A PRACTICAL APPRAISAL OF ON-FARM STORAGE LOSSES AND LOSS ASSESSMENT METHODS IN MALAWI 1: THE SHIRE VALLEY AGRICULTURAL DEVELOPMENT AREA

by

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Abstract

This paper describes a survey of farm-level grain storage losses in Southern Malawi and the practical problems of such surveys. The limitations of two different loss-assessment methods are discussed with regard to observed discrepancies but it is concluded that losses in up to 10 months storage were 3% or less for maize and less than 2% for sorghum. Such losses demonstrate the suitability of the grain varieties stored in the area to conservation during the characteristic dry season. The considerable likelihood of greater losses with high-yielding but more susceptible varieties, if these were introduced to the area, is indicated.

Resumé

Cet article décrit une étude des pertes subies pendant le stockage des grains, au niveau des exploitations agricoles au sud du Malawi, ainsi que les problèmes pratiques posés par de telles études. Les limitations imposées par deux méthodes différentes d'évaluation des pertes sont examinées du point de vue des écarts observés; l'on conclut toutefois que les pertes subies pendant une période de stockage allant jusqu'à 10 mois, s'élèvent à 3% ou moins dans le cas du maïs et à moins de 2% dans le cas du sorgho. De telles pertes démontrent la convenance des variétés de grains entreposés dans la zone de conservation pendant la saison sèche caractéristique. La forte probabilité que des pertes plus importantes interviendraient si des variétés à haut rendement mais plus délicates étaient introduites dans cette région est également examinée.

Resumen

En este artículo se describe un estudio realizado sobre las pérdidas ocurridas durante el almacenaje de grano a nivel de granja en la región meridional de Malawi, así como los problemas prácticos que presentan dichos estudios. Se analizan las limitaciones que ofrecen dos métodos distintos de evaluación de pérdidas con respecto a las discrepancias observadas y se llega a la conclusión de que las pérdidas sufridas en un almacenaje de hasta 10 meses de duración fueron de un 3% o de menos para el maíz y de menos de un 2% para el sorgo. Tales pérdidas demuestran la apropiabilidad de las variedades de grano almacenadas en la zona para ser conservadas durante la temporada árida característica. Se indican las considerables probabilidades de que se produzcan pérdidas mayores con variedades de grano más productivas pero también más susceptibles al ataque, si éstas fueran introducidas en la región.

Introduction

This paper describes a survey of farm level grain storage losses carried out in fifty-four villages in the Shire Valley Agricultural Development Project area in Southern Malawi. The survey was undertaken over 10 months in order to assess the losses sustained by farmers who stored maize or sorghum for their own consumption. A further aim was to test published methodologies (Harris & Lindblad, 1979) and assess the practical problems of undertaking such a survey.

The Shire Valley Agricultural Development Project (SVADP) area

This agricultural development area is situated in the extreme south of Malawi. It is approximately 250 km long and from 15 km to 120 km wide. It is bordered on the east by the Thyolo Escarpment and the Shire River; on the west

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by the Marangwe and Matundwe hill ranges. The Shire River bisects the valley eventually feeding the Zambezi River some 40 km south of the Mozambique border. The valley plain is 55 – 150 metres above sea level whereas some of the hill areas in the west, which are part of the SVADP area, rise to 600 metres.

The SVADP plain is much lower and therefore much hotter and drier than the rest of Malawi. For example Ngabu, which is 122 metres above sea level, has only 68cm of rain each year and a mean maximum temperature above 33^{0}C for eight months each year. The east bank area and the hilly regions have higher rainfall and the hill areas are relatively cool.

Food production and storage in the SVADP area

Maize is the preferred staple food of the population but the crop often fails because of a poor rainfall pattern. In the highland areas of the west and north, and on the east bank, maize is cultivated successfully but the main staple on the valley floor is sorghum. Bullrush millet is cultivated as a secondary staple by most farmers. Other food crops grown include groundnuts, finger millet, cassava, pigeon peas and sweet potato; all being cultivated in small quantities in different localities.

There are two types of maize storage structure in the area. Most farmers in the highlands and on the east bank use the traditional Malawian cylindrical basket, the *nkhokwe* (Figure 1). On the valley floor farmers utilise their rectangular cotton store, the *tchete* (Figure 2), for storing maize. Sorghum is stored for several months after harvest on a platform, either inside or outside the house. It is then threshed and the grain put into a tightly woven spherical basket, the *chikwa,* and stored in the house.

The survey sample

The SVADP is subdivided into six administrative areas, each comprising a number of units. After excluding units with low population density, or low maize production, two villages and five farmers from each village were selected from the remaining 27 units by stratified random sampling. Farms that were extremely inaccessible were also excluded. All the randomly selected farmers, including two in each unit selected as reserves, were forewarned of the survey. Nevertheless, many could not be found on the appointed day so that additional substitutes had to be selected at the time of the visit. About 40% of the original random sample was affected in this way.

Survey procedure

Adams (1977) showed that when making assessments of total storage losses at the farm level it is necessary to relate losses calculated from grain samples to the quantities of grain originally stored and the pattern of grain consumption. In the ideal situation grain would be weighed into and out of the selected stores and samples would be collected from the quantities of grain actually removed. In this survey that ideal could not be realised and estimates of grain quantities had to be made.

At the first visit, made soon after the stores were filled, the amount of produce which had been put into the store by the farmer was calculated from the dimensions of the store and the height occupied by the produce. The total volume of the produce was expressed as the number of baskets it would occupy by dividing the volume by the capacity of the farmer's basket. Each farmer was instructed to use the same basket all the time for removing food from the store and to fill the basket in a standardised way. The basket was regarded as a specific standard measure for each individual, not for all the farmers as a group.

Extension staff from the SVADP made further visits, whilst grain remained in the store, to question the farmers about grain utilisation. Although these visits were planned to occur every four weeks, this was not always possible; sometimes there were only two weeks between visits and at other times as much as nine or ten weeks. Consequently, farmers were often uncertain about the number of baskets of grain they had taken from the store in any particular period, so that information obtained from the farmer on consumption patterns was subject to substantial error. However, it was possible to estimate the quantity remaining at any particular visit and to estimate the losses sustained up to that point.

Collection of grain samples

At each visit the extension officer collected samples of grain from the store for analysis. Originally it was proposed that from each farmer the following samples would be collected at every visit until the grain stores had been depleted:

10 maize cobs or 1 kg shelled maize;
10 sorghum panicles or 1 kg threshed sorghum.

Fig 1. A traditional Malawian storage basket, or ***nkhokwe.***

Photo: TPI

Fig 2. A Malawian cotton store, or *tchete.*

Photo: TPI

For each commodity collected the farmer would in return receive 1 kg of uninfested shelled maize. Thus a farmer providing samples of both commodities would receive 2 kg of maize; while a farmer providing only sorghum would receive 1 kg shelled maize.

After the first week of the survey, when many samples had been analysed, it became apparent that 1 kg of shelled maize was less than the quantity of grain being taken in the 10 cob sample, since 10 cobs shelled out to between 1200 g and 1400 g of grain. Thereafter, only 8 cobs were collected. Sorghum panicles varied greatly in size, but all the samples weighed less than 1,000 g and any differences were ignored during the collections. Most farmers were happy to receive maize in exchange for either of their commodities, and did not raise objections to the quantity they received. This was apparent even when 10 cobs were collected and was probably due to the excellent condition of the shelled grain they were given. Indeed, some farmers wanted to retain this grain for seed. A few farmers would have preferred to receive sorghum in exchange for their sorghum panicles and in one instance the farmer refused to participate for that reason.

Sample analysis

It was established that the primary cause of insect damage was *Sitophilus* species and two methods of analysis were chosen as suitable for assessing the consequent losses. The standard volume weight (SVW) method measures the reduction of dry weight in a standard volume of sieved grain as compared with the dry weight of the same volume of an undamaged reference sample at the same moisture content. The second method estimates the mean weight loss per damaged grain from the numbers and weights of damaged and undamaged grains in individual samples. Both methods are described in detail by Adams and Harman (1977) who compared, under relatively controlled conditions, various methods of estimating losses. In the present survey the two methods were tested under less controlled conditions using samples obtained from different part of the survey area.

Evaluation of the SVW method

Adams and Harman (1977), in Zambia, found that this method gave the best estimate of loss. They showed that the dry weight of a standard volume (DSVW) of undamaged maize was linearly related to the moisture content. The loss of weight of any damaged sample was then calculated by comparing its DSVW to that of an undamaged sample at the same moisture content. For the two maize varieties which Adams and Harman investigated the estimates were found to be most reliable for the variety that was most uniform in grain shape and size.

In the SVADP the maize stored is very heterogenous. The cultivation of a number of different maize varieties has produced hybrids with grain of widely different shapes, sizes and densities. Consequently, when the base line determinations for the SVW method were carried out on a selection of samples of undamaged grain the relationships between moisture content and SVW were very variable. This variability was demonstrated in samples collected from five different areas (Table 1).

Table 1. The Standard Volume Weight of some samples of uninfested local maize.

Moisture content %	SVW (Mean of 10 readings ± SE)
14.1	432.1 ± 5.5
14.1	460.6 ± 2.1
14.6	445.3 ± 5.4
15.1	445.1 ± 1.5
15.8	435.7 ± 5.5

Moisture increase in any particular grain sample, other than very dry grain, will reduce the SVW because the density of water is less than that of the grain; but the variation in the data obtained (Table 1) was so great that this trend was not apparent. Moreover, samples at the same moisture content had very different SVW values. These inconsistencies, due to grain heterogeneity, were a major constraint in using the SVW method for determining losses in this project. To obtain completely consistent results it would have been necessary to have a prepared baseline SVW for each individual store. This was impracticable in this survey and may be so in others because the necessary manpower and facilities are not often available. However, despite the overall variation in SVW it was assumed that the variation in the maize from an individual farmer would not be great. Thus if dry weight SVWs (DSVWs) from each individual store were all compared with the same initial DSVW for an aggregate sample of undamaged grain, it was expected that any substantial weight losses would be revealed and any pattern of increasing weight loss, with time, should become apparent.

In practice it was found that there was an obvious difference, in many cases, between the loss found in samples collected at the start of the survey and that found in samples collected after several months. However, the general month to month variations in the measurements were so large, particularly in the first six months of storage in the dry season when the losses were low, that the loss between one month and the next could not be differentiated. An example of the variation is shown in the data collected from one farmer and summarized in Table 2.

Table 2. Standard Volume Weight analyses on samples of maize from one farmer.

Date of sample collection	m.c. %	DSVW of undamaged reference maize at specified m.c.	Measured DSVW of farmers sample	% Weight loss in sample
13.6.78	13.7	386	382	1.0
15.7.78	12.9	391	377	3.6
9.8.78	11.8	398	401	– 0.8
12.9.78	11.6	399	385	3.5
24.10.78	12.0	397	385	3.0
6.11.78	11.7	399	374	6.3

Comparisons between the SVW method and the "count and weigh" method

Adams and Harman found the "count and weigh" method was particularly susceptible to error where the losses were low. This method does not take into account losses due to internal damage that is not yet apparent as emergence holes or larval tunnels, nor does it allow for preferential infestation of large grains. To compare the methods, using maize from the SVADP, five samples of maize from different areas were put into uncovered containers and left for 5 months. Each sample was then divided into a "damaged" fraction, which had visible insect damage, and an "undamaged" fraction, with no apparent signs of insect damage. The grains in each fraction were counted and weighed and the percentage weight loss was calculated. The DSVWs of the undamaged fractions were measured and then damaged and undamaged were recombined. The DSVWs of the recombined samples were then measured and the weight loss recalculated. (Table 3). As expected, the "count and weigh" method consistently showed lower losses than the SVW method.

Table 3. The weight loss in five samples of maize stored for five months, analysed by different methods.

Sample No.	Percentage loss of weight	
	Calculated using SVW	Calculated by counting and weighing grains
1	1.0	0.3
2	4.3	– 0.3
3	3.2	0.9
4	1.7	1.5
5	11.1	7.4

At the end of the survey a comparison was made between the loss measured by the SVW method and that calculated from the count and weigh method for each maize sample collected (260 in all). A statistical analysis, using a paired sample t-test, showed a mean difference of 2.53% between the two methods, with the SVW method giving significantly higher estimates, at $P<0.01$, with a standard error of differences of 0.239.

In the assessment of losses in stored sorghum it was not possible to use the SVW method because grain heterogeneity was too great.

Computation of cumulative losses

At each monthly visit the farmer was asked whether his wife had discarded any of the food removed from the nkhokwe. Badly discoloured grain and grain producing noxious odours was not eaten by the farmer but was fed to his livestock, used for making beer or thrown away. Much of this type of damage is caused by fungal infestation and although it was not analysed in the laboratory the discarded grain was taken into account as fungal damage in the estimation of losses.

Cumulative losses due to insect damage were calculated by applying the loss in the sample to the quantity of food removed from the store between each visit by the extension officer. From the sample collected the weight loss was determined as described above. This value was then used to calculate the quantity of food that had been lost since the previous visit. This method of computing cumulative loss gives an overestimate but, as the calculated losses were in any case small, the error was considered unimportant. The quantity lost, together with the amount discarded by the farmer's wife, was then expressed as a percentage of the original content of the store. The cumulative total of loss was recorded after each visit. A hypothetical example of the computation is given below.

Example

At the initial visit the farmer has in his store the equivalent of

50 baskets of cobs.

After 4 weeks, 5 baskets full were removed from the nkhokwe; the sample collected indicated 1% loss of grain.

Therefore the quantity lost from the cobs removed is equivalent to:	<u>0.05</u> baskets of cobs

After 8 weeks another 15 baskets full were removed; the sample collected indicated 5% loss of grain.

Therefore the quantity lost from the cobs removed is equivalent to:	<u>0.75</u> baskets of cobs

After 12 weeks another 10 baskets full were removed; the sample collected indicated 10% loss of grain.

Therefore the quantity lost from the cobs removed is equivalent to:	<u>1.00</u> basket of cobs

After 16 weeks the remaining 20 baskets full were removed; the final sample collected indicated a 15% loss of grain.

Therefore the quantity lost from the cobs removed is equivalent to:	<u>3.00</u> baskets of cobs
Thus over the whole period of storage the total loss was equivalent to:	<u>4.8</u> baskets

This represents 9.6% of the original quantity of grain put into the store.

No quantitative attempt was made to assess rodent losses, but any evident signs of rodent damage were recorded during the laboratory examination of each sample of cobs. In general there was very little sign of any such damage.

Interpretation of the observed losses

Maize In the season in which the survey was carried out 70% of the farmers stored less than 30 bags of cobs, equivalent to less than 12 bags of grain. An average sized family in the Shire Valley, with 3 adults and 3 children, requires at least 16 bags of grain for self-sufficiency; so most families could be expected to use up their stored grain well before the next crop was harvested. The farmer would then have to purchase food from the marketing board. By the onset of the rains in late November, at most 36 weeks after harvest, more than 75% of the farmers had consumed their total maize crop.

Damage by insect pests to stored produce in Malawi occurs predominantly in periods of high ambient relative humidity, that is during the rainy season. From harvest in April through to November the relative humidity in the Shire Valley is mostly below 50%, which is much lower than the optimum conditions for insect development. Thus, in this period, damage to the maize was very low and since most farmers did not store grain beyond the dry season they did not lose very much during storage. Even the farmers who stored maize through the rains had very little left in their stores during the rainy season. The grain remaining in the store was subjected to up to 10% loss but it represented only a small proportion of the total crop put into the store after harvest. The overall loss therefore remained at a low level.

The mean loss of maize sustained by all farmers in the SVADP was 3.2 ± 3.4% (SD) calculated by the SVW method and 1.8 ± 3.5% (SD) calculated by the count and weigh method (Table 4). The losses calculated by the SVW method, although significantly higher than those calculated by the "count and weigh" method, were nevertheless low; the maximum being less than 5%.

Table 4. The loss in weight of maize at the end of storage in each area

Area	No. of farmers	Percentage weight loss (Mean ± SD)	
		SVW Method	"Count and weigh" method
1	23	2.5 ± 2.2	1.3 ± 1.8
2	12	2.1 ± 1.6	0.7 ± 1.0
3	17	3.8 ± 5.5	2.4 ± 5.1
4	8	3.6 ± 2.6	1.8 ± 2.6
5	4	4.3 ± 3.0	1.5 ± 2.1
6	8	4.8 ± 6.0	4.0 ± 6.8

Table 5. Loss of maize related to length of storage period

Storage period (weeks)	Observations*	Percentage loss from grain consumed (Mean ± SD)	
		SVW method	"Count and weigh" method
10 – 20	56	1.4 ± 2.6	0.7 ± 1.9
21 – 24	27	3.3 ± 4.6	2.2 ± 4.4
25 – 29	31	3.1 ± 3.1	1.6 ± 2.9
30 – 34	18	2.3 ± 1.1	1.0 ± 1.1
35 – 39	7	1.3 ± 1.5	1.1 ± 1.1
40 +	9	1.7 ± 2.0	1.7 ± 2.5

*The number of observations made on all samples up to the period indicated.

With these low levels of loss there was no correlation between loss magnitude and the length of storage (Table 5) and there was no significant difference between the loss calculated up to 24 weeks storage and that sustained by farmers who stored for 40 weeks. Even the onset of the rains had no apparent effect on the losses, probably because very few farmers stored grain for more than 1 – 2 months into the rainy season.

Sorghum The crop was harvested in April and May. After harvest most farmers, as usual, left the panicles outside their houses on raised wooden platforms to dry and, in this case, to await the end of the cotton harvest in June and July. Thus the sorghum was stored for 2 – 3 months unthreshed. After threshing the grain was stored in tightly woven grass baskets inside the house.

Nearly 70% of all farmers storing sorghum had less than 5 bags of sorghum grain after threshing. Almost all the farmers had consumed this before the onset of the rains. Consequently, sorghum suffered very little damage, the mean loss being 1.7 ± 0.5% (SD). Table 6 shows, by area, the losses sustained. The loss was low in all areas and, as with maize, showed little correlation with storage period (Table 7) and no significant differences between the periods shown.

Table 6. The loss in weight of sorghum at the end of storage in each area

Area	No. of farmers	Percentage weight loss (Mean ± SD)
1	12	1.2 ± 1.9
2	14	1.7 ± 2.2
3	19	1.2 ± 1.0
4	7	0.3 ± 0.7
5	13	2.1 ± 4.5
6	15	3.4 ± 4.6

Table 7. Loss of sorghum related to length of storage period.

Duration of storage (weeks)	Number of samples stored and analysed	Percentage loss of food consumed (mean ± SD)
9 – 13	55	0.4 ± 0.8
14 – 20	32	1.7 ± 3.1
21 – 24	25	2.0 ± 3.7
25 – 29	16	2.4 ± 4.2
30 – 34	12	1.9 ± 2.0
35 +	7	1.5 ± 0.7

Conclusions

This extensive survey encountered many practical problems not allowed for in the currently recommended methodology. Many of these problems were of an administrative nature; for example, the timing of sample collections and the arrangements for transport to visit farmers. These were solved at the time they arose. Other problems, such as choosing the farmers and training local extension staff, could have been solved more effectively if more time had been available to plan and execute the survey. However, when undertaking such surveys many problems will arise, no matter how comprehensively the survey is planned, and provision must be made for adaptation.

The variability in sample collection, loss analysis and information obtained from the farmers was very difficult to control. Both Harris & Lindblad (1979) and Adams and Harman (1977) underemphasise the practical problems that occur when carrying out a loss assessment survey. Storage at the farm level is a dynamic system involving continual movement of food from the store in which there is a changing pest population. The inherent problems in quantifying such a system, compounded with the difficulties due to memory recall on the part of the farmer, can cause significant error in the quantification of loss. This error can only be minimised when studies are undertaken in the controlled environment of research experiments.

Because of the heterogenous nature of the grain stored in the SVADP there were discrepancies between the laboratory methods of estimating loss. The SVW method consistently gave higher estimates of loss than the method involving the counting and weighing of damaged and undamaged grains, especially where the losses were relatively low. However, where the grain is heterogeneous both methods should be used if time allows and the results of both methods should be stated.

The losses sustained by farmers storing maize and sorghum in the SVADP were very low. Unless grain were to be stored throughout the rainy season, when insect damage would increase more rapidly, it would be uneconomic for farmers to treat their produce with a synthetic insecticide. A bag of maize cobs that lost only 3% by weight would also lose 3% in value. To control insect infestation, at least 40g of 2% pirimiphos methyl would be needed for each bag of cobs. This would cost 4% of the cob value and would not completely eliminate the infestation or the damage.

Local maize and sorghum varieties grown by the farmers are relatively resistant to insect infestation. The grains are protected against insect infestation by husks that are typically well developed and tight-fitting. Such husks are a feature of the local maize varieties grown extensively in the SVADP and elsewhere in Malawi. The grains themselves, which are of the semi-flint type, are also relatively resistant to insect damage. The widespread introduction of high yielding susceptible varieties could result in dramatic increases in loss. Consequently, it would be important to monitor the position and to use loss assessment to determine the point at which it would be necessary to treat stored grain with insecticide to reduce losses to an economic level. Even the introduction of new varieties alongside the local ones could lead to problems, because hybrids lacking the desirable inherent resistance of the local variety will inevitably appear.

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