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Determinants of Grain Postharvest Storage Technology Choices in Malawi

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Abstract
The study was conducted to determine factors influencing farmers' choice of grain postharvest storage technologies. The study utilises IHS-3 data conducted by the National Statistics Office (NSO) in Malawi from March 2010 to March 2011. A stratified two-stage sample design was used for IHS-3.The multinomial logit model was used to analyse the factors. The results from the multinomial logit model revealed that farm size, education, production and marital status had an influence in choosing the grain storage technologies. The results further revealed that farm size and education were highly significant ($p<0.001$) in influencing the choice of grain storage technologies. The study, recommends that stakeholders should ensure that farmers have access to farm land to enhance production and access to education to change farmers' perception on grain storage technologies to reduce grain loss thereby improving food security.
Keywords: Multinomial Logit, Postharvest Storage Technology, Malawi

1. Introduction

Grain postharvest loss is a major concern to the growing human population in Malawi as a large proportion of grains is lost along the food chain. Postharvest losses occur from harvesting all the way to consumption. These include losses through threshing, winnowing, drying technologies, transportation, storage and processing (World Bank, 2011). These grain losses are both direct and indirect where direct losses include spillage, damage by insects, rodents, moulds and birds while indirect losses include loss of quality and nutrition value. Grain postharvest loss has an impact on both micro and macro levels of economy. The consequences of postharvest maize loss include increased dry weight losses, early sale at low prices and inability to use the harvest as collateral to access credit (Bassapa, 2007).

Malawi is losing maize grains valued at K16 billion annually (Business Consult Africa, 2012). This is happening in the face of the Ministry of Agriculture and Food Security (MoAFS) subsidized storage insecticides to smallholder farmers in acknowledgement of the growing constraints posed by storage insects (Dorward, 2011). The most economically destructive storage insect pest of grains is *Prostephanus truncates,* commonly known as Larger Grain Borer (LGB) and seconded by *Sitophilus zeamais* (maize weevil). Dry weight losses from maize weevil alone average about 5% by weight after six months of storage (Holst, 2000). Since the arrival of LGB in Malawi, it has become the largest threat to post harvest maize storage with dry weight loss of 10-30% in six months of storage (Dick, 1988). The primary role of an effective postharvest technology is to ensure that the harvested product reaches the consumer, while fulfilling market/consumer expectations in terms of volume, quality, nutrition, food security, and product safety (World Bank, 2011). Currently, small metallic silos, super grain bags and super dust are some of the modern approved storage technologies in Malawi. Super guard dust *(1.6% Pirimiphos-methyl+0.4% Permethrin)*, Shumba super (*1.0% Fenitrothion+0.13% Deltamethrin)*, Actellic super dust (1.6% *Pirimiphos-methyl*+0.3% *Permithrin)* are the recommended storage insecticides that Malawian smallholder farmers admixwith grains to protect them against storage pest such as *P. Truncatus* and *S. zeamais* (Singano, 2008).

Application of insecticides and use of bags have been recommended in order to protect against insect pests and pathogen attack (Golob, 2009). Nevertheless, insecticides and bags are ineffective to rodents. The rodents consume grains and contaminate quality of grains with urine and droppings than they consume. The problem is that they are not taken very seriously as a potential danger to the produce by the farmers (Nuggard, 1998). In realising the losses that come from rodents, termites and infectiveness of the insecticides when the grain is kept for a longer period, the small metallic silo program was introduced. The program started by training artisans to manufacture small metallic silos. The main objectives of the small metallic silo program were (1) to reduce postharvest losses by improving household/community level storage capacities through the provision of grain and food storage facilities; and (2) to enhance local technical capacity for construction of small to medium-scale grain/seed storage silos through transfer of improved storage technologies and training of local artisans (Mazaud and Mejia, undated).

In addition to increasing production, it is essential to recognize that food production does not simply end at harvest because susceptibility to pest during storage can cause tremendous post-harvest losses of up to 30% or more in six months of grain storage (Boxall, 2002). Quite a number of studies have been conducted to come up with different measures to reduce post-harvest loss in grains (e.g., Basavaraja et al., 2007; FAO, 2008; Singano et al., 2012). Over the years several improved technologies for grain postharvest storage technologies have been developed and promoted. This resulted in the MoAFS approving super dusts, super grain bags and metal silos as modern maize storage technologies. In a related study conducted by Singano et al., (2012) in comparison of the effectiveness of storage technologies to existing storage methods, it was reported that the metallic silo is the most effective grain storage technology in Malawi.

However, despite the introduction of improved and effective grain storage technologies, it was reported that farmers in Malawi store their grains in various structures and tools such as unprotected pile, heaped in house, bags in house, *chitandala* in house, *chitandala* outside, traditional *nkhokwe*, improved *nkhokwe*, and few in metallic Silo (NSO, 2012). Maonga et al., (2013), also reported that Malawi experienced low rate of adoption of modern grain postharvest storage technologies despite being approved to be the most effective. Since most studies that were conducted on grain postharvest technology, focused much on the comparison of the effectiveness of grain storage technologies (Singano et al., 2012; Maonga et 2012; Bassapa et al., 2007; Meena et al., 2009) there is lack of sufficient information to address the determinants of grain postharvest storage technology choices. This observed gap suggests that there is a need to conduct a study to fill the knowledge gap. The study therefore, seeks to determine factors influencing household's choice of grain postharvest storage technologies. The study will help stakeholders involved in postharvest grain management to come up with sound policies and technologies that are suitable and accepted to smallholder farmers to minimize losses thereby increasing availability of grains to consumers in Malawi hence improving food security. This is in line with ASWAP focus area on food security and risk management, which includes reduction of farm post-harvest losses from 25% to 12% (MoAFS, 2011).

2. Materials studied and method

2.1 Data Source

The study uses the Third Integrated Household Survey (IHS-3) data which was conducted by the National Statistical Office (NSO) in Malawi from March 2010 to March 2011. IHS-3 survey is a national representative sample survey designed to provide information on the various aspects of household welfare in Malawi. The survey collected information from 12271 households. This sample size was statistically designed to be representative at both national, district and rural levels enabling the provision of reliable estimates for these levels. However, for the sake of this study, a sample of 373 households were used to represent as the number grain postharvest technology users. The survey employs a stratified two-stage sample design with primary sampling units (PSUs) selected at the first stage known as census enumerations areas (EAs) defined for the 2008 Malawi Population and Housing Census. The survey provides information on grain postharvest storage technologies practised in Malawi. These storage technologies include; (i) heaped in the house (ii) bags in the house (iii) chitandala in the house (iv) traditional nkhokwe (v) improved nkhokwe.

2.2. Empirical model

This study intended to determine factors influencing farmers' choice of grain post-harvest storage technologies. In this case, the dependent variable, choice of grain storage technology, is not a continuous variable but one that takes two or several modalities depending on whether the household *i;* chooses a particular storage technology *j*; Since the dependent variable is not continuous, the application of linear regression models is not appropriate. Multinomial logit (MNL) model was used because the model is appropriate for responses with no ordering. This model describes the behaviour of consumers when they are faced with a variety of goods with a common consumption objective. However, the goods and choices must be highly distinguished by their individual attributes. The basic concept was generalized from binary logistic regression but with large number of comparisons. (Aldrich & Nelson, 1984; Hosmer & Lemeshow, 2000).

In a multinomial logistic regression model, the estimates for the parameter can be identified compared to a baseline category (Long, 1997). The multinomial logistic regression model used in this study estimates the effect of the individual variables on the probability of choosing a type of alternative postharvest storage technology. According to Green (2000), the multinomial logit model for a multiple choice problem is specified as follows: Let U_{ij} denote the utility that the household *i* gets from choosing a technology *j=1….5[(i) heaped in the house (ii) bags in the house (iii) chitandala in the house (iv) Traditional Nkhokwe (v) Improved Nkhokwe.*

$$U_{ij} = \beta_j x_{ij} + \varepsilon_{ij} \quad \textbf{(1)}$$

Where β_j varies and x_{ij} remains constant across alternatives; and ε_{ij} is a random disturbance term reflecting intrinsically random choice behaviour, measurement or specification error and unobserved attributes of technologies. Let also P_{ij} denote the probability associated with household's choice of postharvest storage technology *i* from category *j* with; *j=0* if the household does not use a particular grain storage technology, x_i = predictors of response probabilities; *e* is the natural base of logarithms; and β_j are the parameters to be estimated by maximum likelihood estimator (MLE). Then the MNL model can be given by:

$$P_{ij} = \frac{e^{x_i \beta_j}}{\sum_{j=0}^{j=3} e^{x_i \beta_j}}, \quad \textbf{(2)}$$

The estimated equations provide a set of probabilities for the $j + 1$ choice for a decision maker with x_i characteristics. For identification of the model, we need to conveniently normalize by assuming $\beta_0 = 0$ (Greene, 2000). Therefore, the probabilities are given by:

$$prob\left(y_i = j / x_i \right) = P_{ij} = \frac{e^{x_i \beta_j}}{1 + \sum_{j=1}^{J} e^{x_i \beta_j}}, \quad \text{For J>0} \quad \textbf{(3)}$$

$$prob\left(y_i = 1 / x_i \right) = P_{i0} = \frac{1}{1 + \sum_{j=1}^{J} e^{x_i \beta_j}}, \quad \textbf{(4)}$$

The parameter estimates of the MNL model provide only the direction of the effect of the independent variables on the dependent variable, but estimates do not represent either the actual magnitude of change nor probabilities (Greene, 2000). To interpret the effects of explanatory variables on the probabilities, marginal effects are computed. The marginal effects (δij) of the characteristics on the probabilities are given as;

$$\delta ij = \frac{\partial P_{ij}}{x_i} = P_{ij}\left[\beta j - \sum_{j=0}^{J} P_{ij} \beta j \right] = P_{ij}\left[\beta j - \overline{\beta} \right] \quad \textbf{(5)}$$

The marginal effects or marginal probabilities are functions of the probability itself and measure the expected change in probability of a particular choice being made with respect to a unit change in an independent variable from the mean. However, Table 1 shows variables included in the empirical model, the unit measurement of the specific variable and expected sign.

Table 1. Description of variables grain storage technology choices

Independent Variables	Description and Units of Measurements	Expected Sign
Age	Number of years	+/-
Gender	Sex of household (1=male, 0= female)	+/-
Education level	Number of school years of complete education	+/-
Farm size	Total farm area in hectares (ha)	+
Yield	Average grain yield of the household (kg).	+
Marital status	Dummy for marital status of the h/head (1=Monogamy 2=Polygamy 3=Separated 4=Divorced	+/-

3. Results and Discussion

The preliminary analysis was done to check for some inconsistencies that would affect the results before fitting the variables into the Multinomial logit. All outliers were detected and corrected from the dataset for the descriptive and the regression analyses, with final sample size falling to 373 responses obtained. Table 2. Shows the results from the descriptive statistics. The results shows that the average farm size was 1.2 acres with an average yield of 29.8kg and a maximum of 9500kg. The mean age of the respondents were of about 21 years and a maximum of 110 years.

Table 2. Summary statistics for variable in the Multinomial Logit

Variables	Obs	Mean	Std. Dev.	Min	Max
Farm Size	373	1.216402	5.005143	0	350
Grain yield	373	29.75687	165.1709	0	9500
Gender	353	1.511999	.4998604	1	2
Age	373	21.20366	18.37091	1	110
Education	373	1.398427	.9423582	1	7
Marital Status	373	3.206387	2.327764	1	6

3.1 Factors Influencing the Choice of Grain Postharvest Storage Technologies

The results of the multinomial logistic regression model for the grain postharvest storage technologies are presented in Table 3. The chi-square (χ2) distribution measures the overall significance of a model in Multinomial logit model estimation. The likelihood ratio chi-square of 75.18 with a p-value < 0.0000 which is less than 1% concluded that, the variables included explaining choice of grain postharvest technologies fits the multinomial logit model well.

Table 3: Estimate of Multinomial logistic regression model

Technology	Heaped in house		Chitandala in house		Traditional Nkhokwe		Improved Nkhokwe	
Constant	-3.4605** (-1.3592)	0.011	7.298 (1302.46)	0.996	-1.6619** (.7928)	0.036	2.1546 (1612.0)	0.999
Production	-.0298* (0.2722)	0.103	-.0089 (.02222)	0.690	-.0305** (.0101)	0.003	-.0218 (.0534)	0.683
Gender	-.0573 (.5470)	0.917	.8509 (.9809)	0.386	.5400* (.3152)	0.087	.8843 (1.533)	0.564
Age	-.0061 (.0169)	0.717	.0369 (.0235)	0.117	.0076 (.0087)	0.379	.1223* (.0709)	0.084
Education	-.16350 (.1914)	0.393	-14.6593 (1302.46)	0.991	-.8479*** (.2655)	0.001	-12.7340 (1612.01)	0.994
Marital Stat	.3715** (.1437)	0.010	.1803 (.2342)	0.441	.0386 (.0770)	0.616	-.5342 (.6169)	0.387

Number of observation=373; LR chi^2 (24) =75.18, Prob > chi^2 = 0.0000*, Log likelihood = -219.67607, Pseudo R^2 = 0.1461.

Note: **= significant at 10%, ** = significant at 5% and *** = significant at 1%; Base outcome (Bags in the house).*

The marginal effect (Table: 4) gives the unit change in a given independent variable on the choice of storage technologies. The marginal effects shows that household marital status was positively influencing heaping the grains in the house compared to the referent group (Bags in the house) with a probability of 37% and significant (p<0.05). The issue of marital status is very tricky in choice of storage technology. This is because farmers who are married could easily make a unified decision with minimum risk aversion to choose a storage technology that is less costly if it is deemed to improve household socioeconomic status. The finding are constituent to Maonga et al. (2013).

Table 4: Marginal Effects of the Multinomial logit Model

Variables	Heaped house	Bags in house	Chitandala in house	Traditional Nkhokwe	Improved Nkhokwe
Farm size	.002257	-.0154884***	5.72e-09	.0132315***	-9.20e-10
Production	-.0002838**	.0012344**	-1.18e-10	-.0009506**	-2.72e-11
Gender	-.000739	-.0162906*	1.30e-08	.0170296*	1.15e-09
Age	-.000739	-.0001793	5.70e-10	.0002421	1.62e-10*
Education	-.0013349	.027993***	5.70e-10	-.0266579 ***	-1.68e-08
Marital status	.0036444**	-.0047401	2.72e-09	.0010957	-7.14e-10

Grain yield was found to be significant on choice of a storage technologies. The multinomial results revealed that a unit increase in yield significantly (p<0.05) reduced the probability of the farmers to heap the grain in the house and traditional nkhokwe compared to the referent group (Bags in the house) by a probability of 3% and 3.4% respectively. The results suggests that as yield increases, a rational producer would deviate from traditional storage to the most efficient improved storage technologies. Increase in yield increases the potential for surplus to be kept. Yield determines the type and size of storage facilities that farmers consider in postharvest farm planning (Basavaraja et al. 2007).

Farm size significantly (p<0.001) influences positively the probability of choosing the traditional nkhokwe storage technology by 0.23%. This means that the larger the farm size, the more the household can produce assuming all things equal. Hence, the more likely household to choose a traditional nkhokwe which can keep large amount of the grains yields as compared to bags in the house. The findings are consistent to (Maonga et al., 2013) who reported that increasing the size of farmland for grain production improved the probability of adopting the small metallic silo technology and Shongwe (2014) factors influencing the choice of climate change adaptation strategies by households. Gender of a household head turned out to affect the probability choices of grain storage technologies. Being a female headed household significantly (p<0.1) influence the choice of traditional nkhokwe by 54% than men. This is because females are risk averse to food insecurity issues and always choose a grain storage technology that has less labour intensive and effective as compared to bags in the house. Similar results were found in (Alem et al, 2015) on the study of modelling cooking fuel choices in Ethiopia. Age of the household head was a determinant factor in grain postharvest storage technology choices. Age of the household head tends to increase the probability of choosing the improved nkhokwe than the referent group (Bags in the house). An increase in a household age increases the probability of using improved nkhokwe by 0.76%. The results showed that age of the household head was significant ($p<0.1$). The finding is consistent with Adesina and Baidu-Forson, (1995) who reported that age was positively related to adoption of new agricultural technology. Education of the household head was strongly ($p<0.01$) and negatively influencing the choice of traditional nkhokwe with a probability of 85% compared to the referent group (Bags in the house). Education changes farmer's perception on culture, social and tradition hindrances to choice of storage technologies (Basavaraja, 2007). As such, there is probability of farmers shifting from traditional storage technologies to improved technologies. The finding are similar to Alem et al (2015) on the study of modelling cooking fuel choices in Ethiopia; that education enables individuals to understand the negative effects of using biomass fuels both on health and possibly on the environment. Similar results were also found in Maonga et al (2013) who studied determinant of adoption of small metallic silo technology in Malawi.

Although age was positively related to choice of improved nkhokwe, a number of studies have reported that age had a negative influence on improved storage technologies (Maonga et al., 2013; Basavaraja et. al., 2007). However, Rogers (1983) explained that age after some stage becomes negatively influencing the adoption of new technologies. it is argued that beyond some age group people become laggards (people who are less likely to adopt). A positive sign on age is an empirical question: it may mean that older farmers utilize their experience to better evaluate the merits of improved storage technologies than younger farmers. This could also mean that older farmers are more risk averse to food insecurity issues and are more likely to adopt the technology than younger farmers (Mangisoni, 2012).

4. Conclusion and Recommendation

The overall objective of this study was to assess factors influencing farmers' choice of grain postharvest storage technologies in Malawi. The multinomial logit results revealed that farm size and education were highly significant ($p<0.001$) in influencing the choice of traditional nkhokwe storage. In order for farmers to choose the modern improved and effective grain storage technologies, it is recommended that stakeholders should ensure that farmers have access to farm land through proper land tenure system to enhance production and access to education to change their perception on modern improved grain storage technologies to reduce grain loss thereby improving food security.

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