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An Analysis of Costs Associated with Maize Storage Facilities Used by Rural Smallholder Farmers in Uganda

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Abstract

This article assessed the acquisition, maintenance and storage costs associated with different types of storage facilities used by smallholder maize farmers in Uganda, applying cost-based descriptive analysis. These costs influenced the farmers' decisions about the type of storage facility to use. Poor storage exacerbates losses that result from pests, rats and rot. The findings show that the high costs of acquiring storage and maintenance precluded smallholder maize farmers from accessing good storage. For policy purposes, more investment needs to be directed towards acquiring safe storage to reduce exposure to risk and protect smallholder farmers from food and income insecurity. This article serves to illuminate the storage challenges at the household level to increase food and income security and assuage poverty. The study's conclusion on the analysis of storage is indicative only. Further research that includes a representative number of storage facilities per storage type needs to be carried out, including a cost-benefit analysis.

Keywords: storage; cost; maize; rural smallholder farmers; storage type; Uganda

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Résumé

Cet article évalue les coûts d'acquisition, d'entretien et de stockage associés aux différents types d'installations de stockage utilisées par les petits exploitants de maïs en Ouganda, en appliquant une analyse descriptive basée sur les coûts. Ces coûts ont influencé les décisions des agriculteurs quant au type d'installation de stockage à utiliser. Un mauvais stockage accentue les pertes causées par les ravageurs, les rats et la pourriture. Les résultats montrent que les coûts élevés d'acquisition et d'entretien des installations de stockage ont empêché les petits exploitants de maïs d'accéder à de bonnes installations de stockage. D'un point de vue politique, il faudrait investir davantage pour acquérir des entrepôts sûrs afin de réduire l'exposition au risque et de protéger les petits exploitants de l'insécurité des revenus et de l'alimentation. Cet article permet démontrer clairement les difficultés liées au stockage au niveau des ménages afin d'accroître la sécurité alimentaire et des revenus et de réduire la pauvreté. La conclusion de l'étude sur l'analyse du stockage n'est qu'indicative. Des recherches plus poussées sont nécessaires avec un nombre de magasins représentatifs par type de stockage ainsi qu'une analyse coût-bénéfice.

Mots-clés : stockage ; coût ; maïs ; petits exploitants ruraux ; type de stockage ; Ouganda

Introduction

Although ending hunger is a sustainable development goal, this goal may not be achieved, if high food losses through poor storage at the household level are not prevented. The world population is projected to reach 9.1 billion by the end of the year 2050 and this will require an increase in food production by 70 per cent (Hodges, Buzby & Bennett 2011; Yusuf & He 2011). The population of Uganda is predicted to grow from 44 million to 99 million people by 2050 (UN 2019). Since the population is highly dependent on agriculture, this will lead to the increased exploitation of natural resources. Therefore, this study argues for reducing food losses wherever possible, including through storage. Although grain storage plays an important role in stabilising food supply across all seasons, its costs remain a challenge that is not adequately addressed by agricultural scientists. Thus, storage difficulties have continued to undermine food and income security among rural smallholder maize farmers in most developing countries (D'Amour *et al*. 2016).

In most developing countries, three out of four people live in rural areas and derive a livelihood from agriculture (Yusuf & He 2011). According to Gitonga, De Groote and Tefera (2015), in East and Southern Africa, two-thirds of the population live in rural areas where they make a living from agriculture. In sub-Saharan Africa (SSA), agriculture is estimated to contribute about 34 per cent of the gross domestic product (GDP) and employs more than 60 per cent of the active labour force (Amare & Shiferaw 2017). In Uganda, agriculture contributes about 25 per cent of GDP, accounts for 47 per cent of exports and provides employment to more than 72 per cent of the economically active population (Wanyama 2016).

Despite the significant contribution from agriculture, 70 per cent of people living in rural areas live in extreme poverty and hunger (Ndegwa *et al.* 2016). Thus, in developing countries, agriculture is referred to as 'green gold' because of its immense contribution to human life (Mendoza *et al.* 2017). However, due to limited resources, rural smallholder farmers tend to employ rudimentary techniques in their farming system, which cripples the effort to earn much from agriculture (Wanyama 2016). Cereals are known to play a significant role in the livelihood of rural smallholder farmers, with maize being one of the most important for millions of rural farmers in SSA in terms of food and income security (Midega *et al.* 2016). It is the third most widely grown crop globally after wheat and rice (Suleiman *et al.* 2013). More than half of the maize produced is consumed in rural areas where most households have limited economic resources (Tanumihardjo *et al.* 2019).

Although agriculture is the mainstay of many SSA economies, many rural smallholder maize farmers in the region face substantial obstacles that jeopardise their food and income security partly due to post-harvest losses (Yusuf & He 2011; Chuma, Mudhara & Govereh 2020). An important challenge faced by rural smallholder maize farmers is the use of traditional storage facilities made of locally available materials like grass, wood, cow dung and mud, which cannot guarantee adequate safety for stored grain (Chuma *et al.* 2020; Tefera 2012; Yusuf & He 2011). The problem of inadequate and/or ineffective storage affects not only grain for consumption and sale but also the multiplication of seeds (Yusuf & He 2011). Moreover, once a seed is damaged, its viability will deteriorate (Moshi & Matoju 2017). Post-harvest losses are estimated to be between 14 per cent and 36 per cent of production (Gitonga *et al.* 2013), which considerably reduces the farmers' ability to be food secure and fight poverty (Moshi & Matoju 2017).

This study is interested in the quantitative and qualitative post-harvest loss of grain cereals in the value chain system (Hodges *et al.* 2011), including storage. The loss leads to a measurable reduction in the quality and quantity of grain (Affognon *et al.* 2015). For this study, storage is that part of the value chain that is necessary for maintaining maize at the household level for food and income security (Yusuf & He 2011; Suleiman, Rosentrater & Bern 2013; Makaza & Mabhegedhe 2016). Williams, Murdock and Baributsa (2017) and Ndegwa *et al.*, (2016) have argued that preventing pest damage during maize storage is pertinent for food and income security among rural smallholder farmers. It also enables them to realise better prices when they sell their maize.

Many scientists have warned that grain losses are reaching alarming proportions (Gitonga *et al.* 2013; Kaminski & Christiaensen 2014). This has culminated in the Food and Agriculture Organization's (FAO) and World Bank's decision to direct 47 per cent of the aid of USD 940 billion towards the post-harvest sector in SSA (Affognon *et al.* 2015), partly to reduce grain losses in SSA and thus alleviate hunger, especially among the rural poor, which is a key objective of the United Nations hunger task force (Ndegwa *et al.* 2016).

Agriculture in Uganda is dominated by smallholder producers, who account for 80 per cent of the farming community (NPA 2013). More than 80 per cent of Uganda's maize is produced by smallholders (Sserumaga *et al.* 2015). It is cultivated by 86 per cent of the 4.2 million agricultural households in the country (Okoboi, Muwanga & Mwebaze 2012). Maize feeds urban and rural poor populations. It also feeds schools, hospitals, the military, prisons and the police. It is also used for animal and poultry feed (Kaaya & Warren 2005). Therefore, the safe storage of maize at the household level is crucial for food and income security and may directly impact poverty alleviation (Gitonga *et al.* 2015; Ndegwa *et al.* 2016). In a bid to reduce maize grain losses, rural smallholder farmers have adopted protection measures like sun-drying, the use of neem tree leaves, cow dung mixed with water, and smoking the maize by hanging it above the fire. However, these methods offer limited protection to the stored grain (Ndegwa *et al.* 2016).

Maize in Uganda is grown under a low-input rain-fed system with two seasons (David *et al.* 2016). It is usually inter-cropped with beans and groundnuts. Since maize is seasonally grown but demanded throughout the year, it requires storage (Tefera 2012). Its seasonal production leads to a fluctuation in supply (Kimenju & De Groote 2010). However, smallholder farmers in many developing countries still use traditional maize storage methods, which are often not successful in preventing losses that are thus a constraint on food and income security (Ndegwa *et al.* 2016; Tefera 2012; Tefera *et al.* 2011). As a result, rural smallholders sell maize immediately after harvest. However, since this is when prices are the lowest, they are consequently disadvantaged (Ndegwa *et al.* 2016). Therefore, effort needs to be directed towards an even maize supply, which means protecting it through effective storage (Chigoverah & Mvumi 2016).

Losses of maize for smallholder farmers occur at various stages of the value chain: harvesting, preliminary processing, handling, transportation, marketing, and during storage, when pests, spillage, birds, pilferage and rodents eat into the stock (Affognon *et al.* 2015; Abass *et al.* 2014). In SSA, loss from insect pest damage in storage is estimated at 20 per cent (Chigoverah & Mvumi 2016). In East Africa, about 19 per cent of the maize produced is lost in post-harvest storage (Yakubu *et al.* 2016). In Uganda, on-farm post-harvest maize loss is estimated to be about 6 per cent of the quantity harvested (Shee *et al.* 2019). Post-harvest losses resulting from pest attacks in storage are the highest, ranging between 10 per cent and 88 per cent of the maize produced every season (Midega *et al.* 2016).

Because modern storage facilities are too expensive, farmers continue to use traditional storage methods, like granaries, cribs, sacks, the space above the fire, house corners and baskets (Tibaingana, Kele & Makombe 2018). These facilities are susceptible to insect damage, mostly likely because they are not airtight enough to prevent insect damage (Abass *et al.* 2014).

Cost of Storage Associated with Rural Smallholder Maize Farmers

This article assessed the costs associated with storage facilities used by rural smallholder farmers. We classified costs into three broad categories: storage acquisition, maintenance of the storage facility, and maize loss in storage. Storage acquisition costs are incurred when a farmer obtains or constructs a storage facility (Tibaingana *et al.* 2018). They include the cost of materials and labour, when the farmer constructs his/her own storage, and the cost of transport when storage facilities are purchased. Maintenance costs of the storage include chemicals purchased to control pests in storage, the cost of cleaning the storage facility and repairing it before use, and the cost of labour for cleaning and repair. The cost of the loss of maize in storage is calculated in the value of the maize lost, as a result of pests, rats, rodents and rot, among other factors.

Besides damaging the maize, rodents also damage storage facilities like sacks, baskets and granaries. The hermetic bags that were found to be more effective than pesticides in protecting the stored maize are expensive for rural smallholder maize farmers (Ndegwa *et al.* 2016). Inadequate storage used by farmers results in two major consequences. First, farmers have to sell maize at low prices immediately after harvest to avoid losses and, second, they have to buy maize later for consumption when they run out of stock for consumption (Abass *et al.* 2014).

Research Objective

An empirical, comparative assessment of the costs of storage in different facilities for rural smallholder maize farmers is not available generally, nor specifically for Uganda. Consequently, there is limited literature with detailed cost analysis of storage facilities generally in developing countries (Kadjo, Ricker-Gilbert & Alexander 2016; Ndegwa *et al.* 2016; Abass *et al.* 2014). The central objective of this study, therefore, is to analyse the different costs incurred by rural smallholder farmers for different storage facilities.

Data Collection

Data was collected during a survey conducted between January and May 2016 in Eastern Uganda. Eastern Uganda was purposively selected for the study because it is the country's highest maize-producing region, based on the agriculture census of 2008/2009 which indicates that the Eastern region accounted for more than 50 per cent of maize production in 2010. Using the same census we selected the highest and lowest maize-producing districts of Iganga and Katakwi, respectively, and the medium-producing district of Manafwa, where production was closest to the average production of all the districts in the region.

Three sub-counties were selected from each district as follows: the highest maize-producing sub-county, the lowest maize-producing sub-county, and the sub-county with maize production nearest the average of all sub-counties in a district. The census data was not disaggregated to the village level, so extension workers in each sub-county were asked to identify one high-, medium- and low-producing village in each sub-county, resulting in twenty-seven villages. Lists of village households were provided by the local council personnel who are conversant with the people in the respective villages and used as sampling frames. The extension officer estimated that the population of farmers in the target villages was about 800. According to Israel (1992:3), a statistically representative sample for such a population, with a precision of 5 per cent, is 267. Therefore, the SPSS random number generator was used to select ten farmers from each of the twenty-seven villages, resulting in a sample of 270 respondents.

For the acquisition costs of storage types, data was collected from farmers' recall. If it was constructed, the value of the labour and the costs of the materials were used to estimate costs, even if local materials were used. For the cost of maintaining the storage, farmers were asked to estimate, from memory, the cost of purchasing chemicals to control pests in the facility. For the loss of grain during storage, farmers were asked to estimate seasonal maize loss in kilogrammes. The average price of maize realised by farmers who used a specific storage type was used to convert the maize lost in storage to monetary value. The sum of these three costs constituted the costs of storage.

In studying the storage costs, we discovered that storage costs could be further disaggregated, for instance, to include the costs of carrying maize in and out of a storage facility. We missed this level of disaggregation and probably missed this cost unless it was inadvertently included in one of the broad categories we used, which is unlikely.

Results and Discussion

Household Characteristics

Fifty-six per cent of the sample household heads were male, with an average age of 43 years. On average, male households and heads had eight years of formal education. The average female household head's age was 40 years with an average of six years of formal education. The average number of people in the household was six which did not vary by gender of the household head. Almost all respondents who stored maize incurred storage losses, although with some storage facilities, the losses were lower than with others. Farmers used eight different storage facilities: sacks (83 %), granaries (12 %), house corners (19 %) open cribs (3 %), closed cribs (4 %), house roofs (2 %), baskets (6 %) and above the fire (0.7 %). These storage types stored both shelled and unshelled maize. Sacks, baskets and house corners stored mainly shelled maize, whereas other storage facilities such as granaries stored shelled and unshelled maize. Therefore, in assessing the cost of storage, farmers were asked to estimate the loss of maize in storage for shelled and unshelled maize separately. The unshelled was then converted to a shelled equivalent. The average storage length was three months across the sampled districts. Pictures of some of the storage types can be seen in Tibaingana *et al*. (2018). Although pots were mentioned as a storage facility, none of the respondents were using them because they were reported to be very fragile and usually used to store seeds for planting the next season. In addition, although jerrycans were mentioned as a storage type by the respondents, no one was found using this type of storage during the period of study.

Farmers used one or a combination of storage facilities, sometimes in sequence – for example, the house roof for temporary storage and a sack and/or closed crib for more permanent storage. Seventy-five per cent of the respondents used one storage facility, 23 per cent used two, 2 per cent used three and 1 per cent used four storage facilities. This distribution is similar in Manafwa and Katakwi, the medium- and low maize-producing districts, but in Iganga, the highest maize-producing region, 71 per cent of the respondents used one storage facility (mostly sacks) whereas 21 per cent used two storage facilities.

Table 1 shows that of the eight different storage types used by the respondents, sacks were the most common. Farmers reported that this was because they were cheap to acquire and were readily available. In addition, shelled maize can be carried easily in sacks for drying in the sun, and one can tell how much maize there is in storage by counting the number of sacks. House corners were the next most common storage type, followed by granaries, baskets and cribs, respectively.

Table 1: Prevalence of the use of storage types in Iganga, Manafwa and Katakwi districts (n=270)

Storage Type	**Number**	**District (%)**		
		Iganga (High) N=90	**Manafwa (Medium) N=90**	**Katakwi (Low) N=90**
Sacks	224	93	89	67
House corner	52	31	17	10
Granary	33	0	9	28
Basket	16	0	7	11
Crib (closed)	10	0	3	8
Crib (open)	7	0	0	8
House roof	6	4	1	1
Above-the-fire	2	0	0	2
Total number of storage types	350	116	113	121

Source: Authors' fieldwork

Although the respondents numbered 270, the number of storage types shown in Table 1 is 350 because some farmers used more than one storage type. Table 1 shows that in the high maize-producing district only three storage facilities were used – sacks, house corners and house roofs. Farmers explained that they used the house roof least because it is a transitional (temporal) storage space. Most farmers explained that it was very difficult to protect maize on the house roof from damage, especially from birds (domestic and wild). In the medium maize-producing district six storage facilities were used and farmers in the low maize-producing district used all the eight storage types.

Table 2 shows the estimates of the quantities of maize stored in each storage type by the farmers who used that facility as the main storage. On average the highest quantity of maize was stored in the closed crib, which stored more than 2,000 kg of maize. The lowest quantity of unshelled maize was stored above the fire, averaging about 2 kg. This is consistent with the fact that the space above the fire is used to store maize for seed that farmers recycle.

Table 2: Estimate of the amount of maize stored per district (kg)

SN	Storage Type	Estimated Amount of Maize Lost (Kg)			
		Total (n=270)	Iganga (n=90)	Manafwa (n=90)	Katakwi (n=90)
1	Above the fire (n=1)	2	N/A	N/A	2
2	House roof (n=2)	51 (49)	2	N/A	100
3	House corner (n=24)	1,408 (824)	682 (190)	2,669 (1957)	194 (65)
4	Sacks (n=201)	539 (80)	662 6(188)	562 (58)	317 (75)
5	Basket (n=1)	20	N/A	N/A	20
6	Granary (n=29)	480 (141)	N/A	894 (468)	322 (70)
7	Crib (open) (n=6)	263 (152)	N/A	N/A	263 (152)
8	Crib (closed) (n=6)	2033 (790)	N/A	3267 (1,157)	800 (513)

Note: Standard deviations reported in brackets
Source: Authors' fieldwork

Table 2 shows the estimated amount of maize stored in kilogrammes per district in relation to the total. Some variation is due to the size of the storage facility, which differed across districts; however, some variation is due to the way farmers use the different storage facilities. For instance, farmers tend to fill the sacks to different levels although there is a standard sack size. There is no standard deviation for the basket because only one farmer used the basket as the main storage type.

Three storage spaces warrant special discussion, namely, above the fire, the house roof and the house corner. The house corner and house roof were sometimes used as transitory (temporal) storage facilities. Many farmers used these storage spaces in lieu of other more permanent storage types. Therefore, the stored quantities varied and were not easy to estimate for those farmers who used these storage types as transitory (temporal) facilities.

The space above the fire was used by very few farmers. For these reasons, we compare the quantities of maize stored in the other storage facilities and not the house corner, the house roof or above the fire.

The results of the comparison of the quantity of maize stored in the other five storage types (types 4 to 8), ANOVA (F=1.74: F Prob = 0.0991>0.05), show that there is no statistically significant difference in the quantity stored in each storage type. However, we would like to note a caveat in the interpretation of the statistical analyses. We could not estimate the prevalence of the storage types used by farmers a priori. In this regard, our study is therefore explanatory in that it established the types of storage facilities used by rural smallholder maize farmers in Uganda and their prevalence. We are aware that the statistical comparison of the amounts of maize stored by each storage type requires that there be statistical representation in each category of the storage facility. For instance, there are only seven open cribs in our sample, compared to 224 sacks. This means that the amount stored in the sacks is better represented and therefore most likely would give a better estimate than that of open cribs. This may be the source of the failure to observe the differences in the quantities stored by different storage facilities. We therefore note that these results are indicative only and recommend that the quantities stored be studied using statistically representative samples of all the storage facilities. This caveat applies to most of the statistical analyses performed in this study.

Table 3 shows that gender plays a role in the use of the different storage facilities. The p-value of the chi-square for the association between gender and storage type is 0.0200 (<0.05) showing a significant association. Baskets were used by women only, whereas only men used closed cribs and the space above the fire. This is probably a function of both the effectiveness and cost of the storage types. The baskets are cheaper and more accessible but less effective, and therefore the men, who tend to have more access to resources, do not use them. Seventy-six per cent of the granaries were used by males and 67 per cent of the house corners were used by females. Farmers explained that the high use of the house corner storage by female farmers was due to security. Respondents reported that maize kept in the house corner would not be stolen easily compared to maize stored outside the house in granaries or cribs. Women, therefore, tended to use the house corner as more permanent storage than males who used it as transitory (temporal) storage. Some of the storage types were gender-insensitive. For instance, 50 per cent of the open cribs were used by female farmers.

Table 3: Storage type used by gender

Storage Type Used	Gender (%)	
	Male	Female
Sacks (n=224)	55	45
House corner (n=52)	33	67
Granary (n=33)	76	24
Basket (n=16)	0	100
Crib (closed) (n=10)	100	0
Crib (open) (n=7)	50	50
House roof (n=6)	50	50
Above the fire (n=2)	100	0
Chi-square = 16.6011; *p-value* = 0.0200		

Sources: Authors' fieldwork

Analysis of Storage Costs by Storage Type

The analysis of the three broad categories of costs estimated in this study follows.

Cost of acquisition by storage type

Table 4 summarises the results of the cost of acquisition by storage type and district. The cost of acquisition was zero for the above-the-fire space because in this the maize is hung above the cooking place. The basket storage had a lower cost of acquisition compared to closed cribs and sacks. This is because it is a transitory storage facility and is locally made from inexpensive materials like reeds collected from river banks. The most expensive storage facility to acquire is the closed crib. It is quite big and made of materials that are mainly purchased. In most cases, it is constructed by experts.

Table 4 also shows that the lowest acquisition costs were experienced in Iganga, the highest maize-producing district. Although this is an area of further research, we think that the differences between areas are a function of the availability of local materials for constructing storage facilities. Acquisition costs are the first hurdle that farmers face in choosing the type of storage facility they might want to use. Table 4 estimates the extent of this hurdle. We realise and acknowledge the complexity of estimating the acquisition costs for the first three storage facilities, namely, above the fire, the house roof and the house corner. We acknowledge that, for instance, the acquisition costs of a house corner can be better estimated by considering the cost of constructing the house, the lifespan of the house and then apportioning an area-proportionate cost to the annual depreciation of the house. However, we also note that the premise of this study is that the improvement of storage facilities used by rural smallholder maize producers should start by considering the existing storage methods used by farmers. In this regard, we acknowledge that the first three storage facilities would not form part of such a maize storage improvement programme because, whereas it may be possible to reduce acquisition costs by finding innovative ways of constructing a crib, a house corner does not offer a similar opportunity. Thus, although there is no benefit to attempting a reasonably accurate estimate of the acquisition costs of the first three storage facilities, we do provide an indicative estimate.

Table 4: Average acquisition costs by storage type and district (UGX)

SN	Storage Type	Mean Acquisition Cost (Ugx)			
		Total	Iganga	Manafwa	Katakwi
1	Above the fire (n=2)	0 (0)	N/A	N/A	0 (0)
2	House roof (n=6)	325,000 (388,908)	600,000 (0)	N/A	50,000 (0)
3	House corner (n=52)	295,925 (183,360)	272,222 (44,962.3)	300,220 (74,437)	330,000 (76,811)
4	Sacks (n=224)	3,214 (21,180)	5,494 (3,740.7)	1,487 (146)	2,000 (427)
5	Basket (n=16)	12,000 (0)	N/A	N/A	12,000 (0)
6	Granary (n=33)	74,283 (66,842)	N/A	61,250 (12,843)	79,248 (16,474)
7	Crib (open) (n=7)	558,333 (269,103)	N/A	N/A	558,333 (109,861)
8	Crib (closed) (n=10)	1,333,333 (1,046,263)	N/A	2,166,667 (440,958)	500,000 (152,752)
Total (Mean (n=350)		**81,165 (274,087)**	**38,772 (112,582.3)**	**112,164 (418,091)**	**92,558 (191,481)**

Note: Standard deviations reported in brackets

Exchange rate: USD 1 = UGX 3,300 at the time of the survey

Source: Authors' fieldwork

Using the total sample of farmers (that is, not disaggregated by district) who used the storage types 4 to 8 in Table 4 we conducted an analysis of variance in the costs of acquisition. The results (F=71.02: F Prob=0.0000<0.05) show that the differences in acquisition costs are statistically significant. Even though we leave out the house corner in the ANOVA, we note that it was extensively used by women. This gives reason for concern that a storage improvement programme that excludes the house corner would leave out women. The fact that some women prefer this storage space because of safety concerns indicates the urgency of the need to develop effective storage for rural smallholder maize farmers which is also accessible to women.

Maintenance cost by storage type

Table 5 shows that the resultant sample of storage facilities is 350 because some farmers used more than one storage type. The cost of maintenance was zero in the above-fire storage space. It was reported that above-fire storage kept maize for a long time (three to five months) without damage. This was as a result of the smoke produced from daily cooking. However, the drawback of this storage type is that it is viable for small quantities only. Besides, the stored maize turns brown from the smoke. Hence, it is ideal for seed storage as opposed to consumption. Basket storage had higher maintenance costs compared to closed cribs and sacks. The cost of maintenance of the crib was lower than that of the granary and yet the crib stored more maize compared to the granary. The cost of maintaining stored maize was cheaper in open cribs (at UGX 6,000) and sacks (at UGX 7,625). Farmers who stored maize in closed cribs, baskets, granaries and house corners spent, on average, UGX 9,883, UGX 10,000, UGX 12,614 and UGX 13,825 respectively on maintenance.

Table 5: Average maintenance costs by district by storage type

SN	STORAGE TYPE	Mean Maintenance Cost (IN UGX)			
		Total (n=270)	Iganga (n=90)	Manafwa (n=90)	Katakwi (n=90)
1	Above-the-fire (n=2)	0 (0)	N/A	N/A	0 (0)
2	House roof (n=6)	0 (0)	0 (0)	N/A	0 (0)
3	House corner (n=52)	13,825 (22,033)	14,911 (10,829)	15,960 (5,160)	7,600 (1,939)
4	Sacks (n=224)	7,625 (13,038)	5,750 (970)	11,912 (2,251)	4819.2 (932)
5	Basket (n=16)	10,000 (0)	N/A	N/A	10,000 (0)
6	Granary (n=33)	12,614 (18,271)	N/A	8,538 (3,193)	14166.7 (4,523)
7	Crib (open) (n=7)	6,000 (2,607)	N/A	N/A	6,000 (1,064)
8	Crib (closed) (n=10)	9,883 (5,782.9)	N/A	12,500 (4,330)	7266.7 (1,507)
Total (Mean) (n=350)		**8,650 (14,467)**	**6,602 (13,032)**	**12,082 (17,455)**	**7,266 (11,830)**

Note: Standard deviations reported in brackets
Exchange rate: USD 1 = UGX 3,300 at the time of survey
Source: Authors' fieldwork

The results indicate that, on average, maintenance costs were higher for female-headed households. Remarkably, even when female rural smallholder maize farmers used the same storage type as men, they were reported to incur higher costs of maintenance. This is probably because women, being the ones responsible for feeding the family, have a higher appreciation of the need to preserve food and therefore may use more chemicals than men, thus incurring more costs. However, this is an area of further research. Following the same logic as presented for the acquisition costs, we compared the maintenance costs for storage facilities 4 to 8. The results of the ANOVA (F=1.09: F Prob=0.3726>0.05) show that there is no significant difference in the mean maintenance costs for the storage types.

We note that the absence of difference may be due to the fact that we need to compare maintenance costs per kilogramme of stored maize. In Table 6, we calculate the maintenance cost per kilogramme stored by storage type and district.

Table 6: Average maintenance cost per kg by district and storage type

SN	Storage Type	Mean Maintenance Cost Per Amount of Kg Stored (UGX)			
		Total (n=270)	**Iganga (n=90)**	**Manafwa (n=90)**	**Katakwi (n=90)**
1	Above the fire (n=2)	0 (0)	N/A	N/A	0 (0)
2	House roof (n=6)	0 (0)	0 (0)	N/A	0 (0)
3	House corner (n=52)	56 (106)	34 (18)	36 (15)	136 (93)
4	Sacks (n=224)	28 (55)	19 (3)	36 (9)	28 (7)
5	Basket (n=16)	500 (0)	N/A	N/A	500 (0)
6	Granary (n=33)	106 (283)	N/A	22 (12)	139 (72)
7	Crib (open) (n=7)	90 (94)	N/A	N/A	90 (3)
8	Crib (closed) (n=10)	16 (18)	N/A	8 (6)	24 (13)
Total (Mean) (n=350)		**41 (115)**	**21 (34)**	**34 (70)**	**69 (181)**

Note: Standard deviations reported in brackets

Source: Authors' fieldwork

Table 6 shows that the highest maintenance cost per kilogramme was experienced by the farmers who used the basket, whereas the lowest cost was attributed to the above-the-fire and house roof storage spaces, largely because these require little maintenance.

Further analysis of the storage types 4 to 8 (F=4.74: F Prob=0.0000<0.05) shows that there is a statistically significant difference between the means of the maintenance costs per kilogramme of stored maize by storage type.

This result begins to indicate the storage types that could be focused on in the early stages of a maize-storage improvement programme. The apparent low maintenance costs of the sacks and closed crib certainly make these methods attractive.

Cost of maize lost in storage

The losses in storage were estimated in kilogramme for each storage facility. Table 7 summarises the loss in storage in kilogramme by storage type.

Table 7: Estimated maize loss by storage type (kg)

SN	Storage Type	Estimated Loss in Storage (Kg)
1	Above the fire (n=2)	0.5(0)
2	House roof (n=6)	28 (24)
3	House corner (n=52)	64 (21.2)
4	Sacks (n=224)	43 (3.4)
5	Basket (n=16)	20 (0)
6	Granary (n=33)	34 (5.6)
7	Crib (open) (n=7)	28 (6.2)
8	Crib (closed) (n=10)	45 (12.3)
Overall mean = 43 (53.6)		

Note: Standard deviations reported in brackets

Source: Authors' fieldwork

The major causes of maize loss during storage were pests, birds (domestic and wild), rot, pilferage and rats. The loss appeared highest for farmers who stored maize in baskets (20 kg) and house corners (64 kg). Farmers explained that this is because these storage facilities are open which makes it difficult to protect the stored maize from damage. The above-the-fire storage space had the lowest loss (0.5kg). The average maize lost across storage types was 43 kilogrammes. Table 6 tests for the differences in the means for the storage types that could be included in a maize-storage improvement programme.

We converted the losses in storage in Table 7 to losses per kilogramme of stored maize. To facilitate a better comparison, the losses (in kg) were converted into losses per amount of maize stored in a given storage type and expressed as a percentage by multiplying it by 100. Table 8 shows the results of the percentage losses by storage type and district.

Table 8: Amount of maize lost in storage per kilogramme of maize stored (%)

SN	Storage Type	Total	Iganga	Manafwa	Katakwi
1	Above the fire (n=2)	25	N/A	N/A	25
2	House corner (n=52)	18	13	13	38
3	House roof (n=2)	3	2	N/A	4
4	Sacks (n=224)	16	16	132	20
5	Basket (n=16)	100	N/A	N/A	100
6	Granary (n=33)	20	N/A	13	22
7	Crib (open) (n=7)	37	N/A	N/A	37
8	8 Crib (closed) (n=10)	19	N/A	1	38
Total (n=350)		**17**	**16**	**13**	**24**

Source: Authors' fieldwork

The highest percentage loss of stored maize was experienced in Katakwi, the lowest maize-producing area, and the lowest was in Manafwa, the medium maize-producing area. Whether maize losses in storage are truly a function of location needs to be investigated and the causes identified. On average, basket use lost the most maize, close to 100 per cent. The lowest percentage loss was on the house roof. This may be due to the fact that farmers do not store maize on the roof for long periods of time. In Manafwa, the closed crib lost almost no maize whereas in Katakwi the closed crib loss was much higher. The low loss in the closed crib in Manafwa makes this method a good candidate for a maize-storage improvement programme; the causes of the high loss in Katakwi warrant further investigation. We performed ANOVA to test whether there are statistically significant differences in the percentage losses in storage between the storage types 4 to 8. The results ($F=3.22$: F Prob$=0.0027<0.05$) show that there is a statistically significant difference in the percentage losses from the different storage types.

Because we were interested in the monetary value of storage losses, we converted the estimated losses in Table 7 to monetary loss by using a price factor. Table 9 shows the price factors used to convert the losses per kilogramme to a monetary value.

The average price was calculated from the maize that was sold from each storage type. However, because there were price variations resulting from storage type and season, it is recommended that these should be investigated in the future. The highest price was achieved by the closed crib and the lowest was achieved by the house roof. It is important to note that the price is a function not only of the extent to which the storage type protects the maize but also the time of sale. In order to properly compare the prices based on the extent to which the storage types protect the maize, the prices of the maize sold from each storage type should be compared against sales from similar time periods. Table 10 shows the results of calculating the losses in storage in Table 7 per storage type and district.

Table 9: Price factors by storage type (UGX/kg)

SN	Storage Type	Estimated Ugx/Kg Loss
1	Above the fire (n=2)	634
2	House roof (n=6)	547
3	House corner (n=52)	692
4	Sacks (n=224)	758
5	Basket (n=16)	863
6	Granary (n=33)	677
7	Crib (open) (n=7)	700
8	Crib (closed) (n=10)	950
Overall mean=715 (294)		

Source: Authors' fieldwork

Table 10: Amount of maize lost in storage converted to monetary loss (UGX)

SN	Storage Type	Monetary Value Lost (Ugx)			
		Total	Iganga	Manafwa	Katakwi
1	Above the fire (n=2)	317 (0)	N/A	N/A	317 (0)
2	House corner (n=52)	44,973 (74,751)	18,127 (4,095)	76,212 (34,697)	30,817 (9,266)
3	House roof (n=2)	15,306 (18,065)	28,080 (0)	N/A	2,532 (0)
4	Sacks (n=224)	33,338 (48,104)	28,032 (3125)	33,815 (5,118)	40,865 (10,145)
5	Basket (n=16)	57,821 (0)	N/A	N/A	57,821 (0)
6	Granary (n=33)	23,026 (18,698)	N/A	24,449 (6,733)	22,484 (4,149)
7	Crib (open) (n=7)	20,300 (14,247)	N/A	N/A	20,300 (5,816)
8	Crib (closed) (n=10)	44,657 (37,922)	N/A	17,333 (3,333)	71,980 (20,993)
Total (n=350)		**33,061 (48,012)**	**27,042 (26,759)**	**37,144 (53,249)**	**34,996 (57,952)**

In order to facilitate a better comparison, the losses in storage in Table 10 were divided by the quantity stored in each storage facility to get the UGX loss per kilogramme of stored maize. The results are summarised in Table 11.

Table 11: Amount of maize lost in storage per kilogramme of maize stored

SN	STORAGE TYPE	Monetary Value Lost (UGX/KG)			
		Total	Iganga	Manafwa	Katakwi
1	Above the fire (n=2)	0.25 (0)	N/A	N/A	0.25 (0)
2	House corner (n=52)	0.18 (0.23)	0.13 (0.052)	0.13 (0.045)	0.38 (0.174)
3	House roof (n=2)	0.03 (0.014)	0.02 (0)	N/A	0.04 (0)
4	Sacks(n=224)	0.16 (0.20)	0.16 (0.023)	0.132 (0.020)	0.20 (0.031)
5	Basket (n=16)	1 (0)	N/A	N/A	1 (0)
6	Granary (n=33)	0.20 (0.222)	N/A	0.13 (0.056)	0.22 (0.052)
7	Crib (open) (n=7)	0.37 (0.381)	N/A	N/A	0.37 (0.156)
8	Crib (closed) (n=10)	0.19 (0.397)	N/A	0.01 (0.005)	0.38 (0.313)
Total (n=350)		**0.17 (0.219)**	**0.16 (0.197)**	**0.13 (0.160)**	**0.24 (0.271)**

Note: Standard deviations reported in brackets

Source: Authors' fieldwork

In Table 12, further analysis of the storage types 4 to 8 shows (F=3.22: F Prob=0.0027 <0.05). This means that there is no statistically significant difference between the means of the storage type and loss per kilogramme stored.

Table 12: Analysis of variance in storage and loss per kilogramme stored

SN	Storage Type	Loss Per Kg Stored	Anova
4	Sacks (n=224)	0.16 (0.20)	**F-Statistics= 3.22** **Prob>F=0.0027**
5	Basket (n=16)	1 (0)	
6	Granary (n=33)	0.20 (0.222)	
7	Crib (open) (n=7)	0.37 (0.381)	
8	Crib (closed) (n=10)	0.19 (0.397)	

Conclusion

The maize storage facilities used by rural smallholder farmers have not been adequately described in extant literature. This study contends that any effort to improve maize storage for rural smallholder farmers should start with understanding current rural smallholder maize storage practices. In this regard, the study is exploratory. Even so, there are some observations in the study that could guide a maize-storage improvement programme. The study found that the choice of storage type is gender-sensitive. Therefore, any maize-storage improvement programme needs to take this factor into consideration. It also found that farmers sometimes use multiple storage facilities and sometimes in sequence. The decision process used by farmers in choosing storage facilities used needs to be investigated and better understood. The advantages of using more than one type of storage and the sequence of use need to be analysed further. Of the current storage types, there may be an optimal sequence of use that could be established in a maize-storage improvement programme.

This study identifies three categories of costs of storage: acquisition costs, maintenance costs and the cost of loss in storage. In this categorisation, many storage costs were found that were not necessarily estimated in this study, such as drying, shelling, packing and transporting or loading to storage structures. Acquisition cost seems to be one of the main determinants of maize storage choice, which is predominantly the use of sacks, although there seem to be striking location differences. The ready availability of sacks also seems to be an important determinant of storage choice. Whether the prevalence of the use of sacks is a true reflection of preference for this storage type needs further investigation. This can be understood partially by investigating the factors considered by those rural smallholder farmers who used more than one storage type and their decision processes.

The patterns of storage types used in the different maize-producing areas suggest differences by location, which need further investigation. The results suggest that in the high maize-producing district farmers use fewer storage types (three) than in the low maize-producing districts (eight). Whether this is a function of storage costs needs to be better understood. The quantities stored by each storage type need to be better estimated than from farmer recall (perhaps by using measurement), and the comparison of quantities stored by each storage type needs to be made using statistically represented samples of the storage types. It should be noted that the study is indicative; therefore a study of each storage type with a representative sample needs to be carried out to allow more and better comparisons. This study established the prevalence of each storage type but ended up with smaller samples for the least-used storage type. In the proposed study, a cost-benefit analysis could also better inform the constraints faced by farmers in adopting new and/or improved storage methods.

Finally, since this article is exploratory, the results are indicative. It is, however, important that all storage cost be better estimated using measurement. This article provides a solid footing for how such a study could be structured and the important factors to consider, especially the storage types to target.

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