COST-BENEFIT ANALYSIS OF PURDUE IMPROVED CROP STORAGE BAGS FOR MAIZE STORAGE AMONG SMALLHOLDER FARMERS IN NORTHWEST ETHIOPIA

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ABSTRACT

In Ethiopia, post-harvest losses caused by insects are a major challenge in crop production systems. Dried maize is particularly susceptible to insects during storage. Storage loss affects the livelihoods of small-scale farmers leading to food insecurity and loss of income. Therefore, the objective of this study was to assess the cost-benefit analysis of Purdue Improved Crop Storage (PICS) bags on maize storage in Northwest Ethiopia. Cross-sectional data was collected from 392 randomly selected households from both users and non-users of PICS bags, using stratified sampling technique. A structured questionnaire, key informant interviews, focus group discussions, individual in-depth interviews, and field observations were used to gather the data. A cost-benefit analysis was computed to evaluate the viability of PICS bags for maize storage. The binary logistic regression model was used to identify factors that affect the use of PICS bags. Descriptive statistics (percentage, mean, and standard deviation) and inferential statistics (t-test and chi-square test) were employed to analyze the data. The benefit-to-cost ratios (BCRs) of insecticide with both ordinary and PICS bags were greater than one, but PICS bags resulted in more than two-fold higher values as compared to insecticide with ordinary bags. The net present value (NPV) at 15% discount rate in 2018 was 20.73 USD and 25.35 USD per 100 kilograms of stored maize when insecticide was applied to ordinary and PICS bags, respectively. Sensitivity analysis with a 10% cost increment and up to 50% price discount showed that both technologies would still be viable for maize storage. However, PICS bags had higher NPV and BCR; making the technology more viable than insecticide with ordinary bags. The results of binary logit model indicated that educational level, gender, awareness, training, accessibility of the technology, perception of the technology, involvement in leadership activities in the community, and total income of the household positively influenced farmers’ decisions to use PICS bags, whereas price negatively affected the use of the PICS bags. PICS bags had clear economic advantage over insecticide with ordinary bags for maize storage in Northwest Ethiopia. Efforts should be made to disseminate and improve access to PICS bags for strengthening food security and increasing incomes of maize farmers in Northwest Ethiopia.

Key words: Hermetic bag, smallholder farmers, profitability, post-harvest management, food security
INTRODUCTION

In Ethiopia, post-harvest losses caused by insects are a major challenge in crop production systems. Stored maize is highly susceptible to pests, particularly insects [1]. Reducing food losses increases food availability without requiring additional production resources and in least developed countries, it contributes to rural development and poverty reduction [2].

Maize is one of the most important staple food and cash crops in Ethiopia, providing calories for consumers and income for farmers and traders. In terms of grain volume productions (64.9 million quintals, or 25.8%) and area of cultivation (1.99 million hectares, or 16.1%), maize stands first and second, respectively, among cereal grains produced in Ethiopia. However, findings on maize losses during storage in Jimma, Ethiopia show that quantitative average maize damage of up to 64.5% and losses of 41 to 80% are common in the store within three to six months. The PICS hermetic bag is now known to have proven effective in storing a variety of crops, including cowpeas, maize, peanuts, sorghum, wheat, and common beans against insect pests [3]. To determine the viability of the different storage technology options, the economic and financial analysis methodology was used [4].

The use of traditional storage structures, as well as the storage of insecticide-treated maize in ordinary bags by small-scale farmers leads to considerable quantitative and qualitative losses and additional costs. Several studies have also shown that the preservation of cereal grains by the application of chemical insecticides has serious negative impacts on human health and environment. PICS bags help resolve this problem by providing a safe, effective, and eco-friendly storage option. Burie district has been promoting the PICS technology which is said to have the potential of significantly reducing post-harvest losses in maize during storage. However, a systematic study that thoroughly quantifies the economic impacts of PICS bags vis-à-vis the use of ordinary storage bags together with chemical insecticides (that is, a comparative analysis of the two), as well as the factors that hinder smallholder farmers from using PICS bags, has not been done yet and such information is not readily available in the study area.

There is a need for studies that provide information on the costs and benefits of different maize storage technologies. Therefore, this study was conducted to examine the cost-benefit analysis of PICS bags over ordinary storage bags (insecticide-treated grains are commonly stored in polypropylene [PP] bags) and
identify factors that influence smallholder farmers’ use or non-use of PICS bags in Northwest Ethiopia.

MATERIALS AND METHODS

Study area
Burie district, the study area, covers a total area of about 58,795 hectares and was home to 101,788 people in 2017 [5], 97% of whom earn their living from farming (see Figure 1). The district lies at an altitude range of 700 to 2,300 m.a.s.l. and receives an annual rainfall of 900 to 1,400 mm. Maize is one of the major staple crops and the grain most susceptible to storage pests.

Figure 1: Location map of the study area
Source: [42]

Sampling procedure and sample Size
This study employed a multi-stage sampling procedure. It was conducted in Burie district because it is the project site and the PICS storage technology has been already introduced into the area and farmers are already using the technology. Out of 22 rural kebeles (the smallest administrative units in Ethiopia) in the district, 3 kebeles, namely Zalima, Wadra, and Gulim were selected by simple random sampling. Households were stratified as users and non-users of PICS bags. The sample size for each of the two groups was determined by 95% confidence level, 0.5 degree of variability and 5% level of precision.

\[ n = \frac{N}{1 + N(e)^2}, \]

where \( n \) is the sample rural households, \( N \) is the population size (total number of households), and \( e \) is the level of precision. Through a systematic random sampling technique, a total of 392 maize farmers, who were also household heads,
were selected in equal numbers from the lists of both strata (users and non-users of PICS bags), proportional to size of each kebele.

**Data sources and methods of data collection**
Both primary and secondary data were used. Primary data were collected through questionnaires, focus group discussions, direct personal observations, key informant interviews, and measurement of maize by balance. The primary data were supplemented and supported by reviewing documents from several secondary sources, mainly District Agriculture Office (DAO) report and previous studies (published and unpublished).

**Data analysis methods**
The data were analyzed by descriptive statistics (percentage, mean, and standard deviation), cost-benefit analysis, inferential statistics (t-test and chi-square test), and binary logistic regression.

**Cost-benefit analysis**
Cost-benefit analysis (CBA) was used to analyze and estimate the costs and benefits involved in maize storage. The Net Present Value (NPV) was calculated from this formula adopted from Shively [41].

\[
\text{NPV} = \sum_{t=1}^{n} \frac{(B_n - C_n)}{(1 + i)^t}
\]

where \(B_n\) = benefits in each year of the project, \(C_n\) = costs in each year of the project, \(n\) = number of years in a project, \(i\) = interest (discount) rate, and \(B_n - C_n\) = cash flow in \(n\)th year of the project. NPV was calculated based on a stream of incremental benefits of improved maize storage practices and incremental costs of the same, and using a social discount rate of 15%\(^1\). The project is profitable or feasible if the calculated NPV is positive when discounted at the opportunity cost of capital.

Mathematically, according to Shively [41], the Internal Rate of Return (IRR) is that discount rate ‘\(i\)’ such that

\[
\text{IRR} = \sum_{t=1}^{n} \frac{(B_n - C_n)}{(1 + i)^t} = 0
\]

That is, NPV = 0 whereby \(B_n\) = benefits in each year of the project, \(C_n\) = costs in each year of the project, \(n\) = number of years in the project, \(i\) = interest (discount) rate. IRR is defined as the discount rate that causes the present value of project
costs to be equal to the present value of the benefits. In other words, it makes the NPV to be equal to zero [4, 6, 7]. The BCR is the ratio of present worth of benefit stream to present worth of cost stream. The formula adopted from [31, 36, 41] was used.

\[
\text{BCR} = \frac{\sum_{t=1}^{n} B_n / (1 + i)^n}{\sum_{t=1}^{n} C_n / (1 + i)^n} \quad (3)
\]

where \( B_n \) = benefit in each year, \( C_n \) = cost in each year, \( n \) = number of years, \( i \) = interest (discount) rates. The investment is said to be profitable when the BCR is equal to or greater than 1 [7].

Return on storage is calculated by taking the ratio of net gain on storage to net income if selling at harvest plus storage costs. This analysis also considers the ability of PICS bags to be used for a second season. The cost of the PICS bag was straight-line depreciated over two years, and returns on storage presented as an average of years one and two. As production costs vary greatly across the country, these parameters were not included in the model.

**Binary logistic regression model**

Following Gujarati [8], the logistic distribution function for identification of households' decision to use PICS bags for maize storage can be defined as:

\[
\Pi_i = \Phi \left( \frac{1}{\Phi} \right) = \frac{1}{1 + e^{-Z_i}}
\]

Since, \( Z_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_m X_m \), the above formula can be rewritten as shown below for ease of understanding.

\[
\Pi_i = \frac{e^{z_i}}{1 + e^{z_i}}
\]

The above formula indicates that as the value of \( Z_i \) ranges from negative infinitive to positive infinitive. \( \Pi_i \) is the probability of a household's decision to use PICS bags and ranges between 0 and 1. Therefore, if \( \Pi_i \) is the probability of a
household’s decision to use PICS bags, then \((1-\Pi)\) will be the probability of the household’s decision to use conventional storage methods, including ordinary bags. This can be represented as:

\[
1 - \Pi = \frac{1}{1 + e^{Z_i}}
\]

Now the most important element in the logistic regression, i.e. the odds ratio that can be obtained from equation (2) and (3) is represented as \(\frac{\Pi}{1-\Pi}\) as shown in the following expression:

\[
\frac{\Pi}{1-\Pi} = \frac{1 + e^{Z_i}}{1 + e^{-Z_i}}
\]

The odds ratio in logistic model shows the extent or degree of favoring the household’s decision to use PICS maize storage bags. When we take the natural logarithm of equation (4), we can obtain the following formula for logit model which is represented as

\[
\ln\left(\frac{\Pi}{1-\Pi}\right) = Z_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_m X_m + U_i
\]

Then, if the disturbance term \(U_i\) is taken into account, the logit model becomes:

\[
Z_i = \beta_0 + \sum_{i=1}^{m} \beta_i X_i + U_i
\]

where \(\beta_0\) is the intercept. It is the value of the log odd ratio \(\frac{\Pi}{1-\Pi}\) when \(X\) or explanatory variable is zero. \(\beta_1\) is the slope and measures the change in \(L\) (logit) for a unit change in explanatory variables \(X\).

**RESULTS AND DISCUSSION**

Socio-economic and demographic characteristics of respondents

93.8% of household heads were male and 6.2% were female. About 95.9% of users and 89.8% of non-users were married (Table-1). The results revealed that
the adoption of PICS bags by male-headed households was higher than by female-headed households. Similarly, married respondents were more likely to use PICS bags than their unmarried counterparts. Based on chi-square test for gender and marital status, there was a significant difference in the use PICS bags (at 5% significance level) between the two groups (users and non-users). Concerning their educational levels, about 49.7% of the respondents were illiterates (Table 1). The result of χ²-test showed that there was a significant difference in the distribution of illiterate and educated household heads between users and non-users of PICS bags (Table 1).

The mean age of users and non-users of PICS bags were 42.68 and 47.78 years, respectively (Table 2). The family size of the sample households ranges from 1 to 9 persons, with a mean of approximately 5 persons and standard deviation of 1.562; the mean household size in the study area is almost the same as the regional average household size of 4.6 [9]. The average landholding sizes for users and non-users were 2.38 and 2.11 ha, respectively. The average size of livestock in total livestock units (TLU) was found to be 7.3, 5.02 and 6.16 for user, non-user and the total sample pooled together, respectively (Table 2). These figures are higher than the regional and national averages (3.87 and 4.46 TLU, respectively).

**Costs and benefits of PICS bags and chemical insecticide**

The CBA performed for this study compared the cost effectiveness of PICS bags versus grain stored in PP bags after being mixed with a chemical insecticide. The initial costs for both methods are shown in Table 3. When comparing initial costs alone, one may understand why farmers would be reluctant to use PICS bags. The cost of the PICS bag itself is more than twice the cost of the ordinary bag, and even when chemical treatment and labor costs are considered, the insecticide application required for ordinary bags is 21.4% less expensive. The chemical treatment effectively abates losses during the first three months of storage, but its effectiveness requires reapplication. PICS bags, on the other hand, have costs that are paid once every two years (a PICS bag can be used for 3 to 4 years).

The storage costs considered are as follows:

- **Cost of storage bags:** The bags mainly used are ordinary PP bags. Ordinary bags were available in different sizes ranging from 25-kilogram bags to 100-kilogram bags. The most common sizes were the 50 and 100 kg bags. The average cost of a PICS bag and an ordinary PP bag was Ethiopian birr (ETB) 43 and ETB 20, respectively. The effective service life of both bags was assumed to be 2 years.
Maize storage labor costs: This is the average cost of hired labor and hours of family labor used in maize storage. For both types of bags, the total cost of labor for applying insecticide and bagging of grain is ETB 6 for a quintal (100 kg) of maize. The hours of family labor were converted to labor days by dividing by eight, and valued using an average of the rates set by the Ministry of Labor via Proclamation No. 377/2011 (Regulation of Wages).

Insecticide cost: Malathion 5% is the most commonly applied insecticide in the study area. It was found to cost, on average, ETB 12.5 for a 100-kg bag of maize. Because it needs to be re-applied four times a year, its total cost in a year or one cropping season is ETB 50 for a 100-kg bag. Conversely, there are no insecticide costs for storing maize using PICS bags.

The cost of maize storage-related losses: Unlike the PICS bags, the application of insecticides to grain stored in PP bags resulted in insect infestation problems of varying magnitudes during the maize storage period. Holes resulting from insect infestations are generally understood to be a symptom of “grain damage” [10, 11]. The percentage of insect-damaged grain was then calculated as follows [12, 13]:

$$\text{Insect damaged grain (\%) = \frac{\text{Number of insect damaged grain}}{\text{Total number of grains}} \times 100}$$

With the application of chemical insecticides, farmers lost 2.7% of the stored maize (quality discounts for each emergent hole per 100 seeds and changed to kg). Using the estimated grain loss during the storage period, the amount of grain lost was calculated in relation to the kilograms in a quintal of maize. The cost of the maize lost is ETB 21 for a quintal (or 100-kg bag) of insecticide-treated maize stored in the ordinary bags.

Maize storage benefits: The benefits used are the returns from the sale of stored maize. During the storage period, the prices received varied from one month to the next and ranged from ETB 3.5 to 8 per kilogram. Thus, average returns per 100 kg ranged from ETB 350 at harvest to ETB 800 during the lean season.

As shown in Table 4, the benefit gained from the sale of maize during the lean season (June to September) is the same for both untreated maize stored in PICS bags and insecticide-treated maize stored in PP bags. However, storing maize in PP bags comes with the additional costs of applying and reapplying chemical insecticides (that is, costs of insecticides plus labor costs). Therefore, the net profit from the sale of maize stored in PP bags is less than in the case of PICS bags. PICS bags provide benefits at a lower cost and deliver tangible returns throughout
the year. The only costs to consider are the purchase price of the bags and initial bagging labor. Besides this cost advantage, PICS bags have many advantages, including 3 to 4 years of use (versus a maximum of 2 for PP bags), which results in reduced operational costs compared to using PP bags and insecticides. Hence, those households that use PICS bags gain an additional benefit of ETB 66 and ETB 99 in the first and second years or seasons of cropping, respectively. For the CBA, the prices of maize at harvest season (January) and during the lean season (June to September) were taken by referring to the price indices of Burie district (the study area) [5].

Feasibility analysis
To assess the feasibilities of the two maize storage technologies, the BCR and NPV were calculated. Table 5 compares the BCR and NPV per 100-kg or quintal of the two technologies. In Ethiopia, a social discount rate of 10% is commonly used in evaluating public investments, but a discount rate of 15% is assumed for analysis at the household level, taking into consideration the high level of poverty among rural households and the associated high preference for income at present over income in the future [16].

From the BCR results, the PICS bags are more viable with BCRs of 9.18 when compared with chemical insecticides and ordinary bags (BCRs of 4.25). In other words, the use of PICS bags resulted in BCR values that were twice the BCR values delivered by PP bags and insecticides. The NPV of using PICS bags and ordinary bags alongside insecticides was ETB 684.42 and ETB 559.74, respectively (Table 5). A positive NPV means that the investment makes sense financially and an investment that brings higher NPV is preferred. Therefore, PICS bags are preferable (Table 5). Elsewhere, compared to the conventional PP bags and over a two-month period, the use of PICS bags has demonstrated 50% lower cassava losses that result from chipping away during storage [17]. Similarly, Hell and others [18], also reported that PICS bags can provide extremely high rates of protection for maize grain, remaining under 0.5% dry weight loss after a six-month period.

Sensitivity analysis
Sensitivity analysis was done to examine the effects of changes in some of the key variables on the results of the CBA. Maize prices may change in the market and this affects the returns the farmers receive. The storage cost as well as the structure may also change. The above results were subjected to different situations such as what would happen given a certain percent reduction in the price level and a certain percent increment in the cost of storage structure and storage costs. A
sensitivity analysis was therefore carried out at 10% cost increment (for the costs of the technology and labour force) and 30%, 40 % and 50% price reduction (for the grain sales price).

According to Table 6, the BCR with a 10% cost increment and a 30% price reduction showed that both the PICS bags and the ordinary bags are viable with BCRs of 9.9 and 2.7, respectively. Analysis of the NPV (2018/2019) with 10% cost increment and 30%, 40% and 50 % price reductions still yielded positive values as shown in (Table 6). However, it was not possible to apply IRR to the cash flows related to the use of both storage technologies because the net cash flow was positive from year one. Therefore, both storage technologies would still be viable, but the PICS bags had higher NPV and BCR, making the technology more viable than the use of insecticides and ordinary bags.

**Determinants of the use of PICS bags**

In the logistic regression model, 13 potential continuous and discrete variables were entered; out of the total of these explanatory variables, only six were found to significantly influence the use of PICS bags (Table 7). These include education level, awareness of PICS, PICS training, annual income, access to PICS bags, and the price of PICS bags.

Educational level: Education was found to affect the use of PICS bags positively and significantly at 1% significance level. Respondents who are educated are 4.93% more likely to use PICS bags than uneducated respondents. Similar studies [19, 20] have shown that education enables farmers to easily understand the problem of post-harvest losses and the need to use PICS bags. Moreover, education can empower the farmers to change their knowledge and skills into practice in their real life.

Awareness of PICS: This was positive and statistically significant at 1% significance level. This result revealed that those households who were aware of PICS bags were 27 times more likely to use the bags than their counterparts who were unaware of the technology. This suggests that farmers’ awareness of the PICS technology can serve as an information dissemination tool, and this leads to higher probability of using the PICS bags than respondents with no such awareness. This finding is consistent with the findings of Adebabay [21] who found that awareness was an important factor influencing individual behavior to adopt technology.
PICS training: The coefficient for PICS training was positive and statistically significant at 1%. These results indicate that farmers who participated in the village-level PICS bags demonstrations and trainings were 13.8 times more likely to use the technology than those who were not involved in such activities. The justification for such village-level activities targeted at farmers is the need to improve their understanding and level of awareness of importance of PICS in protecting maize from insect damage and maintaining food quality as well as protecting the environment from pollution by reducing the use of chemical insecticides during storage. This is in line with other findings which indicated that farmers who had been trained were better adopters of improved storage systems [22-24].

Annual Income: This was positive and statistically significant at 5% significance level. It was found that as the income of the households increased by 1 ETB, the likelihood of using PICS bag technology increased by a factor of 1.015. This is because with more income the farmers can invest more to increase their output. Farmers with higher income or production levels may have more resources and a greater need of good storage methods and are therefore more likely to adopt the triple-bag technology. This finding is consistent with the findings of a study conducted by Ayodeji [25].

Access to PICS bags: This variable was found to be positively and significantly associated with the use of PICS bags at 1% level of significance and the result confirms the prior hypothesis. The odds ratio of 22.89, implies that, other things kept constant, the probability of using PICS bags increases by the factor of 22.89 when households gain easy access to the bags in terms of the bags being readily available at the nearest market or trading center. As the availability and supply of PICS bags increase, especially at harvest time, farmers’ use of the bags would be enhanced. On the contrary, if supplies of PICS bags are not adequate at the time of harvesting, farmers may be forced to use the more conventional storage technologies even if they prefer the PICS technology. This finding matches the findings of the study conducted by Satyanarayari et al. [26] on the poor adoption of improved storage systems in India.

Price of PICS bags: This variable was found to influence the use of PICS bag negatively and significantly at 1% level of significance. By holding other factors constant, the probability of using PICS bags by households who perceived the price as expensive was 7.796 times less than those households who perceived the price of the bag as affordable. The price of the PICS bags, which was 43 ETB per bag, was considered too high by most households. It is possible to suggest that the
high price of the bags appear to be the main reason for their low adoption by farmers. The company that manufactures the bags is not willing or able to reduce its retail price in light of the possibility of mass production and the fact that price is a major factor influencing farmers’ decision to use PICS bags [26]. Another study [27] revealed that high cost of improved storage systems also accounts for farmers non-adoption of such systems.

CONCLUSION

The return-on-investment (ROI) of a given newly introduced technology is an important factor that determines the decision of the targeted users to use or not to use the technology. A CBA was performed to compare ordinary bags with chemical insecticides and PICS bags. The results showed that the PICS bags were the more profitable maize storage technology of the two and has the potential to increase the household income in the long-run. The PICS bags had higher NPV and BCR. Thus, the CBA showed a clear advantage of using PICS bags. Educational level, awareness, training, accessibility of the technology and total income of the household positively influenced farmers’ decision to use PICS bags, whereas the price of PICS negatively affected their adoption. Therefore, project implementers, local development practitioners and concerned organizations should step up efforts to disseminate knowledge of and improve access to PICS bags for strengthening food security and increasing farmers’ incomes.

ACKNOWLEDGEMENTS

We would like to acknowledge, Debre Markos University, Bahir Dar University, Purdue University, our supervisors, data collectors and study participants for their support and cooperation.

AVAILABILITY OF DATA AND MATERIAL

The datasets used during the current study is available from the corresponding author on reasonable request.

CONSENT TO PUBLICATION

Applicable

FUNDING

The financial support was obtained from Bahir Dar University and Purdue University (PICS3 project (Grant No. OPP1038622) funded by the Bill and Melinda Gates Foundation (BMGF).
AUTHORS’ CONTRIBUTIONS
TK participated in the design, data collection, data analysis, and interpretation. ZA, ZW, BYW and DB also participated in the analysis, interpretation, drafting of the manuscript and funding acquisition. All authors read and approved the final manuscript.

COMPETING INTERESTS
The authors declare that there are no competing interests.
### Table 1: Demographic characteristics of respondents (categorical variables)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Categories</th>
<th>Use of PICS bags</th>
<th>Total observation (n=392)</th>
<th>χ² test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>User</td>
<td>Non-user</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>No</td>
<td>%</td>
<td>No</td>
</tr>
<tr>
<td>Sex</td>
<td>Male</td>
<td>189</td>
<td>96.4</td>
<td>179</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>7</td>
<td>36.7</td>
<td>17</td>
</tr>
<tr>
<td>Marital status</td>
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<td>0.5</td>
<td>0</td>
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<tr>
<td></td>
<td>Married</td>
<td>188</td>
<td>95.9</td>
<td>176</td>
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<tr>
<td></td>
<td>Divorced</td>
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<td>1.5</td>
<td>6</td>
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<td></td>
<td>Widowed</td>
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<td>2.1</td>
<td>14</td>
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<td>Educational status</td>
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<td>23.6</td>
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<tr>
<td></td>
<td>Read and write</td>
<td>123</td>
<td>62.8</td>
<td>44</td>
</tr>
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<td></td>
<td>Primary education</td>
<td>26</td>
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<tr>
<td></td>
<td>Secondary education and above</td>
<td>2</td>
<td>1</td>
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</tr>
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</table>

** Significant at 5% probability level

### Table 2: Demographic characteristics of respondents (continuous variables)

<table>
<thead>
<tr>
<th>Variables</th>
<th>User Mean</th>
<th>St.deviation</th>
<th>Non-user Mean</th>
<th>St.deviation</th>
<th>Total observation (n=392) Mean</th>
<th>St.deviation</th>
<th>T- test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>42.68</td>
<td>6.792</td>
<td>47.78</td>
<td>9.816</td>
<td>45.23</td>
<td>8.803</td>
<td>5.978***</td>
</tr>
<tr>
<td>Family size</td>
<td>4.99</td>
<td>1.625</td>
<td>4.96</td>
<td>1.5</td>
<td>4.96</td>
<td>1.56</td>
<td>-0.194</td>
</tr>
<tr>
<td>Farming experience</td>
<td>23.41</td>
<td>8.087</td>
<td>21.17</td>
<td>6.633</td>
<td>25.64</td>
<td>8.780</td>
<td>5.693***</td>
</tr>
<tr>
<td>Land size</td>
<td>2.383</td>
<td>1.218</td>
<td>2.11</td>
<td>1.295</td>
<td>2.246</td>
<td>1.263</td>
<td>-2.15**</td>
</tr>
<tr>
<td>Number of livestock (TLU)</td>
<td>7.3</td>
<td>2.577</td>
<td>5.02</td>
<td>2.298</td>
<td>6.16</td>
<td>2.692</td>
<td>-9.236***</td>
</tr>
</tbody>
</table>

*** and**, Significant at P<0.01 and p<0.05
Table 3: Comparative cost/100 kg of PICS bag use vs insecticide-treated grain in a PP bag

<table>
<thead>
<tr>
<th>Items</th>
<th>Insecticide treated grain stored in PP bag(n=1)</th>
<th>Untreated grain stored in PICS bag(n=1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bag</td>
<td>20</td>
<td>43</td>
</tr>
<tr>
<td>Insecticide/Malathion dust</td>
<td>12.5</td>
<td>0</td>
</tr>
<tr>
<td>Bagging labor</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Total cost</td>
<td>38.5</td>
<td>49</td>
</tr>
</tbody>
</table>

* 30.2 ETB=1$ USD

Table 4: Cost-benefit analysis of PICS bags and insecticide treated bags per 100 Kg of stored maize (In ETB)

<table>
<thead>
<tr>
<th>Costs and benefit description (ETB)*</th>
<th>Insecticide Treated bags</th>
<th>PICS bags</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Year 1(12 months)</td>
<td>Year 2 (12 months)</td>
</tr>
<tr>
<td>Bag</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>Insecticide cost (Malathion dust)</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Bagging labor</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>Storage loss cost</td>
<td>21</td>
<td>21</td>
</tr>
<tr>
<td>Total cost</td>
<td>115</td>
<td>95</td>
</tr>
<tr>
<td>Harvest price(January)</td>
<td>350</td>
<td>350</td>
</tr>
<tr>
<td>Lean season price</td>
<td>800</td>
<td>800</td>
</tr>
<tr>
<td>Net benefit of storage</td>
<td>335</td>
<td>355</td>
</tr>
<tr>
<td>PICS advantage</td>
<td>66</td>
<td>99</td>
</tr>
</tbody>
</table>

* 1$ USD=30.2 ETB

Table 5: BCR and NPV per 100 kilogram of stored maize

<table>
<thead>
<tr>
<th>Storage structures</th>
<th>BCR</th>
<th>NPV(ETB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PICS bags</td>
<td>9.18</td>
<td>684.42</td>
</tr>
<tr>
<td>Insecticide with Ordinary bags</td>
<td>4.26</td>
<td>559.74</td>
</tr>
</tbody>
</table>
Table 6: Summary of financial indicators under sensitivity analysis

<table>
<thead>
<tr>
<th>Storage Technologies</th>
<th>10% cost increment and 30% price reduction</th>
<th>10% cost increment and 40% price reduction</th>
<th>10% cost increment and 50% price reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BCR</td>
<td>NPV(ETB)</td>
<td>BCR</td>
</tr>
<tr>
<td>PICS bags</td>
<td>9.9</td>
<td>460.59</td>
<td>8.5</td>
</tr>
<tr>
<td>Ordinary bags with insecticide</td>
<td>2.7</td>
<td>323.08</td>
<td>2.3</td>
</tr>
</tbody>
</table>

Table 7: The maximum likelihood estimates of the binary logistic regression model

<table>
<thead>
<tr>
<th>Variables</th>
<th>B</th>
<th>S.E.</th>
<th>Wald</th>
<th>Sig.</th>
<th>Exp(B)</th>
<th>95% C.I. for EXP(B)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower</td>
</tr>
<tr>
<td>GENDER</td>
<td>2.439</td>
<td>0.913</td>
<td>7.134</td>
<td>.18</td>
<td>0.087</td>
<td>0.015</td>
</tr>
<tr>
<td>AGE</td>
<td>-0.068</td>
<td>0.058</td>
<td>1.383</td>
<td>0.24</td>
<td>0.935</td>
<td>0.835</td>
</tr>
<tr>
<td>EDUCLEVEL</td>
<td>1.595</td>
<td>0.479</td>
<td>11.109</td>
<td>.001***</td>
<td>4.928</td>
<td>1.929</td>
</tr>
<tr>
<td>FARMEXP</td>
<td>0.018</td>
<td>0.06</td>
<td>0.087</td>
<td>0.769</td>
<td>1.018</td>
<td>0.904</td>
</tr>
<tr>
<td>LANDSIZE</td>
<td>-0.311</td>
<td>0.334</td>
<td>0.865</td>
<td>0.352</td>
<td>0.733</td>
<td>0.381</td>
</tr>
<tr>
<td>TOTALINCOME</td>
<td>0.015</td>
<td>0.026</td>
<td>4.548</td>
<td>.033**</td>
<td>1.015</td>
<td>0.807</td>
</tr>
<tr>
<td>CREDITACCESS</td>
<td>0.644</td>
<td>0.533</td>
<td>1.462</td>
<td>0.227</td>
<td>1.904</td>
<td>0.671</td>
</tr>
<tr>
<td>EXTENSIONCONTACT</td>
<td>0.463</td>
<td>0.409</td>
<td>1.28</td>
<td>0.258</td>
<td>0.629</td>
<td>0.282</td>
</tr>
<tr>
<td>PICSTRAINING</td>
<td>2.629</td>
<td>0.729</td>
<td>13.014</td>
<td>.001***</td>
<td>13.854</td>
<td>3.322</td>
</tr>
<tr>
<td>AWARENESSPICS</td>
<td>3.307</td>
<td>0.805</td>
<td>16.882</td>
<td>.000***</td>
<td>27.308</td>
<td>5.638</td>
</tr>
<tr>
<td>PICSACCESS</td>
<td>3.131</td>
<td>0.726</td>
<td>18.603</td>
<td>.000***</td>
<td>22.887</td>
<td>5.518</td>
</tr>
<tr>
<td>PICSPRICE</td>
<td>-2.054</td>
<td>0.822</td>
<td>6.24</td>
<td>.012***</td>
<td>7.796</td>
<td>1.556</td>
</tr>
<tr>
<td>MAIZESTORED</td>
<td>0.013</td>
<td>0.023</td>
<td>0.325</td>
<td>0.569</td>
<td>1.013</td>
<td>0.968</td>
</tr>
<tr>
<td>Constant</td>
<td>-3.706</td>
<td>1.939</td>
<td>3.653</td>
<td>.05**</td>
<td>0.025</td>
<td></td>
</tr>
</tbody>
</table>

Pearson chi-square______________________ 395.812***
-2 log likelihood_________________________ 142.029
Overall prediction of the model _____________94.85
Source: Binary Logit Model output
REFERENCES

1. **Girma D, Tadele T and T Abraham** Importance of husk covering on field infestation of maize by *Sitophilus zeae-mays* Motsch (Coleoptera: Curculionidae) at Bako, Western Ethiopia, 2008; AJB **7(20)**: 3777-3782.


12. Lemessa F, Bultosa G and W Wakgari Quality of grain sorghum (Sorghum bicolor (L.) Moench) stored in traditional underground pits: Case studies in two agro-climatic zones in Hararghe, Ethiopia. Journal of food Science and Technology, 2000; 37: 238-244


22. **Adesina AA, Mbila D, Nkamleu GB and D Endamana** Econometric analysis of the determinants of adoption of alley farming by farmers in the forest zone of southwest Cameroon, Agriculture Ecosystems and Environment, 2000; Vol. 80: 255–265. [https://doi.org/10.1016/S0167-8809(00)00152-3](https://doi.org/10.1016/S0167-8809(00)00152-3)


28. **Abebe HG and H Bekele** Farmers' post-harvest grain management choices under liquidity constraints and impending risks: Implications for achieving food security objectives in Ethiopia. Poster Paper Presented at International Association of Agricultural Economists Conference, Gold Coast, Australia, August 12-8, 2006. [https://doi.org/10.22004/ag.econ.25716](https://doi.org/10.22004/ag.econ.25716)


32. **Hodges RJ, Buzby JC and B Bennet** Postharvest Losses and Waste in Developed and Less Developed Countries: Opportunities to Improve Resource Use. *Journal of Agricultural Science*. 2011; 149: 37-45: https://doi.org/10.1017/S0021859610000936


37. **Techane A** Determinants of Fertilizer Adoption in Ethiopia: The Case of Major Cereal Producing Areas. An M.Sc Thesis Submitted to School of Graduate Studies of Haramaya University, 2002.


40. **Shively G** An Overview of Benefit-Cost Analysis. Department of Agricultural Economics, Purdue University, 2000, pp.1–10.