ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 22 No. 9 November 2022 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

Afr. J. Food Agric. Nutr. Dev. 2022; 22(9): 21672-21693 https://doi.org/10.18697/ajfand.114.22100

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

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ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 22 No. 9
November 2022
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

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

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ISSN 1684 5374

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.

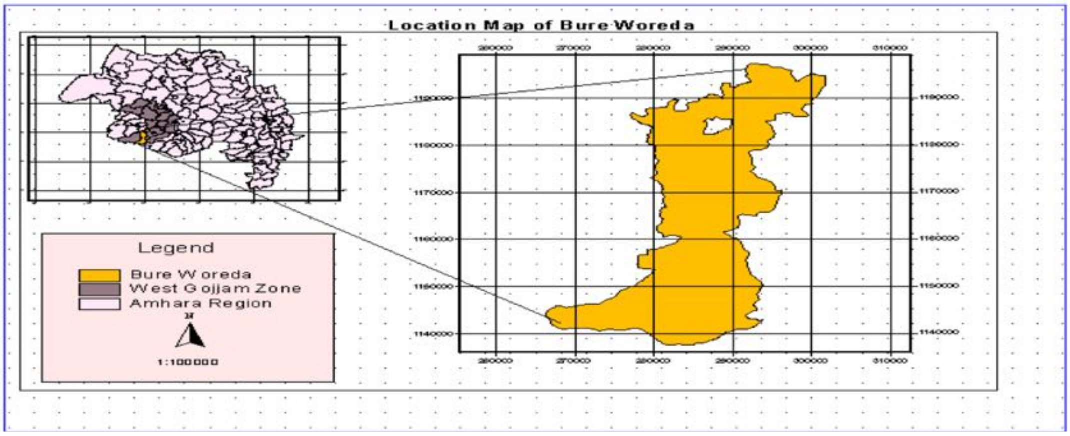

Figure1: Location map of the study area
Source: [42]

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,

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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].

$$\text{NPV} = \sum_{t=1}^{n} (\text{Bn} - \text{Cn})/(1 + i) \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \quad (1)$$

where B_n = benefits in each year of the project, Cn = costs in each year of the project, n = number of years in a project, i = interest (discount) rate, and Bn – Cn = 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

$$\text{IRR} = \sum_{t=1}^{n} (\text{Bn} - \text{Cn})/(1 + i)\, n = 0 \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \quad (2)$$

That is, NPV = 0 whereby Bn = benefits in each year of the project, Cn = 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.

$$\mathrm{BCR} = \frac{\sum_{t=1}^{n} \mathrm{Bn}/(1+\mathrm{i})\mathrm{n}}{\sum_{t=1}^{n} \mathrm{Cn}/(1+\mathrm{i})\mathrm{n}} \quad \text{........ .... (3)}$$

where Bn = benefit in each year, Cn = 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:

$$\mathrm{Pi} = \mathrm{E}\left(\mathrm{Y} = \frac{1}{\mathrm{Xi}}\right) = \frac{1}{1 + e^{-(\beta_0 + \beta_1 X_1 + \beta_2 X_2 .. + \beta m X m)}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 4$$

Since, $Zi = \beta_0 + \beta_1 X_1 + \beta_2 X_2 .. + \beta m X m$, the above formula can be rewritten as shown below for ease of understanding.

$$\mathrm{Pi} = \frac{1}{1+e^{-zi}} = \frac{e^{zi}}{1+e^{zi}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 5$$

The above formula indicates that as the value of Z_i ranges from negative infinitive to positive infinitive. Pi is the probability of a household's decision to use PICS bags and ranges between 0 and 1. Therefore, if Pi 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:

$$1 - \mathrm{Pi} = \frac{1}{1 + e^{Zi}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 6$$

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 $\frac{\mathrm{Pi}}{1 - \mathrm{Pi}}$ as shown in the following expression:

$$\frac{\mathrm{Pi}}{1 - \mathrm{Pi}} = \frac{1 + e^{Zi}}{1 + e^{-Zi}} = e^{Zi} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 7$$

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

$$\mathrm{Li{:}Li} = \ln\left(\frac{\mathrm{Pi}}{1-\mathrm{Pi}}\right) = \mathrm{Zi} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 .. + \beta m X m \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad 8$$

Then, if the disturbance term Ui is taken into account, the logit model becomes:

$$\mathrm{Zi} = \beta_0 + \sum_{i=1}^{m} \beta i X i + \mathrm{Ui} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 9$$

where β_0= the intercept. It is the value of the log odd ratio $\frac{\mathrm{Pi}}{1-\mathrm{Pi}}$ when X or explanatory variable is zero. $\beta_{1=}$ 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 $\chi 2$-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 in to 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.

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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.

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Volume 22 No. 9 November 2022
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Table1: Demographic characteristics of respondents (categorical variables)

Variables	Categories	Use of PICS bags				Total observation(n=392)		χ 2 test
		User		Non-user				
		No	%	No	%	No	%	
Sex	Male	189	96.4	179	91.3	368	93.8	4.438**
	Female	7	36	17	8.7	24	6.2	
Marital status	Single	1	0.5	0	0	1	0.3	7.951**
	Married	188	95.9	176	89.9	364	92.9	
	Divorced	3	1.5	6	3.1	9	2.3	
	Widowed	4	2	14	7.1	18	46	
Educational status	Illiterate	45	23	150	76.5	195	49.7	116.481***
	Read and write	123	62.8	44	22.4	167	42.6	
	Primary education	26	13.3	2	1	28	7.1	
	Secondary education and above	2	1	0	0	2	0.5	

** Significant at 5% probability level

Table 2: Demographic characteristics of respondents (continuous variables)

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

*** and**, Significant at P<0.01 and p<0.05

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ISSN 1684 5374

Table 3: Comparative cost/100 kg of PICS bag use vs insecticide-treated grain in a PP bag

	Costs (birr)*/100kg	
Items	**Insecticide treated grain stored in PP bag(n=1)**	**Untreated grain stored in PICS bag(n=1)**
Bag	20	43
Insecticide/Malathion dust	12.5	0
Bagging labor	6	6
Total cost	38.5	49

* 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)

Costs and benefit description (ETB)*	Insecticide Treated bags		PICS bags	
	Year 1(12 months)	Year2 (12 months)	Year 1(12 months)	Year 2(12 months)
Bag	20	0	43	0
Insecticide cost (Malathion dust)	50	50	0	0
Bagging labor	24	24	6	6
Storage loss cost	21	21	0	0
Total cost	115	95	49	6
Harvest price(January)	350	350	350	350
Lean season price	800	800	800	800
Net benefit of storage	335	355	401	444
PICS advantage	66	99	401	444

* 1$ USD=30.2 ETB

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

Storage structures	BCR	NPV(ETB)
PICS bags	9.18	684.42
Insecticide with Ordinary bags	4.26	559.74

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 22 No. 9
November 2022
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Table 6: Summary of financial indicators under sensitivity analysis

Storage Technologies	10% cost increment and 30% price reduction			10% cost increment and 40% price reduction			10% cost increment and 50% price reduction		
	BCR	NPV(ETB)		BCR	NPV	IRR	BCR	NPV	IRR
PICS bags	9.9	460.59		8.5	387.43	NA	7.05	313.92	NA
Ordinary bags with insecticide	2.7	323.08		2.3	249.92	NA	1.94	176.77	NA

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

Variables	B	S.E.	Wald	Sig.	Exp(B)	95% C.I. for EXP(B)	
						Lower	Upper
GENDER	2.439	0.913	7.134	.18	0.087	0.015	0.522
AGE	-0.068	0.058	1.383	0.24	0.935	0.835	1.046
EDULEVEL	1.595	0.479	11.109	.001***	4.928	1.929	12.59
FARMEXP	0.018	0.06	0.087	0.769	1.018	0.904	1.146
LANDSIZE	-0.311	0.334	0.865	0.352	0.733	0.381	1.41
TOTALINCOME	0.015	0.026	4.548	.033**	1.015	0.807	1.138
CREDITACCESS	0.644	0.533	1.462	0.227	1.904	0.671	5.407
EXTENSIONCONTACT	0.463	0.409	1.28	0.258	0.629	0.282	1.403
PICSTRAINING	2.629	0.729	13.014	.000***	13.854	3.322	57.784
AWARENESSPICS	3.307	0.805	16.882	.000***	27.308	5.638	132.259
PICSACCESS	3.131	0.726	18.603	.000***	22.887	5.518	94.931
PICSPRICE	-2.054	0.822	6.24	.012***	7.796	1.556	39.049
MAIZESTORED	0.013	0.023	0.325	0.569	1.013	0.968	1.06
Constant	-3.706	1.939	3.653	.05**	0.025		

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 zea mais Motsch* (*Coleoptera: Curculionidea*) at Bako, Western Ethiopia, 2008; AJB **7(20):** 3777-3782.

2. **Randela R** The Incidence of Post-Harvest Problems among Small Farmers Surveyed in Three regions of the Limpopo Province. 2003; Agrekon. **42(2).** https://doi.org/10.1080/03031853.2003.9523618

3. **Murdock LL, Margam VM, Baoua BI, Balfe S and RE Shade** Death by desiccation: effects of hermetic storage on cowpea bruchids. *Journal Stored Product Research*, 2012; **49:** 166-170.

4. **Gittinger JP** Economic Analysis of Agricultural Projects. Washington: The Johns Hopkins University Press. 1982.

5. **Burie Trading Industry, and Marketing (BTIM)**. Report, 2017. Annual report of the Burie district, North West Ethiopia.

6. **Berlage L and R Renard** The Discount Rate in Cost-Benefit Analysis and the Choice of a Numeraire. *Oxford Economic Papers*. 1985; **37(4):** 691–699: http://www.jstor.org/stable/10.2307/2663052 *Accessed July 2020.*

7. **Poudel KL, Nepal AP, Dhungana B, Sugimoto Y, Yamamoto N and A Nishiwaki** Capital Budgeting Analysis of Organic Coffee Production in Gulmi District of Nepal. In International Association of Agricultural Economists Conference, Beijing China, August, 2009. https://doi.org/10.22004/ag.econ.51559

8. **Gujarati DN** Basic Econometrics, 4th ed. The McGraw-Hill, Inc., New York, 2003.

9. **CSA.** Agricultural Sample Survey for 2013/14: Report on Area and Production of Major Crops for Private Peasant Holdings, Meher Season, Statistical Bulletin No 532, May 2014, Addis Ababa, Ethiopia.

10. **Mulungu LS, Luwondo EN, Reuben S and R Misangu** Effectiveness of Local Botanicals as Protectants of Stored Beans *(Phaseolus vulgaris L.)* Against Bean Bruchid *(Zabrotes subfasciatus Boh)* (Genera: *Zabrotes*. Family: *Bruchidae*). *Journal of Entomology*. 2007. 210-217. https://doi.org/10.3923/je.2007.210.217

11. **Songa JM and W Rono** Indigenous methods for bruchid beetle (Coleoptera: Bruchidae) control in stored beans (Phaseolus vulgaris L.). International Journal of Pest Management. 1998: https://doi.org/10.1080/096708798228446

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

13. **Wambugu PW, Mathenge EO, Auma and R Havan** Efficacy of traditional maize **(Zea mays L.)** seed storage methods in western Kenya. African Journal of food, Agriculture, Nutrition and development, 2009; **9:**1110-1128. https://doi.org/10.4314/ajfand.v9i4.43882

14. **Central Statistical Agency (CSA).** Agricultural Sample Survey Addis Ababa, Ethiopia. 2019.

15. **Baral S and V Hoffmann** Tackling post-harvest loss in Ghana; cost effectiveness of technologies in international food policy research institute, Washington DC, USA: 2018: https://doi.org/10.2499/1032568653

16. **Senait R** Does it pay to invest post- harvest management? An ex-ante cost benefit analysis of reducing maize storage losses in Darimuworeda, Ethiopia. Swiss agency for development and cooperation SDC global program food security (Sub Saharan Africa) office A.A, Ethiopia, 2014.

17. **Ognakossan KE, Adabe KE, Hell K, Lamboni Y and O Coulibaly** Use of PICS bags for the control of *P. truncatus* and *Dinoderus spp.* on stored cassava chips: First results. Poster presented during the 5th World Cowpea Conference, Saly, Senegal, 2010. https://doi.org/10.13140/RG.2.1.4207.5289

18. **Hell K, Ognakossan KE, Tonou AK, Lamboni Y, Adabe KE, and O Coulibaly** Maize Stored Pests Control by PICS-Bags: Technological and Economic Evaluation. Presentation at the 5th World Cowpea Conference, Saly, Senegal, 2010.

19. **Ervin CA and DE Ervin** Factors affecting the use of conservation practices. Hypothesis, evidence, and policy implications. Land Economics, 1982. **58(3):** 97-307: https://doi.org/10.2307/3145937

20. **Yitayal A** Determinants of use of soil conservation measures by small holder farmers; in Gimma Zone, Dedo District. An M.Sc. Thesis Presented to the School of Graduate Studies of Alemaya University. 2004. pp.65-82.

21. **Adebabay M** Factors influencing adoption of soil conservation practices in South Gondar Zone: The Case of Farta District. An M.Sc. Thesis Presented to the School of Graduate Studies of Alemaya University, Ethiopia. 2003. 129p.

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

23. **Ramji PN, Sharma KR and GB Thapa** Adoption of agro-forestry in the hills of Nepal: a logistic regression analysis, Agricultural Systems, 2002; **72(3):** 177–196. https://doi.org/10.1016/S0308-521X(01)00066-X

24. **Wekesa E, Mwangi W, Verkuijl H, Danda K, and H De Groote** Adoption of maize production technologies in the coastal lowlands of Kenya. Mexico, D.F.: CIMMYT, 2003. https://doi.org/10.22004/ag.econ.56109

25. **Bolaji MA** Potential impact analysis of Purdue improved cowpea storage technology on income of users in north central Nigeria.Thesis submitted to the school of postgraduate studies, Ahmadu Bello University, Zaria, Nigeria. 2014. pp.81-82.

26. **Jokthan G and A Sanni** An Analysis of Triple Bag Intervention for Cowpea Storage in Nigeria. Paper presented at Research into (Use) workshop at Chelsea Hotel Abuja. 2011.

27. **Okoedo O and EA** Onemoleas Impact of the Agricultural Development Programme (ADP) Activities in Arable Crop Production on Rural Poverty Alleviation in Edo State, Nigeria. Ph.D Thesis (Unpublished), University of Benin, Benin City, Edo State, Nigeria, 2009.

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

29. **Adetunji MO** Economics of Maize Storage Techniques by Farmers in Kwara State, Nigeria. *Pakistan Journal of Social Sciences.* 2007; **4(3):** 442-450.

30. **Bett C and R Nguyo** Post-harvest Storage Practices and Techniques used by Farmer in Semi-arid Eastern and Central Kenya. African Crop Science Proceedings 8, 2007. pp.1023-1227.

31. **Cellini SR and JE Kee** Cost-Effectiveness and Cost-Benefit Analysis. Handbook of Practical Program Evaluation, Chapter Twenty-One: 2010. pp. 493–530.

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

33. **ICRA**. Leaning Materials-Cost Benefit Analysis 1-Key Concepts. 2009 available on http://www.icra-edu.org/.../Cost_Benefit_Analysis_1-Key_Concepts,.

34. **Mulugeta E** Determinants of adoption of soil conservation practices in central high lands of Ethiopia: The Case of three Districts of Salale. An M.Sc. Thesis Presented to the School of Graduate Studies of Alemaya University, Ethiopia. 2000. 92p.

35. **Sori W and A Ayana** Storage pests of maize and their status in Jimma Zone, Ethiopia. *African Journal of Agricultural Research.* 2012; **7(28):** 4056-4060. https://doi.org/10.5897/AJAR11.1123

36. **Stevens A** The Application and Limitations of Cost-Benefit Assessment (CBA) for Intelligent Transport Systems. Research in Transportation Economics, 2004; **8(04):** 91–111. Available at: https://doi.org/10.1016/S0739-8859(04)08005-9

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.

38. **Wubeneh N** Farm-Level Adoption of New Sorghum Technologies in Tigray Region, Ethiopia. M Sc. Thesis. Purdue University. 2003. USA.

39. **CSA (Central Statistical Agency).** Agricultural Sample Survey for 2013/14: Report on Area and Production of Major Crops for Private Peasant Holdings, Meher Season, Statistical Bulletin No 532, May 2014, Addis Ababa, Ethiopia.

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

41. **Aleminew A** Market chain analysis of red pepper: The case of Burie district, West Gojjam zone, Amhara national regional state, Ethiopia. Haramaya University, Ethiopia. 2010, 20p.