APHLIS - AFRICAN POSTHARVEST LOSSES INFORMATION SYSTEM

- A TRANSNATIONAL NETWORK OF CEREAL GRAIN EXPERTS

How to assess postharvest cereal losses and their impact on grain supply: rapid weight loss estimation and the calculation of cumulative cereal losses with the support of APHLIS

Prepared by –
Rick Hodges
Natural Resources Institute
University of Greenwich
Chatham Maritime
Kent ME4 4TB
UK
e-mail: R.J.Hodges@gre.ac.uk

July 2013 (Version 1.1)

Federal Office for Agriculture and Food

European Commission

MARS Monitoring Agricultural ResourceS

UNIVERSITY of GREENWICH | Natural Resources Institute

Acknowledgements

Thanks are due to Charles Singano and Godfrey Kambale, postharvest scientists at the Chitedze Research Station in Malawi, Brighton Mvumi of the University of Zimbabwe, Felix Rembold from the European Commission (JRC) and Tanya Stathers (Natural Resources Institute, UK) for very careful appraisal of this manual and validation of certain aspects. Dr Bruno Tran (Natural Resources Institute, UK) kindly looked over the sections that relate to statistics. The example of the questionnaire in the Annex 1 was adapted from an actual questionnaire developed by Dr Tanya Stathers, and the cartoon illustrations appearing in the manual are taken with permission from the UN World Food Programme Training Manual on Postharvest Handling and Storage.

Rationale of the Manual

Postharvest loss assessment of cereal grains is a complex technical subject using approaches and methods devised mostly in the twenty-five year period since 1970. The subsequent development of the African Postharvest Losses Information System (APHLIS), launched in 2009, has brought rigorous knowledge management to cereal postharvest losses as well as new loss assessment tools that complement those already at the disposal of postharvest scientists. In essence, APHLIS takes emphasis way from loss estimates at single links in the postharvest chain, e.g. storage losses, harvesting losses etc., and allows a focus on the purpose of loss reduction which is to increase the supply of cereal grains along the value chains of Sub-Saharan Africa.

This manual puts APHLIS at the centre of an approach to loss assessment by offering stepwise instructions to postharvest scientists who wish to adopt a rapid, systematic approach to generating new loss estimates. Through APHLIS, new estimates can be used to update figures for cereal supply at geographical scales defined by the researcher, which may be local, provincial or even national.

Table of Contents

Overview of the manual

Cereal grains such as maize, rice, millet and sorghum are the main food staples of most countries in Sub-Saharan Africa (SSA). This manual is a unique resource helping postharvest specialists in SSA to make reliable assessments of cereal grain weight losses after harvest. The techniques described can be used to generate data for justifying loss reduction projects, for monitoring the success of such projects and, when combined with the APHLIS calculator, can be used to estimate changes in grain supply. These changes are determined by estimating a cumulative loss from cereal production figures. An increase in grain availability is the ultimate objective of loss reduction projects but in the past projects have usually neglected to demonstrate this explicitly. This no longer needs to be the case as for the first time tools to estimate grain supply due to changes in postharvest losses are available.

Reducing postharvest losses is a more resource-efficient way of increasing food availability than expanding grain production since it does not rely on yet greater use of agricultural inputs such as land, labour and fertiliser. Postharvest losses of cereal grains commence when they have reached physiological maturity in the field, i.e. when the grain production phase is complete. This is followed by a chain of postharvest activities from the field to the consumer. This chain has at least eight links from harvest to market place (Fig. 1). At each link, there are usually some dry matter weight losses when grain is scattered or spilt or as a result of grain becoming rotten or consumed by pests (a process called biodeterioration). The typical magnitudes of such losses are shown in Figure 1.

Harvesting/field drying	**4-8%**
Transport to homestead	**2-4%**
Drying	**1-2%**
Threshing/shelling	**1-3%**
Winnowing	**1-3%**
Farm storage	**2-5%**
Transport to market	**1-2%**
Market storage	**2-4%**
Cumulative loss from production	**10-23%**

Figure 1: Links in the postharvest chain for cereal grains in Sub-Saharan Africa, showing a typical range of weight losses

This manual describes techniques for estimating cereal grain weight losses with special emphasis on rapid methods that give a representative result. The text is a combination of specific instructions on 'how to do' and general principles that will enable users to plan their own loss assessment studies within the constraints of their own situations. But loss estimates at individual links in the chain are only part of the picture. The manual also introduces the cumulative loss calculator, downloadable from the African Postharvest Losses Information System (APHLIS) website www.aphlis.net, which can be used to estimate weight losses from cereal grain production taking into account the losses at all these links. By using this calculator the user can go beyond estimation of losses at one link in the postharvest chain and instead estimate changes in cereal grain supply, in other words changes in the actual amount of grain available for consumption. Users learn how to generate the kind of data that must be entered into the APHLIS calculator in order to make these estimations.

The estimation of postharvest weight loss is a time-consuming and expensive process. Consequently, it is generally not feasible to burden any one development project with measuring the losses at each and every link of the chain. If assessment of losses is to be used as a means of monitoring and/or evaluating a project then loss assessments at specific links in the chain, relevant to a project's own activities, are justified. However, the figures generated in this process, whilst of interest on their own, are more informative when shown as their impact on total cumulative loss from production, taking into account all significant links of the chain. So for example, a certain project by its training activities could achieve a reduction in harvesting loss from say 8% to 1%; a reduction of ⅞ths (= 87.5%). However, the figures by themselves do not give a clear picture of how this benefit increases grain availability (the purpose of loss reduction) unless the losses at other links in the chain are known and a cumulative loss from production is calculated.

The calculation becomes even more complex when there are changes in several links of the chain, if there is more than one season for a crop, and if both the weight loss estimates and production estimates differ between the various seasons within a year. It is in this situation that the APHLIS loss calculator can really help. It can be used to estimate cumulative weight losses from production at the user's choice of geographical scale. Furthermore, in the downloadable calculator the default loss value for each link in the postharvest chain (values are specific for crop, scale of farming and climate) can be altered to accommodate those generated by a research project or simply imagined as part of a modelling exercise to investigate the potential impacts of loss reduction.

The manual is arranged in four parts, as follows -

Part 1 provides a basic understanding of cereal postharvest losses and how APHLIS is a source of data on losses.

Part 2 deals with how to do a loss assessment study in the field and starts by considering how to plan a study with respect to timing, staffing, budgeting, and the equipment needed.

If loss assessment is to be undertaken with farming households then the best option is usually to engage in a full questionnaire survey followed by a series of visits to actually measure the losses. However, limitations on time and/or money may mean that either the survey is confined to measured loss assessment with relevant questions being asked during the measurement process or the process is confined to only a questionnaire survey.

Emphasis is placed on using rapid loss assessment methods and on the principles of how, when and where samples should be taken to obtain loss estimates that are representative of the target population. An explanation is given of how to prepare, test and implement a questionnaire survey and an example is given of a questionnaire (Annex 1). However, the more in-depth questioning required to uncover the likely reasons for losses and potential solutions to the specific loss problem are not included as these are likely to vary between different projects. The rapid methods to measure losses are visual scales which are backed up by a formal questionnaire survey or informal questioning. Finally, an example is given of data gathering for a loss assessment study. This is not a template for other loss studies but offers the reader some insights into how the problem could be approached, and includes the study rationale, data collection sheets, and budgeting.

Part 3 shows how the APHLIS downloadable calculator can be employed to make cumulative loss estimates from cereal production data, gathered according to the methods described in Parts 1 and 2, and how the calculator can benefit users' own investigation of postharvest losses.

Part 4 describes how new data should be submitted to APHLIS.

The process of implementing a loss study using this manual is summarised in the Figure 2.

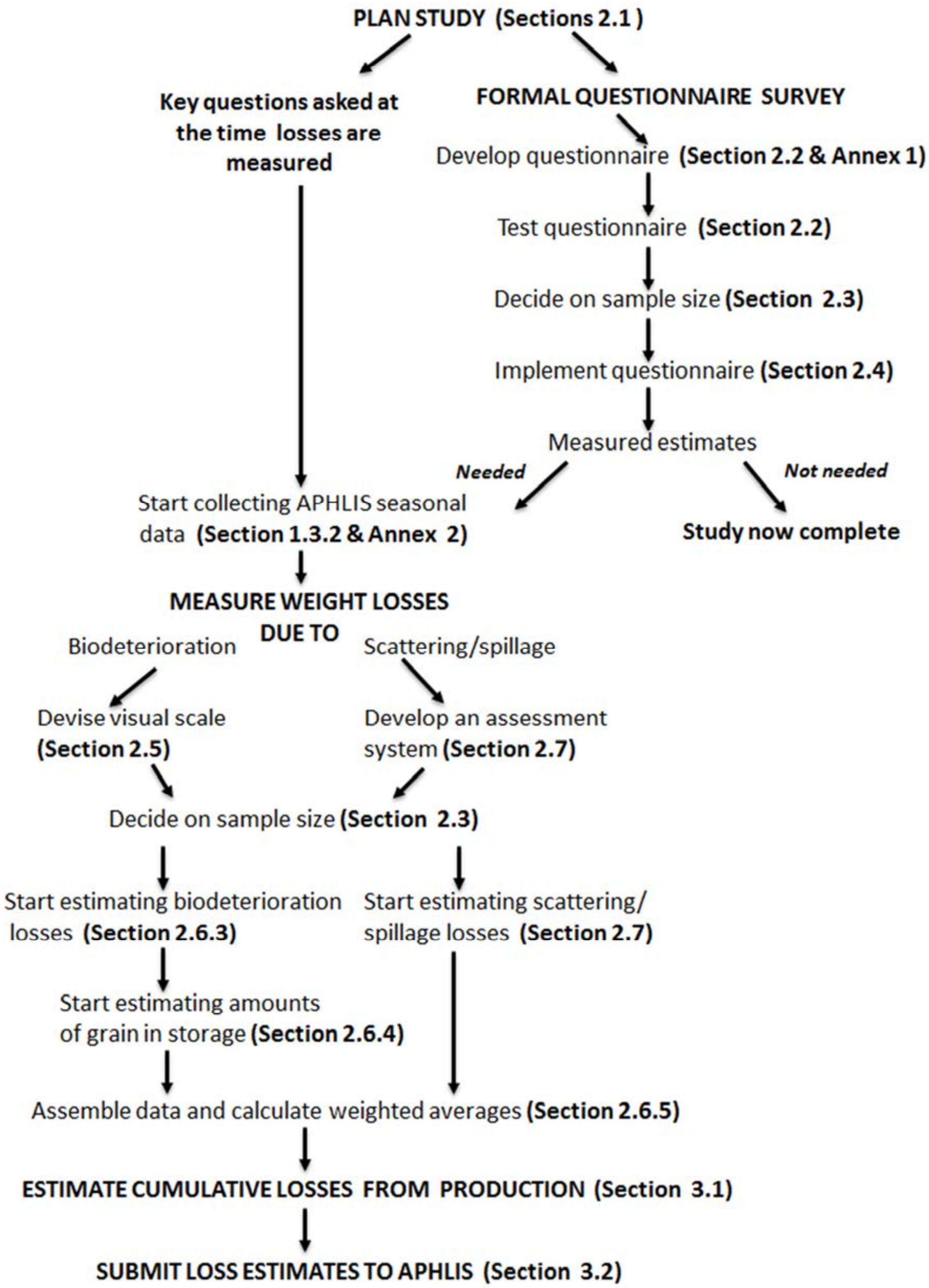


Figure 2: How to implement a loss assessment study using this manual

Glossary and Acronyms

APHLIS	The **A**frican **P**ost**h**arvest **L**osses **I**nformation **S**ystem - is a network of local postharvest experts supported by a database and loss calculator that provide cumulative cereal weight loss estimates from production for Sub-Saharan Africa by province, by country and by region. APHLIS was the initiative of the European Commission's Joint Research Centre and developed by the Natural Resources Institute (UK) and German Ministry of Food. APHLIS can be found at http://www.aphlis.net.
Conditioning (of grain)	Improving poor quality grain so that it will meet the requirements of a higher grade. Smallholder farmers normally do this by winnowing, sieving and handpicking while large-scale grain traders can do most of the job using machinery.
Cumulative loss	A loss value not from a single measurement but from multiple measurements, where at each measurement the previous loss has been taken into account. The most common example is where losses from production are estimated. With each subsequent loss the remaining production is smaller, consequently even if relative (%) weight losses remain the same the absolute losses (tonnages) diminish. A special case of this is farm storage losses where farmers are consuming grain during the season. Losses become greater with time so that each lot of grain that is consumed will have been subject to a different degree of loss. The cumulative storage loss is the weighted average of each loss measure not just the loss observed in the grain that remains at the end of the storage season.
Downloadable loss calculator	The same algorithm as used in to the web-based APHLIS loss calculator can be downloaded from the APHLIS website as an Excel spreadsheet. The User can work at any geographical scale, can alter the default values, and can make estimates of production if data on quantities of threshed grain are available.
eRAILS	The web based information system of the Forum for Agricultural Research in Africa (cf. FARA)
FARA	Forum for Agricultural Research in Africa, a body with regional responsibility for the co-ordination of agricultural research, based in Accra, Ghana.
Formal/informal grain market	A formal grain market is one that is subject to a specified grain standard and in which grain is traded and paid for according to one or more grades. Conversely, an informal grain market is one where grain is not traded at specific grades and there is no specific relationship between quality and price.
Grain standard	A grain standard defines the quality of grain traded in a formal market. Grain standards comprise a set of one or more grades that define the

maximum limits for impurities and imperfections (e.g. foreign matter, mouldy grain, discoloured grain etc.), the minimum limits of desirable qualities (e.g. test weight) and a maximum moisture content.

Loss calculator An algorithm at the heart of APHLIS that makes estimates of cumulative grain weight loss from production. (*cf.* Downloadable loss calculator).

Moisture content The moisture content of grain is a way of expressing how much water is contained within the grain. This usually expresses the weight of water as a proportion of the weight of the grain containing this water (wet weight) rather than the weight of water as a proportion of the weight of grain without water (dry weight). Moisture content is measured by drying the grain in an oven under carefully controlled conditions or, more conveniently, using an electrical meter.

PHL Postharvest loss, *cf.* weight loss and quality loss.

Postharvest loss profile A set of weight loss figures, for each link in the postharvest chain, that are used by the APHLIS loss calculator to make a cumulative weight loss estimate from production for a particular province (primary administrative unit) or in the APHLIS downloadable calculator a loss estimate at a user-defined geographical scale. The profile is specific to cereal type, scale of farming (smallholder/commercial) and climate.

Quality loss A reduction in the quality of food grain so that its market value is reduced. Quality is usually assessed using an official grading system that specifies the appearance, shape and size of grain as well as the proportion of broken grains and foreign matter. Nutritional loss is a component of quality loss but this type of loss requires specialist techniques to measure, i.e. is not measured by official grading, and may include the problem of mycotoxin contamination.

Seasonal factors The ‘seasonal factors’ in the APHLIS system are factors that modify the postharvest loss profile figures due to circumstances that may vary from year to year. Good examples of seasonal factors are rainfall/damp cloudy weather at harvest or attack by the Larger Grain Borer, a particularly destructive beetle pest of maize.

Shared database FARA’s (Forum for Agricultural Research in Africa) eRAILS project Phase II shared database (SDB) holds agricultural data. All APHLIS raw data is entered, stored in and read from the SDB while APHLIS focuses on data analysis. Nevertheless APHLIS is independent of the SDB, since all data relevant to APHLIS are replicated to the APHLIS database and stored permanently.

Shattering (of grain) The dispersal grain from seed heads, panicles or ears from physiological maturity onwards. The degree to which shattering occurs depends on the type of crop, the particular variety, timeliness and method of harvesting. Shattering results in dispersal and so a quantitative loss of grain.

SSA Sub-Saharan Africa –this consists of all African countries that are fully or partially located south of the Sahara. However, the United Nations definition excludes Sudan which for the purposes of this manual has been included.

Visual scale A rapid loss assessment technique that can be used to estimate weight and quality losses that arise from biodeterioration. A series of grain classes are established against which any grain sample can be compared and then classified. The classes usually have some meaning in terms of the end use of the grain, i.e. suitable for formal grain market, suitable only for informal market, suitable only for animal feed etc.

Weighted average The weighted average is similar to an arithmetic mean (the most common type of average), where instead of each of the data points contributing equally to the final average, some data points contribute more than others. The average annual % weight loss for a country is not the average of the % weight loss of each province but must take into account the different weight of grain lost in each province. For example if province A lost 10% of its grain and this weighed 500 tonnes, and province B lost 15% of its grain and this weighed 2000 tonnes, then the weighted average % loss would be (500x10) + (2000x15) /2500 = 14%. For another example see Table 2.6.

Weight loss Loss in weight from production due to poor postharvest handling or attack by moulds, insects pest etc.. Does not include weight changes due to change in moisture content. It is a measure of loss from the human food chain. May be presented as an absolute loss, e.g. as a tonnage of grain, or as a relative loss such as a percentage from production.

Well-being ranking Individual households within a farming community are diverse with respect to their relative wealth. As a result some households are better able than others to adopt improved postharvest practices that influence the losses that they may incur. Well-being ranking is a means of categorising households for the purposes of survey work so that when a survey is implemented it will include some households representing each category. In this way the survey results will be more representative of the population in the target area.

Part 1 - Introduction to cereal postharvest losses

This part of the manual introduces the subject of cereal grain postharvest weight losses in Sub-Saharan Africa (SSA). It explains the nature of these losses, describes the role of APHLIS in providing loss data, and suggests how to identify gaps in loss data that should be filled by further research.

1.1The importance of cereal losses

Losses of grain quantity (weight losses) and losses of grain quality both deprive the farmers of SSA of the benefits of their labours. The significance of grain losses has been reviewed recently in the 'Missing Food' report (World Bank, 2011). This report emphasises the importance of viewing cereal losses not just as a loss of food but as a loss of all the resources that go into creating food, i.e. labour, land, water, fertiliser, insecticide etc.. It suggests that the value of losses amounts to about US$4 billion for SSA, which exceeds the value of total food aid received by SSA in the decade 1998-2008, equates to the value of cereal imports to SSA in the period 2000-2007, and is equivalent to the annual calorific requirement of at least 48 million people.

This loss assessment manual deals mostly with estimating weight loss but a detailed report on the significance of quality losses, which may result in a failure to bring grain to market or a failure to sell grain in a higher value market, can be downloaded from APHLIS (Hodges, 2012). Weight loss is the standard international measure of grain loss because it is useful in quantifying the national impact of losses and for comparing losses across sites and years (De Lima, 1979a). Weight loss is easily understood as a loss of food, on the other hand quality loss often needs to be expressed in financial terms but this poses a problem because the relationship between quality and value may be difficult to determine, not least because it is subject to considerable seasonal and annual variation.

1.1.1 The meaning of cereal postharvest weight losses

Weight losses are normally expressed as loss in dry matter, i.e. this does not include any changes in weight due to changes in grain moisture content. The weight losses are estimated in two ways, 1) by collecting and weighing the grain excluded from the system, e.g. grain that is scattered or spilt at harvest, during threshing, transport etc., and 2) by determining what weight of grain remains after a postharvest activity, e.g. after farm storage where pests may have consumed some of the grain.

Only in extreme cases does APHLIS include loss of quality. If the quality for grain has declined to the extent that it is no longer fit for human consumption then it is considered to be a 100% weight loss (Fig. 1.1), even if this means that it is downgraded to animal feed for which the seller may still receive some, but diminished, financial reward. But grain subject to losses of quality or quantity may consequently be of lowered human nutritional value or present a health hazard, for example may be contaminated with mycotoxins, which are found especially on maize grown in more humid areas (Wagacha and Muthomi, 2008).

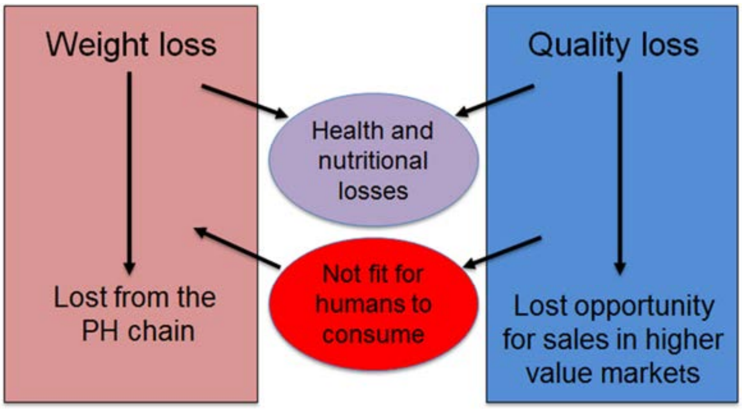


Figure 1.1: Relationship between losses of weight and losses of quality. If quality decline is extreme then food is not fit for human consumption (effectively a 100% weight loss).

1.1.2 Factors leading to grain weight loss

Two factors can lead to weight loss -

1) Grain being scattered or spilt during postharvest handling (harvesting, threshing, transport), and

2) Biodeterioration that results from the activities of mould, insects or rodents. The main organisms attacking grain during postharvest handling and storage are generally:

- arthropods (mostly insects such as beetles and moths but also sometimes mites)
- moulds, and
- vertebrates (mostly rodents such as rats and mice but sometimes birds)

Insects Moulds Rodents

Weight losses due to biodeterioration are exacerbated by -

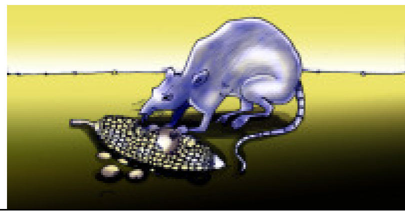
Mechanical damage during handling - Rough handling of grain results in grain breakage, this may happen at any point during postharvest handling and storage but is especially a problem during threshing. For example, many farmers thresh maize by placing maize cobs in a sack and beating them with sticks. This results in a high proportion of broken grain. The presence of broken grain by itself is a reduction in quality for all types of cereals, furthermore broken grains are much more susceptible to other types of quality decline such as attack by moulds and insects (biodeterioration) that lead to weight loss.

Insufficient drying - Grain that is not dried to a safe moisture content shortly after harvest will be attacked by moulds. Moulds may develop on the surface of grain that is above the safe moisture content, which under hot tropical conditions is around 14%. High moisture content is also favourable for the development of insect infestation and may also lead to chemical browning reactions that result in grain discoloration.

Insufficient protection during storage - Poor storage arrangements can allow the entry of water, and give access to insects and rodents.

Factors contributing to weight loss are summarised in Table 1.1.

Table 1.1: The factors that contribute to weight loss of cereal grain
(adapted from Hodges and Stathers, 2012)

<table>
<tr><td rowspan="4">
High quality grain with no weight loss</td><td></td><td>**Broken grain**
Most broken grain comes from poor postharvest handling especially shelling/ threshing, but may also be a consequence of pest attack. Once broken the grains are susceptible to pest attack and as a result of this there is some weight loss.</td></tr>
<tr><td></td><td>**Insect damage**
Insects make holes in grains and hollow them out.
</td></tr>
<tr><td></td><td>**Rodent damage**
Rodents chew into grains and remove the germ.
</td></tr>
<tr><td></td><td>**Mould damage**
Mouldy grains have been dried too slowly or allowed to become wet. They have patches of mould growth on them and may also be discoloured. Mouldy grains are potentially a 100% weight loss as they may be unfit for human consumption.</td></tr>
</table>

1.1.3 The increase of storage weight loss with time

One of the earliest investigations of storage weight loss using modern methods (gravimetric) was of maize cob storage in Malawi by Schulten and Westwood (1972). They followed the increase of weight loss in local, improved and hybrid maize varieties stored in traditional structures (Fig. 1.2). This study demonstrated two important points 1) there are big differences between hybrid and local/improved varieties in the rate of increase in loss, and 2) there is very little loss during the initial periods of storage (first three months). For these reasons, farmers may keep losses low by selling hybrids soon after harvest while keeping local and improved varieties long-term for their own consumption.

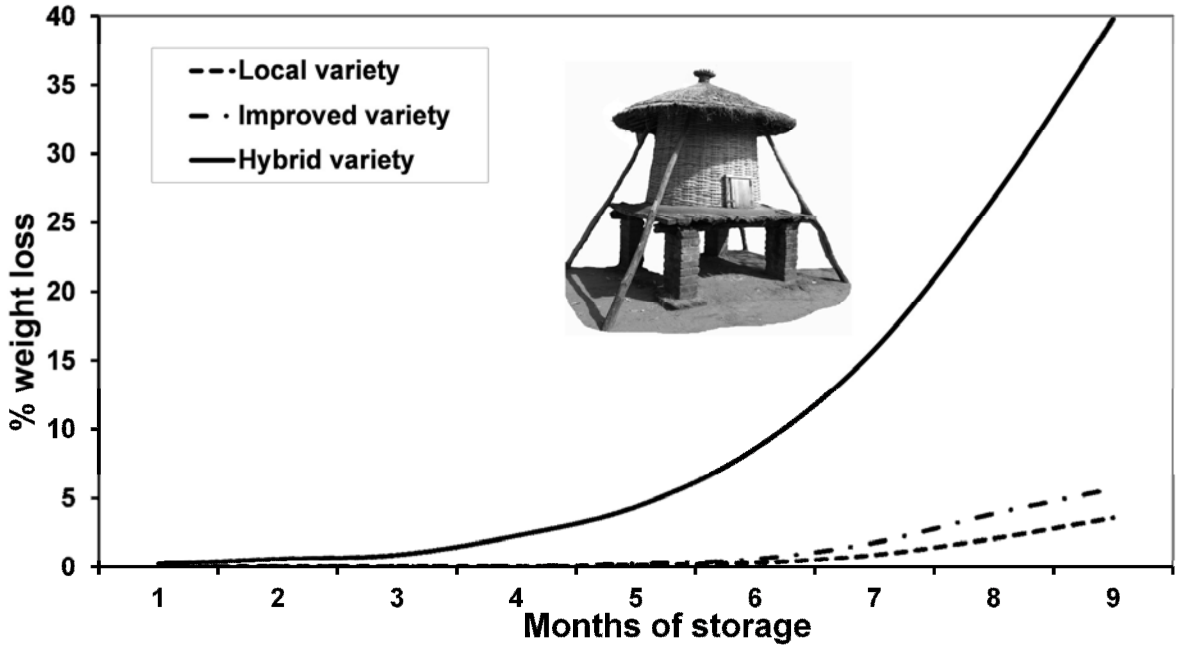


Figure 1.2: % weight loss of different maize varieties stored traditionally in Malawi but with no household consumption and no insecticide treatment
(figure prepared from data presented in Schulten and Westwood, 1972)

1.1.4 Importance of cumulative weight loss

Early studies on losses often did not take into account the grain that was removed from stores during the storage season as a result of household consumption, marketing etc.. But these removals are important because each lot of grain removed will have its own degree of loss, i.e. not the same loss as the grain that remains in store for the whole season. Losses calculated to take into account grain removals are termed 'cumulative losses'. A good example of a cumulative storage loss study is the pioneering investigation of Adams and Harman (1977) who measured storage losses in Zambia using a variety of modern methods (volumetric and gravimetric), offered an economic analysis of the observed losses and considered the costs and benefits of improvements to reduce them. The losses they found (4-5%) and subsequent studies on maize, particularly in east and southern Africa (Kenya – De Lima 1979b; Malawi - Golob 1981), confirmed that on average farmers would lose 2-5% of the weight of their grain during the course of a typical storage season of about 9 months.

They calculated cumulative losses, where the grain removed each month was accorded its own loss (which would be very little in the first three months) and then the total loss was calculated as a weighted average across all months. More will be said about this in **Sub-Section 2.6.5**.

1.1.5 Relative versus absolute losses

Weight losses may be presented in two ways, as an absolute loss which is the actual weight of grain (expressed in say tonnes or kilograms) and as a relative loss which is given as a percentage or proportion. APHLIS presents users with both absolute and relative loss values from production (e.g. the loss might be 17.5% from a production of 1000 tonnes, which is 175 tonnes, leaving 825 tonnes of grain supply). Only when the loss is expressed in absolute terms can the change in available grain supply be determined. It is important to remember that while relative losses may remain constant the absolute losses may change. For example, if grain production was increased to compensate for the 17.5% postharvest loss, mentioned above, and the relative losses remained the same then the absolute losses would increase. So if the production was increased by 17.5% then it would rise to 1175 tonnes but if the loss remains at 17.5% then this loss would be equivalent to 206 tonnes (1175 x 0.175), leaving a grain supply of 969 tonnes. The absolute loss is now 31 tonnes greater (206-175 tonnes) than before even though the relative loss (17.5%) remained constant. This is one reason why reducing postharvest losses may be a more efficient way of increasing grain availability than by increasing production. The same principle applies when losses are reduced at one link in the postharvest chain but remain constant at later links, there will now be more grain to lose at later links, even though the relative loss remains constant (see Box 1.1).

1.1.6 The storage loss estimates used by APHLIS

APHLIS uses storage loss estimates from the literature and those submitted by the APHLIS network as the basis of its calculation of cumulative postharvest weight loss. If storage loss figures are to be combined so that they can be used by APHLIS then they must be standardised. The original loss figures quoted in the literature are the result of various studies undertaken over different time periods and may or may not have taken grain removals, such a household consumption, into account. Where necessary, for the purpose of APHLIS, these loss figures from the literature have been adjusted to a 9-month storage period and also adjusted for household consumption, assuming that the grain was consumed at an even rate over 9 months. The storage loss is standardised to a 9-month period by considering the shape of the curve of loss over time of the original study and then obtaining a 9 month loss figure by extrapolation or interpolation. Alternatively, if there is insufficient data to suggest a loss curve then it would be assumed that by three months, six months and after nine months or more there would be 15%, 30% and 55% of the storage loss figure. In any case, the majority of storage studies are about 9 months long; this is the duration of a typical storage season. APHLIS currently works with 75 adjusted, loss figures. The best quality data are considered to be the measured estimates using modern methods.

Other methods such as questionnaire surveys or guesstimates are expected to be less reliable although the measured estimates may not be much better than other approaches when they are being applied to much wider circumstances than those from which they are derived. When new storage loss data are generated by the methods presented in this manual it is important that they take into account grain removals (see **Sub-Section 2.6.5**) and are accompanied by other important contextual information such as the length of the storage period, the geographical area concerned (including climate type), the situation in which they occurred (including postharvest technologies applied) and finally how they were measured.

Box 1.1 - Reduction in the % lost at one link in the postharvest chain can result in greater absolute losses at subsequent links in the chain

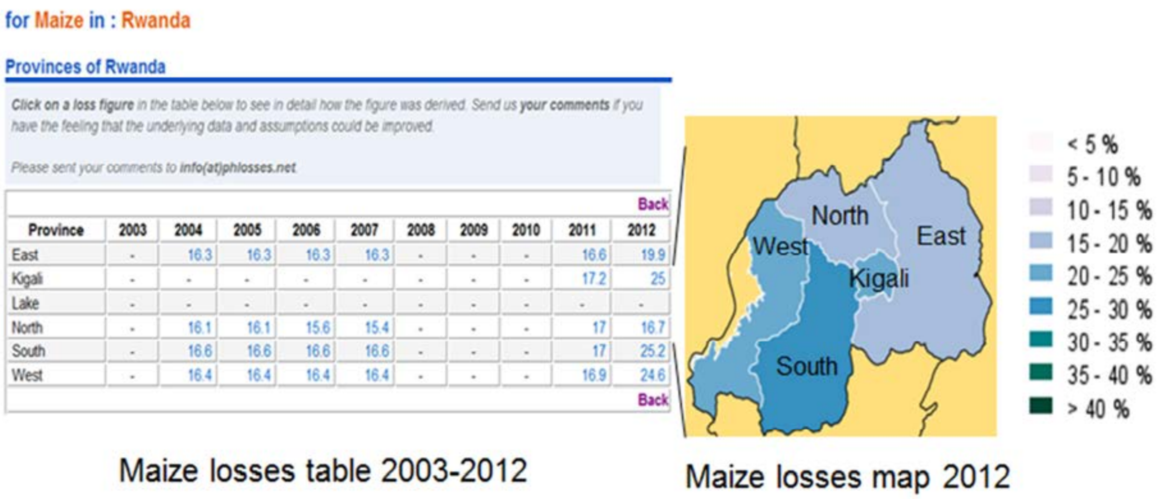
A farmers' group produces 100 tonnes of grain. They improve their harvesting technique and this reduces grain weight loss from 8% to 1%. All other losses in the chain remain the same. In the table below it can be seen that with the harvesting improvement the loss increments (figures in red) at subsequent links actually increase because there is more grain left to lose.

	Without harvesting improvement			With harvesting improvement		
Postharvest link	**% loss**	**Grain remaining**	**Loss increment**	**% loss**	**Grain remaining**	**Loss increment**
Harvesting	8.0	92	8	1.0	99	1
Drying	4.0	88	3.7	4.0	95	**4**
Threshing	1.5	87	1.3	1.5	94	**1.4**
Transport to farm	2.0	85	1.7	2.0	92	**1.9**
Farm storage	5.0	81	4.3	5.0	87	**4.6**
Total grain loss			**19 tonnes**			**12.9 tonnes**

1.2 The contribution of APHLIS to cereal loss assessment

1.2.1 What is APHLIS

APHLIS is a network of local experts in the countries of SSA who submit relevant data into their own space on the APHLIS database. A web-based loss calculator uses these data to estimate cumulative postharvest weight losses of cereal grains by province. These data are aggregated to losses values by country and by region. The results may be viewed as tables or as maps (Fig. 1.3) on the APHLIS web site (http://www.aphlis.net). The main features of APHLIS are presented in Box 1.2.



for Maize in : Rwanda

Provinces of Rwanda

Click on a loss figure in the table below to see in detail how the figure was derived. Send us your comments if you have the feeling that the underlying data and assumptions could be improved.

Please sent your comments to info(at)phlosses.net

Back

Province	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
East	-	16.3	16.3	16.3	16.3	-	-	-	16.6	19.9
Kigali	-	-	-	-	-	-	-	-	17.2	25
Lake	-	-	-	-	-	-	-	-	-	-
North	-	16.1	16.1	15.6	15.4	-	-	-	17	16.7
South	-	16.6	16.6	16.6	16.6	-	-	-	17	25.2
West	-	16.4	16.4	16.4	16.4	-	-	-	16.9	24.6

Back

Figure 1.3: A table and map from APHLIS showing maize postharvest weight losses for the provinces of Rwanda for 2003-2012

> **Box 1.2 – The features of APHLIS**
>
> - APHLIS losses tables can be 'clicked' to reveal a complete breakdown of the loss calculation, the sources of data and an appraisal of the quality of the data used. In this way, users can subject loss estimates to critical examination.
> - APHLIS offers a downloadable version of the loss calculator as an Excel spreadsheet. Users can change default values within the calculator to those relevant to their situation and generate loss estimates for any geographical scale.
> - APHLIS is easily upgraded as more reliable loss figures become available. Users can contribute their own loss figures that can be added to the database.
> - APHLIS can be updated annually, so that users will be able to see trends across years
> - APHLIS (in the near future) will connect to country-specific web pages that show narratives by local experts on postharvest losses and to web pages that offer advice on postharvest loss reduction.

The loss estimates generated by APHLIS have several uses. They assist in

- the formulation of agricultural policy,
- planning and monitoring projects on postharvest loss reduction, and

- the calculation of the cereal supply/demand balances that give an indication of national food security.

For the estimation of postharvest weight losses at geographical scales below the province, such as an individual farmer or Farmer Groups, a special version of the loss calculator can be downloaded from the APHLIS website. The important features of this calculator are that the user can alter loss values to those derived from a particular losses study or even to model 'what if' scenarios by entering imaginary data. The next few sub-sections explain the different kinds of data needed by APHLIS (both versions of the calculator). Part 3 of this manual describes using the downloadable calculator to estimate a cumulative weight loss in your own specific situation.

1.2.2 What sort of data does APHLIS use?

Postharvest losses may be due to a variety of factors, the importance of which varies from commodity to commodity, from season to season, and to the enormous variety of circumstances under which commodities are grown, harvested, stored, processed and marketed (Tyler, 1982). It is therefore important not only to work with figures that are good estimates at the time and in the situation they are taken but to be aware that at other times and situations the figures will differ. This necessitates regular recalculation of loss estimates with the best figures available, a task addressed by APHLIS. This implies a regular supply of production and loss data.

Both versions of the APHLIS loss calculator estimate cumulative weight losses by reference to three sets of data. They require data on:

- **crop production** - so that the scale of loss can be determined,
- **% of grain lost at each link in the postharvest chain** - so that a cumulative loss from production can be calculated, and finally
- **factors that might vary seasonally or annually** - these have a strong influence on the percentage lost at various links in the postharvest chain.

We will now consider each of these types of data.

1.2.2.1 Crop production data

Crop production data are usually available from Ministries of Agriculture although definitive figures may not be available until many months after harvest, consequently provisional figures may have to be submitted to APHLIS initially and then revised when more complete data are available. Production figures can be added directly to the database by APHLIS network members. (Note: when using the downloadable calculator, there is a facility for estimating production from observed quantities of threshed grain (= grain stored + grain marketed, see **Sub-Section 3.1.5**).

1.2.2.2 Grain losses at each link in the postharvest chain

The data on the extent of postharvest loss at each link in the chain come mostly from the scientific literature. However, well researched figures can be submitted by users and, following careful quality control they may be added to APHLIS.

The links in the postharvest chain to be considered are as follows:

- harvesting/field drying,
- drying on platforms,
- threshing/shelling,
- transportation to farm store,
- farm storage,
- transportation to market, and
- market storage.

A set of loss figures that represent each of these links in the chain is called a postharvest loss profile (see Table 1.2 on the following page). The loss figure calculated for each link in the chain is the arithmetic mean of the data available for that link. Where possible the data used to calculate the means are specific to the cereal type, climate type, and farm type (smallholder or large farm).

Within APHLIS it is possible to see the extent to which the data used to estimate profile figures are specific to the situation (climate, cereal, farm type) and also the method used for their collection (precisely measured or based on a questionnaire survey). An example might be the loss value for the harvesting/field drying link for smallholder maize in the Central Province of Malawi (Fig. 1.4). At the time of writing this manual there are ten figures from the literature that are used to derive the mean weight loss value of 6.4% (Fig. 1.4). These figures are either 'specific', represented by green/1, or 'not specific' represented by red/0.

From year to year the PHL profiles will remain much the same, until new, well-founded data have been collected that can be entered into the system to give revised PHL profile values. However, loss values are not necessarily the same for every year, this is because the PHL profile figures are modified by certain 'seasonal factors'. These are described next.

Table 1.2: Examples of PHL profiles, % grain weight losses for each link in the postharvest chain, used by the APHLIS loss calculator to estimate postharvest weight losses

Cereals		Maize	Maize	Rice
Climates (Köppen codes)		Humid tropical (Aw)	Humid sub-tropical (Cwa)	Humid tropical (Aw)
Farm type		Smallholder	Large-scale	Smallholder
Harvesting and field drying		6.4	2	4.3
Transport to household		2.4	1.9	1.3
Drying		4	3.5	-
Threshing and shelling		1.3	2.3	2.6
Winnowing and sieving		-	-	2.5
Storage		5.3	2.1	1.2
Transport to market		1.7	1.0	1.0
Market storage		2.7	4.0	4.0
Total cumulative loss (allowing 20% grain marketed at harvest, other seasonal factors would give higher loss estimates if used)		**18%**	**12%**	**16%**

0 *A datum used in the calculation of a PHL profile value is not specific to this situation or is from a questionnaire survey or a guesstimate, i.e. is not measured.*

1 *A datum used in the calculation of a PHL profile value is specific to this situation or is measured.*

PHL profile figures based on more ***'green/1'*** *data are considered to be more reliable than those based on more* ***'red/0'*** *data. Against each PHL profile value the number of* ***'red/0'*** *and* ***'green/1'*** *assessments is averaged, and displayed in bold, to give a general assessment of the value. Frequently some parts of the profile are more reliable than others, especially those where more loss data are available from the literature.*

References and individual loss figures % for small farms

			Origin of figure			
Stages	Loss figure	Reference	Cereal	Climate	Farm type	Method
	5.5	Egyir I.S. - 2011	1	0	1	0
	2.0	Boxall R.A. - 1998	0	0	1	0
	5.0	Vervroegen D. - 1990	0	1	1	0
	3.2	Singano C. - 2008	1	1	1	0
	6.5	Singano C. - 2008	1	1	1	0
	6.9	Singano C. - 2008	1	1	1	0
	9.9	Singano C. - 2008	1	1	1	0
	9.9	Grolleaud M. - 1997	1	0	1	0
	5.8	Mvumi B.M. - 1995	1	1	1	0
	9.5	Odogola W.R. - 1991	1	1	1	0
Harvesting/field drying	**6.4**		**1**	**1**	**1**	**0**
	3.5	Lars-Ove Jonsson - 1987	1	1	1	0
	4.5	Odogola W.R. - 1991	1	1	1	0
Platform drying	**4.0**		**1**	**1**	**1**	**0**
	1.0	Odogola W.R. - 1991	1	1	1	0
	1.8	Egyir I.S. - 2011	1	0	1	0

Figure 1.4: Data from the literature used to calculate some of the PHL profile figures for smallholder maize postharvest operations in Central Province Malawi. The harvesting/field drying loss of 6.4% is the mean of ten figures from the literature. Against each of these figure is an assessment of its specificity to maize, to the climate of Central Province and the farm type, as well as the method of data collection (measured or questionnaire survey).

1.2.2.3 Seasonal factors that affect grain losses in the postharvest chain

There are 'seasonal factors' to consider that modify the extent of weight losses between seasons and between years. These factors are multipliers of certain PHL profile figures or affect the annual weighted averages of losses and include the following:

a. Rain/damp cloudy weather at harvest time that may hinder grain drying
b. The proportion of the crop that is marketed in the first three months after harvest time, i.e. will not remain in farm storage long enough for significant storage losses to occur
c. The total length of the period of farm storage
d. The incidence of a pest, the Larger Grain Borer, that attacks mature maize

1.2.3 Why more loss data are needed by APHLIS

There is only a limited supply of weight loss data from the literature, consequently the PHL profiles used by APHLIS are derived from figures that are shared between a wide range of situations, i.e. many PHL profile figures are not specific to the situations to which they are being applied. To improve APHLIS estimates it is important to gather new loss data.

Furthermore, in the case of the 'seasonal factors' (described above) until now there have been no guidelines on how to go about obtaining the necessary data. The purpose of this manual is to describe methods for collecting weight loss data for each link in the chain and the collection of data on the seasonal factors, so that APHLIS network members (or anyone else) can go about collecting standardised loss data that will improve the estimates generated by APHLIS. How to identify the new loss data required by APHLIS needed is the subject of the next **Sub-section 1.2.4**.

1.2.4 What are the most important data gaps in APHLIS

The APHLIS tables giving detailed provincial weight loss estimates show the data underlying the PHL profile (Fig. 1.5). Inspection of this table shows the number of different estimates of loss that have been used to give the mean value for a particular postharvest operation. For example in Figure 1.4 the profile figure for 'Harvesting/field drying' of maize was 6.4% and based on ten estimates derived from studies undertaken from 1990 to 2011. The use of ten estimates is good compared with only two estimates for 'Harvesting/field drying' of teff (Fig. 1.5). Clearly, the PHL profile values are better founded when they are based on more estimates. Thus data gaps can be identified by close inspection of the loss tables. Furthermore, the specificity should also be taken into account. Profiles for maize tend to be more specific in respect of cereal, climate and type of farm since a greater number of researchers have published studies on maize. This can be seen in the greater numbers of green/1 markings in Figure 1.4. Other cereals, especially millet, sorghum and teff, have been less well studied and so the loss data is less specific (Fig. 1.5), i.e. have more red/0, and would benefit from the collection of more data. Check the profiles relevant to the crops in your country to identify the links in the postharvest chain that may benefit from the collection of more data.

References and individual loss figures % for small farms						
			Origin of figure			
Stages	Loss figure	Reference	Cereal	Climate	Farm type	Method
	2.0	Boxall R.A. - 1998	0	0	1	0
	5.0	Vervroegen D. - 1990	0	1	1	0
Harvesting/field drying	**3.5**		**0**	**1**	**1**	**0**
	1.0	Boxall R.A. - 1998	0	0	1	0
	6.0	Vervroegen D. - 1990	0	1	1	0
Threshing and Shelling	**3.5**		**0**	**1**	**1**	**0**
	0.0	Boxall R.A. - 1998	0	0	1	0
	5.0	Vervroegen D. - 1990	0	1	1	0
Winnowing	**2.5**		**0**	**1**	**1**	**0**
	2.0	Boxall R.A. - 1998	0	0	1	0
	3.0	Vervroegen D. - 1990	0	1	1	0
Transport to farm	**2.5**		**0**	**1**	**1**	**0**
	0.3	Kidane - 1989	1	0	1	0
Farm storage	**0.3**		**1**	**0**	**1**	**0**
	1.0	Odogola W.R. - 1991	0	1	1	0
Transport to market	**1.0**		**0**	**1**	**1**	**0**
	4.0	Boxall R.A. - 1998	0	0	1	0
	1.3	Egyir I.S. - 2011	0	0	1	0
Market storage	**2.7**		**0**	**0**	**1**	**0**

Figure 1.5: The small farm PHL profile figure for teff in a semi-arid climate. Notice that except for farm storage losses the profile figures are derived from other crops and are being 'shared' with teff, i.e. have more red/0 **than** green/1

Concerning 'seasonal factors', when rain at harvest is given as 'yes' then the normal harvesting and drying loss for all cereals is increased from the usual profile figure to a value of 16.3%. This figure is actually specific to maize and comes from a single study in Swaziland in 1982. We use this figure because no other data are available. Clearly, more studies of the effects of rain at harvest on grain losses are required. Such data may be of particular importance as one effect of climate change is to make the climate more variable, hence increasing the risk of rain at harvest time.

1.3 How new data are collected for APHLIS

APHLIS needs two types of data, weight loss estimates for each link in the postharvest chain and data on those factors that affect grain losses on a seasonal/annual basis such as grain production, rainfall at harvest etc.. This sub-section considers both of these.

1.3.1 Collecting weight loss data

The weight loss estimates of the PHL profile can remain the same from year to year but should be refined by the addition of new data so that the average values used in the calculation of a PHL profile become more representative. Adding new data to the PHL profile may also mean that there is sufficient data available for the calculation that some old, less specific data, included due to data scarcity, can now be excluded. This leads to yet further refinement.

The weight loss estimates from the postharvest chain can be obtained by questionnaire survey of farmers and traders or by researchers undertaking detailed measurements of the weight losses, in farmers' fields, stores and in warehouses. Detailed measurements are time consuming and expensive but are generally accurate. Questionnaire surveys can be done relatively quickly but are generally considered to be inaccurate, relying on the opinions of the interviewee. These opinions are influenced by the way questions are asked, the agenda of the interviewee (who may perceive benefit in suggesting losses are larger or smaller than reality) and the extent to which the interviewee can estimate what the losses are. This can be difficult (for example do you know what weight of food you waste as a percentage of your purchases?). Part 2 of this manual deals with how you can obtain more weight loss data using rapid methods.

1.3.2 Collecting seasonal factor data

Data on the 'seasonal factors' (**Sub-Section 1.2.2.3**) that affect weight losses need to be updated annually. These data have a very strong effect on year to year variations in losses and are just as important as the PHL profile figures. The PHL profiles used by the loss calculator at the centre of APHLIS are modified by four factors that may change on a seasonal basis (Fig. 1.6). Consequently, the loss values recorded on APHLIS for particular cereals in particular provinces will change when there are variations in these factors.

PHL (%) Calculation: Season: 1 Farm Type: *small*		
Grain marketed within the first three months after harvest (%)	7	*If data is missing (**no data**) it is assumed that for subsistence farmers all grain is stored whereas for commercial farmers all grain is marketed.* *Note: Figures in this table are farm type specific (small or large farms). The value **Grain marketed within the first three months after harvest (%)** is used to determine the percentage of total production that is stored and marketed by this type of farm in this particular season (Season 1, Season 2 etc). The calculation only considers the portion that is produced by this type of farm. Consequently, the figures below for **Stored (%)** and **Marketed (%)** will only add up to 100% if all grain in a particular season is produced on this farm type. Otherwise the corresponding percent figures for the other farm type, in the same season, must be included to arrive at a sum of 100%.*
Rain at harvest	no data	*If weather is damp at harvest, leading to exceptional mould damage to the crop, then the value is **yes** and the **Harvesting/field drying** losses figure in the PHL profile is replaced by **16.3%**.*
Storage duration (months)	11	*Effect of storage duration:* *1. 0-3 months % figure for storage is 0 (zero)* *2. 4-6 months the % figure of the PHL profile is divided by 2* *3. More than 6 months or in case of missing data (no data) the % figure in the general profile is used*
Larger Grain Borer	yes	*If the crop is **maize** and the value is **yes** then the **Farm storage** loss figure in the PHL profile is multiplied by **2**.*

Figure 1.6: Listing of 'seasonal factors' on APHLIS for the Southern Province of Malawi (these details can be seen by accessing loss tables and then double clicking on the provincial loss estimates for particular crops). In this case, 7% of the crop of smallholders was marketed in the first 3 months after harvest, there was no rain at harvest, grain was stored on farm for up to 11 months, and Larger Grain Borer was a problem.

Some of the data on seasonal factors can be collected from official sources, some has to be obtained from survey work or the opinions of people working with farmers and traders, such as agricultural extensionists, agricultural NGOs and the leaders of agricultural co-operatives. A telephone call to some key contacts (including farmers themselves) can provide good information quickly. It is therefore very important to establish a network of key contacts.

<u>% Grain marketed</u>

Grain marketed within the first three months of harvest would be expected to have suffered little or no losses in farm storage (see **Sub-Section 1.1.3**). Consequently, for this grain APHLIS does not register any losses in farm storage but instead registers the marketing losses that arise due to transportation to market and market storage.

What proportion of grain is marketed within the first three months may vary from season to season and year to year. Use survey work with farmers or ask key contacts to determine this proportion.

Rain at harvest

Rainfall data are usually available from the Meteorology Department and although there is a tendency to charge for this data, people working in the Agricultural Department can usually obtain them *gratis*. Rainfall data can be added directly to the APHLIS shared database by users.

From rainfall data it is possible to answer the APHLIS query about whether farmers have suffered rain at harvest. Using rainfall data, identify which areas have experienced rainfall at the time of harvest. These areas should be targeted for data gathering using either formal survey work or consultation with key contacts.

If at least 50% of farmers questioned in an area have had problems in grain drying due to rain and/or damp cloudy weather at harvest then 'rain at harvest' should be answered as 'yes' in APHLIS.

Farm storage duration

The duration of farm storage has a direct effect on how much biodeterioration will occur. The duration will depend on the size of the harvest and the opportunities of farmers to market grain.

Larger Grain Borer infestation

In many countries in SSA the Larger Grain Borer (Fig. 1.7), or LGB for short, is an important pest of farm stored maize, causing significantly higher losses than the more usual pests (which are already taken into account in the profile figures for storage losses). Information on the incidence of LGB may be difficult to obtain and because the extent of damage to stored maize may vary greatly in different localities and between different years. When there are bad years this may be reported in the local press (this has happened in southern Kenya). The best source of information is those people within the Ministry of Agriculture responsible for postharvest matters or crop protection. If in doubt then LGB should be marked 'no data'.

APHLIS displays a map showing the year to year variations in the reporting of LGB problems (Fig. 1.7).

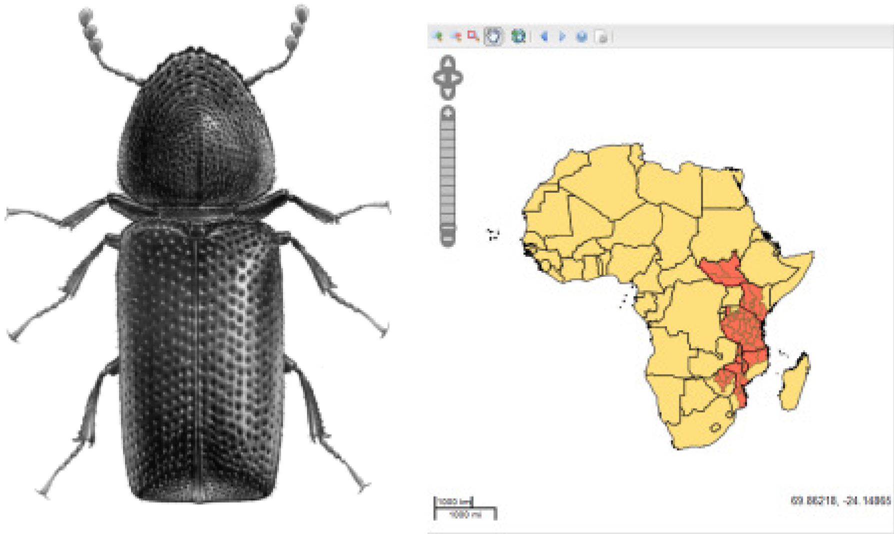


Figure 1.7: The Larger Grain Borer (*Prostephanus truncatus*) a serious pest of farm stored maize, originating from Central America, and the map on APHLIS showing the reporting of LGB incidence as a pest problem in 2007

A suggestion for an interview form that can be used to collect these 'seasonal' data is given in Annex 2. When new data are available they should be submitted to APHLIS. The way to do this is explained in more detail in Part 4.

Once it has been decided what data need to be collected to enable an estimation of grain postharvest weight losses, then the next step is to plan how they can be collected. Part 2 of the manual gives a background to the principles of data collection relevant to weight loss estimation.

Part 2 – How to assess postharvest cereal weight losses

This part of the manual explains what to do to collect new loss data. We start by considering how to plan a losses survey and give a summary of the steps involved. You are then introduced to questionnaire surveys to collect essential data to explain losses and to a rapid approach to measuring losses called 'visual scales', which are mostly relevant to the estimation of storage losses. Consideration is then given to measuring losses at links in the postharvest chain other than storage and finally an example is presented of a loss estimation study complete with data collection sheets.

2.1 Planning loss assessment and the resources needed

2.1.1 The best time to do the assessment

Agricultural activities are very seasonal, consequently assessing the loss associated with farmers' postharvest activities has to be implemented taking into account the seasons. The assessment usually has to start at the beginning of a season, i.e. at harvest time or at least close to harvest. Consequently, it is essential to select the sample sites well before harvest, select and train staff, develop and test questionnaires (formal or informal) and visual scales, and carefully plan data collection and sample analysis.

The assessment of losses elsewhere off farm, e.g. in transport to market, in storage at market or warehouse etc., is less constrained by season but also requires careful planning to ensure that the objective of the assessment can be achieved.

2.1.2 Sources of information in support of the assessment

Before starting any kind of loss assessment survey it is important to gather together all available information that can help plan and implement the study. It may be possible to find the information with government services, larger active NGOs or on the internet, which might include -

- Previous reports on loss assessment studies
- Meteorological data
- Production and marketing data
- Maps of the target areas
- Lists of villages with population statistics
- Farmers' calendars

2.1.3 Equipment

Equipment falls into two categories, that needed to actually make the assessment of loss and that needed to facilitate the survey. Equipment to assess losses includes the laboratory equipment needed in the construction of the visual scale (Section 2.5, Box 2.3) and the grain sampling equipment that is need to take samples in the field (Sub- Section 2.3.4). Equipment need to facilitate a survey includes -

- Clip boards, stationery, pens, sample bags, markers/labels, rubber bands etc.
- Folders to store completed data sheets

- Suitable vehicles
- GPS to record the precise location of sample points and enable these to be plotted on maps of the area (e.g. on Google Earth)
- Camera to record people, places and incidents
- Copies of questionnaires

2.1.4 Staffing needs

Staff for the survey are divided between those with experience of planning, implementing, analysing and reporting on field studies and those who will be used for field work to collect raw data.

When choosing staff to undertake studies of postharvest losses two disciplines are especially relevant, postharvest technology and agricultural economics. In addition, for the design of questionnaires the support of staff with skills in socio-economics and/or social anthropology can be very helpful as well as biometricians/statisticians for advice on the design and analysis of quantitative aspects. Surveys are best managed by teams with a range of skills and ideally any team should include at least a postharvest technologist and an economist, with access to advice from other specialists.

The staff involved in data collection need to have relevant skills and should have a sufficiently strong agricultural and educational background (at least secondary school) so that they fully understand how and why the survey is being implemented and can be trained for specific tasks. Those engaged in questioning farmers must have been trained in the use of questionnaires and must have had some supervised practice with the particular questionnaire to be used. This will ensure that the questions are being asked, and answers recorded, in a standardised way. It is helpful to make local language translations of survey documents before field testing as this will help to reduced variance caused by differential translation of phrases and terms between enumerators. Likewise staff using a visual scale must be trained in its use and in recording the results.

2.1.5 Data management

Most projects involve the collection of substantial quantities of data. Much of the data will probably be collected by enumerators trained to do this job. To ensure quality control of the data and security for its long-term availability, a well-defined system of data management is required (University of Reading, 1998). The main elements of data management involve:

1) Prior to data collection, design and create a database or spreadsheet for the survey data. Many software packages allow the user to design data entry screens that allow someone to type in data easily and with a minimum of error.
2) During the survey check the data sheets to ensure that data is being collected in the required manner and properly and legibly recorded.
3) Enter the data into a computer using a database or spreadsheet and create backup copies in case of loss or damage.
4) Check that the data have been entered correctly.

5) Organise the data into various forms suitable for analysis.
6) Organise the data so that they remain available throughout the subsequent phases of the project and into the future.

On receiving data, the co-ordinator should check a sample of answers for correctness. If there are any queries the co-ordinator should try to resolve these with the appropriate person. Once the co-ordinator is satisfied then the data should be entered into a computer using suitable software.

2.1.6 Budgeting for an assessment – what to include

Loss assessment exercises require considerable preparation. Initial field visits are required to create the implementation plan, the questionnaire and a visual scale. To actually implement the plan may then require a return to the field several times, possibly as many as five or six times in a season involving transport and accommodation costs. The main budget items are as follows –

1. Searching for supporting information
2. Preparation of a loss assessment proposal
3. Initial field visit to plan implementation
4. Preparation of questionnaire
5. Construction of a visual scale
6. Training enumerators on objectives of the exercise, survey techniques, tools, ethics etc.
7. Testing visual scale in the field
8. Testing questionnaire in the field
9. Field implementation of questionnaire and visual scale over the period of an agricultural season (i.e. several visits)
10. Analysis and report writing

2.1.7 Summary of the main steps in a loss assessment survey

For any particular loss assessment project, the main steps in loss assessment are as follows:

Step to follow	Activities required	See Section
Planning	1) Identify what data need to be collected to ensure an effective contribution to project objectives and in addition to enable good loss estimates using the APHLIS calculator which should include information on: • Grain production (tonnes) • % grain marketed up to 3 months after harvest • Climatic problems during and just after harvest time that affect grain drying • Period of grain storage on farm (months) • Infestation of maize by the Larger Grain Borer 2) Identify the potential geographical spread, target groups, and optimal sample size for the loss study. 3) Search all available sources for information materials relevant to the study.	**Sections 1.3 & 2.1** **Sub-section 1.3.2**

	4) Estimate requirements for equipment, staff and other resources. 5) Prepare a written proposal including a budget and timetable for the loss assessment. Ensure that the financial resources available match the proposed budget. 6) If necessary secure additional resources or scale the project to fit the available resources.	
Develop a questionnaire survey	Where loss assessment is focussed on farming households then a questionnaire of some form will be needed. 1) Decide on the questions required with reference to the survey objectives, any information your project has already collected, and the data needs for using APHLIS to estimate cumulative losses from production. 2) Draft the questionnaire and if necessary translate it into the local language. 3) Field test the questionnaire to ensure it is understandable and collects the required information. 4) Train field staff in the use of the questionnaire 5) Determine sample size to give a result that will be representative of the target population. 6) Undertake a field visit to determine the variation in household diversity, using well-being ranking. 7) Select households to include in this study based on a representative cross section of well-being ranks.	**Sub-section 2.2** **Section 2.3** **Section 2.4**
Develop a visual scale	Where grain biodeterioration is a key element of loss, such as in grain storage, a visual scale should be developed for loss estimation. 1) Collect grain samples that represent the range of grain qualities likely to be encountered. 2) Work with stakeholders to determine the end use of grain at these different qualities. 3) Construct a visual scale with grain in classes with specified degrees of damage, weight loss and contamination. 4) Field test the visual scale to determine whether it can be used reliably with stakeholders. 5) Determine sample size to give a result that will be representative of the target population. Where grain losses are at other links in the postharvest chain, often not related to biodeterioration, then other loss assessment approaches will be needed	**Sections 2.5** **Section 2.3** **Section 2.7**
Initiate loss assessment study	1) Make the first visit to the project targets (e.g. households) at the time when loss assessment should start. For farming households this is usually very soon after harvest, but may be before harvest if harvesting is	

	a focus of the study. 2) Implement the questionnaire survey and initiate the loss assessment process. 3) Where storage is being assessed then initiate recording of grain removals to assist in the calculation of a cumulative loss. Then make return visits as required to collect sufficient data to enable an accurate assessment of the loss.	**Section 2.6.2**
Prepare loss estimates and loss narrative	1) Determine loss for each sample unit (e.g. each household). 2) Calculate a weighted average loss based on the grain production by each sample unit (e.g. household) 3) Substitute the new loss estimate for the default values in the APHLIS downloadable calculator to estimate a new cumulative weight loss from production. 4) Prepare a report on the loss assessment that includes, the methods used and relevant observations, photos, maps of sample sites etc., that will provide a narrative explaining the loss or reduction in loss.	**Section 2.6.3** **Section 2.6.5** **Section 3.1** **Section 4.3**
Submit loss data to APHLIS	Present the loss report to APHLIS (aphlis3@gmail.com) so that loss data can be added to the system to upgrade the default loss profiles. This improves the performance of the web-based loss calculator and makes loss figures available to other users.	**Part 4**

2.2 The tools and approaches to loss assessment

2.2.1 Approaches to generating new weight loss data using loss surveys

In the 1970s several techniques were developed for assessing postharvest grain losses which are detailed in Harris and Lindblad (1978) and reviewed in Boxall (1986). They mostly concern grain storage losses and the proposed techniques, although relatively accurate, are very time consuming. They involved taking samples, returning them to a laboratory and then analysing them. This had several disadvantages, only relatively few samples could be processed, grain was taken from its owners (the sample units which could be farmers, farmers groups, co-operatives, traders etc.) and not returned, the grain owners did not participate in the assessment of the loss, and usually there was no feedback to the grain owners on the outcome of the analysis. From the 1990s onwards researchers became more aware of these problems and decided to shift from purely lab-based techniques to rapid methods (called visual scales, see **Section 2.5**) that could be implemented on site and done with the participation of grain owners (Compton *et al.*, 1995, 1999). Furthermore, any grain samples extracted remained with its owners. The approaches recommended in this manual are rapid methods. In addition, these rapid methods can be linked to questionnaire surveys and designed so that these two methods are complementary in providing the data required by APHLIS for loss estimation.

2.2.2 The questionnaire as a basis to the loss assessment survey

2.2.2.1 Questions to ask

An interview with the owner of the grain (farmer, co-operative, trader etc.) should complement the actual measurement of losses although the extent of questioning may vary greatly according to the needs of the project. Consequently, a project may have a full formal questionnaire survey in advance of loss measurements and/or abbreviated questioning exercises running parallel to loss measurement. Either way it is essential to put the loss data obtained into the context both of farming and of the household. For most cases certain basic questions are likely to be required in order to give an understanding of the context of the investigation, to ensure the collection of the data required by the APHLIS calculator on losses and seasonal factors that affect postharvest losses, and/or to provide a narrative to accompany the losses that the study reveals. Typically, the grain owner would be asked questions relevant to the survey objectives and in the case of households these questions could include -

- the timing of postharvest activities
- the postharvest methods employed,
- the number of bags of grain produced
- the number of bags of grain sold and when sold
- the duration of storage of grain for household consumption,
- their normal grain consumption rate,
- their knowledge of losses and which stages and factors are most problematic,
- how losses vary between harvesting seasons and from year to year, and
- access to extension advice/services.

An example of a formal questionnaire for a postharvest losses survey of householders is given in Annex 1. This example is fairly general in nature, so that more specific questions on particular links in the postharvest chain would be added to address the interests of a specific project.

The time available for you to spend with each grain owner answering a questionnaire will always be limited (typically about 1 hour), so engaging in lengthy discussions may not be possible, but at least in the case of farming households a detailed briefing from a local agricultural extensionist would provide much needed background information.

2.2.2.2 Analysis of questionnaire results

It is possible to use questionnaires to quantify key aspects of the postharvest system and in order to do this advice should be sought from a statistician or biometrician on the design, data management and the analysis of the questionnaire. Furthermore, instead of being used to collect new data on losses a questionnaire could also be designed that will validate existing data on losses, i.e. confirm that loss data established elsewhere applies to a different community or geographical area.

During a questionnaire survey it should never be assumed that the answers given by individuals are accurate, they may given because they are thought to please the questioner or because they are to the advantage of the interviewee. In order to overcome some of these problems the approach taken should involve some degree of 'triangulation' (Pretty *et al*. 1995). This can be achieved by 1) having study teams with members coming from different disciplines so that the topics under study can be viewed from 'different angles', 2) interviewing more than one key informant or group, using the same questions, so that responses can be compared, and 3) use different tools to investigate the same phenomenon, for example questioning farmers about the significance of quality decline or losses at a particular link in the postharvest chain, assessing the losses using rapid techniques, and then comparing the farmer's perceptions with actual loss data.

2.2.2.3 Field testing and refining the survey questionnaire

When you have decided on the questions you need to ask in the questionnaire and have drafted it then you are ready to field test it. Field testing is an important step in developing an effective questionnaire. It is a way of checking that:

- questions make sense and are easily understood by respondents,
- questions do actually need to be asked,
- important questions haven't been forgotten
- responses can be analysed by whatever analysis protocol has been selected, and
- the questions can be understood by the enumerators and they can be delivered by them in the vernacular.

Field testing should be done by the questionnaire designers backed up by one or two of the staff who will implement the survey. It should be done at a convenient location with not less than five respondents who will be similar to the targets of your survey. Section 2.4 gives guidelines on how to do the interview with respondents.

After field testing, the survey group should consider the results and refine the questionnaire accordingly.

2.2.3 How losses can be measured and the advantages of rapid techniques

Losses occur at each step in the postharvest chain. The methods used in their measurement have to vary according to the nature of the loss, typically whether the measurement is of grain biodeterioration or of grain scattering/spillage.

2.2.3.1 Measuring with rapid methods

If grain is lost due to biodeterioration, which may occur due to pest attack throughout the postharvest system but especially during storage, then the least time consuming approach to measuring grain weight losses is to use a visual scale.

Visual scales are a relatively quick and easy way to estimate the grain weight losses that are due to insect pest attack and also to assess grain quality. This involves preparing samples of grain with different degrees of pest damage/contamination that have a known weight losses. Samples of grain can then be assessed for weight loss, contamination/damage by comparison with the visual scale. If only weight loss is of concern then it is possible to simplify this further and work with just a simple calibration that converts observed percentage of grain damaged into a weight loss value.

There are some other methods that can be used to estimate weight losses (Boxall, 1998) which are more accurate but all are much more time consuming as they involve weighing and counting grain and determining its moisture content etc.. The advantages of visual scales are that they:

- Avoid the need to return samples to the laboratory
- Avoid time consuming laboratory analyses
- Increase the number of samples that can be assessed
- Avoid taking grain from farmers
- Involve farmers in the assessment, and
- Link the assessment to both weight and quality (value) loss

A visual scale can be used to assist loss assessment at any link of the postharvest chain where there has been biodeterioration but the method gives no measure of losses due to scattered or spilt grain or those grains completely removed by rodents, ants etc.. For that other methods would be required.

How to construct a visual scale is presented in **Section 2.5** and how to estimate losses using the scale is presented in **Section 2.6**.

2.2.3.2 Measuring losses with other methods

If grain is scattered/spilt during operations such as harvesting, winnowing, threshing and transport then careful grain recovery is required to determine how much would have been lost. Detail of this are given in **Section 2.7**.

2.3 Making loss estimates representative - how many samples to take and where to take them

It is essential that the samples you take, whether they are the households to participate in a questionnaire survey or the grain stores of a loss assessment study, are representative of the 'population' of households or grain stores that fall in the area you have chosen to investigate. The principles for determining the number of households to visit during a questionnaire survey are similar to those for determining the numbers of grain samples to take when assessing grain losses. Households and grain samples are both 'sample units' and the principles for determining how many units are needed, and whereabouts you should take them from, are described in this section. This section also deals with the practicalities of sampling grain.

2.3.1 The balance between sample size and accuracy of individual measures

The extent of postharvest losses can vary greatly, in some situations they can be severe in others only minor. The reasons for this variation are diverse. It may have to do with small differences in the time of harvest, the postharvest handling technique employed especially how much attention given to hygiene, the prevailing climate, or it could be just a matter of chance. A good example of chance is the attack on maize cobs by the Larger Grain Borer (LGB). There are good years and bad years for this pest, but also certain farmers suffer severe infestations while their neighbours may suffer none. This relates to the way that the pest finds its food. Male beetles locate maize purely by chance (it appears they cannot smell maize). Once a male has found some maize it releases a chemical signal (pheromone) that attracts females and also other males (Hodges, 2002). The result is that in some farm stores a large infestation develops but in maize stores close by there may be no infestation at all.

When making an assessment of losses it is important that this variation is taken into account. For example, it would distort the truth if a loss study just reported the losses from sample units that were unlucky enough to have had a severe LGB infestation. Instead it is important to make an assessment of many sample units (farmers/co-operatives etc.), which will be representative of all those in the area in question; for example the group should include those suffering severe infestation, moderate infestation and no infestation. This is known as a representative sample, the average (mean) loss from all units is calculated and this mean represents the population of the area.

If the loss assessment technique employed is time consuming (and/or expensive) then relatively few assessments can be made. The more time consuming methods generally have the advantage of giving more accurate results for individual sample units but have the disadvantage that when smaller numbers of estimates are used to calculate mean loss values for the wider population they have a low accuracy (i.e. are not very representative). Conversely, rapid loss assessment techniques are less accurate than their conventional counterparts but for the same, or a lower cost, they can be applied to many more sample units. In this way they are likely to offer a more representative estimate of loss.

This brings us to the question of how many sample units to include in order to make a good estimate of the loss.

2.3.2 How many sample units to take

It is very difficult to determine the number of samples to take without knowing in advance how variable losses are between sample units (the more variable losses are between units the more units needed to be sampled in order to give a good estimate of the whole population). If you have information on 1) the degree of precision required (i.e. the estimate of the overall mean loss to be within say 1%, 2%, 5% of its true value, and 2) the range of loss values that can be expected (i.e. difference in % between highest and lowest loss), then you can use Table 2.1 to determine the number of samples units (e.g. households, grain samples etc.) that are required to obtain a specified degree of precision.

Table 2.1: Number of samples required to achieve a given degree of precision (Harris and Lindblad, 1978)

Desired precision	**Range of weight losses expected (%)** (difference in % between highest and lowest)								
	100	**80**	**60**	**50**	**40**	**30**	**20**	**10**	**5**
±1%	5625	3600	2025	1406	900	506	225	54	14
±2%	1406	900	507	351	225	126	57	14	4
±5%	225	144	81	56	36	20	9	2	-
±10%	57	36	21	14	9	5	3	-	-

If the predicted number of samples represents a workload that cannot be supported by the funding available then a lower degree of precision would have to be accepted. Normally, we do not know the range of loss values expected, so some guess work is required.

2.3.3 Deciding which households to sample

There are also other things that need to be taken into account when planning the sampling of households. For example, it is important to ask whether the study area has some parts that are different from others, such as farmers with different practices at certain locations, different climates etc.. Even within a village there may be differences, it is common to find that some farmers are much better off than others (referred to as a difference in 'well-being'), it is therefore important that farmers in different well-being categories are included in the study. So in planning the study you must 'stratify' your sampling effort so that at least some samples will be taken from any areas that may be regarded as different.

But this still does not tell you exactly how many samples you should take. If the sample unit is farmers or grain bags then there may be hundreds or even thousands that could be chosen for assessment. In this case the simplest ‘rule of thumb’ is to take the square root of the number of farming households in the whole area (Table 2.2).

Table 2.2: Number of units (households, bags etc.) to sample (Source)

No. of sample units	No. of units to be sampled
Up to 10	Every unit
11 to 100	10 units, selected at random
More than 100	Approximately the square root of the total number of units, selected at random. So for 500 units you would sample 22 units, 2000 units sample 45 units etc.

In other words if there were 2000 farming families in an area then you would visit 45 of them ($\sqrt{2000}$ = 45). If 500 of 2000 households were different for some reason, e.g. a different ethnic group, or further up the mountain so subject to a different climate etc., then it would be important that 25% (500/2000), or 11 farmers (0.25 x 45) in the sample of 45 come from this group. You now have two distinct groups to investigate 34 farmers in Group A and 11 in Group B (34+11 = 45).

The next question is how do you decide which households to visit? If Group A farmers were located in 5 villages of more or less equal size then you would choose 5 or 6 households from each village. If Group B were all from a single large village then all 11 samples would be from that village. Within any village you may then have to decide which households to visit. You must avoid visiting only the more well-off farmers who will have more land and more resources to devote to better postharvest practices. You need to work with a group from the area to decide what ‘well-being’ categories are relevant to farming families. You should then select some families from each well-being category. This is discussed in more detail in **Sub-Section 2.4.1**.

2.3.4 Using grain spears to take samples

Taking grain samples from stores, whether these stores are grain bags, metal or mud silos, underground pits etc., is most easily done using a grain spear of the appropriate type.

Grain stored in bags can be sampled using a bag spear. These are hollow metal tubes with one pointed end (Fig. 2.1) that can be pushed into a bag of grain. Grain fills the tube which is then removed from the bag, the grain then drains through the handle of the spear into whatever sample receptacle has been provided, tray, plastic sample bag etc.. These spears are relatively cheap, simple and quick to use; two common designs are the cylindrical and tapered types (Fig. 2.1). The tapered sampling spear penetrates bags easily and causes minimal damage to bag material. The cylindrical sampling spear takes a larger and much more even sample. But it is more difficult to push into a bag and tends to leave large holes in the bag material, although the

Figure 2.1: Bag sampling spears - cylindrical spear (left), tapered spear (right)

woven bag material can usually be pushed back into place after taking the sample to prevent grains falling out through it.

Generally, bag spears with an external diameter of about 12mm are designed for small grains such as sorghum and millet, while 25mm diameter spears are suitable for larger grains such as maize and common beans. For good penetration into a bag, the spear should be 40 to 45cm in length. Shorter spears will be unable to obtain material from deeper inside bags. If grain spears are not available locally then it is possible to make them from metal tubing. Most metal workers should be able to do this for you.

The correct way to obtain a sample with a bag spear is to insert the spear with the open side facing downwards and then, when fully inserted, to twist the spear so that the open side faces upwards. If a sampling spear is inserted into a bag with the open side facing upwards, it will be filled with material from the outer few centimetres thus preventing material deeper in the bag from being sampled (Fig. 2.2).

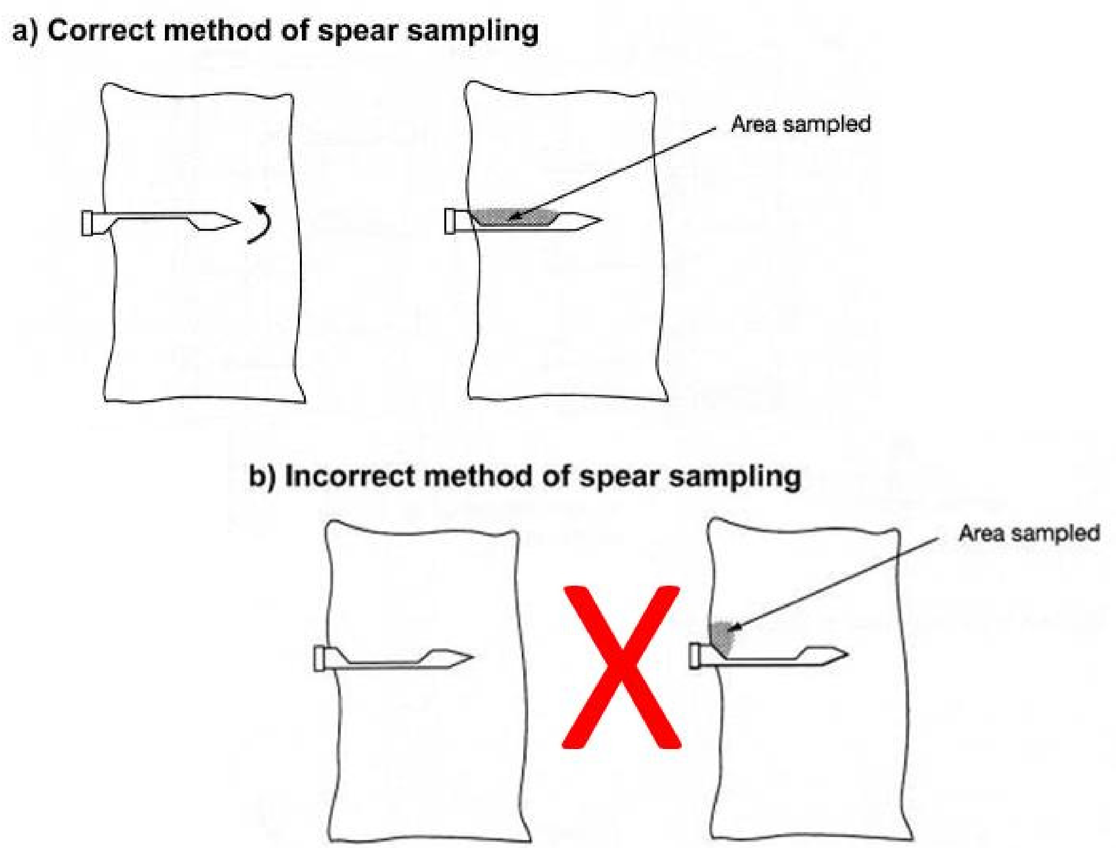


Figure 2.2: Correct and incorrect methods of taking a sample with a bag spear

Important points to remember when using a sampling spear are:

- Normally a sampling spear is inserted once into a 50kg bag to obtain a sample of about 25g of grain and twice into a 100kg bag to obtain 50g of grain. In the case of a 100kg bag, make sure that the two places where the spear is inserted are far apart. When sampling successive bags don't always sample in the same place, take some samples from the middle, some from the top, and some from the bottom of the different bags.
- As spears damage the bag material, they must be used with care. After sampling, the hole made by the spear should be closed by gently pulling the weave of the bag material back together so that grain doesn't keep falling out through it. This may also be achieved by gently tapping the hole with the handle of the sampling spear.

If instead of sampling grain from bags, the grain is in bulks in metal/mud silos, store compartments etc., then a double-tube spear should be used (Fig. 2.3 & 2.4). These consist of two metal tubes, one fitting closely inside the other and each with several slots corresponding to similar slots in the other tube (Fig. 2.4). The intake apertures are opened or closed by turning the inner tube. Spears of this type may vary in length from 45cm to 3.5 metres, and in width from 12 to 50mm. The multi-compartment spears used for the job should be long enough to reach to near the bottom of the grain mass. Note that the tip of the spear needs to be masked with soft tape if the store is susceptible to puncture. It should also be marked at the top end to indicate the maximum depth of insertion.

Figure 2.3: Using a 2m multi-compartment spear to sample a millet granary in Namibia

Figure 2.4: Multi-compartment sampling spears (160cm or 102cm) to sample bulk grain from various depths

Typically, a spear will have from 3 to 6 compartments. There should be a block (cork or other suitable material) between the compartments of the spear to prevent the grain sampled by each compartment mixing with that of another compartment. In this way it will be easy to distinguish the quality of grain from different depth. Very often the grain at the surface and at greater depths is more damaged by insects than grain at intermediate depths.

The spear is inserted into grain with the tubes in the closed position so that no material enters until the sampling position has been reached. Then, the inner tube is turned to open the slots and grain is collected from several positions along the line of penetration. Before withdrawing the spear, the inner tube is turned to close the slots so that none of the sample material is lost as the spear is removed.

After each insertion, lay the spear horizontally and rotate the inner tube so that the grain is released to form several small piles of grain, each corresponding to a certain depth within the grain. The grain from the second insertion can be placed by the side of that from the first insertion and the two mixed to give a larger samples corresponding to each depth (Fig. 2.5).

Figure 2.5: Empty the grain spear after each insertion and then combining samples taken from the same depth in the grain

Before proceeding to sample another store, it is a wise precaution to clean the spear to avoid transferring contamination (insects) between stores.

2.4 How to undertake a questionnaire survey as part of a loss estimation assessment exercise

In Sub-Section 2.2.3 we discussed the need for asking questions of the relevant stakeholders as part of our postharvest loss assessment and considered the questionnaire as an integral part of this process. We will now consider how to implement a household survey using a questionnaire that has already been developed following the process described in Section 2.2.

2.4.1 Household diversity as a factor in the design of surveys

Our survey will seek to find out about grain management practices and losses but these will vary both within and between communities according to ethnic/cultural background and access to resources. In effect, there is diversity both between different communities and also between the households that make up those very same communities. We need to know about this diversity in advance of our 'survey' so that we can ensure that our chosen survey respondents reflect this diversity – in other words that they come from the wide range of circumstances that pertain to the communities under study. To help with this a process of well-being ranking is described in the next sub-section; this is used to distinguish the diversity of households according to access to resources and activities. Once households have been identified in this way then a selection from each well-being category can be used to obtain further information.

In our survey work, besides aspects of ethnic/cultural and resource diversity we also need to give special consideration to gender. We must ensure that the gender balance of our sample of respondents closely matches the manner in which postharvest activities are gendered in the community under study. This is essential since there may be a strong gender-bias on postharvest activities and household management.

The next section describes the essential steps in implementing the survey. These are the minimum required and much abbreviated. A more detailed discussion of farmer survey methodology, rather than just questionnaire surveys, can be found in Nabasa *et al.* (1995).

2.4.2 Planning and implementing households surveys

Step 1: Approach the Extension Service

Approach the extension service to explain the project and ask for help in selection of communities. Help is also needed for an introduction to the communities.

For selection of communities, first ask about ethnic groups in the area (provided this is not a sensitive issue), known differences in agricultural/postharvest practices, accessibility for transport, and general seasonal activities. You should select communities to cover the widest range of the diversity described by the extension agent. In other words, there will be a purposeful choice of communities in order to capture diversity of practice.

Step 2: Visiting the Community Leader

a. Arrange with the Extension Agent to visit the leaders of the chosen communities. Ask the Agent to explain that you wish to talk with the Community Leader and later both the Community Leader as well as senior and respected members of the community, school teachers, pastors etc. (including at least one woman) as a group. It is important to follow any local protocol that is advised by the extension worker.

b. On arrival in the community, explain to the Community Leader the purpose of the project and ask permission to work in the community.

c. Ask a group consisting of the Community Leader and the respected members of the community to describe a range of wellbeing indicators for the communities (e.g. ownership of land, cattle, transport, processing facilities, wages from non-agricultural activities etc.). Alternatively, this might be done with an extension worker who knows the community very well.

d. Ask the group to select symbols (stones, green leaf, dried leaf, bank notes, etc.) to represented each of the well-being indicators and then group the indicators to help decide how many well-being categories there are in a community.

Figure 2.6: Creating well-being classes by using various symbols to represent indicators of well-being (Ghana)

e. Ask the group to indicate how many of their households there are in each category.

f. You can now calculate how many households you should interview in each category if say the number should not exceed 12, an example is given below.

Category	No. in community	% of community	No. to interview
1	25	12.5	2 (=12x12.5%)
2	50	25	3
3	75	37.5	4
4	50	25	3
Total	200	100	12

g. Ask the Community Leader to provide a listing of twice as many households in each well-being category as required by the study. The required number of respondents can be selected at random from this list by drawing names/numbers from a hat or by using a random number table (Annex 3).

h. Ask the Extension Agent to check through the list of households to identify those that may not be available, are inaccessible etc., and select replacements from the list.

i. Arrange a timetable of visits with the Community Leader and Extension Agent and ensure that the households are warned in advance of your coming.

Step 3: Planning and implementing household interviews

Before implementing the survey it is important that the survey staff is briefed on its roles. They should also have had an opportunity to practice the use of the questionnaire. Staff can be grouped in teams of two, since not more than two should interview any one household, although two or three teams might be active in anyone community at the same time. There should be a division of labour in the two-person team, one person can do the talking while the other can listen and write the responses into the questionnaire form.

Planning the interview

- Inform the local Extension Agent of the proposed visit in advance in order to alert respondent households and arrange interview times etc..
- Brief team members on the rationale and format of the visit.
- Designate the interviewer and recorder in advance; if possible the local Extension Agent should also be part of the team.
- No more than 3 people should be present, in addition to household members (and non-participants who might prove to be a distraction are probably best steered away, providing this doesn’t place the interviewee under any additional strain).

Just before the interview

- Meet and greet farmer and household – Local Extension Agent could make the initial introductions.
- The interviewer should mention the purpose of the project (i.e. to understand postharvest operations, assess losses, and seek solutions to reduce losses).
- The interviewer should state explicitly -
    - ✓ Who is sponsoring this research

- ✓ Which organisation is implementing it
- ✓ That participation is voluntary and that farmers can withdraw at any time
- ✓ The finding will remain anonymous
- ✓ The Interviewer should confirm farmer's interest in taking part in the interview, and that s/he is happy to undertake the interview now (or at a later specified time), and
- ✓ The Interviewer must explain his/her and the reporter's roles, and that of anyone else that may be present.

The actual interview

- Deliver the questions carefully and allow the respondent to answer fully without any prompting.
- Once the questionnaire is completed, ask respondent if there are any questions s/he would like to ask.
- With permission, take pictures of the farmer in front of his/her house so that construction and roof details are shown and any other interesting assets (e.g. ox cart, oxen, stores). Take pictures of postharvest equipment and stores whenever possible. Well cited pictures can capture aspects of wealth or poverty.
- Wind-up the interview; offer thanks and indicate the probable return dates if applicable.

You now have some ideas about implementing a questionnaire survey as part of the loss assessment exercise. Suggestions have been given concerning the questionnaire, the approach to testing it for suitability, and how to implement the survey. During the questionnaire interview or subsequently, you may initiate the process of making an actual assessment of losses. This may be done using a visual scale. How to construct a visual scale is the subject of the next section.

2.5 How to construct a visual scale for undertaking rapid loss assessment

Visual scales are a rapid method of determining the weight loss and/or quality of grain samples. They are usually prepared for threshed cereals but in the case of maize they can also be prepared for cobs. Their advantages have already been listed (see **Sub-Section 2.2.3**). This section describes how to prepare visual scales for threshed cereal grains and for maize cobs, while **Section 2.6** describes how visual scales are actually used to estimate losses.

A visual scale can be used to assist loss assessment at any link of the postharvest chain where there has been biodeterioration but give no measure of losses due to scattered or spilt grain or those grains completely removed by rodents, ants etc. For assistance with these see **Section 2.7**.

2.5.1 The principles of a visual scale

The best way to understand a visual scale is to see one (Figure 2.7). The example in Figure 2.7 was constructed for the loss assessment of millet in traditional farm stores. The first four classes are fit for human consumption and have associated weight loss values. In the case of Class 5, the grain is no longer fit for human consumption and has an associated weight loss of 11% but as it is outside the human food chain it may therefore be regarded at 100% weight loss, despite the fact that it could be fed to animals and so retains some residual value.

The scale is prepared in four basic steps:

Step A- a set of grain samples of widely differing qualities, from best to worst is obtained from farmers and traders.

Step B – stakeholders are consulted on the end-uses of different grain qualities.

Step C – in the laboratory several samples of grain representing each distinct quality ('Class') with distinct end-uses are prepared. The weight loss associated with each Class is determined using the 'count and weigh' technique (Box 2.2), and a description of grain quality prepared for each class.

Step D - each sample is a 'Class' and is placed transparent plastic container (plastic bag, Petri dish etc.). They are presented to stakeholders to confirm that they relate to the identified end-uses and that they can be used easily to assess samples taken from stakeholders grain stocks.

The loss assessment is made by comparing a sample taken at the relevant link in the postharvest chain with the set of pre-prepared grain classes.

Class	% insect damage (% weight loss*)	Contamination	End use	Sample photo
1	0 (0)	None	Suitable for sale to Namib mills or a local commercial miller (ABC)	
2	15 (2.12)	1.5% frass/sand, almost no moth webbing	For household consumption, sales to local people and possibly ABC millers	
3	30 (4.25)	3% frass/sand, moth webbing frequent small portions, occasional rodent pellets	For household consumption, sales to local people	
4	60 (8.5)	Large amounts of moth webbing, frequent rodent pellets, mud from basket plastering	To be hand picked, infested material fed to animals, the rest used as human food	
5	80 (11)	Vast amounts of moth webbing, frequent rodent pellets, straw and , mud	To be fed to animals	

Figure 2.7: Visual scale for loss assessment of millet in Namibia

*determined by the count and weight methods (Box 2.2)

2.5.2 Constructing a visual scale for threshed grain

To establish a visual scale, it is usually necessary to prepare four or five different grain classes. These are made using high quality grain (Class 1), the other classes are derived by mixing in different proportions of grain that are insect damaged, broken, mouldy or discoloured and foreign matter such as dockage, sand, insect frass etc.. Each class is assessed for its implied weight loss by analysis using the 'count and weight method' and its degree of contamination described to show its quality loss. It is intended that each class will be assigned to an end-use; this makes the scale intuitively easier for stakeholders to understand and may allow it to be associated with a market value, so that in more advanced studies a quality loss could be given a financial value. The relationship between quality and value is often complex, for a discussion of this see Hodges (2012). After consultation with stakeholders, the classes might be arranged like this:

Class 1 – highly valued in a formal market (something like grade 1 in a formal grain standard)

Class 2 – acceptable in a formal market (something like grade 2 in a formal grain standard)

Class 3 – not likely to enter a formal market without some conditioning to make it equivalent to Class 2 but acceptable on a local, informal market

Class 4 – acceptable for home consumption and sale or exchange to neighbours especially if subject to some conditioning

Class 5 – not generally fit for human consumption but would be fed to livestock

These different end-uses are established by showing samples of the pre-prepared classes to the relevant stakeholders (farmers, traders etc.) to gain their feedback on what the classes mean to them. The classes of a visual scale may be presented in the form of photographs and/or grain in containers such as plastic bags or Petri dishes and the user can assign a grain sample to a class or place it between two classes. Following stakeholder feedback, the classes may have to be 'redesigned', i.e. classes added or combined or redescribed. During an assessment of millet losses in Nambia, stakeholders were asked to assess the visual scale samples presented in saucers (Fig. 2.8). It was observed that they required almost no explanation on what to do and were extremely quick to assign end-uses. They recognized issues of grain contamination and of grain damage and assessed both when making a decision about the class of a sample.

Figure 2.8: Members of a local co-operative assigning the end uses of the five millet classes of a visual scale (Namibia)

A visual scale is simple to use. It is just a matter of taking samples of the grain under test and assessing which of the classes they resemble most closely. Samples can even be positioned between two classes, where the grain damage or contaminations values are taken as mid-way between the two classes (i.e. 2.5 is between Class 2 and Class 3). It is possible to rate samples according to insect damage (which also gives a measure of weight loss) and their quality. They may often have the same rating on both measures but may sometimes differ.

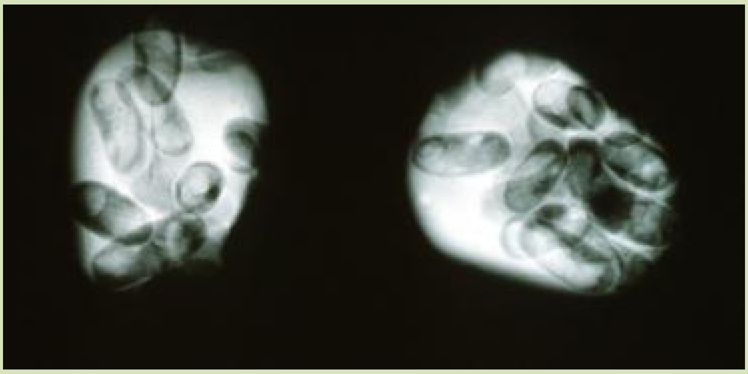
The following steps should be followed to create a visual scale for threshed/shelled grain.

A. Obtain grain samples

1. Obtain grain samples (about 1kg of each) with widely differing degrees of insect damage/contamination of the grain type and variety that is the subject of study.
2. These samples should vary from completely undamaged/uncontaminated grain through to the most damaged and contaminated grain that is likely to be encountered.
3. Obtain the samples by visiting various stakeholders, i.e. farmers, traders, market stalls etc., at various times in the postharvest season (early, middle, late)
4. All samples should be treated to avoid any further deterioration. If they have a moisture content of more than 13.5% then they should be dried in the sun or in an oven if available. When fully dried they should be disinfested (of insects) either by placing in a freezer (-18°C) for at least one week or subject to a phosphine fumigation. Box 2.1 explains how to do these methods of disinfestation

Box 2.1 – How to disinfest grain samples

Grain samples will continue to be eaten by insects if care is not taken to disinfest them and then keep them in insect-proof containers. This is important because time and effort is required to prepare the samples of a visual scale and their loss would be a considerable waste of effort. The immature stages of insects that infest grain can be completely hidden within the grain and then emerge later as adults to lay eggs that will result in more insects and more grain damage. It is important not to assume that sound looking grain is uninfested, such grain must still be treated to ensure that any hidden infestation is destroyed.



An X-ray of insect infestation hidden within maize grains that have a sound external

appearance

Disinfestation by freezing
Place 1-2 kg of grain to be disinfested in a plastic bag and close tightly. Put the bag in a freezer (at -18°C) and leave there for a minimum of 7 days. Remove the bag from the freezer and allow the grain to warm to room temperature before opening the bag. Opening the bag whilst the grain is still cold could result in moisture condensation and consequently an increase in grain moisture content. This might lead to mould growth.

Disinfestation by phosphine fumigation
Instead of freezing, insects could be destroyed by fumigation with phosphine gas. Place the grain samples in an open weave sack, paper bag or other container that is easily permeable to air. Place the grain into a plastic or metal drum or other container (up to 0.5 m^3 capacity) that can be sealed easily to make it airtight. Place one 3g tablet of aluminium phosphide in a lightly sealed paper envelope and put this in the drum. Seal the drum and leave for a minimum of 5 days. During this time the drum should be in a well ventilated place away from human habitation. This is important as phosphine gas can be lethal to humans. At the end of the fumigation period, open the top of the drum in an open-air, fully ventilated location. Remove the grain samples and leave them in the open air to ventilate for a minimum of two hours. Dispose of the phosphide residues in the envelope by burying at 50cm in the ground at a location at least 25m from human habitation or water source.

B. Establish the scale classes

5. When collecting the samples from stakeholders discuss with them what the different end-uses and values of the samples represent. This will help in the initial establishment of the scale.

C. Preparing the visual scale

6. Undertake the following analysis of those samples that most closely represent the end-uses and values identified by the stakeholders. For each sample:
    a. Record the total weight of each sample (you will need weigh scales that read to 2 decimal places)
    b. Select out the good grain, each category of damaged grain and foreign matter, this will typically be
        - Good quality grain
        - Broken grain
        - Pest (insects, rodents) damaged grain
        - Mouldy and discoloured grain
        - Foreign matter
    c. Record the weight of each of these fractions and calculate this weight as a percentage of the sample weight.
    d. Undertake a ‘count and weigh’ loss assessment of the pest damaged grain (Box 2.2) so that the weight loss associated with each class of the scale is known.

Box 2.2 Count and weigh loss assessment

The pest damaged and undamaged grain from the sample are first counted and then weighed. The % weight loss can then be calculated using the following equation

$$\text{Weight loss \%} = \frac{NdWu - WdNu}{(Nd + Nu) \times Wu} \times 100$$

Where

Nd = Number of damaged grains in the sample

Nu = Number of undamaged grains in the sample

Wd = Weight of damaged grains in sample

Wu = Weight of undamaged grains in the sample

7. Take pictures of each class of grain so that assessment can be done using pictures; have the class number showing in each picture (as in Figure 2.7). Once prepared each picture should be enlarged so that two pictures will fit on an A4 page. Place the pages in clear plastic envelopes to keep them dry and clean. Sufficient sets of these photographs need to be prepared to distribute to each loss assessment team.
8. Place the grain samples representing each class in clear plastic bags that are labelled with the class number and tightly closed, or in clear plastic Petri dishes sealed at their edges with tape. These grain samples and the pictures (see 7. above) should both be available when the visual scale is to be used.

D. Validating the scale classes

9. Now that the visual scale has been prepared it is time to practice its use. Visit a sample of stakeholders that are representative of the range to be included in the loss assessment exercise; include two or three of each category, e.g. two or three small holder farmers, market traders etc.. Take with you the visual scale (as photographs and/or a set of grain samples representing each class), some grain samples to be assessed and equipment for taking grain samples. Explain to the stakeholders the use of the scale. Ask them to make a visual scale assessment of the grain samples you have brought with you, you could ask for a class value according to both the grain damage and quality (contamination). Then take a sample of the stakeholders' own grain and ask them to assess that. Record the results for both the samples you provided and the one belonging to the stakeholder. Repeat with other stakeholders.
10. Now assess how well the stakeholders managed to make the assessment and also how consistent the results were between the same stakeholders and different stakeholders. From this you should be able to conclude whether or not adjustments need to be made to the scale to make it more meaningful in terms of end-use or to make it easier to apply.

A list of the equipment needed for the construction of a visual scale is given in Box 2.3.

Box 2.3 – Equipment needed for the preparation of a visual scale

Sampling spear – to take grain samples for the construction of the visual scale

Forceps – for handling grain

Metal trays – for handling grain

Sample divider – to separate samples in a representative manner

Sieves (appropriate sizes relevant to the grades used locally)

Balance (weighing to at least 2 decimal places) – for weight loss estimates

Plastic sample bags – for collection and transport of samples and to display them

Plastic Petri dishes – to display samples of each class of the visual scale

Sellotape – to seal Petri dishes

Access to freezer/ phosphine fumigation – to disinfest grain samples

Camera – to take pictures of visual scale samples

Colour printer (laser or inkjet) – to print out the visual scales (alternatively photographs could be glued to paper).

Now we will consider the practical details of creating a visual scale for maize cobs.

2.5.3 Constructing a visual scale for maize cobs

Making visual scales for maize cobs is similar in principle to that for shelled grain but differs in that - a) a sample of cobs is taken and from this sample the cobs are sorted into damage categories, and b) in preparing the scale the count and weight technique can be refined to take into account grain that are missing from the cob (Compton *et al.*, 1998). Use the following procedure:

A. Obtain a large sample of maize cobs

Find a location where it is possible to obtain a large sample of maize cobs that have varying degrees of damage. Sort these maize cobs into several distinct categories according to their degree of damage; typically four, five or six categories, with about 50 cobs in each category.

B. Establish the scale classes

Work with farmers to define the end uses of the damage categories that have been identified, in a similar way to that described for shelled grain.

C. Preparing the visual scale

Determine the weight loss associated with each damage class by selecting about 30 cobs from each class. Shell these cobs and bulk the grain from each damage class. Undertake a modified 'count and weigh' analysis on each sample (see Box 2.4) to determine its 'damage coefficient.

Box 2.4 Modified count and weigh for maize cobs

1. Shell about 30 maize cobs from 'one class'. Record the number of missing and destroyed* grains in each cob. These are then summed over all cobs in the sample to give the total number of destroyed and missing grains (TND).
2. Sift the shelled grain from each cob through a standard nested sieve set (e.g. 3.35/2.0/0.85 mm).
3. The sifted grains from all the cobs are then pooled. The pooled sample is weighed and the weight recorded to the nearest gram. This is the final weight (FW).
4. A box divider (riffle divider) is used to sub-divide the pooled sample several times to obtain two sub-samples containing about 400-600 grains each. The number of grains should be increased if there is a high proportion of damaged grains. There should be a minimum number of 50 undamaged grains in the sub-sample.
5. The grains in each sub-sample are separated into two groups, damaged and undamaged.
6. For each sub-sample the groups of damaged and undamaged grains are counted and weighed as in the conventional method.
7. The following formula is used to calculate the weight loss.

$$\text{Weight loss \%} = 100 \times \frac{TND(Wd - Wu)Wu + FW(NdWu - NuWd)}{TND(Wd + Wu)Wu + FW(Nd + Nu)Wu}$$

The weight loss is calculated separately for sub-samples 1 and 2, and the average of these two values is taken as the estimated weight loss of the cob sample.

FW = Final weight

Nd = Number of damaged grains in the sample

Nu = Number of undamaged grains in the sample

TND = Total number of damaged and missing grain

Wd = Weight of damaged grains in sample

Wu = Weight of undamaged grains in the sample

*Destroyed grains are those that are crushed during shelling into fragments smaller than one third of a grain or pass through a 3.35mm sieve in step 3.

Take pictures of maize cobs from each damage class including examples of the best and the worst cobs from each class (Fig. 2.9). Also keep examples of cobs from each damage class in tough transparent plastic bags, which should be disinfested using one of the methods described in Box 2.1. Use the pictures and examples of cobs during field assessments.

Class 1 - Undamaged

Class 2 – light damage

Class 3 – medium/high damage

Class 4 – severe damage

Figure 2.9: Example of a visual damage scale for maize

2.5.4 Simple calibrations to convert observed grain damage to weight losses

It is possible to determine grain weight loss by reference to the percentage of damaged grain observed in a sample. In the past 'rule of thumb' conversion factors have been used to convert grain damage into weight loss (Table 2.3). Put simply, it is possible to work with an average figure for the proportion of grain that is removed by insects; in the case of maize grain insect damage is expected to remove about 1/8th of the weight of each infested grain, so if the proportion of grain with insect damage is known then dividing this by 8 will give an estimate of the weight loss due to infestation.

Table 2.3: Conversion factors between grain damage and grain weight loss (Adams and Schulten, 1978)

Crop	Conversion factors (divide % damage grain by this factor to obtain % weight loss)
Maize (stored as shelled grain or a cobs without husk)	8
Maize (stored as cobs with husk)	4.5
Wheat	2
Sorghum	4
Paddy	2

If you plot the relationship between damaged grain and weight loss on a graph then this typically follows a simple straight line at levels of grain damage up to about 50% but thereafter weight losses tends increase more quickly so if conversions of grain damage above 50% are required then a carefully constructed curve rather than the simple rule of thumb will significantly improve accuracy. The collection of a range of samples of widely differing levels of damage and their assessment for weight loss using the count and weigh technique (Box 2.2) will provide data from which such a graph can be constructed.

To determine grain weight losses take sample consisting of several hundred grain. Count the numbers of grains that are damaged and then apply the appropriate conversion factor.

The next section describes how to undertake loss assessment exercise using the visual scale, how to estimate the loss and adjust it in a way that can be used in the APHLIS system.

2.6 How to estimate storage losses using a visual scale

For some years, visual scales have been used to estimate losses in grain storage although at least in theory they might be used at other links in the postharvest chain. Sampling a store to give a representative sample is an important part of the process and has been dealt with in **Section 2.3**. The current section addresses five important questions when using a visual scale a) when to do the sampling, b) how to determine the quantity of grain present at each sampling interval (to assist in estimating a cumulative loss for the whole storage period), c) how to use the visual loss data to estimate weight loss at each sampling interval, d) how to estimate the cumulative loss, and finally e) how could the visual scale be used to estimate qualitative losses.

2.6.1 When to take the samples

In the case of **farm stores**, samples need to be taken early in the storage season and again at intervals so the progress of loss over time is recorded. How this is done depends on the household plan for storage. If the grain will be removed by the household for sale, consumption etc. during the storage period then more frequent visits are required than if the grain will remain untouched for the entire duration of storage. The reason for this is that if grain is being removed then the loss associated with the weight of grain removed at each interval must be recorded in order to compute a cumulative loss (explained in **Sub-section 2.6.5**). On the other hand, if the grain is untouched during storage then the same loss value applies to all the grain and no cumulative loss calculation is required. Likewise it is important to know if grain is actually added during the storage period as this would make a loss computation very difficult.

Whatever the circumstances, a visit to the farmers early in the storage season is essential to gather data on which to base the sampling plan and record the grain weights held in storage; this is usually the time when the questionnaire survey is done. If grain will be removed there need to be several visits at intervals of four to six weeks over the duration of storage. Experience has shown that losses are minimal in the first three months; they begin to rise in the fourth to sixth month and may then proceed more rapidly after the seventh month (Fig. 2.1). So a sampling plan starting at 6 weeks after the start of storage then at six to eight week intervals to the end of storage is likely to be adequate (giving a maximum of about 7 visits across the season). However, to obtain the most accurate baseline of grain damage, i.e. to know precisely the condition of grain entering storage, it would be best to be present at the time grain is put into store. If the storage techniques that have been adopted result in minimal storage losses then the frequency of visit can be reduced (giving three or four visits across the season).

2.6.2 Determining how much grain is in store

Under most circumstance it is important to know how much grain is present in a store at the time of sampling. This is even more important if a cumulative loss over several sampling intervals is to be calculated. To determine the weight of grain lost during storage and to make cumulative loss estimations it is essential to know how much grain is present at the start of the loss assessment study, how much is removed from store during the study and finally how much remains at the end. For grain stored in bags or in parallel sided containers, estimating the amount at these intervals is relatively easy and described below. If stores are of other shapes then special arrangements will be needed and these depend on the shape (an example of estimating the grain weight in a spherical granary is presented in Annex 4).

2.6.2.1 Grain bags

It is relatively easy to determine how much grain is held in a store when grain bags are in use. All that is required is to observe how many bags are present, the capacities of these bags (e.g. 50kg, 90kg 100kg), and by recording how full they are, i.e. full, half or quarter.

2.6.2.2 Parallel side stores

For stores with parallel sides, the volume of grain in cubic meters (m^3) is calculated very simply by multiplying the length by the width of the store by the depth of grain in it. For examples if a store is 1.80m long, 1.0m wide and is filled to a depth of 2.10m with sorghum grain, then the volume of grain is

$$1.8m \times 1.0m \times 2.1m = 3.78m^3$$

The weight of grain is then determined by multiplying this volume by the bulk density of sorghum. Examples of various bulk densities are shown in Table 2.4 but may vary according to how the grain is stored (bag or bulk), by grain variety, by plumpness (how well grain is filled) and by moisture content. For the store in our example, the weight of the sorghum grain would be -

$$3.78 \times 730 = 2759kg$$

Table 2.4: The bulk density of some common cereal grains (from Golob et al., 2002)

Crop	Bulk density (kg/m^3)
Barley (bulk)	605-703
Maize (shelled, bagged)	613
Maize shelled (bulk)	718-745
Millet (bagged)	640
Millet (bulk)	853
Paddy rice (bagged)	526
Paddy rice (bulk)	576
Rice (bagged)	690
Rice (bulk)	579-864
Sorghum (bulk)	730
Wheat (bagged)	680
Wheat (bulk)	768-805

2.6.3 Making the visual assessment in farm stores

Bags

First assess how many bags should be sampled by reference to the required number of bags Table 2.2. In many farm stores it will be possible to sample most if not all the bags present in the store. Every effort should be made to sample as many bags as possible. A typical farm store holds 1-2 tonnes which would be 20-40 bags of 50kg or 10 to 20 bags of 100kg. Some bags of grain may be inaccessible; these may have to be left unsampled.

Sample each of the selected bags with a sampling spear (**Sub-Section 2.3.4**), placing each sample in a separate plastic bag ready for visual assessment. Once the samples have been taken, work together with the householder to assess each sample for its class for insect damage and class for quality. Record the results on a data sheet that includes details of the household and quantity of grain present in store. If time is short then it is possible to combine all the samples taken in one household and assess that single sample as representative of all of them. However, if possible the assessment should be done on each individual sample as this will show the degree of variation within one household.

Grain Bulks

In some cases the household will be storing its grain in bulk. The bulk could be contained in a silo or grain store compartment or be loose as a pile on a drying floor or heap of grain in a house. In all these situations it may be possible to use a multi-compartment spear (**Sub-Section 2.3.4**) to take the samples. The sampling spear chosen for the job should be able to reach to near the bottom of the grain mass. Typically the spear will have 3 to 6 compartments. If the spear has say 5 compartments each extracting about 25g then each insertion take a total of about 125g which is equivalent to sampling five 50kg bags. If a store holds 1 tonne of grain (i.e. holds the equivalent of twenty 50kg bags) then the spear should be inserted 4 times so that in effect twenty bags (5 bags x 4) have been sampled. The four insertions should be as far from each other as possible. In shallow, loose bulks, a scoop (such as a long handled spoon) could be substituted for a sampling spear. When sampling from bulks using the multi-compartment sampling spear each compartment will represent a different sample from a particular depth within the store. Grain quality is likely to vary according to depth. Once the samples have been taken, work together with the householder to assess each sample for its class for insect damage and class for quality according to depth.

Maize cobs stores

Maize cobs could be sampled in the field, from a drying floor, or from a drying crib. They need to be selected at random from as many locations as possible. When sampling cobs, take a minimum of 30 cobs, but preferably 50 to 100 cobs, with the cobs taken from as many locations in the bulk as possible. If necessary remove the sheathing leaves from the cobs and then sort them into the damage categories (whatever number of categories you have defined).

2.6.4 Sampling to make a visual assessment of grain in a large bag store

When working in the bag store of a large trader the situation is different as many of the bags cannot be accessed because they are inside a big bag stack. A true representative sample can only be taken from a large bag stack when it is being built or being taken down, so that all the bags in the stack have an equal chance of being sampled. It may not be practical to sample the bags during bag movements so instead it has to be assumed that the bags in the stack have been placed randomly and that those on the outside represent the quality of those on the inside (which would normally be the case). It is important that samples are taken from each of the sides and the top of the stack, i.e. the sampling operation is stratified by the sides and top of the stack. The number of samples taken from any side or the top should be in proportion to the numbers of bags present, i.e. if for example the top has twice as many bags as any of the sides then twice as many samples should be taken from the top. This stratification is important as insects are not likely to be evenly distributed on the surface of a bag stack. So when the number of bags to be sampled has been determined (Table 2.2) then these should be divided according to the numbers of bags available for sampling on each of the five surfaces. The bags on each surface should be selected at random for sampling. The bags to be sampled can be selected by drawing names/numbers from a hat or by using a random number table (Annex 3).

2.6.5 Calculating weight losses from visual scale assessments

2.6.5.1 Visual losses from threshed grain

The data collected will represent a number of visual scale estimates for a particular farming household. It might appear as follows (Table 2.5) when ten sacks of equal size (e.g. 50kg) have been sampled:

Table 2.5: Class values and weight loss of ten 50kg sacks of grain showing a visual weight loss calculation

Sample no.	Bag weight	Class	% weight loss	Comment
1	50kg	1	0	
2	50kg	2	2.12	
3	50kg	2.5	3.31	Between class 2 and 3
4	50kg	3	4.5	
5	50kg	1	0	
6	50kg	3	4.5	
7	50kg	2	2.12	
8	50kg	3.5	6.5	Between class 3 and 4
9	50kg	4	8.5	
10	50kg	1	0	
		Mean % weight loss	**3.2**	

The weight loss is calculated by taking the simple arithmetic mean of the weight losses (=3.2%). However, if the samples taken were representatives of different weights, for example if there was a mixture of bags and some were 100kg and others 50kg then it would be necessary to calculate a weighted average as shown in Table 2.6.

Table 2.6: Class values and weight loss of five 50kg sacks and five 100kg sacks of grain showing the calculation of a weighted average visual loss

Sample no.	Bag weight (a)	Class	% weight loss (b)	Weight loss proportion (a x b)	Comment
1	50	1	0	0	
2	50	2	2.12	106	
3	50	2.5	3.31	165.5	Between class 2 and 3
4	50	3	4.5	225	
5	50	1	0	0	
6	100	3	4.5	450	
7	100	2	2.12	212	
8	100	3.5	6.5	350	Between class 3 and 4
9	100	4	8.5	850	
10	100	1	0	0	
Totals	750			2658.5	
Weighted mean % weight loss 2658.5/750 =				**3.54**	

The weighted average calculation applies to any situation where one or more samples represent a greater quantity of grain than others. This might happen in a spherical grain store (Fig. 2.10) where a sample taken from a 20cm layer near the top and one taken from a 20cm layer near the middle would represent layers of the same height but quite different widths (the middle section of a sphere is much wider than the top or bottom sections).

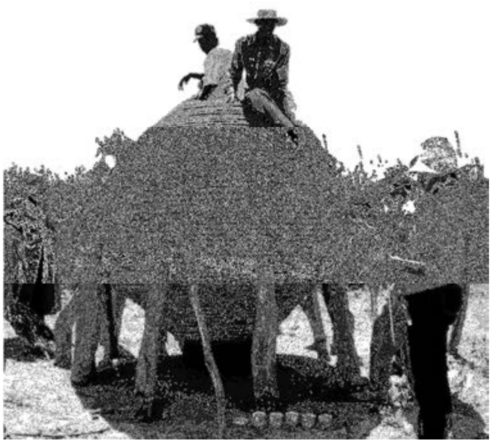


Figure 2.10: A spherical grain store where the width of the area sampled is much wider close to the middle of the store than towards to top or bottom of the store

Having obtained a weight loss estimate for a particular situation, say the weight loss of grain in one particular household at a certain time after harvest, then it will be necessary to put this together with the loss estimates for other households to give a representative estimate of weight losses for the 'population' that is the research target, e.g. a particular village, harvest season, province etc.. In most postharvest surveys the weight loss estimates for each household are combined to give a mean value without any regard to the amount of grain held by each household (i.e. it is assumed that they all produce similar quantities). However, where they are big differences between households then again a weighted average loss, taking into account the total weight of grain held by each household would be more accurate.

2.6.4.2 Visual loss from damage cobs

Your sampling exercise will have recorded the number of maize cobs in each damage class. Using this data, the following equation is employed to calculate the visual weight loss in the sample -

$$\text{Visual weight loss} = \frac{aN_1 + bN_2 + cN_3 + dN_4 + eN_5}{N_T}$$

$N_1 - N_5$ = Number of cobs in classes 1 to 5 in sample
N_T = Total number of cobs in sample
and a-e are damage coefficients (i.e. % weight loss associated with each class).

2.6.6 Computing a loss value that takes grain removals into account

From any situation where a storage loss value is being estimated, if grain removal has occurred during the storage period then the loss should be expressed as a cumulative loss.

In this situation determining the cumulative loss requires knowledge of -

1) The quantity of grain in store at the start of the loss monitoring exercise
2) The quantities removed from store at specified intervals (this could be taken as monthly if more precise data not available). It is also important to know if any grain has been added as this may affect any loss estimation.
3) A weight loss value that can be attributed to each quantity removed from store, this is estimated using the grain remaining in the store at that time
4) The weight and loss associated with the grain that remains at the end of the storage period.

The example shown in Table 2.7 illustrates the data that might be collected in a losses study.

Table 2.7: An example of data collected in a loss assessment study of grain storage where grain is removed by the household at intervals, a loss value is assigned to the grain removed by assessing the grain remaining in the store at roughly the same intervals as the removals

	Sampling Date	Quantity of grain removed/ left at end of storage	% weight loss by visual scale of grain in store
Start	2nd Feb	Store filled with 900kg of grain	0%
	2 March	70kg removed	0%
	2 April	90kg removed	0.25%
	2 May	150kg removed	0.75%
	2 June	130kg removed	1.8%
	2 July	190kg removed	2.6%
	2 Aug	60kg removed	5.2%
	2 Sept	72kg removed	9.7%
	2 Oct	55kg removed	15.0%
End	2 Nov	Grain remaining 47kg	20.0%

A cumulative loss is then computed using the method shown in Table 2.8.

Table 2.8: The calculation of a cumulative loss based on field data gathered at monthly intervals

Total quantity stored = 900 kg on 2 Feb										
Date	02-Mar	02-Apr	02-May	02-Jun	02-Jul	02-Aug	02-Sep	02-Oct	02-Nov	Total
Observed quantity removed (kg) (a)	70	90	150	130	190	60	72	55	47	864.0
% of grain removed (a/900) =(b)	7.8%	10.0%	16.7%	14.4%	21.1%	6.7%	8.0%	6.1%	5.2%	
Observed weight loss at each interval (c)	0.00%	0.25%	0.75%	1.80%	2.60%	5.20%	9.70%	15.00%	20.00%	
Weight loss as % of total stored (b*c)	0.00%	0.03%	0.13%	0.26%	0.55%	0.35%	0.78%	0.92%	1.04%	
Cumulative % weight loss	0.00%	0.03%	0.15%	0.41%	0.96%	1.31%	2.08%	3.00%	4.04%	
Total lost = 4.04% of 900kg = 900*0.404 = 36kg										

It may not always be possible to gather complete field data and it may be necessary to make assumptions about certain variables. For example, the data concerning grain removals may be incomplete so the researcher may have to assume a certain pattern of removals based on what farmers say is their own normal experience. So taking the example above, it might be assumed that the consumption pattern was even between the months. This would give the cumulative loss shown in Table 2.9. The loss here is greater because more grain is left until later in the storage season which is a time when losses are higher.

Table 2.9: The calculation of a cumulative loss based on field data but with an assumed consumption pattern

Total quantity stored = 900 kg on 2 Feb										
Date	02-Mar	02-Apr	02-May	02-Jun	02-Jul	02-Aug	02-Sep	02-Oct	02-Nov	Total
Assumed quantity removed (kg) (a)	100	100	100	100	100	100	100	100	54.0	854.0
% of grain removed (a/900) =(b)	11.1%	11.1%	11.1%	11.1%	11.1%	11.1%	11.1%	11.1%	6.0%	
Observed weight loss at each interval (c)	0.00%	0.25%	0.75%	1.80%	2.60%	5.20%	9.70%	15.00%	20.00%	
Weight loss as % of total stored (b*c)	0.00%	0.03%	0.08%	0.20%	0.29%	0.58%	1.08%	1.67%	1.20%	
Cumulative % weight loss	0.00%	0.03%	0.11%	0.31%	0.60%	1.18%	2.26%	3.92%	5.12%	
Total lost = 5.12% of 900kg = 900*0.0512 = 46kg										

The situation could be even more difficult. For example if only the beginning and end of storage are observed then it might be known what quantity entered storage (900kg) and what loss was observed at this time (0%) and then the store was visited again at only the end of storage when the quality remaining and loss have been observed. In this situation then the removal pattern would again be assumed on the same basis as before and a general rule of thumb applied to the rate at which insect infestation increases in store which would be that the first 3 month period suffers 15% of the losses, the second 3 month period 30% of the losses, and the final three months 55% of losses. Table 2.10 demonstrates the losses that are estimates in this case.

Table: 2.10: The calculation of a cumulative loss based on field data but with an assumed consumption pattern and assumed pattern of loss based on the final % weight loss value

Total quantity stored = 900 kg on 2 Feb										
Date	02-Mar	02-Apr	02-May	02-Jun	02-Jul	02-Aug	02-Sep	02-Oct	02-Nov	Total
Assumed quantity removed (kg) (a)	100	100	100	100	100	100	100	100	37	837
% of grain removed (a/900) =(b)	11.1%	11.1%	11.1%	11.1%	11.1%	11.1%	11.1%	11.1%	4.1%	
Assumed/observed weight loss at each interval (c)	1.0%	2.0%	3.0%	5.0%	7.0%	9.0%	12.7%	16.3%	20.0%	
Weight loss as % of total stored (b*c)	0.1%	0.2%	0.3%	0.6%	0.8%	1.0%	1.4%	1.8%	0.8%	
Cumulative % weight loss	0.1%	0.3%	0.7%	1.2%	2.0%	3.0%	4.4%	6.2%	7.0%	
Total lost = 7.0% of 900kg = 900*0.069 = 63kg										

The losses are again somewhat higher due both to the assumed removal pattern and due to the fact that the loss values for the first three months are higher than actually observed in the field. However, the overall range of losses are not great 4.0 – 7.0% (in this example) and likely to fall within the range of individual household variation. When loss data like this are combined into a cumulative loss value for the postharvest chain the difference has only a relatively modest impact. Clearly it is better to work with a full data set from the household but estimation of this type is likely to provide a much better understanding of the true situation than just guessing, i.e. the loss value is not being taken as 20% which would have been wildly inaccurate.

The visual scale can be used to assess losses in storage and some other situations, but other techniques are required when dealing with most grain held elsewhere. These other techniques are dealt with in **Section 2.7**.

2.6.7 Estimating quality losses with the visual scale

The visual scale offers a means of determining quality loss, especially if the class values reference directly to a formal grading system, e.g. class 1 = grade 1, class 2 = grade 2, class 3 = grades 3 and 4. The method for determining the class value is the same as for determining the weight loss as described in **Sub-Section 2.6.3**. The weighted average class value must then be expressed in terms of its equivalent formal grade (if the visual scale has been constructed so that this can be done).

Once the classes of grain held by farmers or farmers' groups have been identified then a market value, or loss of market value, can be assigned to the grain. The time chosen for grain sales does not necessarily coincide with maximum grain prices but varies considerably according to farmers' cash needs, storage capacity and the shelf-life of the grain (a function of initial quality and storage method). Nevertheless assessment of economic loss is possible and an approach to this has been described by Adams and Harman (1977). A copy of this report can be downloaded from the APHLIS website.

2.7 How to measure the losses at links in the postharvest chain other than storage

In the literature describing postharvest losses of cereal grains, the majority of loss estimates are figures for storage losses (Fig. 2.11). Figures for losses at other links of the chain are relatively scarce. There are two reasons for this. The first is that loss assessment has generally been undertaken when there is a project to actually improve an aspect of the postharvest system and links other than storage have rarely been the subject of such improvement projects. The second reason concerns the difficulty of making the estimates. As farm stores are protected, discrete entities, assessing the losses associated with them is relatively easy, but nevertheless it is still a time-consuming and expensive job.

	Number of loss figures
Harvesting/field drying	38
Transport to homestead	19
Drying	2
Threshing/shelling	23
Winnowing	7
Farm storage	83
Transport to market	2
Market storage	3

Figure 2.11: The number of loss figures for each link in the postharvest chain that are currently available to APHLIS for the construction of postharvest loss profiles

The accounts of approaches to loss assessment for the other postharvest links that are given below present general guidelines rather than precise recipes of what to do. This allows researchers to at least propose a general plan for loss assessment while leaving the detailed procedures to be developed to the time when the nature of the situation is fully understood.

To show how a loss assessment study might be designed, an example of a plan is given in the **Sub-Section 2.8.**

2.7.1 Harvesting and field drying

Losses at the time of harvest arise from two sources, 1) the scattering (sometimes referred to as shattering) of grain due to a combination of the method of harvest, the type and variety of crop and its maturity, and 2) the grain that is not harvested, i.e. remains on the plant. Crops harvested too late suffer much greater scattering losses, they may also suffer losses due to bird attack and this can be estimated separately by estimating the weight of grains missing from panicles or heads at time of harvest. To allow further drying, the crops may also be stacked or 'stooked' in the field and further losses may occur due to more scattering and consumption by pests (insects, rodents and birds).

Figure 2.12: Harvesting the crop

Loss assessment at harvesting is potentially a very time consuming process. The basic approach is to measure the potential yield of the crop. There are two ways to do this.

1) To harvest a test area very carefully, avoiding scattering losses and grain remaining on the plant, or
2) To collect up (glean) the grain that has fallen on the ground and the grain that is still attached to the plant then add these back into the actual yield of threshed grain to give the potential yield.

The advantages and disadvantages of each approach are discussed by Boxall (1986); both present difficulties. It is also important in any study to make it quite clear on what basis the loss is being expressed. First, is the loss being calculated as a percentage of the potential or of the actual yield? Boxall (1986) considers that it is more appropriate to express the loss as a % of the food available at harvest, so loss as a percentage of the actual yield is probably justified. Also, is the harvesting loss only grain scattered at the time of harvest or does it also include sound and mature grain left on the mature plant during the harvesting operation? Have other losses, such as grain removed by birds or termites been included (although it is often difficult to distinguish between bird losses and those resulting from scattering).

The losses that happen during the stooking and stacking of grain in the field should be included as part of the harvesting operation. Hence in APHLIS the first category of postharvest loss is 'Harvesting and Field Drying'. A simple approach to determining the extent of these losses is to place a plastic sheet under the stacks or stooks and weigh the grain that collects on the sheet. However, there may also be some biodeterioration were a visual scale could be used to estimate losses. One special category of biodeterioration, rotting grain, is a particular problem when the harvest is close to a wet season that commences before harvesting is completed. The damp cloudy weather prevents the harvested crop, or even the crop still on the plant, from drying. Consequently, the grain suffers mould attack that renders it unfit for human or even animal consumption. This may be an increasing problem as climates become more variable as a result of climate change. Determining losses in this case can be done relatively easily. Farmers need to be encouraged to place their damaged seed heads in sacks (these need to be provided by the loss assessment project) and from this the proportion of damaged grain can be easily estimated (see example of loss assessment **Section 2.8**).

2.7.2 Platform drying

Prior to threshing, grain may be subject to further drying in and around the homestead. The seed heads may be hung on racks or placed on specially constructed platforms or in drying cribs (Fig. 2.13).

Figure 2.13: An improved drying crib

These are effectively grain storage situations and loss could be determined by the use of visual scales to estimate losses due to biodeterioration, while sheets and gleaning can be used to collect scattered/spilt grain.

2.7.3 Threshing/shelling and winnowing

Losses at threshing may arise because the threshing is incomplete (i.e. some grain remains on the seed head), the grain is scattered and spilled, or the grain becomes damaged in the process. In the case of winnowing the loss arises from scattering.

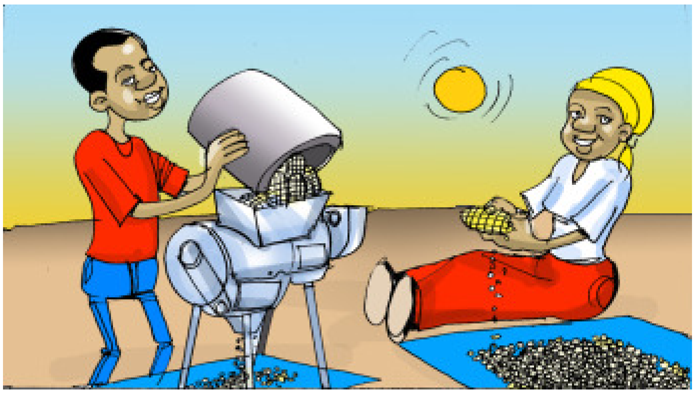


Figure 2.14: Grain threshing/shelling

Assessing grain that remains on the seed head (cob, panicle) can be done fairly easily by sampling heads at random after threshing/shelling and counting and weighing the remaining grain. Then for comparison, a sample of the same number and size of heads can then be carefully threshed so that the weight of grain after complete threshing is known. It may be necessary to take the moisture content of the two samples and adjust them to a standard moisture content (normally 14%, see Table 2.10) if there is likely to be a difference in moisture content between them. The weight loss is expressed as the weight of the sample remaining after threshing as a percentage of the weight of completely threshed grain.

To estimate grain scattered during threshing a large plastic sheet can be spread in the area to catch such grain, which can then be collected and weighed. The loss should be expressed as the weight of scattered grain as a percentage of the weight of grain successfully threshed plus the scattered grain.

2.7.4 Drying

To measure physical losses of grain from the drying process, the amount of grain entering and leaving this part of the system could be measured. For example, grain may be weighed before and after sun drying and the difference would be the loss due to spillage, scattering, removal by birds, wind etc.. It is important to remember that drying losses do not include changes in moisture content, so the grain weights before and after drying should be adjusted to standard moisture content (14%, see Table 2.10).

Figure 2.15: Sun drying the crop

Drying losses of paddy grain need separate consideration since grain damage at drying can result in a significant increase in broken grains, which has a negative impact on the value of rice. For more details of loss assessment of rice during drying consult Boxall (1986).

Table 2.10- Conversion factors to obtain grain weights at 14% moisture content*

Multiply by -

Moisture content %	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
8	1.0698	1.0686	1.0674	1.0663	1.0651	1.0640	1.0628	1.0616	1.0605	1.0593
9	1.0581	1.0570	1.0558	1.0547	1.0535	1.0523	1.0512	1.0500	1.0488	1.0477
10	1.0465	1.0453	1.0442	1.0430	1.0419	1.0407	1.0395	1.0384	1.0372	1.0361
11	1.0349	1.0337	1.0326	1.0314	1.0302	1.0291	1.0279	1.0267	1.0256	1.0244
12	1.0233	1.0221	1.0209	1.0198	1.0186	1.0174	1.0163	1.0151	1.0140	1.0128
13	1.0116	1.0105	1.0093	1.0081	1.0070	1.0058	1.0047	1.0034	1.0023	1.0012
14	1.0000	0.9988	0.9977	0.9965	0.9953	0.9942	0.9930	0.9919	0.9907	0.9895
15	0.9884	0.9872	0.9860	0.9849	0.9837	0.9826	0.9814	0.9802	0.9791	0.9779
16	0.9767	0.9756	0.9744	0.9733	0.9721	0.9709	0.9698	0.9686	0.9674	0.9663
17	0.9651	0.9641	0.9628	0.9616	0.9605	0.9593	0.9581	0.9569	0.9558	0.9547
18	0.9535	0.9523	0.9512	0.9500	0.9488	0.9477	0.9464	0.9452	0.9442	0.9430
19	0.9419	0.9408	0.9395	0.9384	0.9372	0.9360	0.9349	0.9337	0.9326	0.9314
20	0.9302	0.9291	0.9279	0.9267	0.9256	0.9244	0.9233	0.9221	0.9209	0.9198
21	0.9189	0.9174	0.9163	0.9151	0.9140	0.9118	0.9116	0.9105	0.9093	0.9081
22	0.9070	0.9058	0.9047	0.9035	0.9023	0.9012	0.9000	0.8988	0.8977	0.8965
23	0.8953	0.8942	0.8930	0.8919	0.8907	0.8895	0.8884	0.8872	0.8860	0.8849
24	0.8837	0.8826	0.8814	0.8802	0.8791	0.8779	0.8767	0.8766	0.8744	0.8733
25	0.8721	0.8709	0.8698	0.8686	0.8674	0.8663	0.8651	0.8640	0.8626	0.8616
26	0.8605	0.8593	0.8581	0.8570	0.8558	0.8547	0.8535	0.8523	0.8512	0.8500
27	0.8488	0.8477	0.8465	0.8453	0.8442	0.8430	0.8414	0.8407	0.8395	0.8384
28	0.8372	0.8360	0.8349	0.8337	0.8326	0.8314	0.8302	0.8291	0.8279	0.8267
29	0.8256	0.8244	0.8233	0.8221	0.8209	0.8198	0.8186	0.8174	0.8163	0.8151
30	0.8140	0.8128	0.8116	0.8105	0.8093	0.8081	0.8070	0.8058	0.8047	0.8035
31	0.8023	0.8012	0.8000	0.7988	0.7977	0.7665	0.7953	0.7942	0.7930	0.7919
32	0.7903	0.7895	0.7884	0.7872	0.7860	0.7849	0.7837	0.7826	0.7814	0.7802

Source: Toquero 1981

* For example if there is 10 tonnes of grain at 16.3% moisture content then at 14% mc the weight of the grain would be 9.733 tonnes (10 tonnes x 0.9733 = 9.733 tonnes)

2.7.5 Transport

The measurement of losses during transport requires careful collection of scattered grain or weighing of grain bags at the two geographical ends of the transport process. Weighing at start and finish is likely to be the easier option provided accurate scales and labour are available. If transport is relatively rapid, e.g. done within a 24h period, then no adjustments for moisture content change are likely to be needed. Otherwise, weights before and after transport should be adjusted to standard moisture content (14%, see Table 2.10).

Figure 2.16: Various means of transport from field to farm, from farm to market

2.7.6 Collection point, market and large-scale storage

Assessing the grain losses at sites where Farmers' Groups and Co-operative etc. aggregate their grain, in market stores and in large-scale stores, can be challenging. The sources of loss are usually two-fold, grain discarded due to sorting/conditioning, and grain loss due to biodeterioration from insects, water leakage into the store etc..

Figure 2.17: A collection point store, the first aggregation point for farm produce

Grain sorting and conditioning is undertaken in order to raise grain quality to a standard at which it can be marketed; usually in order to comply with a specified grade in a formal trading standard. This can result in a considerable loss, since the grain that is removed in this process is often not fit for human consumption. Although, the damage to this grain will have accrued at earlier stages in the postharvest chain the actual weight loss is realized at this stage. The loss can be measured by following grain in the system and first measuring the gross weights of grain entering the system and then measuring the weight of good grain that comes out. For example, this could be done by following specific bags of grain submitted to the system by a particular farmer and observing how much remains after conditioning. Additional grain drying is often part of the conditioning process so correction of weights to a standard moisture content (14%) is important (see Table 2.10).

To obtain a measure of loss due to biodeterioration, it is necessary to make an assessment of the grain soon after arrival at the store. If possible, samples should be taken from grain bags as they enter the store. The sample should be taken with a grain spear (**Sub-Section 2.3.4**). Decide on the number of samples to take by reference to Sub-**Section 2.3**.**2.** The condition of the grain can be determined using a visual scale **(Section 2.6)**. The grain will be sampled again at appropriate intervals (not more than monthly) and samples taken at random from the accessible outer layers of bags. Changes in grain condition are monitored using the visual scale, but these will not be the only losses. A careful watch has to be kept on the grain that is discarded. This may be the sweeping of spilt grain (which in a well run store would be carefully reconditioned and returned to a sack set aside for the purpose) or grain that has been damage for one reason or another, especially water leaking from the roof. These other sources of loss are likely to be small compared with the general change in grain quality over time.

2.8 Example of an approach to determine maize losses due to damp weather at harvest

In this particular example, the project wanted to help Farmers' Groups to supply traders with more and better quality maize grain. The significant postharvest loss points were expected to be:

1) A portion of the crop is not harvested at physiological maturity but sometime afterwards when the weather is damp. This delay led to insect infestation, damp grain and grain damaged by mould that was apparent at harvest.
2) Grain breakage at time of shelling due to poor shelling technique.
3) Once shelled, grain is still not sufficiently dried and held in farm stores at high moisture content (15-16%) for delivery to traders or eventually for self-consumption.
4) The traders receiving poor quality grain, sieve out and/or handpick to remove poor grain to make the quality acceptable to clients. The removals are a grain loss (even if fed to chickens).

Item 1) must be monitored since any losses due to discarded maize cobs will not be reflected elsewhere in the system. Item 2 (broken grain) and item 3 (high moisture grain) can monitored by observations of grain in farm stores over the storage season and item 4 can be assessed at the traders warehouses.

Data on losses were to be collected by individual farmers under instruction of lead famers who had excelled in previous training activities. In each participating Farmers' Group, three members who have been trained were selected to help gather data. This data should be from their own farms and from two other 'average' farmers.

<u>Data to be gathered</u>

1st July to 31st August– Harvesting pattern and damage at harvest (see Data Sheet 1)

a. Note prevailing weather conditions daily – dry sunny, dry cloudy, wet cloudy, each day for the whole period.
b. When harvesting remove husk cover and use the usual method to sort cobs into good and bad. Place those cobs that are too damaged for human consumption in polypropylene bags provided. Count the number of bags of bad cobs and record for each day. Keep the bags of bad cobs for verification by the supervisor[1] and check on grain moisture content. Continue in the same way until the harvest is complete (records will show harvesting pattern).

[1] Supervisor will convert the number of bags of damaged cobs into the equivalent number of bags of grain (and grain weight at 14% moisture content), so that the % lost grain can be calculated. For the loss calculation it will be assumed that the size of damaged cobs and size of good cobs is the same.

c. After shelling good cobs, count the number of bags of grain produced and record daily.

d. Record the pattern of grain bags marketed. For example bags of grain sent to traders, bags of grain sold to other traders.

1st July to 31st October – weight loss incurred at traders warehouse in order to achieve required quality (see Data Sheet 2)

e. At the traders warehouses, monitor grain cleaning to meet quality requirements. Weigh a bag of grain before processing and recorded grain moisture content. Complete the processing procedure (sieving/hand picking) then place the good grain back in the bag, weigh it and record moisture content. If possible, do this for at least two bags from each farmer. Give some information about what will happen to the poor quality grain that is removed (its end use).

1st July to 31st March – weight loss in farm storage (see Data Sheet 3)

f. At each visit record the amount of grain that has been consumed by the household since the previous visit.

g. Record the change in grain weight loss and quality in farm store at monthly intervals. Do this using a visual-scale for up to 5 bags in each household. Where possible sample and assess grain from the same bags on each visit. Assess the condition of the grain by rating it on the visual scale giving a class value for both weight loss and grain quality.

The data sheets constructed for the collection and recording of the data are shown on the following pages.

Data sheet 1 – Harvesting, shelling and marketing of maize grain

Month: July Farmer: ....

Trader: ....

Date	**Weather** Wet = W Cloudy =C Dry = D Sunny = S	**No. bags damaged cobs**	**No. bags of good shelled grain**	**Bags of grain marketed to traders etc.**
1 July				
2 July				
3 July				
4 July				
5 July				
6 July				
7 July				
8 July				
9 July				
10 July				
11 July				
12 July				
13 July				
14 July				
15 July				
16 July				
17 July				
18 July				
19 July				
20 July				
21 July				
22 July				
23 July				
24 July				
25 July				
26 July				
27 July				
28 July				
29 July				
30 July				
31 July				

Data sheet 2 - Loss of grain during processing at the traders warehouse

Trader: ....

Province: ....

Date	**Name of farmer**	**Wt of grain in bag before processing (kg) and grain moisture content**		**Wt of grain in bag after processing (kg) and grain moisture content**		**Weight of grain lost corrected to 14% moisture content**	**% weight loss at 14% moisture content**
End-use for discarded grain =							
End-use for discarded grain =							
End-use for discarded grain =							
End-use for discarded grain =							
End-use for discarded grain =							
End-use for discarded grain =							
End-use for discarded grain =							
End-use for discarded grain =							

*End-use is the purpose to which the discarded grain will be put, e.g. animal feed, destroyed (burnt/buried), brewing etc.

Data sheet 3 - Household grain storage and consumption pattern

(monitoring up to 5 bags using visual-scale, farmers to be encouraged to consume/market these five bags last)

Record card for one household

Farmers' group:	Swedru	**Province:** Eastern
Household name	: Kambale	**No. members in household =** 5
No. bags of grain reserved for HH consumption at harvest = 12		

Date of visit	**Grain consumed per month (kg)**	**Visual scale assessment of grain weight and quality loss**									
		Bag 1		**Bag 2**		**Bag 3**		**Bag 4**		**Bag 5**	
		Vis. scale classes Wt loss : Quality	Bag wt (kg)	Vis. scale classes Wt loss : Quality	Bag wt (kg)	Vis. scale classes Wt loss : Quality	Bag wt (kg)	Vis. scale classes Wt loss : Quality	Bag wt (kg)	Vis. scale classes Wt loss : Quality	Bag wt (kg)
Start	0	Class 1: Class 1.5	50	Class 1: Class 1	50	Class 1: Class 1	50	Class 1.5: Class 1	50	Class 1: Class 1	100
Month 1	50kg	Class 1: Class 1.5	50	Class 1: Class 1	50	Class 1: Class 1.5	50	Class 1.5: Class 1	50	Class 1: Class 1	100
Month 2	75kg	Class 1: Class 2.0	50	Class 1: Class 1	50	Class 1: Class 2	50	Class 1.5: Class 2	50	Class 1: Class 1.5	100
Month 3											
Month 4											
Month 5											
Month 6											
Month 7											
Month 8											
Month 9											

Resource implications

The project faced a number of costs to implement the loss assessment exercise.

Field team costs

Field team staff fees and transport costs were a major expense. Their time inputs were as follows -

Date	Activity	Time required
May	Visit 8 Farmers' Groups, identify lead farmers (3/Group) and agree their participation	4 days
June	Train lead farmers, 3 from each group	8 days
July	2 monitoring visits to each Farmers' Group and to traders stores (mid-month, end-month)	8 days
August	ditto	8 days
September	ditto	8 days
October	1 monitoring visit to each Farmers' Group (mid-month, end-month)	4 days
November	ditto	4 days
December	ditto	4 days

Incentive payments to lead farmers

Incentive payments to the lead farmers were considered necessary to ensure their assistance. Advice was taken from the field team on the level of payment and its frequency. It proved a better incentive to offer a small interim payment followed by a final lump sum than say to pay a monthly retainer. There were 24 lead farmers each was paid US$10/month, for the 6 month loss assessment exercise (July – Dec) this gave a total to US$1,440. The individual farmer could be paid an interim of 25% in September (US$15) and the rest in December (US$45). However, it should be noted that in some countries there is a policy not to pay farmers cash for this type of service as it may create unrealistic expectations on the part of farmers offered involvement in future projects.

Polypropylene bags

About 360 polypropylene bags were supplied to farmers for them to store rotten cobs at harvest time. Costs were US$1.5 per bag when purchased second hand from the local market.

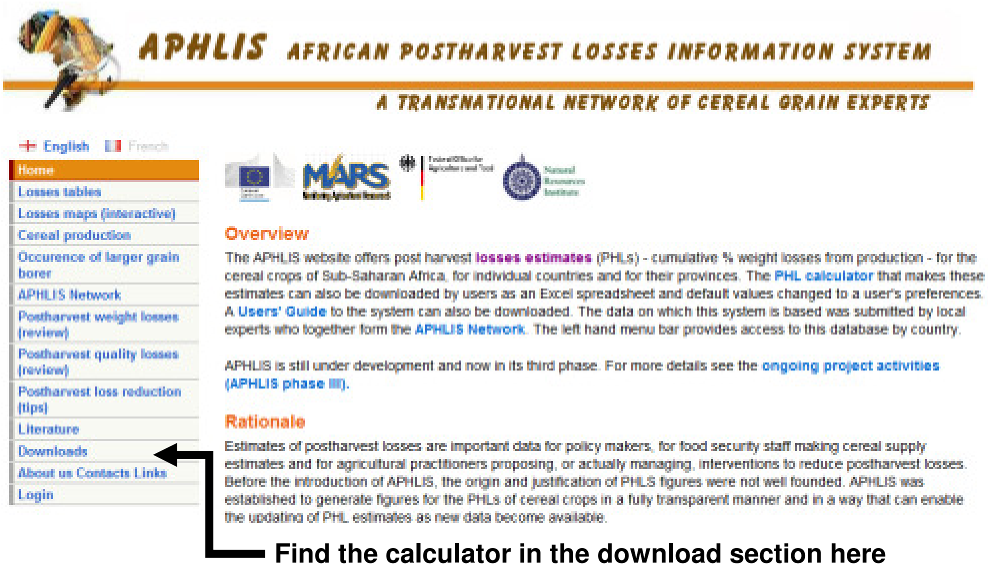
Part 3 – How to use APHLIS in loss assessment studies

3.1 Using the downloadable PHL calculator to estimate cumulative losses

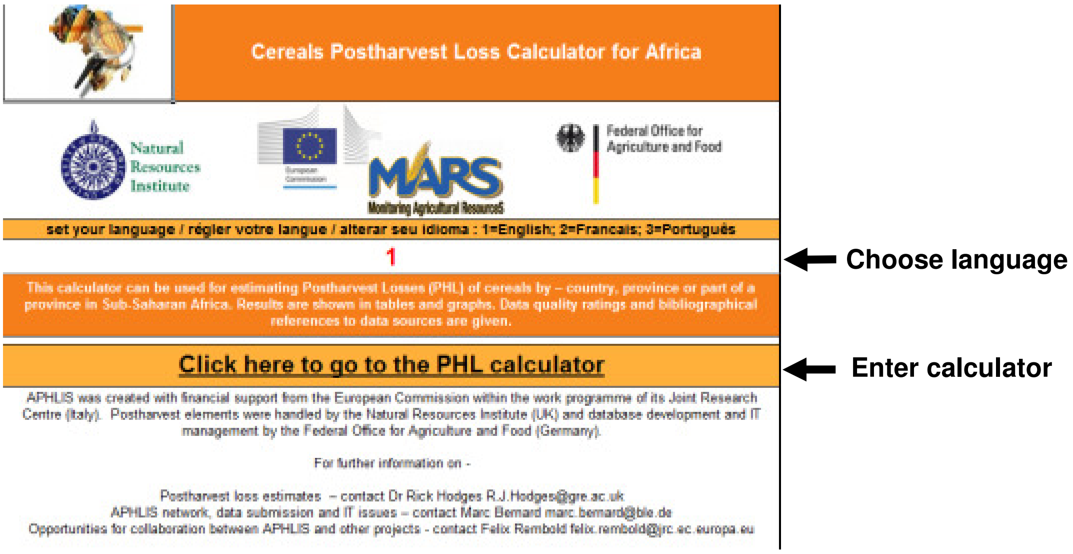
APHLIS offers a loss calculator that can be downloaded from its website as an Excel spreadsheet. In this part of the manual, practitioners learn how to use this calculator to determine cumulative weight losses from production along the postharvest chain by entering their own data for a specific geographical location or to enter hypothetical data in order to model a 'what if' scenario. Estimates of cumulative loss from production show how grain availability is changed by interventions designed to reduce losses.

3.1.1 Downloading the calculator

You can download a copy of the calculator from the website (http://www.aphlis.net), simply click the 'Download button' and you will be offered the various files that can be downloaded from APHLIS.

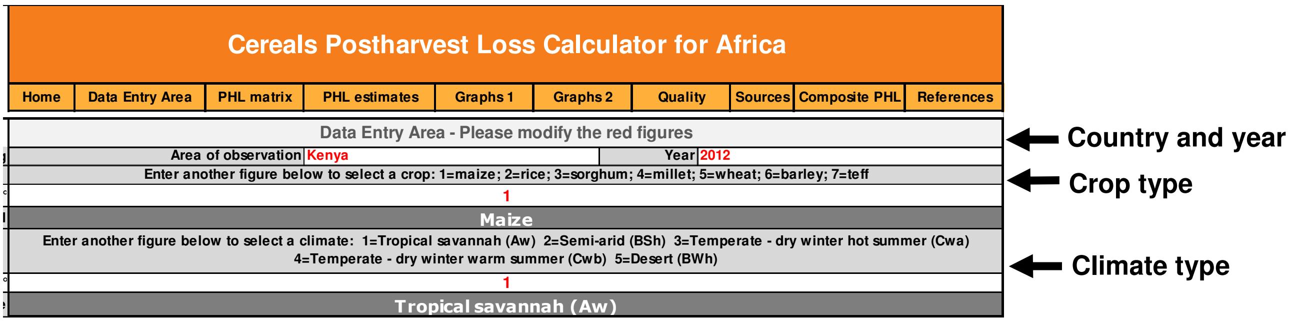


Open the file and you will see the front page (below). Choose your language and then 'click' to enter the calculator.



3.1.2 Entering data into the calculator

Once you have entered the calculator you will be presented with a series of boxes, where the red figures can be altered by the user (all other elements of the calculation are automatic). The first box sets the geographical data, crop type and climate type relevant to your study. If you are unsure about the climate type, consult the Köppen map on the APHLIS website (from the menu - Losses maps, General, Köppen).



Set the relevant geographical data, crop type and climate type (here, Kenya, 2012, maize and tropical savannah)

In the next box you should then enter the seasonally relevant data for the farmer (smallholder or large scale), group of farmers, etc. for whom you are making a loss estimate. There is an option to enter data for one, two or three seasons. Note that in the case of cereal production data, if there is no data for a particular season then you should enter a zero ‘0’. You should not leave the cell blank, if you do then a warning message will be displayed.

	Enter the SEASONAL DATA by replacing the red figures					
	1st season		2nd season		3rd season	
Farm type	small	large	small	large	small	large
Production	1500 tonnes	345 tonnes	300 tonnes	100 tonnes	0 tonnes	0 tonnes
Marketed at harvest	50 % (0-100)	100 % (0-100)	20 % (0-100)	0 % (0-100)	0 % (0-100)	0 % (0-100)
Rain at harvest	1 1=yes	1=yes	1=yes	1 1=yes	1=yes	1=yes
Storage duration	7 months	0 months	4 months	7 months	0 months	0 months
Larger Grain Borer	1=yes	1=yes	1 1=yes	1=yes	1=yes	1=yes

Enter data for - crop production, % marketed at harvest (=first 3 months from harvest) and, if relevant, check rain at harvest data (i.e. enter 1 if there was damp, cloudy weather at harvest and, in the case of only maize enter 1 if there was Larger Grain Borer infestation, otherwise leave blank). If you are going to enter your own storage loss estimate (see Sub-section 3.1.3) then always enter 9 months for 'Storage duration' and leave 'Larger Grain Borer' unchecked.

The relevant postharvest data are as follows (for more details see **Sub-Section 1.2.2**) –

- Production – an estimate of the tonnage of grain produced in the season (if you have no production estimate then it may be possible to create one, see **Sub-Section 3.1.5**),
- Marketed at harvest – this is the % of grain marketed in the 1st three months after harvest,
- Rain at harvest - if there has been wet/damp cloudy weather at harvest time that makes it difficult to dry the grain then enter '1' into the 'rain at harvest' box.
- Storage duration - the number of months grain will be held in farm storage (**BUT** if you are going to change the default storage loss in the PHL profile to a specific figure that you have measured, which is described in the next section, then you **should always** enter here a period of 9 months storage, even if it wasn't, this ensures that APHLIS will not make further adjustments to your storage loss figure)
- Larger Grain Borer – if LGB is a problem during storage of maize then enter '1' into the 'Larger Grain Borer' box (**BUT** if you are going to change the default storage loss in the PHL profile to a specific figure that you have measured then leave this unchecked as any losses due to Larger Grain Borer will already be included in your own storage loss measurement).

Once you have entered this data then postharvest loss profiles are offered for smallholder and/or larger-scale commercial farming. These profiles include a % weight loss figure for each link in the postharvest chain (except winnowing as this is not relevant to maize).

PHL (%) Calculation: Maize - Kenya - 2012

1st season	Farm type	small					large				
Share of production		9					91				
Destination			store		market			store		market	
Share			5		4.5					90.9	
Steps		adjusted PHL profile	remaining grain	loss increment	remaining grain	loss increment	adjusted PHL profile	remaining grain	loss increment	remaining grain	loss increment
Harvesting/field drying		16.3	4	0.7	4	0.7	3.8			87	3.4
Platform drying		4.0	4	0.2	4	0.2	3.5			84	3.1
Threshing and Shelling		1.3	4	0.0	4	0.0	2.3			83	1.9
Winnowing		-									
Transport to farm		2.4	4	0.1	4	0.1	1.9			81	1.6
Farm storage		5.3	3	0.2							
Transport to market		1.7			3	0.1	1.0			80	0.8
Market storage		2.7			3	0.1	2.7			78	2.1
Total			3	[illegible]	3	1.2				78	12.9

2nd season	small					large				
Share of production	75					25				
Destination		store		market			store		market	
Share		60		15.0			25			
Steps	adjusted PHL profile	remaining grain	loss increment	remaining grain	loss increment	adjusted PHL profile	remaining grain	loss increment	remaining grain	loss increment
Harvesting/field drying	6.4	56	3.9	14	1.0	16.3	21	4.1		
Platform drying	4.0	54	2.2	13	0.6	3.5	20	0.7		
Threshing and Shelling	1.3	53	0.7	13	0.2	2.3	20	0.5		
Winnowing	-									
Transport to farm	2.4	52	1.3	13	0.3	1.9	19	0.4		
Farm storage	5.3	49	2.7			2.3	19	0.4		
Transport to market	1.7			13	0.2	1.0				
Market storage	2.7			12	0.3	2.7				
Total		49	10.8	12	2.6		19	6.1		

3rd season	small					large				
Share of production										
Destination		store		market			store		market	
Share										
Steps	adjusted PHL profile	remaining grain	loss increment	remaining grain	loss increment	adjusted PHL profile	remaining grain	loss increment	remaining grain	loss increment
Harvesting/field drying	6.4					3.8				
Platform drying	4.0					3.5				
Threshing and Shelling	1.3					2.3				
Winnowing	-									
Transport to farm	2.4					1.9				
Farm storage										
Transport to market	1.7					1.0				
Market storage	2.7					2.7				
Total										

Smallholder farmer PHL profile for the Season 1 harvest. Note farm storage loss is 5.3%.

3.1.3 Changing the default values of the PHL profile

An important feature of the downloadable calculator is that it is possible to change the default values. At the far right of the spreadsheet there are boxes where your new values can be entered to replace the defaults according to season and by scale of farming (small/large). Enter the postharvest loss values that are relevant to your study or loss figures that you wish to use to generate a 'what if' scenario. In the example below, a 10% loss figure was determine by a project and so this figure has been entered to replace the default value of 5.3% (which you saw in the previous figure).

This box is at far right of spreadsheet

1st season	Farm type	small					large				
Share of production		9					91				
Destination			store		market			store		market	
Share			5		4.5					90.9	
Steps		adjusted PHL profile	remaining grain	loss increment	remaining grain	loss increment	adjusted PHL profile	remaining grain	loss increment	remaining grain	loss increment
Harvesting/field drying		16.3	4	0.7	4	0.7	3.8			87	3.4
Platform drying		4.0	4	0.2	4	0.2	3.5			84	3.1
Threshing and Shelling		1.3	4	0.0	4	0.0	2.3			83	1.9
Winnowing		-									
Transport to farm		2.4	4	0.1	4	0.1	1.9			81	1.6
Farm storage		10.0	3	0.4							
Transport to market		1.7			3	0.1	1.0			80	0.8
Market storage		2.7			3	0.1	2.7			78	2.1
Total			3	1.4	3	1.2				78	12.9

Notice that the storage loss of 5.3% has now changed to 10%

Personalised profiles – Replace default values	1st season		2nd season		3rd season	
	small	large	small	large	small	large
Harvesting/field drying						
Platform drying						
Threshing and Shelling						
Winnowing						
Transport to farm						
Farm storage	10.0					
Transport to market						
Market storage						

Enter new values in the yellow boxes to customise the PHL profile.

Below you will be able to see two estimations of loss, % weight loss (relative loss) and the tonnes lost (absolute loss). This includes transport to market and market storage for the marketed portion of the crop. In the case where you have entered your own storage loss value into the storage loss profile then when making your report on the cumulative loss you should mention the length of the storage period since this will be specific to the storage loss value that you entered into calculator.

Farm type	small	large	small	large	small	large
Grain remaining	58.5	16.0	61.6	18.9		
Lost grain	22.8	2.7	13.4	6.1		
	1st season		2nd season		3rd season	
Grain remaining	74.5		80.5			
Lost grain	25.5		19.5			
Total remaining	76 %					
Annual loss	**24 %**					

	PHL (tonnes) Calculation: Maize - Kenya - 2012					
	1st season		2nd season		3rd season	
Farm type	small	large	small	large	small	large
Production	1,500	345	300	100		
Grain remaining	1,079	296	247	76		
Lost grain	421	49	53	24		
Production	1,845		400			
Grain remaining	1,375		322			
Lost grain	470		78			
Annual production	2,245 tonnes					
Total remaining	1,697 tonnes					
Annual loss	**548 tonnes**					

470 + 78 tonnes = 548 tonnes

A loss of 24% (this includes season 1 and season 2) which amounts to 548 tonnes

3.1.4 Resetting the calculator to model losses

The calculator can be used to model different scenarios, in the last section you saw how to change default values of the PHL profile. You can also change the value for 'seasonal' data to observe their effect on loss estimation. So for example, if it would be of interest to model loss without grain marketing by smallholders then the marketed crop can be removed from the calculation by setting 'Marketed at harvest' to zero, as show below.

Marketed at harvest set to zero

	1st season		2nd season		3rd season	
Farm type	small	large	small	large	small	large
Production	34.5 tonnes	345 tonnes	300 tonnes	100 tonnes	0 tonnes	0 tonnes
Marketed at harvest	0 % (0-100)	0 % (0-100)	20 % (0-100)	0 % (0-100)	0 % (0-100)	0 % (0-100)
Rain at harvest	1 1=yes	1=yes	1=yes	1 1=yes	1=yes	1=yes
Storage duration	7 months	0 months	4 months	7 months	0 months	0 months
Larger Grain Borer	1=yes	1=yes	1 1=yes	1=yes	1=yes	1=yes

This results in no losses accruing due to transport to market or due to market storage.

Farm type	small					large				
Share of production	9					91				
Destination		store		market			store		market	
Share		9							90.9	
Steps	adjusted PHL profile	remaining grain	loss increment	remaining grain	loss increment	adjusted PHL profile	remaining grain	loss increment	remaining grain	loss increment
Harvesting/field drying	16.3	8	1.5			3.8			87	3.4
Platform drying	4.0	7	0.3			3.5			84	3.1
Threshing and Shelling	1.3	7	0.1			2.3			83	1.9
Winnowing	-									
Transport to farm	2.4	7	0.2			1.9			81	1.6
Farm storage	10.0	6	0.7							
Transport to market	1.7					1.0			80	0.8
Market storage	2.7					2.7			78	2.1
Total		6	2.8						78	12.9

No transport to market or market storage losses are registered

The loss value returned has now increased to 26% and 582 tonnes (see below), since farm storage at 10% is much more severe than the losses due to transport and market storage that would have affected the 50% of grain sent to market.

Farm type	small	large	small	large	small	large
Grain remaining	56.7	16.0	61.6	18.9		
Lost grain	24.7	2.7	13.4	6.1		
	1st season		2nd season		3rd season	
Grain remaining	72.7		80.5			
Lost grain	27.3		19.5			
Total remaining	74 %					
Annual loss	26 %					

	PHL (tonnes) Calculation: Maize - Kenya - 2012					
	1st season		2nd season		3rd season	
Farm type	small	large	small	large	small	large
Production	1,500	345	300	100		
Grain remaining	1,045	296	247	76		
Lost grain	455	49	53	24		
Production	1,845		400			
Grain remaining	1,341		322			
Lost grain	504		78			
Annual production	2,245 tonnes					
Total remaining	1,663 tonnes					
Annual loss	582 tonnes					

In this case a higher loss is estimated if no grain is marketed

However, although the % loss is correct the tonnage includes grain that previously was marketed. This may be satisfactory for some purposes but if it should be excluded from the estimate then this can be done by reducing the maize production estimate by 50% (which is the amount of grain that was marketed).

3.1.5 Using APHLIS calculator to help make a production estimate

To calculate a cumulative postharvest loss, the PHL calculator uses an estimate of production as its starting point. If you do not have an estimate of production then the calculator has a facility that will help you make one. This is called the Cereals Production Calculator and it can be found on the far right hand side of the PHL Calculator spreadsheet and looks like the following illustration.

Cereals Production Calculator								
Farm type	small				large			
Weight of grain in store	200				3000			
Weight of grain marketed and consumed	150				4375			
Rain at harvest (1=yes)	1							
Steps	adjusted PHL profile	store	market	% of production	adjusted PHL profile	store	market	% of production
		Grain weight				Grain weight		
Transport to farm	2.4	205	154	82	1.9	3057	4458	1712
Winnowing	-	205	154	82	-	3057	4458	1712
Threshing and Shelling	1.3	208	156	83	2.3	3126	4558	1750
Platform drying	4.0	216	162	86	3.5	3235	4718	1812
Harvesting/field drying	16.3	251	188	100	3.8	3357	4896	100
Production	439				8253			
Marketed at harvest	43%				59%			
Stored at harvest	57%				41%			

But to use the Production Calculator you must have data on both the tonnage of grain being stored and tonnage that has already been removed (sold/consumed). These two figures together represent the total amount of threshed grain from a particular harvest. The weight of grain produced is then estimated by adding back all the expected weight losses that occur between storage and harvesting (i.e. the estimate is made by effectively running the PHL calculator in reverse).

To use the Production Calculator-

1. Set the PHL calculator to the correct crop type and climate type (see **Section 3.1.2**)

2. In the production box add in the weight (tonnes) of grain in store and the weight of grain already marketed and/or consumed. There are separate entries for either smallholder or larger commercial farmers.

3. The production in each farm type is displayed. Now that you have a production estimate, this can be entered into the PHL calculator (under 'Seasonal' data) to help obtain a cumulative weight loss estimate.

3.1.6 Using APHLIS as a component of loss assessment studies

Projects on loss assessment are designed to collect loss data in order to -

i) justify/plan the implementation of loss reduction measures, and/or

ii) to document the impact of loss reduction measures as a component of project monitoring and evaluation (M&E). Such projects typically deliver postharvest training, introduce new postharvest techniques (better stores, drying methods, mechanisation etc.), and/or connect farmers to more quality conscious markets.

In either case APHLIS is an invaluable tool. General loss estimates for provinces can be obtained from the APHLIS website (they are either displayed or will require data input for them to be displayed). Such figures are a useful benchmark against which to compare the progress of projects that are working at a smaller geographical scale. Most postharvest practitioners work on projects that address losses at a relatively small geographical scale (i.e. not the whole country or a whole province) and generate loss data specifically for this situation. Such practitioners need to use the downloadable PHL calculator to obtain a cumulative estimate of postharvest losses. It is very unlikely that a project could collect loss data for all links in the postharvest chain but APHLIS can provide these whilst the practitioner can enter into the calculator the figures relating to those links in the postharvest chain that are relevant to the project. The impact of the new data on the postharvest system as a whole can be seen when the calculator returns an estimate of the cumulative loss of the whole chain. So for example, if losses during storage have been reduced from 10% to 1%, it will now be possible to see what effect this has on the cumulative losses (which would not be a 9% reduction). It will be possible to estimate how much more grain is available and, if farm gate prices are available, then to calculate how much better off farmers might be if they can sell this grain.

In cases where projects have investigated adopters and non-adopters of a technological improvement then for purposes of comparison the groups should be as similar as possible in all respects except for the adoption of the improvement. In the real world they may not be very similar because where an intervention is now well embedded it may have altered the behaviour of the adopters (e.g. they may market more or less grain, store grain for longer or shorter periods or apply or not apply insecticides). In this situation the calculator maybe used to generate different scenarios, such as the losses of these two groups as actually observed, or their losses modelled by inserting the different weight loss values that result from adoption on non-adoption into each other's loss profiles (Table 3.1).

Table 3.1: The various estimates of cumulative loss that can be generated to compare the cumulative losses of adopters and non-adopters of a postharvest intervention

Cumulative loss of -	Loss estimated by -
Adopters (A_1)	entering observed new values for 'seasonal' data and the PHL profile relevant to adoption
Non-Adopters (NA_1)	entering observed values for 'seasonal' data and the PHL profile relevant to non-adoption
Adopters if they had not adopted (A_2)	substituting into the 'seasonal' data and PHL profile those values relevant to non-adoption (from NA_1 - this models non-adoption in adopters)
Non-adopters if they had adopted (NA_2)	- substituting into the 'seasonal' data and PHL profile those values relevant to adoption (from A_1 - this models adoption by non-adopters)

The types of advantage of adoption can be expressed in the following ways

Type 1 - The difference between adopters and non-adopters of the intervention = $NA_1 – A_1$

Type 2 – The advantage to adopters of the intervention (removing other factors that might affect the non-adopters) = $A_2 – A_1$

Type 3 - The potential advantage if non-adopters adopted the intervention = $NA_1 – NA_2$

If the circumstances of adopters and non-adopters are well documented then a narrative can be created to explain the types of advantages (disadvantage) that has been estimated.

An example of the way that the APHLIS downloadable calculator can be used to assess the potential advantages that accrue from a loss reduction project is presented in Box 3.1.

Box 3.1 – Using the downloadable calculator to support a loss reduction project

There is a grain storage project in Ghana that has introduced metal silos for smallholder farmers last year. The researchers now want to estimate how much more maize **grain is available** from those farmers who adopted metal silo storage compared with those who did not adopt the new method. To estimate the new grain availability requires a determination of a cumulative loss that takes into account all links in the postharvest chain; this is what the APHLIS calculator does (not just the change in loss during storage). During 2011, researchers measured the weight losses of maize grain stored in the metal silos of 20 farmers (Group A) using a visual scale (this is explained in Part 2 of the manual). They also assessed the losses of another (control) group of 20 farmers (Group B) who were still using the usual method of grain storage, which is to keep the maize in jute bags in the house without any insecticide treatment.

Groups A and B both live in the same agro-ecological zone (same climate type) and apart from the difference in storage method had exactly the same postharvest practice (but their behaviour was different with respect to % marketed at harvest and length of storage period). To estimate the actual losses from the two groups, the researchers used the downloadable calculator. The features of the two groups were as follows:

Group A - 20 maize farmers using metal silos to store their grain

Estimated maize production = 108 tonnes

Weight losses in storage = 1%

Proportion of grain marketed at harvest (i.e. was stored on farm <3 months) = 10%.

Storage period = 9 months (between harvests)

Group B - 20 maize farmers using jute bags to store their grain

Estimated maize production = 121 tonnes

Weight losses in storage = 10%

Proportion of grain marketed at harvest (i.e. was stored on farm <3 months) = 20%.

Storage period = 7 months (between harvests)

For the Group A (metal silos), APHLIS returned a loss of 14.6% or 16 tonnes (see table below) and for the Group B (jute bags) 21.1% or 26 tonnes (see table below). These are not just storage losses but the expected losses in the postharvest chain from harvesting to market storage. The advantage in terms of the grain availability was that farmers using metal silos storage were able to contribute 6.5% (21.1%-14.6%) more grain than those using jute bags which amounted to 10 tonnes. The comparison however includes not only different grain stores but also the differences in the % marketed at harvest and the difference in storage period.

	Cumulative weight loss or difference	Tonnage loss/difference
Estimate 1 - with marketed grain in the estimate		
Group A	14.6%	16
Group B	21.1%	26
Advantage B-A	6.5%	10
Estimate~~s~~ 2 - marketed grain now excluded from the estimate		
Group A	14.3%	14
Group B	22.1%	21
Advantage B-A	7.8%	7
Estimate 3 - Group B modelled with the storage losses of metal silos		
Group B (bags)	21.1%	26
Group B_1 (silos)	14.9%	18
Advantage B-B_1	6.2%	8

The storage loss can be brought into sharper focus by making the estimates with no marketing entered into APHLIS. To do this the production must be reduced by the amount that is marketed and 'Marketed at harvest' entered as zero. When this is done the % weight loss increased from 6.5% to 7.8% but this now represents a lower tonnage (7 tonnes).

It could be argued that the storage period and marketing arrangements are an essential part of the comparison and grain storage cannot be considered in isolation when trying to assess benefits. It may therefore be of interest to estimate the grain losses if Group B adopted silo storage without changing their marketing arrangements and the length of farm storage, i.e. substitute the storage loss value of B with that of A (assuming that for 7 months storage it would still be 1%). The result is a 6.2% reduction in loss which is equivalent to 8 tonnes of grain. The difference is lower than for Group A as the higher proportion marketed at harvest is unaffected by the adoption of metal silos.

Other comparisons are possible and they should be explored depending on the situation and on what features the researcher wishes to emphasise.

Part 4 – How to submit new data to APHLIS

There are various kinds of new data required by APHLIS and these are described in **Sub-Section 1.2.2**. When new data are available then they can be submitted to APHLIS as described below.

4.1 Postharvest weight loss data

These data are required for improving the PHL profile figures (see **Sub-Section 1.2.2.2**). New data together with details of how they were gathered should be e-mailed to APHLIS3@gmail.com. The data will be assessed and if suitable will be added to the database and will be drawn upon for the calculation of loss profile figures.

4.2 Data on cereal production, climatic variables and 'seasonal factors,'

APHLIS network members with a login and password can submit this data directly into the APHLIS database.

Seasonal data (described in more detail in **Sub-Section 1.3.2**) may be assembled in the form of a simple table. An example of the 2012 data for maize collected in Malawi using the questionnaire form shown in Annex 2, is presented in Table 4.1.

Table 4.1: Seasonal factors data for maize in 2012 for the three provinces of Malawi

Maize, Smallholder, Season 1	**North**	**Central**	**South**
% marketed in 1st 3 months	66.5	39.3	44.7
Length of farm storage	6.5	6.3	6
Rain at harvest	No	No	No
Problems with LGB	Yes	Yes	Yes
Maize, Smallholder, Season 2			
% marketed in 1st 3 months	65	36.3	16.7
Length of farm storage	4	3.7	3.7
Rain at harvest	No	No	No
Problems with LGB	Yes	Yes	Yes
Maize, Large scale, Season 1			
% marketed in 1st 3 months	91	10	-
Length of farm storage	7	-	-
Rain at harvest	No	No	-
Problems with LGB	Yes	Yes	-

4.3 Narrative explanation and information on national postharvest losses

The postharvest loss narratives on the APHLIS website (soon to be posted on eRAILS) are under the control of the country network member. Any useful observations should be submitted to the country member for posting (country members are listed under 'APHLIS network' in the menu of the APHLIS web page).

References

Adams J.M. and Harman G.W. (1977) The evaluation of losses in maize stored on a selection of small farms in Zambia with particular reference to the development of methodology. Tropical Products Institute, London, UK. Report G109, pp. 150.

Adam J.M. and Schulten G.G.M. (1978) Losses caused by insects, mites and micro-organisms. In: Post-Harvest Grain Loss Assessment Methods. (Compliers : K.L. Harris and C.L. Lindblad) pp. 83-95. USA: American Association of Cereal Chemists, pp. 193.

Boxall R.A. (1986) A critical review of the methodology for assessing farm-level grain losses after harvest. Report of the Tropical Development and Research Institute (now Natural Resources Institute), Chatham Kent, UK, G191 viii+139pp.

Compton J.A.F. (1999) Rapid assessment methods for stored maize cobs: weight losses due to insect pests. Journal of Stored Products Research 35, 77-87.

Compton J.A.F., Floyd S., Ofusu A. and Agbo B. (1998) The modified count and weigh method: An improved procedure for assessing weight loss in stored maize cobs. Journal of Stored Products Research34, 277-285.

Compton J.A.F, Floyd S., Magrath P.A., Addo S., GbedeviS.R., Agbo B. Bokor G., Amekupe S., Motey Z., Penni H. and Kumi S. (1998). Involving grain traders in determining the effect of post-harvest insect damage on the price of maize in African markerts. *Crop Protection* **17**, (6) 483-489.

Compton J.A.F., Ofusu A., Magrath P.A., Motte F. Acquaye K., Addo S. and Boxall R.A. (1995) Rapid methods for small farm storage surveys. International Conference on Post-Harvest Technology and Commodity Marketing, Accra, Ghana Nov. 1995. Pp11.

De Lima C.P.F. (1979a). Appropriate techniques for use in the assessment of country loss in stored produce in the tropics. Tropical Stored Products Information 38, 15-19

De Lima C.P.F. (1979b \) The assessment of losses due to insects and rodents in maize stored for subsistence in Kenya. Tropical Stored Products Information 38, pp21-25.

Golob P. (1981) A practical appraisal of on-farm storage losses and loss assessment methods in the Shire Valley of Malawi. Tropical Stored Products Information 40, 5-13.

Golob P., Farrell G. and Orchard J.E. (Eds) (2002) Crop Post-harvest: Science and Technology. Volume 1 Principles and Practice. Blackwell Publishing, Oxford, UK. pp. 301-309.

Harris K.L. and Lindblad C.J. (1978) Postharvest grain loss assessment methods: A manual of methods for the evaluation of postharvest losses. American Association of Cereal Chemists. Pp. 193.

Hodges R.J. (2002) Detection and monitoring of the larger grain borer, *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae). Integrated Pest Management Reviews 7, 223-243.

Hodges R.J. (2012a) Postharvest quality losses of cereal grains in Sub-Saharan Africa. (http://www.erails.net/FARA/aphlis/aphlis/quality-losses-review

Hodges R.J. (2012b) Postharvest losses of cereal grain in Sub-Saharan Africa. http://www.erails.net/FARA/aphlis/aphlis/weight-losses-review/

Hodges R.J. and Stathers T.E. (2012) Training Manual on Postharvest Handling and Storage. UN World Food Programme (Rome, Italy) and Natural Resources Institute (UK). Pp. 246 (http://www.wfp.org/content/p4p-training-manual-improving-grain-postharvest-handling-and-storage)

Nabasa J., Rutwara G., Walker F., and Were C. (1995) Participatory rural appraisal: principles and practicalities. Natural Resources Institute, Chatham, UK. Pp. 52.

Pretty J.N., Gujit I., Thomson J. and Scoones I. (1995) A trainers guide to participatory learning and action. IIED Praticipatory methodology series. London: International Institute for Environment and Development. Pp. 270

Schulten G.G.M. and Westwood D. (1972) Grain storage project Malawi. December 1969 - June 1972. Ministry of Agriculture, Malawi.

Toquero Z. (1981) Action programme for the protection of food losses. Review of loss assessment activities of PFL projects in the Asian region (particularly in Nepal and Pakistan). UN Food and Agriculture Organisation, Rome, Italy. Pp. 47.

Tyler P.S. (1982) Misconception of food losses. United Nations University **http://www.unu.edu/Unupress/food/8F042e/8F042E05.htm**

University of Reading (1998) Data management guidelines for experimental projects. Biometric guidelines. Reading: Statistical Services Centre, University of Reading. Pp20 http://www.reading.ac.uk/ssc/n/resources/Docs/Data_Management_Guidelines.pdf

Wagacha J.M. and Muthomi J.W. (2008) Mycotoxin problem in Africa: Current status, implications to food safety and health and possible management strategy. International Journal of Food Microbiology 124, 1-12.

World Bank (2010) Missing Food: The case of postharvest grain losses in Sub-Saharan Africa. Wolrd Bank, Washington, USA. Report number 60371-AFR. Pp. 96 http://siteresources.worldbank.org/INTARD/Resources/MissingFoods10_web.pdf

Wright M.A.P. (1995) Loss assessment methods for durable stored products in the tropics: appropriateness and outstanding needs. Tropical Science 35, 171-185.

Annex 1 - Example of a postharvest questionnaire

The following questionnaire would need to be customised to the needs of your specific postharvest project. In particular, if you are involved in a postharvest loss reduction project then it must contain questions that relate specifically to improvements that you are trying to introduce.

	Year	Season		Crop		Province	District		Qu'aire No.		
Questionnaire number – 2013-A		-		-			-				

Postharvest Questionnaire

(*Suggested greeting*) We are representing (*insert the relevant organisation*) and are doing a survey in order to learn more about postharvest losses that effect farming households. The point of this work is to get an accurate understanding of the size of losses so that we can support farmers to improve their postharvest practices and thus reduce these losses.

We ask that you answer the questions as accurately and honestly as possible so that our understanding and future activities are then based on addressing the real postharvest situation and problems faced by farmers like yourself.

This interview should not take very long. Are you happy to participate?

A. QUESTIONNAIRE IDENTIFICATION (to be filled in prior to interview)	
Date of interview *(dd/mm/yyyy)*	*__ __ / __ __ /2013*
Cropping season	
Enumerator code	[__ __]
B. LOCATION, CROP, FARM SCALE, HEAD OF HOUSEHOLD GENDER (to be filled in by enumerator)	
Province:	
District:	
Village:	
GPS co-ordinates:	
Focal crop of the survey:	
C. FARMER DETAILS (Farmer to answer)	
Total land area farmed by this household:	[__ __] Ha
Female headed household (Yes/ No):	[__]
Child headed household (Yes/ No):	[__]
Who in your household is responsible for this crop's postharvest management? *(Note: interview this person):*	
Name of the person responsible for postharvest management of this crop: Sex (M/ F):	[__]
Number of household members over 16 years old?	[__ __]

D. FARMER'S CROP POSTHARVEST ACTIVITIES (Farmer to answer – note: answers must be specific to the focal crop)	
1. Do you harvest this crop from just one piece of land or several (if several, how many)?	[__ __] pieces
a) Total area of this crop harvested (state the unit e.g. ha or paces)	[__ __] Ha OR [__ __ x__ __] Paces
2. How long is your experience of cultivating this crop?	[__ __] years
3. What varieties of this crop did you grow in this season?	
4. Did you sell some of this crop harvested in this season? Yes/ No a) If yes, then what markets did you access: b) How did you transport the crop to market:	[__]
5. When was this crop harvested?	[__ __] weeks
6. How many bags of grain of this crop were harvested in this season? (if necessary convert unthreshed in to threshed grain equivalent) a) What is the typical weight of one bag of this grain?	[__ __ __] bags [__ __] kgs

7. What type of structure is used for grain storage	
8. How many bags of this grain were sold soon after harvest (within 3 months)?	[__ __ __] bags
9. How many more bags were/will be sold? (after 3 months)	[__ __ __] bags
10. How many bags of this grain will be kept for the household to eat?	[__ __ __] bags
11. How many weeks will this household food grain last for? *(Calculate how many weeks from harvest until it has all been consumed)*	[__ __] weeks
12. Was there rainfall or damp cloudy weather at harvest time so that this grain was difficult to dry? Y/N a) Any other details about the weather at harvest time?	[__]
13. How do you dry your grain of this crop? *(Probe by asking them to describe: the structure they dry it on, how long they dry it for, where it is dried, and who does it)?*	
14. What method do you use to shell/ thresh this crop? (*Probe by asking them exactly how they do it, what they use, who does it, when, where and over what period of time*)	
15. How do your store your grain of this crop? (*Probe by asking about the storage structure, storage location, form the crop is stored in (cob/grains etc), who manages it, how long is it stored for?*)	

a) Grain stored for household consumption b) Grain stored for later sale	
16. What kinds of pests attack your stored grain?	
17. Do you add anything to your stored shelled/unshelled grain to protect it against insect pests: Yes / No a) If yes, then what do you add? *(Probe by asking about <u>what</u> they add, <u>when</u> they add it, <u>how</u> they add it, <u>how much</u> of it they add, <u>who</u> adds it, <u>whether it works</u>?)*	[__]
E. FARMER'S PERCEPTIONS OF CROP POSTHARVEST LOSSES *(This section could be expanded into several questions, depending on the aims of the survey)* **(Farmer to answer)**	
18. At which postharvest stages (harvesting, transporting, drying, shelling/threshing, storing, milling, marketing, consuming) do you have the most constraints (or losses)? <u>What</u> are these constraints?	

Do you have any questions you would like to ask us?

THANK YOU FOR YOUR TIME.

NOTES (if responses to any of the questions are too long for the space provided, please continue to record the response on the back of this sheet, make sure you state the question number).

Supervisor to confirm that the data has been collected correctly and/or entered inot the computer correctly by signing the relevant boxes below.

F. QUALITY CONTROL	***Supervisor name***	***Date (dd/mm/yyyy)***	***Signature***
Information collected correctly?		__/__/____	
Information entered into computer correctly?		__/__/____	

Comments

Annex 2 - Interview form for the collection of APHLIS seasonal data

This form is the basis for an interview with experienced individuals to gather data about agricultural factors that vary from season to season. These factors affect the weight losses calculations of APHLIS.

The interview is expected to last about 40 minutes and may either be 'face to face' or done over the phone. Before proceeding with the interview, the interviewer should establish that the interviewee has sufficient experience to be able to answer the questions with a reasonable degree of accuracy. If not an alternative interviewee should be sought.

A. Interviewee details

Name: ....

Description of position in organisation: ....

Main area of expertise: ....

Length of time working in this area: ....

Name of interviewer: ....

Date of interview ..../......../.......

B. Context

1. Which area are we covering in this interview? (circle then add names below)

Agric. extension unit District (s) Province Other

....

2. Year of observation ....

3. Which crops are important and for which you could give us information? (tick)

Maize		Rice		Sorghum		Millet	
Wheat		Barley		Teff		other	

4. What proportion of farmers cultivate each of the crops in the area you are considering? (insert % of farmers for each crop)

Maize		Rice		Sorghum		Millet	
Wheat		Barley		Teff		other	

5. How many harvests are there each year for each of the important cereal crops and in which month is the harvest?

Crop	**Number of harvests**	**Month of harvest 1**	**Month of harvest 2**	**Month of harvest 3**
Maize				
Rice				
Sorghum				
Millet				
Wheat				
Barley				
Teff				
Other				

6. Are there large scale and smallholder farmers in your area? (‘Y’ or ‘N’)

Crop	Smallholder	Large scale
Maize		
Rice		
Sorghum		
Millet		
Wheat		
Barley		
Teff		
Other		

C. Seasonal factors

Rain at harvest

1) **Do farmers experience rainfall or damp cloudy conditions at harvest?** (mark ‘Y’ or ‘N’)

Crop	Smallholder			Large scale		
	Harvest			Harvest		
	1	2	3	1	2	3
Maize						
Rice						
Sorghum						
Millet						
Wheat						
Barley						
Teff						
Other						

1b) **Was this year (harvest) different from previous years (harvest) and if so what was the difference?** Record any details.

2) **If there was rainfall or damp cloudy conditions at harvest then did farmers experience problems in drying their grain?** (mark 'Y' or 'N')

Crop	Smallholder			Large scale		
	Harvest			Harvest		
	1	2	3	1	2	3
Maize						
Rice						
Sorghum						
Millet						
Wheat						
Barley						
Teff						
Other						

3) **If farmers had drying problems in any of the seasons then what % of farmers are believed to have experienced this problem?** (mark %)

Crop	Smallholder			Large scale		
	Harvest			Harvest		
	1	2	3	1	2	3
Maize						
Rice						
Sorghum						
Millet						
Wheat						
Barley						
Teff						
Other						

<u>Grain marketed</u>

1) **How much grain do farmers produce on average?** (record number of bags, stating bag size, or tonnes)

Crop	Smallholder			Large scale		
	Harvest			Harvest		
	1	2	3	1	2	3
Maize Bag size						
Rice Bag size						
Sorghum Bag size						
Millet Bag size						
Wheat Bag size						
Barley Bag size						
Teff Bag size						
Other Bag size						

2) **Do farmers sell any of their grain?** (mark 'Y' or 'N')

Crop	Smallholder			Large scale		
	Harvest			Harvest		
	1	2	3	1	2	3
Maize						
Rice						
Sorghum						
Millet						
Wheat						
Barley						
Teff						
Other						

3) **If yes, then how many bags/tonnes of their harvest do they sell?** (mark bags/tonnes)

Crop/harvest number	Smallholder			Large scale		
	Season			Season		
	1	2	3	1	2	3
Maize						
Rice						
Sorghum						
Millet						
Wheat						
Barley						
Teff						
Other						

4) **How many bags/tonnes of their grain do they sell within the first three months after harvest?** (mark bags/tonnes)

Crop	Smallholder			Large scale		
	Harvest			Harvest		
	1	2	3	1	2	3
Maize						
Rice						
Sorghum						
Millet						
Wheat						
Barley						
Teff						
Other						

Length of farm storage period

1) **Indicate the name of the month in which farmers finish consuming all the grain from the first (or only) harvest, 2nd harvest, 3rd harvest**

Crop	Smallholder			Large scale		
	Harvest			Harvest		
	1	2	3	1	2	3
Maize						
Rice						
Sorghum						
Millet						
Wheat						
Barley						
Teff						
Other						

<u>Larger grain borer infestation</u>

1) **Do you know LGB? If yes then describe it?** (indicate 'Y'/'N' below, if yes proceed to 2)

Y / N

2) **Does LGB occur on maize grain in your province?** (If yes, then indicate where and which years).

Y / N

Where	Years

3) **Did farmers complain about LGB on maize in your area this season?** (indicate 'Y' or 'N' and provide any additional details)

Y / N

Annex 3 - Using a random number table to select grain bags for sampling

Tables of random numbers are composed of numbers produced in a completely random manner by computer and from a definite range of numbers. Table 1 contains one thousand randomised numbers in the range from 1 to 100. [Note that the numbers 1 to 9 are printed as 01 to 09, and that 100 is indicated by 00 to maintain a two-digit configuration, and is intended to facilitate reading of the table]. Numbers are presented in blocks of twenty-five pairs of digits for the same reason.

There is some degree of flexibility in the way a table of random numbers can be read provided that two basic rules are observed:

a) you must adhere to the method decided upon at least until all possible number combinations obtainable from it have been exhausted;

b) you must never start at a point in the table which has been used as a starting point before.

Selecting bags for sampling from consignments of 11 to 100 bags

We know that ten bags should be selected at random from consignments of 11 to 100 bags. The example below illustrates how this is done using a table of random numbers.

Example 1

Ten bags have to be selected from a consignment of 53 bags. Using the random numbers in Table 1, read the numbers horizontally from left to right starting at the beginning of the top line (from 73). The first ten numbers within the range 01 to 53 are: 47, 50, 37, 33, 23, 41, 17, 52, 13, and 12. These numbers are re-arranged in their proper order and, as the consignment passes the sampling station, the sampler extracts the 12th 13th 17th 23rd 33rd 37th 41st 47th 50th and 52nd bags. The number 12 in the table should be marked to indicate that it was the last number used, and that the next number (22) is the next starting point.

Alternatively a simple lottery system might be used to make a random selection of bags for sampling. The example below shows how this is done.

Example 2

Ten bags have to be selected from a consignment of 98 bags. Prepare 98 slips of paper or card and number them from 1 to 98. Place the numbered slips in a container, mix them up and draw out 10. The numbers on these slips when re-arranged in their proper order, represent the bags to be sampled.

The numbers on the slips drawn at random were: 14, 9, 23, 31, 73, 39, 17, 61, 46, and 97. These are re-arranged in their proper order and as the consignment is moved, the sampler selects the 9th 14th 17th 23rd 31st 39th 46th 61st 73rd and 97th bags.

Table 1: Numbers 1 to 100 randomised

73 47 50 81 37	99 33 23 41 87	70 17 91 52 73	13 64 12 22 56	42 11 09 87 67
72 74 49 15 76	86 71 97 12 78	48 35 68 27 51	56 05 67 82 93	17 47 14 17 82
97 30 18 66 35	62 67 99 63 47	30 40 36 18 58	47 26 24 62 24	38 26 91 18 69
09 62 27 30 42	72 76 36 81 49	65 19 64 42 45	64 87 61 34 25	73 19 38 97 06
61 56 92 94 75	90 21 60 17 69	94 09 77 34 41	27 31 15 18 87	85 44 58 77 56
40 45 21 69 38	44 71 05 95 02	55 47 69 97 63	29 87 40 30 06	75 72 12 97 93
71 36 67 15 74	76 81 87 44 65	75 04 26 75 91	18 25 39 18 34	62 33 76 55 70
81 47 31 22 32	62 42 02 56 80	08 25 20 55 93	34 22 07 78 36	88 72 10 64 50
07 50 66 70 98	34 56 86 53 66	48 94 00 92 67	12 09 98 83 48	36 91 35 41 83
14 80 26 50 50	19 18 26 21 08	95 60 74 72 97	02 21 14 81 04	54 86 28 52 62
17 90 57 54 48	30 65 15 13 17	70 81 78 93 72	59 21 93 32 87	96 46 87 52 06
06 60 60 48 97	18 65 64 46 96	55 85 73 77 02	07 87 59 33 71	88 47 70 13 81
46 66 98 62 98	84 90 60 64 74	86 00 11 53 63	44 61 93 35 83	70 83 36 54 14
22 39 12 36 78	64 76 18 44 56	61 86 31 84 24	56 18 95 42 28	42 78 46 25 74
62 40 81 48 31	29 41 23 37 67	60 29 27 70 77	99 07 71 78 13	60 02 82 85 12
63 23 85 13 53	93 93 76 82 45	29 39 67 50 13	85 08 61 22 48	71 83 89 27 39
28 38 93 22 61	67 66 54 53 58	71 95 55 82 72	28 34 94 87 16	62 76 58 96 34
31 69 03 31 27	33 68 54 84 48	82 50 75 05 28	09 06 27 21 76	36 95 11 89 82
92 17 82 54 42	66 84 27 52 68	48 25 35 92 25	19 45 11 86 96	70 15 67 03 71
72 23 78 50 85	84 19 57 98 57	27 27 18 37 11	81 29 93 12 36	35 95 66 87 59
33 90 61 20 23	01 73 37 75 91	39 78 16 86 66	69 60 21 77 56	32 33 36 11 19
77 20 63 33 26	38 19 94 69 65	84 24 08 88 50	21 31 41 64 53	30 85 55 62 99
44 41 90 90 34	36 46 14 15 51	61 45 87 72 01	31 54 00 42 57	16 74 68 43 22
23 30 15 89 06	63 33 88 49 96	29 34 71 00 32	93 77 02 97 84	63 08 36 86 50
87 11 78 24 39	77 14 29 71 38	85 11 82 35 46	46 00 74 48 79	26 03 46 70 70
76 82 02 80 57	35 98 02 63 11	35 98 02 63 11	79 20 15 38 19	06 00 41 38 50
39 87 83 58 72	35 75 75 81 55	48 80 73 84 95	52 52 37 06 22	78 76 03 26 92
33 38 10 49 42	28 12 27 13 75	30 29 96 17 96	06 46 75 75 21	08 87 87 85 07
24 64 16 87 72	15 91 76 71 83	21 13 66 51 64	06 78 19 88 96	64 78 27 21 16
13 77 53 95 17	14 96 12 68 55	21 30 57 97 71	09 23 57 55 04	77 26 52 07 53
24 84 24 46 77	11 83 83 19 27	22 38 50 63 67	04 15 12 34 01	95 14 72 48 26
62 08 91 79 38	69 21 23 90 93	13 27 34 58 64	14 45 29 02 53	06 57 92 57 71
51 02 66 99 85	20 43 65 67 69	82 06 04 96 37	94 80 67 70 58	65 15 87 21 70
55 63 95 22 96	24 10 25 73 19	52 84 04 51 89	32 15 55 45 76	62 20 14 14 34
84 36 50 90 24	30 54 77 92 84	36 50 04 87 00	62 85 18 41 09	46 98 64 00 04
72 53 85 61 90	20 90 49 02 34	62 44 65 84 78	79 50 31 92 09	24 69 27 12 90
98 46 89 72 14	97 23 66 64 20	15 03 79 37 82	46 60 11 19 37	33 21 70 66 22
06 24 34 88 30	15 45 54 17 35	00 36 54 73 00	35 51 22 67 90	23 24 44 41 35
58 04 12 76 64	86 67 89 49 16	42 68 37 98 71	24 43 90 05 76	73 23 95 33 18
41 84 53 49 74	89 35 92 48 41	43 22 75 96 75	47 41 00 81 92	34 86 03 32 65

(Note: Numbers 1-9 are represented by 01–09 and 100 is represented by 00)

Selecting bags for sampling from consignments of 101 to 10,000 bags

For a consignment of more than 100 bags, ISO recommends that the number of bags to be sampled should be approximately equal to the square root of the total number bags in the consignment.

The square root (symbol √) is a number which when multiplied by itself gives a particular value.

How to find the square root of a number using a pocket calculator

To find the square root of 225.

First enter the figure 225, then press the square root (√) key.

The number displayed is the square root.

(If the figure is not a whole number then round it up to the next whole number).

If you don't have a calculator, Table 2 will help you to find how many bags to select from consignments containing from 101 to 10,000 bags.

Referring to Table 2 you will see, for example, that the square root of 144 is 12 (12x12 =144) and the square root of 400 is 20 (20x20 = 400)

Table 2: Approximate square roots

N	n	N	n	N	n
101 ... 121	11	1601 ... 1681	41	4901 ... 5041	71
122 ... 144	12	1682 ... 1764	42	5042 ... 5184	72
145 ... 169	13	1765 ... 1849	43	5185 ... 5329	73
170 ... 196	14	1850 ... 1936	44	5330 ... 5476	74
197 ... 225	15	1937 ... 2025	45	5477 ... 5625	75
226 ... 256	16	1026 ... 2116	46	5626 ... 5776	76
257 ... 289	17	2117 ... 2209	47	5777 ... 5929	77
290 ... 324	18	2210 ... 2304	48	5930 ... 6084	78
325 ... 361	19	2305 ... 2401	49	6085 ... 6085	79
362 ... 400	20	2402 ... 2500	50	6242 ... 6400	80
401 ... 441	21	2501 ... 2601	51	6401 ... 6561	81
442 ... 484	22	2602 ... 2704	52	6562 ... 6724	82
485 ... 529	23	2705 ... 2809	53	6725 ... 6889	83
530 ... 576	24	2810 ... 2916	54	6890 ... 7056	84
577 ... 625	25	2917 ... 3025	55	7057 ... 7225	85
626 ... 676	26	3026 ... 3136	56	7226 ... 7396	86
677 ... 729	27	3137 ... 3249	57	7397 ... 7569	87
730 ... 784	28	3250 ... 3364	58	7570 ... 7744	88
785 ... 841	29	3365 ... 3481	59	7745 ... 7921	89
842 ... 900	30	3482 ... 3600	60	7922 ... 8100	90
901 ... 961	31	3601 ... 3721	61	8101 ... 8281	91
962 ... 1024	32	3722 ... 3844	62	8282 ... 8464	92
1025 ... 1089	33	3845 ... 3969	63	8465 ... 8649	93
1090 ... 1156	34	3970 ... 4096	64	8650 ... 8836	94
1157 ... 1225	35	4097 ... 4225	65	8837 ... 9026	95
1226 ... 1296	36	4226 ... 4356	66	9026 ... 9216	96
1297 ... 1369	37	4357 ... 4489	67	9217 ... 9409	97
1370 ... 1444	38	4490 ... 4624	68	9410 ... 9604	98
1445 ... 1521	39	4625 ... 4761	69	9605 ... 9801	99
1522 ... 1600	40	4762 ... 4900	70	9802 …10000	100

N = the total number of bags in the consignment
n = the approximate square root.

Procedure

The bags to be sampled are selected according to the following procedure:
First divide the consignment into *n* groups of bags (where *n* = the approximate square root of the number bags in the consignment). Any remaining bags will constitute a separate group. Select one bag for sampling at random from each group. The examples below illustrate how this is done.

Example 3 - A consignment of 200 bags

According to Table 2, the approximate square root (*n*) of 200 is 15.

This means that we can have 15 groups of 13 bags and one group of 5 bags.

One bag from each group must be sampled. Select a number at random in the range 1-13 and use this to identify the bag within a group to be sampled. (If the number selected was 7, then sample the 7^{th} bag in each of the first 13 groups) From the remaining group of five bags, select one bag at random.

Example 4 - A consignment of 2,000 bags

According to Table 2, the approximate square root (*n*) of 2,000 is 45.

This means that we can have 44 groups of 45 bags and one group of 20 bags.

One bag from each group must be sampled. Select a number at random in the range 1-45 and use this to identify the bag within a group to be sampled. (If the number 28 was selected, then sample the 28th bag in each group of 45 bags) From the remaining group of 20 bags, select one bag at random.

This system can be rather laborious and a simpler and more convenient procedure is to take the approximate square root *n* and then sample every n^{th} bag. For example, if the square root is 16, select every 16th bag. Usually, when following this procedure a few bags will remain, and one of these bags must be selected at random.

Example 5 - A consignment of 186 bags

The approximate square root of 186 is 14. If every 14th bag is sampled, this can be done 13 times (14 x 13 = 182) and then there will be four bags left over. Take a sample from one of these bags as well.

[Instead of using the square root of the number of bags, some people prefer to sample 10% of the bags by selecting every tenth bag as a consignment is received or issued. Although this does not strictly conform to the principles of representative sampling it may be acceptable, since more bags are selected for sampling than are really necessary, and the unloading or loading of bags is usually carried out in non-uniform manner.]

Annex 4 – Example of measuring a spherical store to estimate its capacity and the weight of grain it contains

Estimation of weight losses requires that we have estimates of the amounts of grain present in the stores we are studying. Traditional millet stores in Namibia are about spherical in shape so their volumes may be estimated assuming they are spheres. Some stores also have an additional cylinder below the sphere (Fig. A); the capacities of cylinders have to be estimated separately.

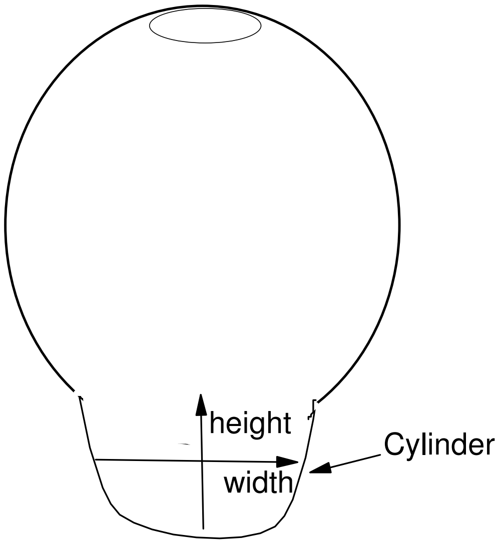


Figure A: Spherical millet store with a cylinder at its base

The volume of a sphere is calculated using the formula

$$4/3\ \pi r^3$$

The only figure that you need to obtain to use this formula is the radius (r); this is half the diameter of the store. Neither the radius nor diameter of traditional stores can be measured easily when they have grain in them. However, the circumference of the store can be measured easily with a tape measure (Fig. B) and the diameter calculated using the equation

$$\text{Diameter} = \frac{\text{Circumference}}{\pi}$$

$\pi = 3.141$

So for example, a store with a circumference of 4.5 m would have a diameter of

$$\text{Diameter} = \frac{4.5}{3.14} = 1.43\text{m}$$

The radius of this store would be 1.43/2 = 0.716 m

The volume of this store would be

$$\text{Volume} = 4/3 \times 3.141 \times 0.716^3$$

that is

$$1.33 \times 3.141 \times (0.716 \times 0.716 \times 0.716) = 1.536m^3$$

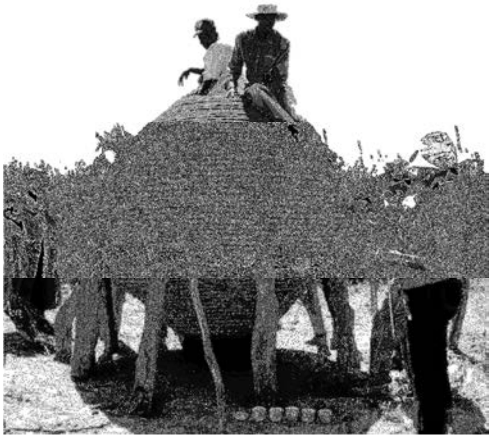


Figure B: Measuring the circumference of a traditional millet granary

If the store has a cylinder at its base then to calculate how much is present, measure the height and width (diameter) of the cylinder. You may determine the width (diameter) directly or by measurement of the circumference. The formula for estimating the volume is

$$\text{Volume} = \pi r^2 h$$

So, for example, if there was a cylinder at the bottom of a store with diameter of 0.5 m and a height of 0.8 m then the volume would be

$$\text{Volume} = 3.141 \times (0.25 \times 0.25) \times 0.8 = 0.1571m^3$$

The total volume of the store is therefore the volume of the sphere plus the volume of the cylinder

$$\text{Total volume} = 1.5355 + 0.1571 = 1.6931m^3$$

Before you can calculate how many tonnes of millet would fit into a store with a volume of 1.6931 m^3, you need to know the weight of millet that occupies $1m^3$, this is called the bulk density and an average value for millet is 853 (853kg in every m^3). If the store is full then it would contain

$$1.6926 \times 853 = 1443\text{kg or } 1.443 \text{ tonnes}$$

If the store is not full then you will have to reduce this amount. To determine how many tonnes there are in a partially filled store we will use the formula for calculating the volume of a partially filled sphere which is as follows

$$\pi h^2(R-h/3)$$

where h=height of grain in store and r = radius of store (half the diameter calculated from the measurement of the circumference). To determine the height of grain, measure the space between the store opening and the grain surface using a rigid tape measure. Then subtract this value from the diameter of the store. If for example the store diameter is 1.43m and the grain surface is now 48cm below the opening then the grain height is 0.95m. The calculation would then be as follows -

$$3.141 \times (0.95 \times 0.95) \times (0.71 - 0.95/3) = 1.112 m^3$$

and so the weight of grain in the spherical part of the store is now

$$1.112\ m^3 \times 853 = 948.5 kg \text{ or } 0.949 \text{ tonnes}$$

The weight of grain in the cylinder is

$$0.1571\ m^3 \times 853 = 134$$

added to the weight of grain in the sphere give a total of

948.5 + 134 = **1.083 tonnes**