Comparative Analysis of Maize Storage Structures in Kenya

By

Nduku, Tabitha M[ab]., De Groote, Hugo[a] and Nzuma, Jonathan, M.[b]

[a]*International Maize and Wheat Improvement Center (CIMMYT), P. O. Box 1041-00621, Nairobi, Kenya*

[b]*Department of Agricultural Economics, University of Nairobi, College of Agriculture and Veterinary Sciences, P. O. Box 29053-0625, Nairobi Kenya*

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Abstract

This paper assesses the feasibility of the maize storage structures used in Kenya. Maize is the most important staple crop, but produced seasonally, and consumed continuously at farm level, hence the need for on-farm storage. However, heavy post harvest losses occur mainly during harvesting and storage stages and these are a cost to the farmer. A cost benefit analysis was employed to evaluate the viability of ten maize storage structures. The results showed that, apart from the in-house storage and the traditional crib, the benefit-cost ratio (BCR) of the other structures was greater than one. The net present value (NPV) at 15 percent discount rate ranged from KSh 25 to KSh 40 for a kilogram stored in the traditional granary and the metal silo respectively. The internal rate of return (IRR) results were compared to a market interest rate of 15 percent and only the separate structure, improved granary (wicker wall), the basket and the metal silo were feasible with IRRs of 19.3, 23.3, 27.2 and 59.6 percent respectively. The payback period (PBP) ranged from three to 16 months for the metal silo and traditional crib respectively. Sensitivity analysis with a ten percent cost increment and up to 50 percent price reduction showed that only the metal silo was viable although it is the least used maize storage structure. Farmers have an opportunity to shift from the traditional storage methods to upcoming technologies like the metal silo and reduce their maize storage costs and losses.

Keywords: Maize, storage structures, comparative analysis, Kenya

1. Introduction

The importance of enhancing post-harvest storage and handling of cereals and in particular maize, wheat and rice in Kenya cannot be overemphasized. Storage evens out the seasonal driven supply and hence stabilizes inter-temporal price variation and consequently smoothens farmers' income (Komen et al., 2006). This is besides its role in reducing food insecurity created by the intermitted supply. Maize is the most important staple crop, but it is produced seasonally, and consumed continuously at farm level. There is therefore the need for on-farm storage, but heavy post harvest losses occur mainly during harvesting and storage stages. The Cereal Growers' Association (2010) estimates that 30 to 40 percent of the total grain production in Kenya is lost due to inefficiencies in post-harvest handling and these impacts negatively on farmer's income, market supply, cereal prices and food security.

Farmers use different maize storage structures but the type, their cost and storage loss to the farmers are unknown. The need for technologies that are effective, affordable and safe for humans and the environment led to the development of the actellic super, super grain bag and the metal silo technologies. Since 2009, CIMMYT has been promoting the metal silo technology which is said to have the potential of significantly reducing post harvest losses in maize during storage. However, there is very little evidence that these technologies have been subjected to neither economic analysis before being promoted (Kimenju and De Groote, 2010) nor a comparative analysis been undertaken on the existing storage structures.

Previous research describes some maize storage structures used in specific study areas but no overall country study based on solid evidence of the typical patterns and trends of use as well as the types and cost to the farmer. There is therefore a dearth in knowledge and the research problem addressed in this study is that, the costs and benefits of different storage structures in Kenya are not well understood. In order to fill this gap, there is need for empirical studies that provide such information.

A cost benefit analysis was used to evaluate the feasibility of the maize storage structures farmers are currently using. There is need to establish the worthiness of adopting a new storage technology in relation to the current structures. A cost benefit analysis is appropriate as it systematically measures the costs and benefits that occur during the storage period. The research findings are based on data from a maize storage structures household survey with a representative sample of 1344 maize farmers and augmented with data from 124 metal silo users. Literature review was used too as a secondary source of information. This paper is organized as follows. Maize storage and post harvest losses are outlined in section 2. The cost benefit analysis and how it has been applied in the study is presented in section 3. Section 4 presents the results while section concludes with a discussion and policy recommendations.

1.1 Background

Efficient post-harvest handling, storage and marketing can tremendously contribute to social economic empowerment of rural communities as stipulated in Kenya Vision 2030 (Republic of Kenya, 2007). Thus, reducing food losses increases food availability without requiring additional production resources and in least developed countries, it contributes to rural development and poverty reduction (Hodges et al., 2011; Randela, 2003).

Cereals production remains a key source of food for a majority of the people in Kenya. The major cereal crops grown in Kenya across all the agro-ecological zones (AEZs) include maize, wheat, rice, sorghum, and millet. Maize is Kenya's main staple food while the other cereal commodities are important food security items. The area under maize cultivation has stabilized at around 1.8 million hectares (ha) (Kangethe, 2011), producing about 3.2 million metric tonnes (MT) per annum (FAOSTAT, 2010) against an estimated consumption of 36 million bags (Kangethe, 2011).

However, Kenya loses 30 to 40 percent of the total grain output due to inefficiencies in post-harvest handling especially during harvesting and storage (Rembold et al., 2011). In spite of the availability of a wide range of storage techniques, significant grain loss occur on-farm in Kenya each year (Komen et al., 2006; Zorya et al., 2011). Bett and Nguyo, (2007) estimate that in the semiarid regions of Kenya, annual maize storage losses range from five to17 percent which is estimated in monetary terms to be 1.8 million 90 kilogram bags valued at KSh 8.1 billion. Majority of these post-harvest loses are attributed to storage pests like the common weevil and the larger grain borer (LGB) (Derera et al., 2001).

In order to reduce the losses incurred after harvesting, farmers take measures such as sufficiently drying maize before storage, using storage structures which are moisture proof and are adequately aired. These include the metal silos, granaries, bags, cribs, baskets or earthen pots. Farmers will also store their cereals in the living houses, which are perceived to be secure as grain losses through theft are minimized. In addition to the use of traditional storage structures, farmers' use other coping strategies aimed at reducing these post-harvest losses like the use of traditional knowledge. These include the use of herbs like the Mexican marigold and hot pepper in storage, selling grain soon after harvest and cleaning or dusting the storage structure with pesticide thoroughly before depositing the maize or acquire the new maize storage technologies (Bett and Nguyo, 2007).

Storage of cereals plays an important role in evening out fluctuations in production from one season or year to the other (Kimenju and De Groote, 2010). In addition, storage is useful in crop and seed preservation, quality improvement, quantity equalization and market price stabilization of agricultural produce (Sekumade and Akinleye, 2009) and is a form of saving (Adetunji, 2007). Farmers would only store cereals if and only if their storage benefits outweigh their costs or future prices rose enough to cover storage costs (Komen et al., 2006; Fackler and Livingston, 2002).

In choosing the storage technique to use, farmers have to gauge the benefits versus the costs. On the one hand the use of traditional storage structures as well as storage of cereals like maize in the houses by small scale and subsistence farmers leads to considerable losses. On the other hand, air-tight storage technologies like the metal silos which are said to have zero storage loss costs are expensive for the individual farmer to afford. There are therefore costs and benefits to storage regardless of the storage structure used.

To inform the policy making process, there is need for studies that provide information on the costs and benefits of different maize storage structures. Yet, such information in Kenya is not readily available. This study attempts to provide information that would enable farmers to choose the appropriate storage technologies.

3. Methodology

3.1 Cost benefit analysis (CBA)

A financial cost benefit analysis was used to estimate the costs involved in maize storage and the benefits of replacing the traditional methods with the metal silo, an upcoming technology. The two major ways of conducting a CBA are financial and economic analysis. A financial CBA is made from the perspective of the person; group or unit directly involved in the project, for example a farm (Gittinger, 1982). Only the expenses that will be made by the farm and the benefits that will accrue to the farm (externalities not included) are taken into account in a financial analysis (ICRA, 2009). An economic CBA takes the broader perspective of the society. In calculating prices, the main difference between a financial and economic CBA is that while the former uses market prices, the later uses shadow prices. A financial CBA was carried out from the farmers' perspective of the costs incurred and benefits obtained from on-farm maize storage.

The costs included: cost of the storage structure, labour costs (both family and hired), cost of sisal and polypropylene bags, insecticide costs, storage loss costs. The only direct and measurable benefit was obtained from the sale of maize. These were valued at the prevailing market prices during the survey. Future flows of costs and benefits were inflated by five percent and discounted at 15 percent for a period of 15 years to obtain their present values.

The NPV was calculated from this formula adopted from (Shively, 2000).

$$NPV = \sum_{t=1}^{n} {(Bn - Cn)}\Big/{(1+i)n} \qquad \dots\dots\dots\dots\dots\dots\dots\dots (1)$$

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, $B_n - C_n$ = cash flow in n^{th} year of the project

The project is profitable or feasible if the calculated NPV is positive when discounted at the opportunity cost of capital (Berlage and Renard, 1985; Gittinger, 1982; and Poudel et al., 2009).

Mathematically,

According to Shively, 2000, IRR is that discount rate 'i' such that

$$\sum_{t=1}^{n} {(Bn - Cn)}\Big/{(1 + i)n} = 0 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

That is, NPV = 0

Where:

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.

A project is profitable or feasible for investment when the IRR is higher than the opportunity cost of capital (Berlage and Renard, 1985; Gittinger, 1982; and Poudel et al., 2009).

The BCR is the ratio of present worth of benefit stream to present worth of cost stream. The formula adopted from (Cellini and Kee, 2010; Stevens, 2004; Shively 2000) was used.

$$BCR = \frac{\sum_{t=1}^{n} {\mathrm{Bn}}\big/{(1+\mathrm{i})^{\mathrm{n}}}}{\sum_{t=1}^{n} {\mathrm{Cn}}\big/{(1+\mathrm{i})^{\mathrm{n}}}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

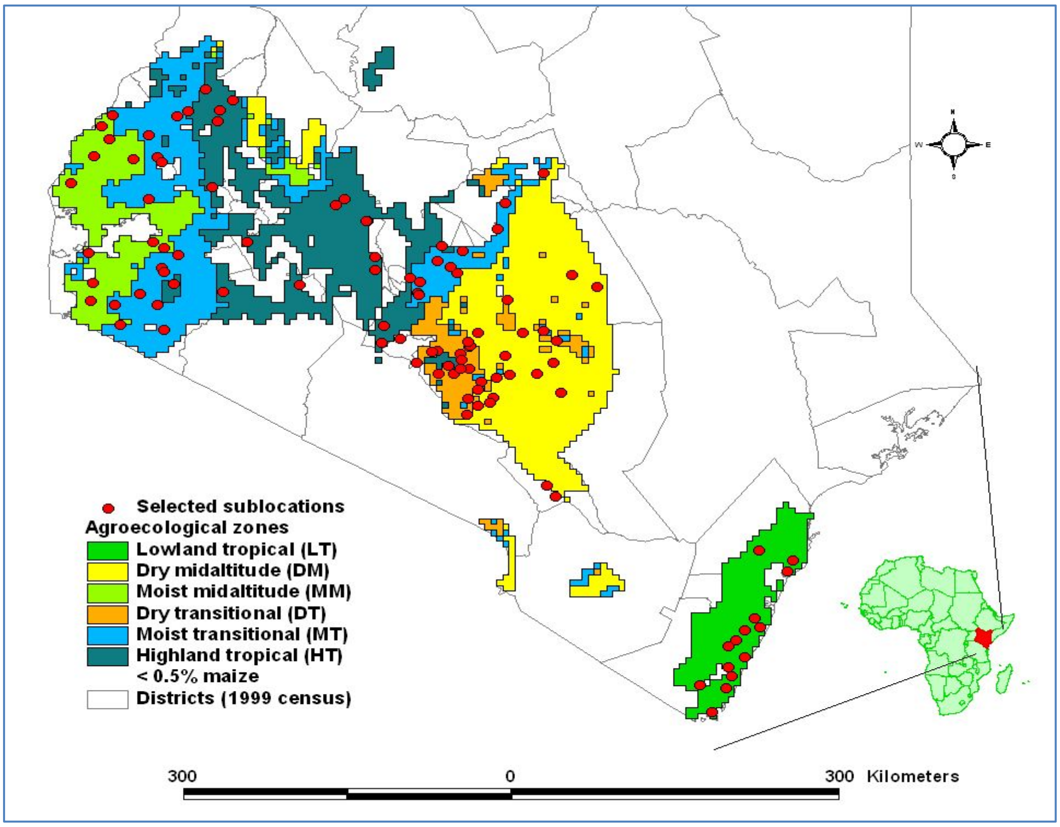
Where:

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 one or greater than 1 (Berlage and Renard, 1985; Gittinger, 1982; and Poudel et al., 2009).

3.2 Data analysis

Secondary data from CIMMYT was used in this study. The target population was 1344 maize farmers sampled in 121 sub locations from the six maize AEZs as shown in Figure 1 below who use different storage structures. This was augmented with data from 124 farmers using metal silos in selected pilot sites of the Effective Grain Storage Project, CIMMYT in Homabay and Mbeere located in the Moist Mid Altitudes and Dry Mid Altitudes AEZs respectively.

Data for cost benefit analysis provided by the maize farmers included; the storage structures used by the farmers, capacity and cost of the storage structures, actual bags of maize stored after the harvest, maize taken from storage for home consumption and sale each storage month, monthly maize prices received per kilogram, percentage estimate of maize grain loss during storage, cost of insect control measures and maize storage labour hours. Descriptive methods were used to capture the different storage methods in the study area, their distribution, costs and benefits. Excel and SPSS Version 17 computer packages were used to manage and analyse data. A CBA was used to compare the costs and benefits of storage for the ten storage structures.



Source: CIMMYT, Nairobi, Kenya.

Figure 1. Maize agro-ecological zones and sub-locations in the maize household survey

4. Results

4.1 Household and farm characteristics

Most (81.5 percent) of the interviewed farmers were male. The average age of the farmers was 52 years, their main occupation is farming (66.8 percent) and 58.8 percent had more than 20 years of farming experience. The average household size was six members. Results from the perspective of the agro-ecological zones (AEZs) where the farmers live show that those living in the Low Tropics (LT) own larger pieces of land (3.3 hectares (ha)) while those in the High Tropics (HT) own an average of 2.3 ha as shown in Table 1 below. In comparison, farmers living in the other AEZs own between 1.3 ha to 1.9 ha of land. Although the farmers in the Dry Transitional (DT) zones own the least land size of 1.3 ha; they cultivate the largest part of their land (64 percent) while only 42 percent of the land is cultivated in the LT.

Further analysis shows that, 1.2 ha of land in the LT is put under maize but the average production is 387 kilograms compared to the HT where maize is grown on 0.7 ha but the average production is the highest at 1,531 kilograms as shown in Table 1 below. The average land size owned shows that those interviewed were mainly smallholder farmers.

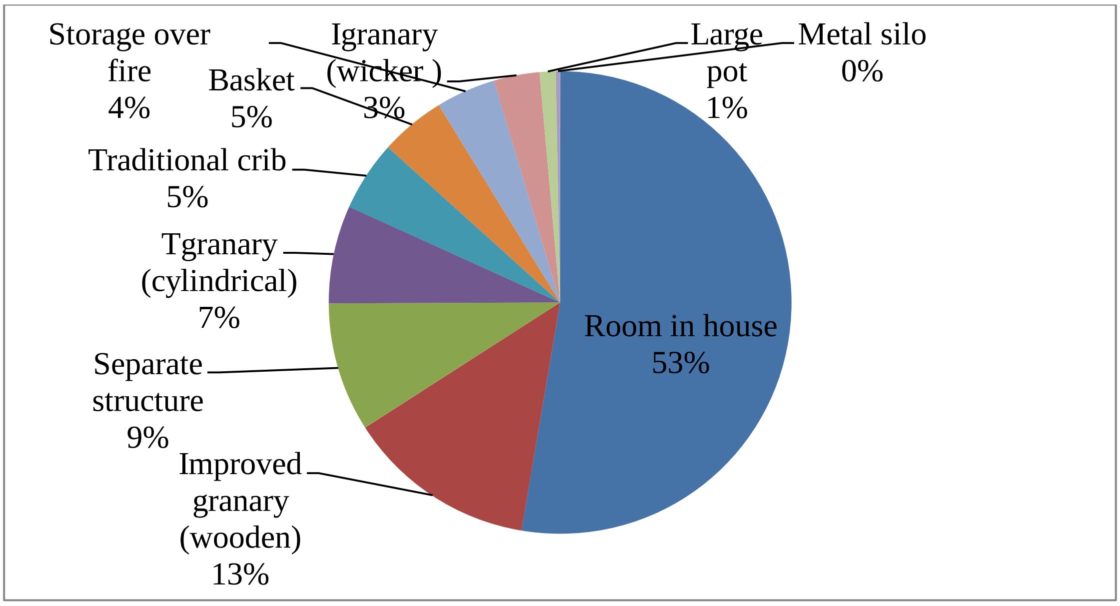
Table 1: Farm characteristics of the farmers

Agro-ecological zone	Land owned (ha)	Land cultivated (ha)	Area under maize (ha)	Area cultivated (%)	Average production (Kg)	Cultivated area under maize (%)
Lowland Tropics (n=90)	3.3	1.4	1.2	42.3	387.5	83.6
Dry Mid-Altitudes (n=217)	1.9	0.9	0.8	50.2	615.4	79.6
Dry Transitional (n=203)	1.3	0.8	0.6	64.4	637.0	71.6
Moist Transitional (n=354)	1.6	0.9	0.6	53.7	1,006.8	71.5
Highland Tropics (n=240)	2.3	1.0	0.7	44.5	1,531.2	72.5
Moist Mid-Altitudes (n=240)	1.5	0.8	0.6	54.3	385.1	71.6

Source: Authors' calculations

4.2 Maize storage structures in Kenya

Storage of maize in a room in the living house is the commonly used facility by more than half (53 percent) of the farmers as shown in Figure 2 below. The metal silo is the least used structure with only 0.3 percent of the farmers storing maize in it while traditional storage structures are used by 21.6 percent of the farmers.



Source: Authors' illustration

Figure 2: Percentage use of maize storage structures in Kenya

3.2 Costs and benefits of storage

The storage costs considered in this study are discussed in details below.

Cost of storage bags

The bags mainly used in maize storage are polypropylene and sisal bags. Sisal bags are short duration storage facilities that were earlier used widely in Kenya until the introduction of the polypropylene bags however; maize farmers still use sisal bags. They usually come in different sizes ranging from 25 kilogram bags to 100 kilogram bags. The most common bags are the 90 kilogram bags normally used for maize storage and the average total cost of sisal and polypropylene bags used ranged from KSh 29.30 to KSh 58.80 for bags used in by those who stored maize over the fire and in a room in the house respectively.

Maize storage labour costs

The study used the average cost of hired labour and hours of family labour used in maize storage. The total cost of hired labour for dusting, bagging and storage management ranged from KSh 2.20 to KSh 10.10 for a kilogram of maize stored in a separate structure and traditional crib respectively. The hours of family labour were converted to labour days by dividing by eight and valued using an average of the rates set by the Ministry of Labour, Kenya, Regulation of Wages Act, 2009 and 2010 for all the other structures and 2010 and 2011 for the metal silo depending on the time of the survey. The rates were KSh 231.90, KSh 255.10 and KSh 287 in 2009, 2010 and 2011 respectively. This yielded an average cost of family labour used for dusting, bagging and storage management of between KSh 0.30 to KSh 4.40 for a kilogram of maize stored in large pots and storage over fire respectively.

Insecticide cost

The cost of insecticides used during maize storage were the highest storage costs and ranged from KSh 0.30 to KSh 9.40 for a kilogram of maize stored in the metal silo and the traditional crib respectively. However, those who stored maize in a room in the house used a wider range of insecticides. While the labour costs of airing, application of ash or traditional herbs like pepper may be covered in the hours of family labour under storage management, the actual cost of the ash and traditional herbs including pepper was not considered in the study. The transportation cost during maize sales was not added as most of these were done at the village level with a very small percentage selling to NCPB, cereal banks and schools.

Maize storage loss and control measures

All the maize storage structures had insect problems of varying magnitude during the storage period. The farmers estimated the percentage loss of the grain lost and indicated the control measures that they used to reduce these losses as shown in Table 2 below.

Table 2: Percentage maize storage loss and control measures used

Storage structure	Storage loss	Control measure: Insecticide use	Airing	Ash
Metal silo	0.5	2.7	4.5	1.2
Separate structure	7.9	6.4	5.8	1.5
Room in house	8.9	33.6	36.6	10.8
Improved granary (wooden wall)	9.2	9.6	6.7	1.0
Improved granary (wicker wall)	9.2	2.3	1.9	0.5
Basket	9.4	1.7	3.9	2.2
Storage over fire	11.1	1.8	2.3	0.6
Traditional granary (cylindrical)	11.3	5.4	4.3	2.2
Large pots	12.2	0.4	0.7	0.5
Traditional crib (round bottom)	12.7	2.8	3.2	1.9

Source: Authors' calculations

Farmers who use the traditional storage methods lost more than ten percent of their stored maize compared to the improved structures. To prevent or minimize the losses, farmers used insecticides, aired or applied ash to their stored maize as insect control measures. They used different insecticides to dust their stores and maize and the commonly used ones were actellic dust, actellic super, skana super, malathion dust, blue cross spider dust while phostoxin was only used with the metal silo. While only 0.4 percent of the large pots users applied insecticide to their maize, farmers who store maize in a room in the house (33.6 percent) apply most insecticides, ash and air their stored maize as shown in the results in Table 2 above. The study used the average total cost of each insecticide.

Farmers also aired their stored maize and this was practiced by 36.6 percent of those who store maize in a room in the living house. While only 22.3 percent of the farmers applied ash on the stored maize to reduce storage losses, this practice was also highest among the farmers who stored maize in the house at 10.8 percent. The cost of the insecticides and the cost of hired or family labour used in the application of the insecticides, ash and airing the maize were considered in this study. While some farmers used sieving and winnowing to remove the weevils from the maize others used traditional herbs and pepper, the cost of these locally available materials was not included in the study. As a result of the weevil and the LGB attack on the stored maize, farmers reported making unplanned and hurried sales at lower prices to minimise losses. Others increased the number of ash and insecticide applications as well as the time used to air their maize while the rest reported food shortage due to the loss as damaged grain was fed to livestock and poultry. In order to reduce losses, farmers sometimes make use of the discoloured damaged and mouldy grain. The study assumed no further use for the maize grain lost.

Storage loss cost

Using the estimated grain loss by the farmers during the storage period, the amount of grain lost was calculated in relation to the number of stored bags per structure. The average price per kilogram that the farmers received per storage structure from their maize sales during the storage period was used to cost the loss. The cost of the maize lost ranged from KSh 0.10 to KSh 3.30 for a kilogram of maize stored in the metal silo and large pots respectively as shown in Table 3. Apart from the metal silo and the storage over fire, the storage loss cost was higher than that of the structure for all the other structures.

Cost of storage structure

Using the average cost of the structure and its capacity, the cost of the structure per kilogram of maize stored was highest (KSh 2.70) for the storage over fire and least (KSh 0.20) for the basket as shown in Table 3 below. Results further showed that, the metal silo is not more expensive than the other storage structures farmers are currently using as cited in literature. However, it is worth noting that the farmers interviewed used metal silos of a lower capacity than the harvested maize. The total storage costs of storing a kilogram of maize were highest in the traditional crib (KSh 26.90) and lowest in the metal silo (KSh 6.30).

Table 3: Costs and benefits of storing a kilogram of maize in Kenya shillings

Structure	Cost of structure	Storage costs	Storage loss cost	Total storage costs	Price per Kg
Metal silo	0.3	5.9	0.1	6.3	24.7
Separate structure	0.6	4.9	1.4	6.8	17.0
Improved granary (wicker wall)	0.5	5.2	1.4	7.1	17.8
Large pots	0.6	6.0	3.3	10.0	15.9
Basket	0.2	9.9	1.7	11.7	15.8
Improved granary (wooden wall)	0.7	9.7	1.7	12.2	18.1
Traditional granary (cylindrical)	0.3	10.3	1.8	12.4	15.3
Storage over fire	2.7	11.1	2.3	16.0	19.3
Room in house	0.9	20.5	1.5	22.9	18.6
Traditional crib (round bottom)	2.0	22.6	2.3	26.9	20.2

Source: Authors' calculations

Maize storage benefits

The benefits used in this study are the returns from the maize sales during storage. The farmers used several sales options. 17 percent of the farmers sold to small traders while the rest sold to large traders, neighbours and millers. Less than one percent of the farmers sold to the National Cereals and Produce Board (NCPB), cereal bank, schools and Non-Governmental Organisations (NGOs). Thus, most farmers sold their maize at the farm gate while others use transport cost advantage of taking regular consignments along on periodic visits to the market towns.

The farmers sold from small amounts of 2.5 kilograms (*gorogoro*), 18 kilograms (*debe*) to 90 kilogram bags. The prices received per month differed and ranged from KSh11.60 to KSh 30 per kilogram during the storage period. Perhaps this depends on the ability of the farmers to negotiate a good price and hold onto maize.

The average returns per kilogram ranged from KSh 15.30 to KSh 24.70 for a bag of maize stored in the traditional granary and the metal silo respectively as shown in Table 3 above. The results also show that the storage costs are higher for most of the structures. Only the cost of improved granaries both wooden and wicker wall, the separate structure and the metal silo are higher than their storage costs. The storage loss costs Table 3 below is a summary of the maize storage costs and benefits used in the CBA and the results are discussed below.

4.4 Feasibility analysis

To assess the feasibility of the ten structures, the benefit cost ratio (BCR), net present value (NPV), internal rate of return (IRR) and the payback period were calculated. Table 4 below compares the BCR, NPV, IRR and the PBP per kilogram of the ten structures.

From the BCR results, the separate structures, improved granary with wicker wall and the metal silos are more viable with BCRs of 2.5, 2.5 and 3.9 respectively. The IRR when compared to a 15 percent market interest rate that prevailed during the survey period shows that the separate structures, improved granary wit wicker wall, basket and the metal silo were most feasible. The PBP ranged from three months to 1.3 years for a kilogram of maize stored in the metal silo and the traditional crib respectively. Only the traditional crib and the room in a house had a PBP of over one year as shown in Table 4 below.

Table 4: BCR,NPV,IRR and PBP per kilogram

Storage structure	BCR	NPV (KSh)	IRR (%)	PBP (years)
Metal silo	3.9	40	59.6	0.3
Basket	1.3	26	27.2	0.7
Improved granary (wicker wall)	2.5	29	23.3	0.4
Separate structure	2.5	28	19.3	0.4
Large pots	1.6	26	10.6	0.6
Traditional granary (cylindrical)	1.2	25	10.2	0.8
Improved granary (wooden wall)	1.5	29	9.3	0.7
Storage over fire	1.2	31	2.2	0.8
Room in house	0.8	30	0.7	1.2
Traditional crib (round bottom)	0.8	33	0.6	1.3

Source: Authors' calculations

4.5 Sensitivity analysis

The following harvest may or may not be what the farmers experienced during the survey period. 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 on all the storage structures at ten percent cost increment and 30 percent, 40 percent and 50 percent price reduction. Further sensitivity analysis at 15 percent interest rate on the NPV and IRR yielded the results shown in Table 5 below.

The BCR with a ten percent cost increment and a 30 percent price reduction showed that only the separate structure, the improved granary with a wicker wall and the metal silo are viable with BCRs of 1.6, 1.6 and 2.5 respectively. At ten percent cost increment, 40 percent and 50 percent price reduction, the three structures still had BCRs greater than one as shown in Table 5 below indicating that they were very viable.

Analysis of the NPV with ten percent cost increment and 30, 40 and 50 percent price reductions, still yielded positive values as shown in Table 5 below. However, the IRR subjected to the same changes showed that only the metal silo was financially feasible with IRRs still above the 15 percent market interest rate. Therefore, the sensitivity analysis assuming cost increment but with possibility of price reduction in the maize market revealed that even at 50 percent price reduction, the metal silo would still be viable for maize storage. Using the IRR decision criteria, it was however found difficult to maintain sound financial statement in reducing maize price even by 30 percent for all the other structures.

Table 5: Summary of financial indicators under sensitivity analysis

	10 % cost increment 30 % price reduction			10 % cost increment 40 % price reduction			10 % cost increment 50 % price reduction		
Storage structure	BCR	NPV	IRR	BCR	NPV	IRR	BCR	NPV	IRR
Metal silo	2.5	28	34.0	2.1	24	26.2	1.8	20	18.3
Improved granary (wicker)	1.6	20	10.7	1.4	17	7.0	1.1	14	3.3
Separate structure	1.6	19	8.9	1.4	17	5.8	1.1	14	2.8
Large pots	1.0	18	1.2	0.9	16	0.4	0.7	13	0.2
Room in house	0.5	21	0.9	0.4	18	0.8	0.4	15	0.7
Basket	0.9	18	0.9	0.7	15	0.5	0.6	13	0.3
Traditional granary	0.8	17	0.8	0.7	15	0.6	0.6	12	0.4
Traditional crib	0.5	23	0.8	0.4	20	0.7	0.3	16	0.6
Storage over fire	0.8	22	0.3	0.7	19	0.2	0.5	16	0.2
Improved granary (wooden)	0.9	21	0.0	0.8	18	-0.1	0.7	15	-0.1

Source: Authors' calculations

4.6 Comparative analysis of the structures

The benefit from the structures can also be calculated as the loss abated as compared to the control. Table 6 below shows the different gains from using the various storage structures and comparing them with the metal silo which has the least storage costs and it is also the most feasible. The farmers who use the large pots, storage over fire and traditional crib would reduce the storage loss cost by more than KSh 2.20 a kilogram if they shifted to the metal silo as shown in Table 6 below. The traditional crib users and those who store maize in the house would reduce their total storage costs by KSh 20.70 and KSh 16.70 respectively.

Table 6: Value in Kenya shillings of maize storage loss abatement per kilogram

Storage structure	Total cost saved (KSh)	Loss abated (KSh)
Large pots	3.7	3.2
Storage over fire	9.8	2.2
Traditional crib (round bottom)	20.7	2.2
Traditional granary (cylindrical)	6.2	1.7
Basket	5.5	1.6
Improved granary (wooden wall)	5.9	1.6
Room in house	16.7	1.4
Separate structure	0.6	1.3
Improved granary (wicker wall)	0.8	1.3

Source: Authors' calculations

5 Discussion and Conclusions

Maize farmers store their produce on-farm for durations of eight to nine months. They use different storage structures and the results showed that the storage of maize in a room in the living house was the commonly used facility. Farmers also face storage problems especially inadequate storage capacity as seen among farmers who use the baskets, pots, storage over fire and the metal silo. Inadequate storage facilities are a marketing constraint that hinders smallholder farmers from participating in commercialized marketing systems. Although more farmers sell their maize within the initial months of storage, they store maize even when storage costs outweigh their benefits contrary to literature. Overall, maize consumption was above 50 percent among the farmers. It is both the main food crop and a cash crop in some areas in Kenya. This means that it may take long for subsistence farmers to commercialise through maize sales.

There was storage grain loss in all the structures and this was higher with the traditional ones as some farmers still use traditional insect control measures. Losses were however lowest with the metal silo which was not commonly used probably due to its cost. The structures also had a higher storage capacity than what the farmers harvested during the survey period. One can therefore conclude that, farmers always expect a good harvest as the previous yields determine the size of the storage structure acquired. However, there was inadequate storage capacity among farmers using the baskets, storage over fire, large pots and metal silo. One can therefore conclude that, farmers bought the metal silo they could afford other than that which could store their expected yields.

Farmers who used traditional structures incurred the highest maize losses during storage compared to the improved structures. Although most farmers store maize in a room in the living house, the storage losses are not among the highest. However, these farmers use more insecticide, apply more ash and air their maize most compared to the other structures. This increases the storage labour costs.

The cost benefit analysis showed that the metal silo was the most profitable maize storage structure. Despite the fact that most storage structures are not viable, the study concludes that maize storage is important to farmers as most of them consumed more than they sold. Besides the home consumption, maize sales provide the farmers with income which can be used to meet other household needs. Although maize storage in the traditional structures may not increase the household income from maize sales, the metal silo has the potential to increase the income in the long run. The data limitations were that there were few observations on maize sales in some months to conclude on the price per kilogram.

6. Recommendations

From the results, recommendations can be made to reduce the PHLs during storage. There is need for more widespread education to farmers on the causes of PHLs and on the costs and benefits of the maize storage structures they are currently using. Farmers need to be provided with information on how much they lose during storage to make more informed decisions when investing in the maize storage structures. This should be coupled with information on storage management. While majority of the farmers store maize in the house, they farmers need to be advised against storing maize in the house as the losses range from storage insects to attack by domestic animals and poultry. There is need for research on ways of minimizing the storage insects and pests. CIMMYT should promote the use of the metal silo which is more feasible for maize storage. However, the cost of the metal silo is prohibitive for most small scale farmers and this may slow down its adoption. Without credit provision to these farmers, it may take long for farmers to shift from the traditional storage structures to new technologies like the metal silo. Financial support is therefore needed to enable the maize farmers to acquire the metal silos. Farmers can also purchase as a group to store their maize at village or community level therefore building farmer-owned reserves necessary for food security. Maize sales in groups will also increase their bargaining power for better prices. More earnings flow in with the use of the metal silo which although expensive is durable but since it reduces maize storage losses, there should be provision of credit for farmers to purchase it. This will increase the adoption of the metal silo, reduce PHLs and increase household income. Small scale farmers store maize in different structures but do not record or quantify the actual costs and benefits incurred. It is in this backdrop that the comparative analysis of the costs and benefits of the various maize storage structures used in Kenya and the dissemination of the findings are of great importance to the farmers, researchers and policy makers.

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