expected to influence the use of hermetic bag technology. Table 5 presents the model results for the variables influencing maize producers' decision to use hermetic bag technology. Ten distinct continuous and discrete variables were entered into the model; only five of these predictor variables were shown to be significantly influencing the adoption of hermetic storage bag technology. The variables that have a positive and significant influence include access and price of hermetic storage bags, training, awareness and farming experience while the remaining five variables namely, age, education level, land size, sex and annual income were found to have little significant impact on the adoption of the hermetic bag technology in the study area [17,18].

Table 5 Logistic Regression Model Estimates of the Factors that Influence the Adoption of Hermetic Bag Technology

Variables	B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
							Lower	Upper
Age	-0.021	0.064	0.105	1	0.746	0.979	0.863	1.111
Sex	2.167	1.392	2.425	1	0.119	8.734	0.571	133.61
Education level	0.699	1.105	0.4	1	0.527	2.012	0.231	17.549
Training	2.992	1.48	4.086	1	0.043**	19.929	1.095	362.625
Access of hermetic bags	2.968	1.426	4.333	1	0.037**	19.461	1.189	318.427
Price of hermetic bags	-2.387	0.729	10.723	1	0.001***	0.092	0.022	0.384
Annual income (TZS)	-1.36	1.34	1.033	1	0.309	0.256	-3.97	1.26
Awareness	3.395	1.412	5.782	1	0.016**	29.8	1.873	474.033
Farming experience	2.407	0.79	9.289	1	0.002***	11.106	2.361	52.228
Land size (ha)	-1.052	0.632	2.771	1	0.096*	0.349	0.101	1.205
Constant	-3.578	3.869	0.855	1	0.355	0.028		

Pearson chi-square: 195.467***, −2 log likelihood: 35.039, overall prediction of the model: 97.2, sensitivity: 95.8, specificity: 93.9, sample size: 180; households, *** and ** indicate significance at 1% and 5% level respectively. 1: the success of prediction of the model based on a 50% probability classification Table. 2: correctly predicted households that use hermetic bag technology on a 50% probability Classification. 3: correctly predicted households that did not use hermetic bag technology based on 0.5 cut point probability table, source: binary logit model output.

4. Discussion

The following section of this paper discusses the relevance of the five predictor variables in influencing the adoption of hermetic bag technology.

4.1. Farmers Awareness

This variable was found to be both positive and statistically significant at a 5% significance level (Table 5). This finding demonstrates that respondents that had awareness of hermetic bags are more likely to use the technology compared to others who are not aware of this technology. Additionally, the results indicate that farmers' awareness on hermetic bags could be used as a method for information transmission, which may result in a higher likelihood of the technology adoption. The findings of this study are consistent with Mwaijande [11]'s research, who found that farmers who are informed and knowledgeable about post-harvest technology are more likely to adopt the technology than those who are not. Moreover, attendance at more extension sessions and training activities has a significant impact on farmers' awareness.

4.2. Training on hermetic Bags

In the model it was observed that the coefficient for hermetic bag technology training was positive and statistically significant at 5%. These results indicate that farmers who participated in the hermetic bag training were 19.9 times more likely to use the hermetic bag technology than those who were not involved in demonstration and training. The findings are consistent with the findings of Kattel *et al.,* [27], who concluded using an adoption model that respondents' training substantially impacted the adoption of major post-harvest practices. Likewise, Wekesa *et al.,* [29] found that farmers who had received training were more likely to use improved storage technologies. Furthermore, active engagement or attendance in field demonstrations and training has a substantial impact on technology adoption, particularly in developing countries [24]. Finally, the training element has a direct impact on smallholder farmers' willingness to accept technology.

4.3. Farming Experience

The coefficient of farming experience was positive and statistically significant at 1% level. The findings show more likelihood of the more experienced farmers in using the technology compared to the less experienced farmers. This results implies that farming experience is useful in the early phases of a given technology's adoption, while farmers are still assessing its potential benefits, which later influence whether it is maintained. Furthermore, when farmers gain experience in farming and become more aware of post-harvest operations, they are more likely to adopt advanced grain storage technology. Additionally, adoption rates of agricultural technology vary from farmer to farmer and are dependent on the level of experience the farmer has with the technology. Finally, the results of this study correspond with those of Ainembabazi and Mugisha [30], who found that adoption rates increase as the farmer gains more experience with it.

4.4. Access to Hermetic Bags

This variable was found to be positively and significantly correlated with the use of hermetic bag technology at 5% level of significance. According to the findings, the likelihood of farmers adopting the technology increases by a ratio of 19.461 when farmers have access to hermetic bags in their near area compared to those who do not have access in their near area. Respondents' top reasons for not employing hermetic bag technology included an unavailability of bags in their local area when they needed them, particularly during harvesting season. The result of this model correspond with other studies that reported, farmers could use hermetic bag technology more as bag supplies increase throughout the harvesting season. In the study by Moussa *et al.,* [31] lack of local availability of bags was the most often cited reason for not using hermetic bags. Furthermore, increasing the availability of hermetic bags as well as the efficiency of the supply chain could contribute to increasing access and uptake of the technology [32].

4.5. Price of Hermetic Bags

The Logistic Regression Model results show a negative correlation between price of hermetic bags and adoption of hermetic bag technology in the study area. The predictor significantly and negatively influenced the use of hermetic bag at 1% level of significance. This results indicate that, when all other parameters were held constant, households who regarded the price of the bag as expensive were 0.092 times less likely to employ hermetic bag technology than households who perceived the price of the bag as low -cost. A considerable percentage of respondents cited the expensive cost of hermetic bags as a major challenge. Through a focused group discussion with agro dealers in the study area it was reported that, the price of hermetic bags ranges between 4,500 and 5,000 TZS per bag, which is regarded as too expensive by most farmers. This study's findings are consistent with earlier studies that reported, the high cost of the bags appears to be the primary cause of farmers' slow adoption of the technology [32]. The model's results also correspond with research conducted in five regions of Tanzania's main land by Mwaijande, [11] to examine farmers' readiness to adopt and pay for enhanced modern post-harvest storage technology; he concluded that prices limits the extent of smallholder farmers to use the technology. Furthermore, the findings are consistent with earlier studies conducted in European, which revealed that the high cost of technology has a significant impact on customers' uptake [33].

5. Conclusions and Recommendation

Grain storage is a critical component of food security in both developing and developed countries. The widespread adoption of improved post-harvest storage technologies in rural communities might dramatically reduce maize grain storage losses in the developing countries. The reduced maize losses could have reversed the observed high levels of food and nutrition insecurity. This study employed the binary logit regression model to analyze the determinants that influence farmer's decision to adopt hermetic bag technology in the study area. The model results indicated that factors such as, training, awareness, farming experience, access and price of hermetic bags significantly influenced the technology use. Education level, annual income, land size, age and sex slight influenced technology adoption in the study area.

Given that grain storage losses are the most significant constraints to the agricultural value chain, deploying suitable storage systems is essential for enhancing farmers' livelihoods and the national economy as a whole. The availability of the hermetic bags in close proximity encourages the farmers to use the technology. The accessibility of the hermetic bags could be improved by the government in cooperation with local agro-dealers to establish the selling point near to farmer's residence. Additionally, hermetic bags manufacturing plants may be established in areas with high maize production. Awareness and extension services among farmers had a significance influence on the acceptance of any technology. The government, in collaboration with NGOs Extension Officers, might step up efforts to raise awareness and educate farmers about the advantages of utilizing hermetic bags. Moreover, post-harvest platforms focusing on creating awareness and promoting the use of hermetic bag technology may be established at the village level. The importance of regular training cannot be overstated; it constantly reminds farmers on best practices regarding post-harvest operations. The high cost of the hermetic bags is the most critical barrier for technology adoption. The government of the United Republic of Tanzania is urged to remove the imposed VAT on hermetic bags so as to facilitate availability of the technology at low price. The increased annual income resulting from the use improved storage method in particular hermetic bags, is the important motivating aspect that encourages the farmers to adopt the technology. To address that farmers based organization may be established at village level through which farmers can sell their produce during the lean season with a common voice that guarantees increased grain value and farmers income. Furthermore, regarding the high price of hermetic bags in the study area, the government is also urged to have a special window that can offer soft credits to train farmers to facilitate the purchase of hermetic bags and payment after selling their produce. In addition to that, subsidizing the price of these hermetic bags could be a long-term and fundamental strategy for promoting improved grain storage technologies and, as a result, minimizing post-harvest losses at the household level. The hermetic bag technology considerably reduces maize grain losses; nevertheless, the magnitude of the technology's contribution to the nation's food security is not yet known, therefore further research is recommended to address this knowledge gap.

Compliance with ethical standards

Acknowledgments

I am grateful to my supervisor, Prof. Valerian Cosmas Silayo, of the School of Engineering and Technology, for agreeing to take on this task. I am grateful for his consistent guidance, encouragement, constructive criticism, and patience throughout my studies. I consider myself lucky to have had the opportunity to work beside him. I'd also want to thank Prof. Geoffrey Christopher Mrema for his time and advice, which enabled me to complete my work. I'd like to thank the Ministry of Agriculture for their contribution and financial support in my research work; additionally, the field work would not have been successful without the cooperation of Extension Officers in the villages of Ilonga, Chanzuru, and Msowero; and farmers whose contributions enabled me to successfully complete my study. Finally, I'd want to thank the lecturers and the entire staff of the School of Engineering and Technology.

Disclosure of conflict of interest

No competing interests.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

Author Contributions

Conceptualization up to development of the manuscript: Vedasto Evelius; review, editing and supervision of the work: Valerian Cosmas Silayo and Geoffrey Christopher Mrema.

References

[1] Likhayo P, Bruce AY, Tefera T, Mueke J. Maize grain stored in hermetic bags: Effect of moisture and pest infestation on grain quality. J Food Qual. 2018;2018.

[2] National Bureau of Statistics. National Sample Census of Agriculture 2007/2008: Crop Sector - National Report. 2012;2:1–507.

[3] Ndegwa MK, De Groote H, Gitonga ZM, Bruce AY. Effectiveness and economics of hermetic bags for maize storage: Results of a randomized controlled trial in Kenya. J Crop Prot. 2016;90:17–26.

[4] Kumar D, Kalita P. Reducing Postharvest Losses during Storage of Grain Crops to Strengthen Food Security in Developing Countries. J Foods. 2017, 6(1):8.

[5] Evelius V, Silayo V, Mrema G. Performance of Triple and Double Hermetic Bags for Maize Grain Storage. Int J Agric Environ Bioresearch. 2022;07(05):13–24.

[6] APHLIS. African Post-Harvest Losses Information System. (2020). Dry weight loss (%): Tanzania - All crops - All years. 2020.

[7] Tefera T. Post-harvest losses in African maize in the face of increasing food shortage. J Food Secur. 2012, 4(2):267–277.

[8] Baoua IB, Amadou L, Ousmane B, Baributsa D, Murdock LL. PICS bags for post-harvest storage of maize grain in West Africa. J Stored Prod Res. 2014, 58:20-28.

[9] Baoua IB, Margam V, Amadou L, Murdock LL. Performance of triple bagging hermetic technology for postharvest storage of cowpea grain in Niger. J Stored Prod Res. 2012;51:81–5.

[10] Dijkink B, Broeze J, Vollebregt M. Hermetic Bags for the Storage of Maize: Perspectives on Economics, Food Security and Greenhouse Gas Emissions in Different Sub-Saharan African Countries. Front Sustain Food Syst. 2022;6(1).

[11] Mwaijande F. Farmers' adoption and willingness to pay for post-harvest technologies in Tanzania: policy implication for enhancing food security. J Postharvest Technol. 2017;5(1):1–6.

[12] Jacob P Anankware; Obeng-Ofori D; Afreh –Nuamah K; Fatunbi A Oluwole; and Martin Bonu-Ire. Triple-Layer Hermetic Storage: A Novel Approach Against Prostephanus Truncatus (Horn) Coleoptera: Bostrichidae) and Sitophilus Zeamais (Mot)(Coleoptera: Curculionidae). J Entomol Ornithol Herpetol Curr Res. 2013;02(03).

[13] Rabé MM, Baoua IB, Baributsa D. Adoption and profitability of the purdue improved crop storage technology for grain storage in the south-central regions of Niger. J. Agronomy. 2021;11(12).

[14] Chegere MJ, Lokina R, Mwakaje AG. The impact of hermetic storage bag supply and training on food security in Tanzania. J Food Secur. 2020, 12(6):1299–316.

[15] Williams, S.B.; Murdock, L.L.; Baributsa D. Safe storage of maize in alternative hermetic containers. J. Stored Prod. J Stored Prod Res. 2017;(71):125–129.

[16] Bokusheva R, Finger R, Fischler M, Berlin R, Marín Y, Pérez F, et al. Factors determining the adoption and impact of a postharvest storage technology. J Food Secur. 2012, 4(2):279–93.

[17] Conteh AMH, Yan X, Moiwo JP. The determinants of grain storage technology adoption in Sierra Leone. J Cah Agric. 2015;24(1):47–55.

[18] Mekonen TK, Wubetie BY. Determinants of the Use of Hermetic Storage Bags for Maize Storage among Smallholder Farmers in Northwest Ethiopia. Adv Agric. 2021;2021.

[19] Uwera G, Ritho C, Irungu P. Assessment of factors affecting the decision of smallholder farmers to use alternative maize storage technologies in Gatsibo District-Rwanda. J Heliyon [Internet]. 2021;7(10):e08235.

[20] Ngowi ER, Selejio O. Post-harvest Loss and Adoption of Improved Post-harvest Storage Technologies by Smallholder Maize Farmers in Tanzania. African J Econ Rev. 2019;7(1):249–67.

[21] Kimaro DN. Potential land for Agricultural use in Tanzania: the case of Kilosa District. J L Soc. 2014, 1(1):14–24.

[22] Kamala A, Kimanya M, Haesaert G, Tiisekwa B, Madege R, Degraeve S, et al. Local post-harvest practices associated with aflatoxin and fumonisin contamination of maize in three agro ecological zones of Tanzania. Food Addit Contam - Part A Chem Anal Control Expo Risk Assess. 2016, 33(3):551–9.

[23] Kothari CR. Research Methodology : Methods and Techniques. 2nd ed. New Delhi: New Age International (P) Ltd; 2004.

[24] Adesina AA, Chianu J. Determinants of farmers' adoption and adaptation of alley farming technology in Nigeria. Agrofor Syst. 2002, 55(2):99–112.

[25] Damodar N. Gujarati. Basic Econometrics. 3rd ed. New York, USA: McGraw-Hill Companies, Inc; 1995.

[26] Damodar N. Gujarati. Basic Econometrics. 4th ed. New York, USA: McGraw-Hill Companies, Inc; 2003.

[27] Kattel RR, Regmi PP, Sharma MD, Thapa YB. Factors influencing adoption of major post-harvest handling practices of large cardamom in Nepal. Cogent Food Agric. 2020;6(1).

[28] Ruzzante S, Bilton A. Adoption of agricultural technologies in the developing world: A meta-analysis dataset of the empirical literature. J World Dev. 2021;146.

[29] E. Wekesa, W. Mwangi, H. Verkuijl, K. Danda A, H. De Groote. "Adoption of maize production technologies in the coastal lowlands of Kenya," Miscellaneous Reports 56109, CIMMYT. 2003.

[30] Ainembabazi JH, Mugisha J. The Role of Farming Experience on the Adoption of Agricultural Technologies: Evidence from Smallholder Farmers in Uganda. J Dev Stud. 2014, 50(5):666–79.

[31] Moussa B, Abdoulaye T, Coulibaly O, Baributsa D, Lowenberg-DeBoer J. Adoption of on-farm hermetic storage for cowpea in West and Central Africa in 2012. J Stored Prod Res. 2014, 58:77–86.

[32] Alemu GT, Nigussie Z, Haregeweyn N, Berhanie Z, Wondimagegnehu BA, Ayalew Z, et al. Cost-benefit analysis of on-farm grain storage hermetic bags among small-scale maize growers in northwestern Ethiopia. J Crop Prot. 2021;143.

[33] Long TB, Blok V, Coninx I. Barriers to the adoption and diffusion of technological innovations for climate-smart agriculture in Europe: Evidence from the Netherlands, France, Switzerland and Italy. J Clean Prod. 2016, 112(3):9–21.