

A GUIDE TO THE OBJECTIVE AND RELIABLE ESTIMATION OF FOOD LOSSES IN SMALL SCALE FARMER STORAGE

by

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Abstract

Losses in storage are of different types and the ultimate use of any estimates must be considered when conducting loss assessments. Selection of areas, farmers, and grain samples should be made using standard procedures. The grain sample may be analysed using several alternative methods to yield an estimate of loss within the sample. This information is then combined with data on consumption to produce an estimate of total loss for a storage season. The main causes of loss are insect and vertebrate pests, and fungi. The guide is based mainly on experience with maize in Africa.

Résumé

Les pertes en cours de stockage sont de différents types, et il faut considérer l'emploi final de toute estimation lorsqu'on procède à des évaluations de pertes. Le choix des terrains, des cultivateurs et des échantillons de céréales doit être fait suivant des procédures normalisées. On peut analyser l'échantillon de grain en utilisant plusieurs méthodes, en alternative, pour obtenir une estimation de la perte dans l'ensemble de l'échantillon. On combine ensuite cette information avec des données sur la consommation, pour avoir une estimation de la perte totale pour une saison de stockage. Les principales causes de perte sont les ravageurs (insectes et vertébrés) et les champignons. Le guide est principalement basé sur l'expérience du maïs en Afrique.

Resumen

Las pérdidas durante el almacenamiento son de diferentes tipos, y la utilización última de cualquier estimación debe tenerse en cuenta cuando se llevan a cabo las evaluaciones de pérdidas. La selección de zonas, agricultores y muestras de grano debe realizarse utilizando procedimientos estandar. La muestra de grano debe analizarse utilizando varios métodos alternativos para producir una estimación de pérdidas dentro de la muestra. Esta información se combina luego con datos sobre consumo para producir una estimación total de pérdidas durante la época de almacenamiento. Las principales causas de pérdidas son las plagas de insectos y vertebrados y los hongos. La guía se basa principalmente en experiencias sobre maíz en Africa.

Objective

Before any attempt is made to assess losses, the purpose and extent of the exercise must be clearly defined. Thus it must be decided what area of the country is to be covered, what commodities are to be included and what degree of accuracy is necessary to meet the objective.

A primary purpose for estimating food losses during storage with a fair degree of accuracy, rather than making subjective estimates or guesses at them, will be to get reliable figures of the economic and nutritional wastage being sustained and to be able to assess the economic worthwhileness of possible improvement schemes. On the strength of this information such improvements may be allocated appropriate priority by the authority involved.

It is obvious, that, where food resources are limited, losses need to be reduced as effectively as possible, over the maximum possible area and at minimum cost. However, it can cost very large sums of money to mount extensive and detailed surveys, with measurements of loss to a high degree of accuracy, and it is important to decide in advance just how accurate the assessment needs to be for the purpose involved. In some instances all that may be necessary is to identify the order of magnitude and major cause of losses and to indicate the worst affected areas; this may be achievable quite quickly by the observation of an experienced investigator. But where reliable quantitative loss data is required, much more work over longer periods will be inevitable.

Nature of Losses

Losses may be of the following types:

Quantitative

This is a physical loss of substance (as shown by reduction of weight or volume) and is the form of loss that can most readily be accounted for and valued.

Qualitative

This may be more difficult to measure and value. The existence of grading standards may, however, enable values to be placed on certain aspects of quality.

Nutritional

This, in a sense, is the product of the quantitative and qualitative losses; but, more specifically, it is the loss in terms of nutritional value to the human population concerned, which, in turn will depend on the nutritional status of that population.

Seed

This relates to loss in seed germination which is important for its effect on future food supplies.

There are other categories of loss which are applicable in commerce, but these are not included here as they do not have much bearing on the farm level situation.

Farmer Practices

In assessing losses it will often be a parallel aim to suggest what improvements could be made and how might they be achieved. The key to this is keen observation. What do the farmers do and why? Why is loss permitted by the farmer? Is it because of:

- a. ignorance of loss
- b. awareness of loss but acceptance of it as inevitable
- c. concern but ignorance of what can be done
- d. concern but acceptance of loss despite control measures

Any improvements must relate to the farmer's practices and attitudes. Such observation is basic to the field survey which is the heart of any loss assessment project.

Preliminary Field Survey

A preliminary survey should be made throughout the (total) area to be covered and this should seek to determine the storage pattern and methods present, identify any localised traits or significant climatic differences and arrive at an appropriate sub-division of the area into reasonably homogeneous sub-areas that can subsequently be studied on a sample basis. The survey is best undertaken at a time when there is still grain in store and when damage is most likely to be found eg following a period when the temperature and humidity have been high. Normally the preliminary field survey would be quite brief with a few days being spent in each of the sub-areas which are likely to be selected. The boundaries of the sub-areas must then be defined and any maps, aerial photographs or lists of the population of the area obtained where possible. Valuable background information about population and its distribution may be obtained cheaply by collaboration with census organisations.

Sampling of Farmers

Within the defined sub-areas it is necessary to select farmers whose stores can be sampled regularly throughout the season. Selection may be made on a completely random basis or by choosing the first farmer at random and the rest at regular intervals. Alternatively farmers may be placed in categories, such as size of farm, and selected randomly within these categories. This is known as stratified random sampling and the number of farmers sampled in each category should be in the same ratio as the total number of farmers in the area within each category.

Choice of the farmers may be made using lists either completely at random or by a regular pattern eg every fifth farmer. If a farmer is not available the next one on the list is taken. This can create a problem of excessive travelling between farms when farmers are unavailable. Another method which avoids this problem is to use a grid such as a latin square design and superimpose this on to a map or aerial photograph. The grid should be of a suitable size as selection will be of one farm in a square and of

only a certain number of squares. De Lima (1973) used a 7 x 7 Latin square numbered 1A, 1B ... 1G to 7A 7G; in area 1 he took 1A ... 1G as the sampling squares and the first farm in each chosen square. For area 2 7 he repeated the process. Where more farmers than 7 were needed he moved to 2A etc, in the same area. If a farmer was unavailable he chose the adjacent farm.

Questionnaire

The selected farmers are visited prior to storage and details of their stores and other relevant background information collected on a questionnaire. The problems of using a questionnaire are discussed by Zarkovitch (1965, 1966). It is important at this stage to test the farmers' acceptance of the next stage in the project, sampling of the store.

Sampling

Method

The weight of grain entering the store should be recorded as accurately as possible and the first samples taken at random as the grain is placed in store. These are used to establish reliable baseline data concerning moisture content, damage and bushel weight. If maize is stored on the cob a large random sample of cobs should be taken, weighed, shelled and reweighed to enable the weight of cobs stored to be converted into an equivalent weight of shelled grain. All future recording should be done using shelled grain.

Any treatment or selection of the crop eg rejection of mould damaged grains as it passes into store should be recorded as this may influence the effect of future improvements.

Frequency

Samples of grain should be taken regularly so that an accurate estimate of losses may be obtained; monthly sampling should be sufficient in most cases. In addition a record needs to be kept of the pattern of grain removal from the store and its use between sampling dates. The latter information is needed for any economic evaluation of loss.

If sampling is done regularly and consumption is also regular, samples need only be taken as if for consumption, that is from that part of the store where the next removal would be made. However if an overall picture of loss within the store at each time interval is required then the store will have to be sampled systematically at various points as the loss may not be uniform throughout it. This may apply where the crop is stored without disturbance and all is removed at one time. The disadvantage of this method is that disturbance during sampling may upset the natural progression of loss. If seed grain is normally kept separately a small random sample should be removed sufficient to carry out a germination test. It is important to replace any seed taken either in kind or with money.

Size

The sample size should be approximately 1-1.5 kg or its equivalent in maize cobs or sorghum heads etc. This will need to be reduced into subsamples before analysis using a recognised method such as a sample divider or by coning and quartering (Golob, 1976).

In some cases the size of the sample taken may have to be reduced in relation to the amount in store, eg small amounts from valuable seed reserves. Where the grains are mixed it will be difficult to sample but an approximate representation of the mixture should be obtained. As the seasonal effects on loss are important, records of the climate during the period of sampling should be kept and compared with other years.

Estimation of loss in a sample

On the Farm

After the sample is removed from the store the farmer or his wife should be asked to sort through it and set aside any grain that they would not consume as food. Any alternative use for such grain should be recorded and it should be kept for weighing since it will represent part of the loss in the sample. If the sample grain is on a cob, in a pod or on a panicle it should be shelled and the grains placed in a labelled plastic bag and sealed.

If analysis is likely to be delayed for more than a day or two samples should be fumigated by adding a small quantity of liquid fumigant such as carbon tetrachloride to the plastic bag in order to prevent an increase in damage through insect development. Such bags should not be opened for analysis in a

confined space and care should be taken that any gas remaining is not inhaled. Although a proper assessment of loss cannot be made without laboratory analysis, the visible damage in the sample will give an approximate indication of the severity of the loss.

Laboratory analysis

The basic requirements for sample analysis are bench facilities and equipment for weighing. Several methods can be used according to the type of damage and the level of accuracy required.

An accurate method for estimating weight loss is the use of the dry weight of a standard volume of sieved grain. This is done using a simple apparatus (Fig 1) and a balance. The moisture content of the grain must first be measured to convert the weight to dry weight. In doing this consideration needs to be given



Fig 1. Apparatus for obtaining a standard value of grain.

to the fact that the volume of grain, as well as its weight, is related to moisture content; in general the higher the moisture content the higher the volume and therefore the lower the dry weight of a fixed volume. To account for this at least a 5 kg sample of grain needs to be taken at the beginning of the storage period and divided into a number of subsamples each of which should be conditioned to a different moisture content within the range expected during the storage season. The dry weight of the standard volume of grain is then determined for each of these moisture contents. A graph is drawn of the dry weight against the moisture content. The equation for this graph can then be used to predict the dry weight of the

standard volume at any moisture content within the range. This is used as a baseline since it is the weight prior to any storage loss. To estimate the loss in a sample taken from the farmer's store the weight of the standard volume and its moisture content are measured. The dry weight of this volume is calculated and subtracted from the predicted baseline dry weight at the moisture content of the sample to obtain the loss in weight.

It is possible to improve on this estimate by incorporating other variables, such as insect damage, by using multiple regression analysis but this is outside the scope of this paper (Adams and Harman, 1976). This method has obvious disadvantages, such as the amount of preliminary work required, but the measurement of samples is very simple using a standard bulk density (bushel weight) apparatus, a balance, and a moisture meter. However the admixture of insecticidal dust with grain can increase the volume occupied by the grain mass. With an increase in the volume caused by dust sticking on the grain surface the bulk density will be reduced, leading to a possible over-estimation of losses.

A simpler method using only hand counting and a balance has been used by French workers (Anon 1969). The grain is separated into undamaged and damaged categories, the latter being subdivided according to cause. Grains in each category are counted and weighed, the resultant data being substituted in the formula below:-

$$\% \text{ Weight Loss} = \frac{(UNd) - (DNu)}{U(Nd + Nu)} \times 100$$

Where U is the weight of undamaged grains

Nu is the number " "

D is the weight of damaged grains

Nd is the number of " "

The disadvantages of this method become apparent at both low and very high levels of damage. Hidden infestation results in an underestimation of loss because grains that have lost weight are included as visibly undamaged. It also assumes that insects choose grains at random. Nevertheless with minimum apparatus at moderate infestation levels it will give a useful estimate.

A simple method of estimating weight loss, even in the absence of weighing facilities involves separating the sample into undamaged and damaged grains but only counting the grains in each.

Recent research in Zambia has suggested that for an infestation of maize by *Sitophilus zeamais* in which a few grains have more than one emergence hole, the percentage of damaged grains may be converted to percentage weight loss, multiplying by 0.12 (Adams & Harman 1976). However if a lot of grains with more than one emergence hole are present, the number of holes in 100 grains should be taken and multiplied by 0.12 to give an approximate answer. This will be approximate because there are many variables affecting the amount eaten by a developing weevil, but it is nevertheless a quick usable indication of weight loss.

To assess loss of quality it is best to use the local marketing organisation's acceptance standards relating to damaged grain and foreign matter but ignoring any moisture content limitations. These enable a known, locally decided value to be placed on loss in quality. If there are no such standards a set needs to be drawn up for use in the assessment, based on local experience. These should be objective and should not take account of the fact that people will accept poorer quality grain when supplies are low.

Losses in seed grain may be estimated using standard germination tests on samples drawn from the farmers seed (Int. Seed. Testing Assoc., 1966). The estimation of nutritional loss requires analysis of the grain for the particular nutrients that are of interest. In doing this weight losses must be taken into account since a comparison of 100 g of undamaged grain with 100 g of damaged grain will be misleading. This is because the damaged grain is equivalent to a greater weight of undamaged grain, that is the weight of the same number of grains prior to the occurrence of damage. Therefore the same number of undamaged and damaged grains should be compared rather than similar weights. Prior to analysis any grain that would be rejected by the farmer should be removed.

Estimation of total losses

In making such estimations it is important to relate losses to the pattern of grain consumption. If grain is left untouched throughout the storage period and at the time of removal the estimated loss is 10% then this represents the total loss over the storage period. However, in most cases grain is removed at intervals during the storage period and each quantity removed will have suffered a different degree of loss since it will have been exposed to deterioration for a different length of time. The total loss over the season can be obtained by accurately weighing all the grain in and out of the store and comparing the totals. This does not, however, indicate the relationship between loss and time, ie whether the loss reached a peak or whether it was related to a particular part of the season.

If an accurate measurement of the quantity removed is available then estimates from samples may serve to cross check with the total loss as well as showing the pattern of loss.

If, as often happens on subsistence farms, the amount removed is quoted in volume terms (eg tins), then the volume removed will be the same whether or not the grain is damaged but the weight will be different. In this case the weight of grain that occupies the farmer's measure should be recorded carefully at the beginning of the storage period. For each subsequent removal of grain this weight can be reduced by the percentage of loss estimated from the appropriate sample. If samples are taken at monthly intervals and the dates of removals are known, an approximation can be made by applying the estimated loss to removals two weeks either side of the sampling date. To obtain the total loss all the individual losses can be totalled.

Where the removals are roughly estimated the loss may be obtained by calculating the percentage of the total quantity stored which was removed at each sampling date and applying the percentage loss to this. The resulting losses are then summed to produce an overall percentage loss, as in Table 1 below.

Table 1 The relationship between weight loss and consumption

Months in store	1	2	3	4	5	6	7	8
Quantity removed %	10	10	10	10	10	10	15	25
% weight loss in sample	1	2	3	5	8	12	18	25
Weight loss as % of total stored	0.1	0.2	0.3	0.5	0.8	1.2	2.7	6.25
Cumulative weight loss as % of total	0.1	0.3	0.6	1.1	1.9	3.1	5.8	12.05

This loss of 12.05% compares with a loss of anything between 1 - 25% (as measured in month 8 above) if only a single final visit was made and there was no allowance made for consumption. This is shown by the accompanying two graphs (Fig 2). Line A represents a farmer who holds a quantity of grain in store for sale when the price is high and does not remove any until the date of sale, when the store is completely emptied. Line B represents a subsistence farmer who regularly removes grain from the store for family consumption. The total loss in weight suffered in case B is considerably reduced because a decreasing proportion of his total stored grain is exposed as the level of loss increases with time.

The same procedure may be adopted in relation to nutritional loss, bearing in mind that damage may cause greater losses in preparation of food where soaking of the grain is involved. It may also be used to evaluate quality loss in terms of money. For seed grain the loss is the drop in germination from the time of storage to the date the seed is required and is simply the difference between the percentage germination recorded on the two dates.

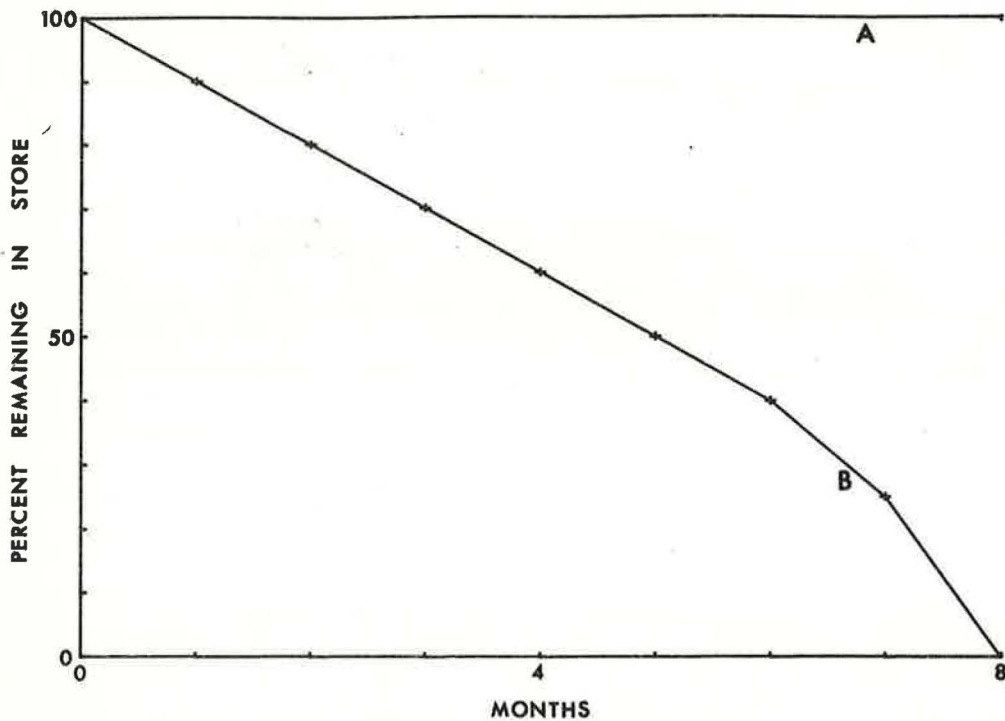
Losses caused by fungi

Although most of the previous sections were formulated with insect damage in mind the methods are equally applicable to fungal damage. A considerable proportion of the grain rejected by the farmer is often discarded because of mould and the presence of infected grain causes a drop in quality grading. Therefore the impact of fungal infection on loss can be estimated by including the separation of mould damage from other types of damage during the analysis. The hidden effects of mouldy grain that may be consumed are more difficult to assess because of the possible presence of toxins and the tendency for repeated consumption of infected grain to cause chronic illnesses. These will lead to a reduction in output by an affected person and may be likened to the effects of nutritional loss.

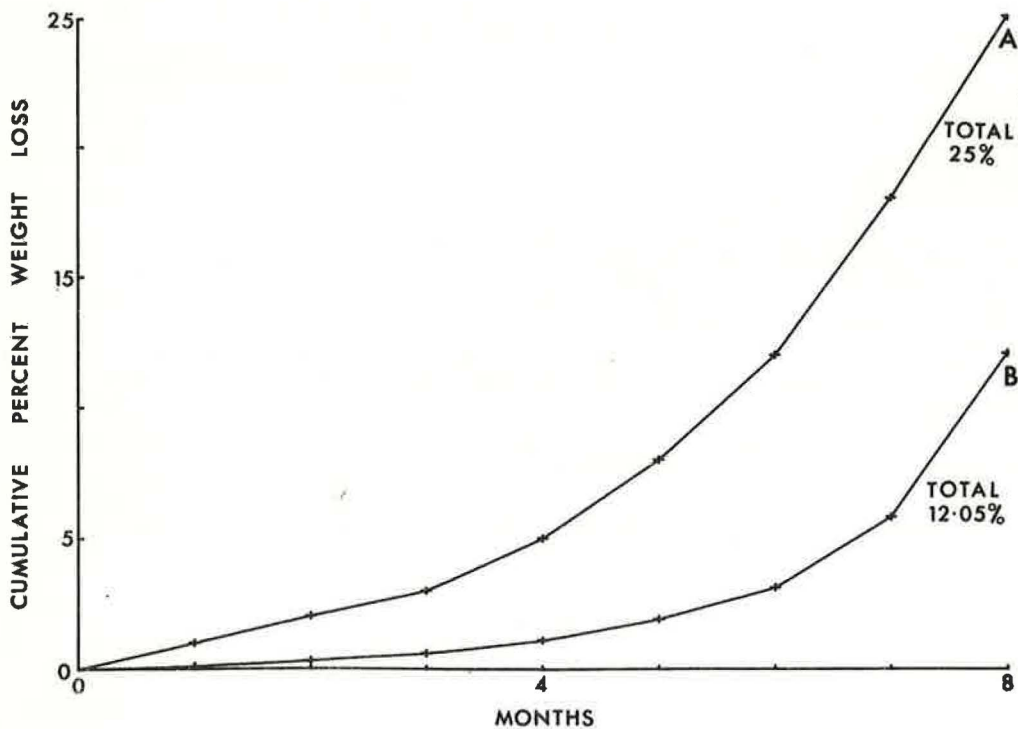
Losses caused by vertebrate pests

Losses caused by vertebrates such as rodents and birds are difficult to assess directly since many grains are completely removed from the store. The usual method of estimation is to blame vertebrate pests for all losses that cannot be accounted for in any other way. It is difficult to obtain an accurate estimate without accurate weighing of the grain throughout the season.

Fig 2. An example to show the effect of rate of consumption by the farmer on the cumulative weight loss of stored produce.



Graph A - A represents no consumption by the farmer during the storage period
 B represents the pattern of consumption shown in Table 1 (when all grain is used over 8 months)



Graph B - Demonstrates the result of the consumption pattern in Graph 1 on the cumulative weight % weight loss over 8 months. A - no consumption
 B - consumption as B in Graph 1

Another method is based upon an estimation of the pest population, usually by trapping methods. Consumption trials are then conducted with captured animals after the population study to obtain a figure for daily food intake. However, allowances need to be made in a situation in which the store is not the only source of food and also to account for the difference between unlimited food supply in the trial and foraging in the field situation.

Interpretation of results

It is clearly not possible to avoid a degree of approximation in a subsistence farmer situation unless it is possible to use enumerators within each village to physically check and weigh each removal of grain. In most cases, provided that the same method of estimation and similar approximations are used, the loss estimates will be comparable and will enable allocations of improvements to be made. The pattern of loss and any factors influencing this should also be recognisable. If testing of improvements with great accuracy is required then it will be necessary to carry out a trial using accurate weighing of quantities, replication and simulation of normal usage. The necessary data for this will need to cover the whole storage season and can be best obtained from the type of general losses survey described in a previous section.

With the interest that is now being shown in this problem it is hoped that a better interchange of ideas may take place leading to the adoption of improved methods and comparability of results on a world wide basis.

References

- ADAMS, J M and HARMAN, G W. 1976. The evaluation of losses in maize stored on a selection of small farms in two areas of Zambia, with particular reference to methodology. (To be published as a Tropical Products Institute G. Report).
- ANON, 1969. Rapport d'activite de la commission d'evaluation des pertes dans les denrees stockees crie a l'issue du Congress de Marseille sur la protection des cultures tropicales. *L'Agronomie Tropicale, Nogent* 24 (9) 872-876.
- DE LIMA, C P F. 1973. A technical report on twenty two grain storage projects at the subsistence farmer level in Kenya. Kenya Dept. of Agric. Proj/Res/AG21.
- GOLOB, P. 1976. Techniques of sampling bagged produce. *Tropical stored Products Information*, 31.
- INTERNATIONAL SEED TESTING ASSOCIATION. 1966. International rules for seed testing. *Proceedings International Seed Testing Association* 31 (1), 49-91.
- ZARKOVITCH, S. 1965. Sampling methods and censuses. Rome: United Nations, Food and Agricultural Organisation viii + 213 pp.
- ZARKOVITCH, S S. 1966. The quality of sample statistics. Rome: United Nations, Food and Agricultural Organisation xi + 395 pp.