Factors Influencing Maize Farmers' Adoption and Use Intensity of Hermetic Storage Bags In Dormaa, Ghana

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Abstract

Maize is a key staple in Ghana with a high production rate. With the growing development of the poultry and livestock sector, there is a need to boost maize production to meet the growing demand. The unfortunate thing is a significant amount of maize produced is lost during storage. The hermetic storage bag is an innovation proven to reduce maize storage loss. This study ascertains factors influencing smallholder maize farmers' adoption and use intensity of hermetic storage bags in Dormaa, Ghana. We used a multi-stage sampling technique and collected data from 217 maize smallholder farmers from four communities where maize production is the main economic activity in Dormaa Municipality, Ghana. The analytical framework incorporates descriptive statistics, the Probit model, and the Ordinary Least Square Estimation (OLS) technique. The probit results reveal that age, marital status, membership in a professional association, and training have a positive and significant influence on the adoption of hermetic storage bags. Based on the intensity of use of hermetic bags, our study finds that farm size, length of storage, and quantity of maize farmers sold each season had a positive and significant influence on the number of hermetic bags used by farmers to store maize each season. This study provides us with factors development agencies, the Ministry of Food and Agricultural Organization (MoFA) in Ghana, Extension, and other stakeholders should consider disseminating hermetic bags in Dormaa, Ghana to enhance the adoption of hermetic storage bags by smallholder farmers.

Keywords: post-harvest loss, smallholder farmers, adoption, hermetic storage bags, use intensity

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Introduction

Maize is a staple food in Ghana and has a high production rate, accounting for over 50% of Ghana's total cereal production (Awunyo-Vitor et al., 2016). With the growing development of the poultry and livestock sectors and the use of maize as a major component of poultry and livestock feed, it is crucial to enhance maize production (Awunyo-Vitor et al., 2016). Unfortunately, much of the maize produced does not leave the farm and get to the consumer.

In Ghana, about 5-70% of maize produced is lost during post-harvest processes (Darfour & Rosentrater, 2016). Research found that approximately 30-40% of maize is lost at the storage level (Opit et al., 2014), and attribute the loss to the storage methods adopted by maize farmers (Darfour & Rosentrater, 2016; Gitonga et al., 2013; Manu et al., 2019). Many of these methods expose the maize to insect, rodent pest damage, and mold (aflatoxin) contamination when the maize is not dried to the appropriate moisture content level before storage (Danso et al., 2018; Manu et al., 2019). These existing methods of maize storage cause both quantitative and qualitative losses (Baoua et al., 2014), which can result in a decrease in farmers' income and contribute to the country's food insecurity (Manu et al., 2019; Sheahan & Barrett, 2017). To strengthen food security and increase farmers' income, reducing post-harvest loss of grain is critical for developing countries (Kumar & Kalita, 2017).

One possible storage innovation to increase the shelf life of maize is hermetic storage bags. Hermetic storage bags create an atmosphere that controls moisture and insect pests through reduced gas exchange. The hermetic bags can reduce food loss to less than 1% since the bags can increase insect mortality by 100% (Bributsa & Ma Cristine, 2020). Despite the benefits of using hermetic bags, farmers are slowly adopting the technology. The adoption and use of hermetic bags by farmers would increase maize availability. However, we do not know what factors influence the adoption of hermetic storage technology by smallholders' maize farmers in the Dormaa Municipality, Ghana. Illuminating the potential factors influencing the adoption of hermetic storage technology is critical to increasing adoption. Therefore, the paper sought to ascertain socio-economic and institutional factors influencing the adoption and intensity of use of hermetic storage bags and the intensity of their use in the case of Ghana. Understanding these factors is essential to policymakers, governments, and Non-Governmental Organizations (NGOs) in planning and implementing hermetic storage technology-related programs to enhance greater economic resilience of farmers, local communities, and Ghana.

Studies have identified factors determining agricultural technology adoption (Uaiene, 2011). Some studies found that to increase smallholder farmers' likelihood of adopting an agricultural innovation, access to Extension services and membership in farmers' associations were significant factors (Moussa et al., 2014). Attendance at training was another determining factor in the adoption of hermetic storage technology (Baributsa & Njoroge, 2020; Mekonen & Wubetie, 2021).

Previous studies have classified factors influencing adoption into several categories. Mignouna et al. (2011) classified them into household-specific, farm-specific, technological, and institutional factors, while Mwangi and Kariuki (2015) categorized them into economic, institutional, technological, and household-specific factors. From review of literature, the socio-economic and institutional factors are the categories selected for this study. No research publication is available to ascertain farmers socio-economic and institutional factors influencing the adoption of hermetic storage technology in Ghana. This creates a research gap.

Purpose and Objectives

The purpose of this study is to fill the research gap by identifying the socio-economic and institutional factors influencing farmers' adoption of hermetic bags and to explain factors influencing farmers' adoption and intensity of use of the hermetic bags.

Specifically, we sought to:

(1) Identify the socio-economic factors influencing farmers' adoption of hermetic bags.
(2) Identify institutional variables influencing farmers' adoption of hermetic bags.
(3) Explain factors influencing farmers' adoption and intensity of use of the hermetic bags.

Methodology

Research Design, Subjects, and Data collection

This study utilized a quantitative cross-sectional research design. The population for the study was maize farmers in the Dormaa Municipality in the Bono Region of Ghana involved in the production of maize in the last two years (2019-2020). A multistage sampling technique was used – First, Dormaa was selected because it represents Ghana's major maize production area (Opit et al., 2014). There are four agricultural zones (i.e., Amasu, Koradaso, Nsuhia, and Agyemangkrom) in the Dormaa Municipality. With collaboration from Extension agents, one community (i.e., Amasu, Koradaso, Duasidan, and Suromani) was selected from each zone where maize is the main source of income for farmers. A systematic sampling technique was used to select 217 maize farmers in the four communities. Each of these communities had one entry route. We started with the first house at the entrance into the community and surveyed one adult in every third house who was involved in maize production. If no adult was involved in maize production in a household, we skipped and moved to the third house to maintain consistency.

The primary contact method with farmers was a researcher-administered survey using closed and open-ended survey questions and designed based on the review of literature (Mariano et al., 2012; Mignouna et al., 2011; Ullah et al., 2018) with some modifications of the instrument. Data were gathered via an offline Qualtrics survey in July 2021 on farmers' socio-demographic, economic, and institutional factors. Five faculty members and the Director of the Center for Sustainable Rural Livelihoods at a four-year state university evaluated the questionnaire, made recommendations on improving it, and assessed it to determine content and face validity.

The vector of explanatory variables for the socio-economic factors includes the gender of the farmer (SEX), age of the farmer (AGE), farmers' educational level (EDUCA), marital status (MSTATUS), ownership of farmland (OWNFLAND), farm size (FSIZE), duration of maize storage (DSTORAGE), the quantity of maize sold by farmers each season (QTY), membership in a farmers' organization (MEMBER). Institutional variables included: training (TRAIN), ownership of mobile phones (OWNPHONE), access to credit (ACCREDIT), and access to Extension services (SERVEXTN). The definition of each variable and the *a priori* expectation is presented in Table 1.

Table 1.
Description of Variables and Descriptive Statistics

Variables	Description	Expected sign
Dependent variables		
ADOPT/NON-ADOPT	1 if farmer is an adopter; 0 otherwise	
LBAGS	The number of hermetic bags farmers use to store maize each season	
Independent variables		
SEX	1 if farmer is a male; 0 if female	+/-
AGE	Age of farmer in years	+
EDUCA	Level of education of the farmer	
EDUCA2	Primary education	+
EDUCA3	Junior secondary	+
EDUCA4	Secondary	+
EDUCA5	University/Tertiary	+
MSTATUS	Marital status of the farmer	
MSTATUS2	Unmarried	+/-
MSTATUS3	Widowed	+/-
MSTATUS4	Divorced	+/-
MSTATUS5	Cohabiting	+/-
OWNFLAND	1 if farmer own land; 0 otherwise	+
FSIZE	Measured in hectares	+
DSTORAGE	Measured based on number of months farmers store their maize	+
QTY	Measured by quantity (bags) of maize farmers sold each season	+
MEMBER	1 if the farmer is a member in any farming association; 0 otherwise	+
TRAIN	1 if the farmer has received training on use of hermetic bags; 0 otherwise	+
MOBILE	1 if the farmer owns a mobile phone; 0 otherwise	+/-
CREDIT	1 if farmer has access to credit; 0 otherwise	+
SERVEXTN	1 if farmer is served by Extension; 0 otherwise	+

Source: Analysis of field data, 2021.

Empirical Estimation Approach

The Probit, Logit and Ordinary Least Square (OLS) estimation techniques were used to estimate the coefficients of the regression model. This approach gained empirical inspirations from the works of Hailu et al. (2014) who adopted the probit and OLS regression model to assess factors that determined the adoption of agricultural technology by smallholder farmers in Tigray,

Ethiopia. The selection of the probit estimation technique on the one hand is based on the fact that the dependent variable for the adoption model is a dummy, while the OLS technique is chosen for the intensity model because the dependent variable is continuous.

The intensity of adoption focuses on the number of hermetic bags used by a farmer in Dormaa, Ghana to store maize. The intensity of use of technology is contingent on the decision taken by the farmer based on the decision to adopt. There is a likelihood that this decision is not random (Hailu et al., 2014). The OLS estimation technique was used to estimate the intensity of use of the hermetic storage bags by farmers who adopted the technology.

Practically, the probit or the logit models are used to determine the probability that $Y_i = 1$. The probit is a standard normal distribution, while the logit is based on a standard logistic distribution. According to (Maddala, 1997) these two models would lead to the same conclusion. Therefore, it is difficult to make a choice between these two models on a theoretical basis. In this study, both estimation techniques are used for robustness of results.

The Probit model was derived by introducing a random variable y* which is a function of a vector of variables. The model is constructed as follows:

$$Y^* = X_i\beta_i + \varepsilon_i \quad (1)$$

$$\text{Where } Y = \begin{Bmatrix} 1 \; if \quad Y^* > 0 \\ 0 \; otherwise \end{Bmatrix} = \begin{Bmatrix} 1 \; if \quad X_i B_i > 0 \\ 0 \; otherwise \end{Bmatrix} \quad (2)$$

$\varepsilon \sim N(0, 1)$.

Thus, Y can be viewed as an indicator for whether this latent variable is positive: Where y* (the latent variable) is observed for values greater than 1 and 0 otherwise, which represents an index for hermetic storage bags adoption. The outcome variable is therefore binary in nature and defined as: 1 = if farmer stored their maize using hermetic bags and 0 = otherwise. X_i represents a vector of explanatory variables, b_i is a vector of unknown parameters, and e_i is the error term. The latent variable y* is the dependent variable indicating whether the farmer used hermetic bags to store maize in the last two years. The variable is defined as: P(Y=1) if farmers adopt hermetic bags and 0 otherwise.

Two regression models were estimated viz; to identify the factors influencing the adoption of hermetic storage bag technology and to estimate the factors influencing the intensity of use of the hermetic bags. Based on the two dependent variables: the adoption (ADOPT/NON-ADOPT) and the intensity of use of the hermetic storage bags (LBAG), the Probit and OLS models are respectively specified as equations (3) and (4) below:

Model 1: Factors Influencing the Adoption of Hermetic Storage Technology

Socio-economic and institutional factors are identified to influence the adoption of agricultural innovations (Nkamleu & Adesina, 2000; Sodjinou et al., 2015). There is no specific theory that dictates the choice of explanatory variable to include in the Probit model to explain technology adoption decisions of farmers. However, previous research has suggested age, education, household size, farm size, membership, cell phone usage, extension services, and credit access (Mariano et al., 2012; Mignouna et al., 2011; Ullah et al., 2018).

$$P(Y=1) = d_0 + dSEX_i + d_1AGE_i + d_2EDUCA_i + d_3MSTATUS_i + d_4OWNFLAND_i + d_5FSIZE_i + d_6DSTORAGE_i + d_7QTY_i + d_8MEMBER_i + d_9ACCREDIT_i + d_{10}SERVEXTN_i + e_i \quad (3)$$

Model 2: Factors influencing the intensity of use of the hermetic bags

$$LBAG_i = a_{0+} dSEX_i + a_1AGE_i + a_2EDUCA_i + a_3MSTATUS_i + a_4OWNFLAND_i + a_5FSIZE_i + a_6DSTORAGE_i + a_7QTY_i + a_8MEMBER_i + a_9ACCREDIT_i + a_{10}SERVEXTN_i + \mu_i \quad (4)$$

Where: *LBAG* = continuous dependent variable indicating the number of bags used by farmers to store maize each season.

Results

Farmers' Demographic Characteristics

The demographic descriptive results are presented in Table 3. The results show that male farmers (58.41%) dominate maize production in the study area. The majority respondents are within the 40-49 age range and the average age of a maize farmer is 44.05 years. Most of the farmers (28.5%) have primary or junior secondary (28.5%) levels of education. The majority of the farmers are married (72.9%).

Table 3.
Farmers' Demographic Characteristics

Variable	Observation	Frequency	%
Sex			
Male	212	125	58.41
Female	212	89	41.59
Age			
20-29	212	23	10.85
30-39	212	56	26.42
40-49	212	66	31.13
50-59	212	48	22.64
60-69	212	17	8.02
70+	212	2	0.94
Education			
No education	214	40	18.69
Primary education	214	61	28.50
Junior Secondary	214	61	28.50
Secondary education	214	41	19.17
Tertiary/University education	214	11	5.14
Marital Status			
Married	214	156	72.90
Unmarried	214	33	15.42
Widowed	214	12	5.61
Divorced	214	11	5.14
Unmarried but cohabiting	214	2	0.93

Source: Analysis of field data, 2021

Descriptive Statistics of Socio-economic and Institutional Variables

Objectives one and two were to identify the socio-economic and institutional factors influencing farmers' adoption of hermetic bags in Dormaa. Research studies have found that socio-economic and institutional factors should be targeted to increase the adoption of agricultural technologies (Adesina et al., 2000; Mwangi & Kariuki, 2015). The descriptive

statistics of the socio-economic, institutional, and dependent variables used in the study are displayed in table 4.

Table 4.
Descriptive Statistics of Socio-economic and Institutional Variables

Variable	Observation	*M*	*SD*	Min	Max
adoption	217	0.58	0.49	0	1
lbags	121	2.35	0.93	1	150
Socio-economic factors					
Own Farmland (0 = no)	211	0.54	0.50	0	1
Farm Size (hectares)	217	2.59	1.01	1	5
Duration of Storage (months)	204	2.42	0.96	1	6
Quantity of maize (bags) sold each season	217	27.51	17.39	1	61
Association Membership (0 = no)	206	0.50	0.50	0	1
Institutional factors					
Training (0 = no)	201	0.67	0.47	0	1
Mobile Phone (0 = no)	208	0.98	0.15	0	1
Credit (0 = no)	213	0.46	0.50	0	1
Served by Extension (0 = no)	212	0.86	0.35	0	1

Note: *M* = Mean; *SD* = Standard deviations.

The results reveal that about half of the respondents are members of farming associations. On average, about 54% of the farmers own farmland, with an average farm size of 2.59 hectares. Also, on average, approximately 67% of farmers indicated they received Extension training in the last two years. Based on farmers' access to credit, the results reveal that, on average, approximately 46% of farmers had access to credit to support their maize farming activities. Extension agents served an average of 86% of farmers in the area in the last two years. We also found that most farmers (98%) own mobile phones.

Diagnostic Tests

The estimated results are validated based on the *a priori* expectation (expected sign), statistical first order test and econometric second order test. The expected signs of the coefficients were presented in Table 1 for each variable. For the probit model, the statistical criteria or 1st order tests like pseudo R^2 and Prob>chi2 were used to test the goodness of fit of the model and the significance of the individual coefficients. In a cross-sectional data set, multicollinearity and heteroscedasticity are very common problems. The Breusch-Pagan test (hettest) and the Cook-Weisberg test were used to test for heteroscedasticity problems with fitted values of hermetic bags. Fortunately, a constant variance was detected, Chi-square = 0.12 and Prob > Chi-square = 0.7241. The Jarque-Bera test was used to test for normality, with normality test results = 2.476 and Chi-square = 0.29.

Meanwhile, the Variance Inflation Factor (VIF) was used to tests for multicollinearity among independent variables in the OLS regression model. Table 5 presents the result for the test of multicollinearity based on the Variance Inflation Factor (VIF).

Table 5.
Results for Variance Inflation Factor (VIF)

Variable	VIF	1/VIF
EDUCA2	2.55	0.39
EDUCA3	2.48	0.40
EDUCA4	2.10	0.48
Age	1.76	0.57
Member	1.68	0.60
Sex	1.52	0.66
Widowed	1.51	0.66
Farm size	1.48	0.67
Co-habiting	1.42	0.70
Quantity of maize	1.39	0.72
Own Land	1.38	0.72
Credit	1.31	0.76
Divorced	1.30	0.77
Unmarried	1.25	0.80
Extension service	1.23	0.81
EDUCA5	1.22	0.82
Train	1.21	0.83
DStorage	1.15	0.87
Mobile	1.07	0.94

Source: Analysis of field data, 2021.

From the VIF results, it is evident there is no problem of multicollinearity among the independent variables, thus the variables can be used in the estimation of the results.

From the results for the test of heteroscedasticity and normality test, the null hypotheses for both normality in residual and for constant variance are not rejected. Thus, the results are Best Linear Unbiased Estimator (BLUE) and can be used for statistical tests and inferences.

Empirical Results

Factors influencing the adoption and intensity of use of hermetic bags by farmers

The probit model was used to ascertain factors influencing the decision of maize farmers to adopt or not to adopt hermetic storage bags.

The results of the probit and logit techniques are presented in Table 6. The estimation of the adoption model was also done using the logistic regression technique to check the robustness of the results. Column 2 and 3, respectively, presents the z-score and the log of odds coefficients for the probit and logit techniques. Columns 4 and 5 present the marginal effect coefficients for probit and logit. Column 6 presents the OLS result for the intensity model of the hermetic bags used.

Table 6.
Results of Probit, Logit, and Ordinary Least Squares (OLS)

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
Variables	Probit	Logit	dprobit	dlogit	OLS (intensity)
SEX	-0.434 (0.382)	-0.573 (0.707)	-0.145 (0.123)	-0.118 (0.144)	-0.0129 (0.200)
AGE	0.0374** (0.018)	0.0655** (0.033)	0.0129** (0.006)	0.0135* (0.007)	-0.0120 (0.010)
EDUCA2	0.0698 (0.505)	0.190 (0.921)	0.024 (0.170)	0.039 (0.189)	-0.071 (0.276)
EDUCA3	-0.238 (0.490)	-0.323 (0.899)	-0.084 (0.176)	-0.067 (0.185)	0.354 (0.270)
EDUCA4	0.089 (0.525)	0.364 (1.002)	0.0303 (0.175)	0.075 (0.206)	0.151 (0.273)
EDUCA5	-1.612** (0.796)	-2.503* (1.359)	-0.571*** (0.198)	-0.515* (0.271)	0.279 (0.642)
MSTATUS2	1.102** (0.561	2.059** (0.998)	0.278*** (0.090)	0.424** (0.204)	-0.139 (0.251)
MSTATUS3	-0.110 (0.715)	0.217 (1.283)	-0.039 (0.258)	0.045 (0.264)	0.359 (0.425)
MSTATUS4	-0.866 (0.789)	-1.485 (1.397)	-0.331 (0.301)	-0.306 (0.289)	0.252 (0.464)
MSTATUS5	0.713 (1.388)	1.282 (2.502)	0.190 (0.258)	0.264 (0.517)	-0.812 (0.877)
OWNLAND	-0.244 (0.329)	-0.432 (0.602)	-0.083 (0.111)	-0.089 (0.123)	-0.141 (0.183)
FSIZE	0.225 (0.199)	0.434 (0.367)	0.077 (0.068)	0.089 (0.076)	0.255** (0.106)
DSTORAGE	0.713*** (0.245)	1.223*** (0.447)	0.245*** (0.082)	0.252*** (0.089)	0.272** (0.105)
QTY	-0.238 (0.149)	-0.537* (0.291)	-0.0820 (0.051)	-0.110* (0.061)	0.175** (0.084)
MEMSHIP	0.981*** (0.357)	1.770*** (0.663)	0.333*** (0.109)	0.364*** (0.128)	0.258 (0.222)
TRAIN	2.979*** (0.523)	5.518*** (1.095)	0.863*** (0.067)	1.136*** (0.274)	0.364 (0.457)
MOBILE	0.828 (0.844)	1.162 (1.436)	0.318 (0.324)	0.239 (0.296)	0.540 (0.601)
CREDIT	0.376 (0.334)	0.557 (0.625)	0.128 (0.113)	0.115 (0.129)	-0.145 (0.179)
SERVEXT	-1.076* (0.550)	-2.190** (1.098)	-0.276*** (0.102)	-0.451* (0.239)	-0.052 (0.380)
Constant	-5.017*** (1.665)	-8.432*** (2.987)		-1.735*** (0.640)	-0.027 (1.031)
Observations	178	178	178	178	110

Probit: Log likelihood = -47.126496; LR chi2(19) = 141.52; Prob > chi2 = 0.0000; Pseudo R-Squared = 0.6002
Logit: Log likelihood = -47.44841; LR chi2(19) = 140.87; Prob > chi2 =0.0000; Pseudo R2 = 0.5975
OLS: F(19, 90) = 2.56; Prob > F = 0.0016; R2 = 0.3508; Adj R2 = 0.2137; Root MSE = 0.81516
Note: Standard errors in parentheses; *** = p<0.01, ** = p<0.05, * = p<0.1

The results from the OLS used to estimate the intensity of hermetic storage bag usage by farmers, reveal that three (3) variables, namely farm size (FSIZE), length of storage (DSTORAGE), and quantity of maize sold (QTY) by farmers each season had a positive and statistically significant influence on the intensity to use hermetic storage bag technology.

Socio-economic Factors on Adoption/Non-adoption

The results reveal that among the socio-economic factors, the age of the farmers had a positive and statistically significant effect on farmers' likelihood to adopt hermetic bags. This finding implies that as farmers' age increases by one year, ceteris paribus, the probability to adopt hermetic bags increases by 3.7%. Age is found to be a determining factor and is found to be statistically significant at 5% level and is consistent with the a priori expectation.

Also, membership in farming associations has a positive and statistically significant influence on farmers' likelihood to adopt hermetic bags. The result shows that being a member of a farmers' association, ceteris paribus, increases the probability of adopting hermetic bags by 33.3% based on the probit results and by 36.4% based on the logistic results. This effect is statistically significant at 1% level of significance.

Duration of maize storage shows a positive and significant influence on farmers' likelihood to adopt hermetic storage bags and the intensity of use of the bags. This finding implies that for an additional month of storing maize, everything being equal, the probability of adopting hermetic bags to store maize would increase by 24.5% for the probit model. The result is statistically significant at the 1% level of significance indicating that farmers who use hermetic bags are more likely to store their maize longer than non-adopters of the hermetic bags.

Regarding marital status, the results reveal a statistically significant influence on farmers' likelihood to adopt hermetic storage bags. The estimated coefficient of marital status is statistically significant at 5% level, hence, unmarried farmers, keeping all other things constant, have a 27.8% more likelihood than married farmers to adopt hermetic bags based on the probit model.

The results reveal that farmers' educational level has a negative but significant influence on farmers' likelihood of adopting hermetic storage bags. The results indicated that farmers with university/tertiary level of education are less likely to adopt hermetic bags by 57.1%. The result is statistically significant at 1% level of significance. The results, based on the level of education contradicts the a priori expectations and this might be explained by the fact that educated people are not so much involved in the agricultural sector, especially if agriculture is not their principal activity. This factor might have had an impact on the results.

Institutional Factors on Adoption/Non adoption

In line with other agricultural adoption studies (Ali et al., 2018; Mmbando & Baiyegunhi, 2016), institutional factors are seen to explain maize farmers' adoption decisions positively and are statistically significant. The results reveal that training has a positive and statistically significant influence on farmers' likelihood to adopt hermetic bags. The coefficient is positive and statistically significant at 1% level of significance. Therefore, additional training will increase farmers' probability of adopting hermetic bags by 86.3%.

Estimates from the probit model (Table 6) indicated negative but statistically significant results for farmers served by extension agents. The magnitude of the negative sign shows that farmers who obtained training from extension workers were 27.6% points less likely to adopt hermetic bags. This result contradicts the *a priori* expectations and may be explained by the fact that farmers producing on a larger scale who are already using hermetic bags do not take part in training. Or sometimes, extension training focuses on disseminating information about farming resources and the various methods to increase productivity with less emphasis on the importance and adoption of the hermetic bags to mitigate maize storage loss.

Intensity of Use of Hermetic Bags

The OLS regression results show an increase in farm size results in an increase in the quantity of hermetic bags used. Similarly, the length of time farmers store maize influences the number of hermetic bags used by farmers to store their maize such that an increase in duration of storage by one month increases the quantity of bags used by 27.2%.

Also, the quantity of maize farmers sold each season was found to have a positive and statistically significant influence on the number of hermetic bags used by farmers to store maize. The result shows that an increase in maize production by one bag will increase the number of hermetic bags used by 17.5%.

Hence, duration of storage, quantity produced and sold, and farm size are key variables influencing the quantity of hermetic bags used by farmers.

Discussion

The study finds that both socio-economic and institutional variables influence farmers' likelihood to adopt the hermetic bags to store maize after harvest. The age of the farmer was found to influence the likelihood of farmers to adopt hermetic bags. A plausible explanation is that as age increases, farmers gain many years of farming experience through practice and observations and experiment with new technologies, especially after trials and hands-on training. The overall finding is consistent with Ngowi and Selejio (2019), who indicated that the age of farmers had a significant influence on the adoption of improved post-harvest loss storage technologies by smallholder maize farmers in Tanzania.

Also, membership in farmers' associations positively and significantly influences farmers' likelihood to use hermetic bags. This could be because membership in farmers' associations increases the chances for farmers to access information about a storage technology, which could boost adoption decisions positively. This finding is consistent with the study of Moussa et al. (2014), who found that membership in an association increased the adoption of on-farm hermetic storage by 9% in Benin, Togo.

The length of time farmers store their maize was captured in the study as the duration of storage positively and significantly influenced farmers' adoption decision in Dormaa. This could partly be attributed to the fact that farmers who produce in large quantities can access credit, market information, and access to extension services which may significantly influence the quantity of bags used to store maize.

Regarding institutional variables, training had a positive and significant influence on farmers' likelihood to adopt the hermetic storage bags. This result corroborates the findings of Mekonen and Wubetie (2021), which showed that training has a positive and statistically significant effect on adoption, indicating that farmers who participated in the Purdue Improved

Crop Storage (PICS) training were 13.8 times more likely to adopt the PICS bag technology in Ethiopia and also in line with the study of Baributsa and Njoroge (2020) who found that farmers who live in villages where hermetic storage technology training activities took place are more likely to adopt the technology and share it with other farmers in their community. The justification is that attendance at training increases farmers' knowledge and awareness of hermetic storage technologies and enhances their understanding of the importance of protecting their maize by storing it using hermetic bags.

Moreover, the findings showed that farmers served by extension agents, were less likely to use hermetic storage technologies. This could be attributed to the fact that, although extension agents serve more farmers in the area, the focus is more on methods to increase production with little emphasis on maize storage methods. This was visible in the field where farmers in one of the communities surveyed had never been educated or trained about hermetic bags but were making use of the bags. Those who used the bags have heard about hermetic bags during their visits to other areas, moved to the area with gained knowledge from their previous settlement, and have heard about the bags from friends.

Conclusion and Recommendations

This study aimed to identify the socio-economic and institutional factors influencing the adoption of hermetic bags and examine factors influencing farmers' adoption decision and intensity of use of hermetic storage bags by smallholder farmers in Dormaa, Ghana. Primary data were used for the study collected using a structured questionnaire from a sample of 217 farmers. The data were analyzed using a regression model to determine the factors influencing adoption and intensity of use of hermetic bags.

From the regression results, the probit and the logit techniques showed that mainly age, marital status, Membership, training, and duration of storage, were positive and statistically significant while education and served by an Extension agent had negative and statistically significant influence on the probability to adopt hermetic storage bags.

Overall, the results point to training, membership in farmers' associations, and duration of maize storage as the primary factors pushing hermetic bags adoption in Dormaa, Ghana. The results also showcase farm size, duration of maize storage, and the quantity of maize farmers sold each season as primary factors pushing the number of hermetic bags used by smallholder farmers to store maize.

Based on the above findings, it is recommended that Extension agents in the study area incorporate training and demonstrations on the proper use and benefits of using hermetic bags for maize storage on their yearly plan of activities. Also, broadcasting training opportunities to all maize farmers using appropriate communication channels and multiple reminders prior to training to create awareness of training programs is necessary. Strategies should be adopted to target and invite more women maize farmers to the training to boost the number of female adopters in the study area. This could be enhanced by targeting and sending prior training reminders to women associations to ensure all farmers receive information for future training in the area.

It is also recommended that the formation of farmers' associations in the communities be encouraged because when farmers are in groups, they could assemble their maize, dry it to the required temperature, and store it together. Also, farmers benefit when they are part of an association as shown by the USAID Feed the Future Post-harvest Loss Innovation Lab (PHLIL)

in which the lead author was a part of the delegation to Dormaa who donated a solar dryer to women in poultry in Dormaa.

Also, to increase the duration of maize storage by smallholder farmers, it is recommended that the government and NGOs target and build storage facilities and equip with hermetic bags for farmers to store maize after harvest when prices are low and sell when prices surge. The United States Department of Agriculture AMPLIFIES project built a storage facility in Koradaso and provided Purdue Improved Crop Storage (PICS) bags where farmers store their maize for as long as they want and pay a token of two Ghana Cedi (US$ 0.33). When farmers bring their maize together, it can serve as an avenue to market their products jointly and search for markets and better prices.

Furthermore, trust must be established for farmers to store their maize in the warehouse and receive money later after it is sold. When NGOs, and other stakeholders build storage facilities in communities, management of these facilities should be given to individuals with high moral values and well-trusted by citizens in the community. On this note, when warehouse facilities are built by MoFA or other NGOs in the communities, we recommend these bodies partner with local community leaders whom the farmers trust to manage these warehouses and provide the donors with information on warehouse management.

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