



APHLIS - AFRICAN POSTHARVEST LOSSES INFORMATION SYSTEM

- A TRANSNATIONAL NETWORK OF CEREAL GRAIN EXPERTS

Postharvest Weight Losses of Cereal Grains in Sub-Saharan Africa

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1. Introduction

Estimates for postharvest weight losses have several uses, including in agricultural policy, the formulation and monitoring of postharvest loss reduction projects and the calculation of the cereal supply/demand balances of developing countries. This review is as an explanatory document for APHLIS (African Postharvest Losses Information System <http://www.aphlis.net>) that estimates postharvest losses by crop, by country and by province in Sub-Saharan Africa. APHLIS was initiated by the Joint Research Centre of the European Commission and combines a method of loss calculation, a database of key information and a network of local experts to provide the latest data and to verify loss estimates (for more details of the project see Annex 1). This review is intended to provide network members and others involved in using the system with a background to postharvest losses data on which the system is based but may also be of interest to other postharvest technologists. For critical and more wide ranging reviews of grain postharvest losses, readers are referred to Greeley (1982), Boxall (1986), Grolleaud (1997) and Boxall (2001).

Postharvest operations for cereal grains follow a chain of activities starting in farmers' fields and leading eventually to cereals being supplied to consumers in a form they prefer. When determining the losses that may occur in this chain it is conventional to include harvesting, drying in the field and/or on platforms, threshing and winnowing, transport to store and then farm storage. Additional links in the postharvest chain are included in the cereal supply loss calculation such as such as transport to market and market storage but although in some contexts cereal processing losses might be included this is not the case for with APHLIS.

APHLIS provides loss figures that are especially useful in cereal supply calculations. This requires the postharvest loss data to be defined very specifically. First of all the key issue is food availability. During postharvest operations there may be losses of both cereal quantity and quality but what is of concern is loss of quantity (weight loss). The reason for this is that if, after a quality change, cereals are still fit for human consumption then there has been no loss in food availability. It is of course true that in other contexts, food quality decline may reduce market value and this obviously has a negative impact on farmers' livelihoods. By the same logic, grain spilt during handling and consumed by farmers' animals is a loss, since it is no longer available for human consumption, even if the animals are a component of the farmers' livelihoods. For cereals supply calculations the losses are only those from this year's production, cereals from the previous season(s) are carryover stocks and dealt with separately. The effect of this is that loss calculations are focussed on the current year's crop for which there may be one or more harvests. Finally, cereal supply calculations are reported for national and sub-national units (provinces) which follow political rather than agro-climatic boundaries, therefore loss estimates for any particular unit and may hide wide internal variations.

For a review of cereal grain quality loss, download 'Postharvest quality losses' from the APHLIS website (<http://www.aphlis.net>).

2. What are postharvest weight losses?

Prior to the 1970s, most figures for postharvest weight loss of cereals were anecdotal. In 1977, the UN Food and Agriculture Organisation (FAO) presented a survey on postharvest crop losses (FAO, 1977), which concluded that there were few well supported postharvest loss figures for cereals. This inspired an upsurge in the development of improved loss assessment techniques, first detailed in Harris and Lindblad (1978) together with documentation on the losses themselves (National Academy of Sciences, 1978 a&b). The development of new techniques went hand in hand with FAO's Prevention of Food Losses (PFL) programmes of the late 1970s to 1990s.

Losses may occur for two main reasons. During harvesting, handling, processing and transport grain may be scattered, dispersed or crushed. Alternatively, the grain may be subject to biodeterioration. Postharvest losses due to biodeterioration may start as the crop reaches physiological maturity, i.e. when grain moisture contents reach 20-30% and the crop is close to harvest. It is at this stage, while the crop is still standing in the field, that storage pests may make their first attack and when unseasonal rains can dampen the crop resulting in some mould growth. A key issue is the weather conditions at the time of harvest. All small-scale African farmers rely on sun drying to ensure that their crop is sufficiently dry for storage. If weather conditions are too cloudy, humid or even wet then the crop will not be dried sufficiently and losses will be high. Climate at the time a crop should be drying is key to understanding the potential losses of durable crops. However, successful drying alone is not a remedy against all postharvest losses since insects, rodents and birds may attack well dried grain in the field before harvest and/or invade drying cribs or stores after harvest.

It might be thought that higher crop yields of cereals, i.e. bigger harvests, are associated with greater postharvest losses but this effect is likely to be small compared with other factors such as climate at harvest. With very big harvests it is possible that in some locations there is insufficient manpower to bring in the crop or it would be harvested with a reduced efficiency but this would be unusual since the same manpower was available at sowing. Perhaps a special case of this would be where there is armed conflict or civil unrest and fields remain unharvested. African farmers are usually supplied with sufficient storage capacity so that good harvests can be accommodated in fixed stores and in exceptional years they are content to store surplus grain in sacks in their houses. Good harvests are accompanied by a fall in grain prices and a slower flow in the market leading to longer storage periods for grain. In this situation there may be an increase in loss due to attack by insects and rodents.

At least in the 1970s, there was a popular view that postharvest losses at farm level were high and traditional farming practices were the problem. But traditional practice is an unlikely culprit since farmers have survived difficult conditions over long periods by adapting their practice to prevailing circumstances (Greeley, 1982). Nevertheless, serious losses do sometimes occur and these may have resulted from agricultural developments for which the farmer is not pre-adapted. These include the

introduction of high yielding cereal varieties that are more susceptible to pest damage, additional cropping seasons that result in the need for harvesting and drying when weather is damp or cloudy or farmers producing significant surplus grain which because it is to be marketed, rather than being for consumption in the home, is less well tended. In addition, the arrival of new pests can be a problem, as in the case of the larger grain borer (LGB – *Prostephanus truncatus*) in Africa; this will be discussed later.

There have often been demands for simplified loss figures. This for example has led to the postharvest losses of maize for a country or region being reduced to just a single figure representative of many years. However, such an approach is likely to be misleading since as noted by Tyler (1982) “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.” 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 the new Post Harvest Losses Information System.

Besides using appropriate loss assessment methods and understanding the variable nature of losses it is also important to ensure that losses are calculated correctly. For example, a series of loss figures, for the links in the postharvest chain, can not simply be added since the amount of grain subject to loss is diminished at each step in the chain. So for example, if 10% of the potential crop is lost during harvesting and a further 10% is lost during threshing, then the cumulative loss over both stages totals 19%. A further example of cumulative loss concerns farm storage. If grain remains in store over a long period and none is consumed by the household then any loss observed at the end of storage represents the loss over the storage period. However if, as usual, households consume grain then each amount that is removed will have suffered a different degree of loss, this must be taken into account when estimating total loss. Correction for household consumption can make dramatic reductions in grain storage loss estimates, a cumulative loss of 30% without household consumption could be reduced to 11% when that is taken into account (Fig. 1).

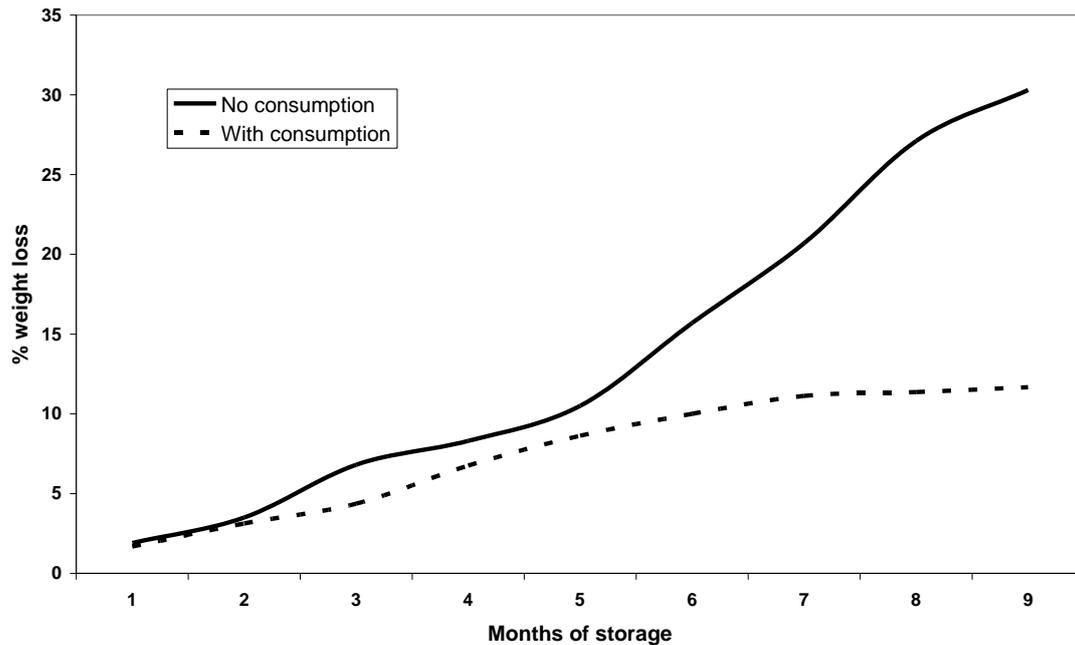


Figure 1: Cumulative % weight loss from maize cobs in Tanzanian farm stores, as observed without household consumption or with a consumption calculation applied evenly so that by the 9th month all grain is consumed (data from Henckes, 1992)

In the 1980s, the larger grain borer (LGB) a pest from meso-America, spread across Africa attacking farm stored maize and dried cassava roots. Loss estimation gained a new lease of life since this pest is significantly more damaging than native storage pests and weight loss estimates for storage increased from around 5% to an average of more like 10% (Dick, 1988) although losses for individual, unlucky farmers could be 20% or even 30% (equivalent to 100% grain damage). In the 1990s, procedures for rapid loss assessment in farm stores were developed and used very successfully for estimating farm weight loss of maize in Ghana due to LGB (Compton and Sherington, 1999) although to date and they have not be widely applied.

3. Postharvest Losses in Sub-Saharan Africa

Since the 1970s, efforts have been made to assess the grain losses suffered by African farmers. Most measures of loss have focused on grain once it has entered farm storage; little data have been generated on harvesting, drying, threshing/winnowing or transport losses. Few data on harvesting, drying or transport losses are measured, instead they have been mostly derived from questionnaire surveys or are just guesstimates (Table 1). Maize is the crop with the most data although two data sets in Table 1 from Ethiopia are for cereal crops in general.

3.1 Non-storage losses

3.1.1 *Harvesting and drying*

Of special interest is the harvesting/drying loss of 16.3% for Swaziland (Table 1). This was measured for two seasons when maize was harvested under damp conditions. These losses indicate what might be expected when climatic variations in the future lead to crops being harvested in unfavourably wet weather. More typical harvesting/drying losses are shown by the two figures from Zimbabwe 9.5% and 5.8% (Table 1). The only figure found for harvesting/drying losses of African rice is 6.9% and is from Madagascar. This is rather high compared to Asian losses which for China are 4.3% (IDRC, 1989), several Asian countries combined 4.0% (Calverley, 1996) and Bangladesh 1.95% (Huq and Greeley, 1980). The figures for harvesting and drying of sorghum and millet (11.3% and 12.2% respectively) appear also to include threshing losses. Platform drying, which raises the maize off the ground for longer-term drying, has been associated with losses of 3.5% (Zambia) and 4.5% (Zimbabwe).

3.1.2 *Threshing and shelling*

There are two threshing/shelling loss figures for maize, both from Zimbabwe. For small-scale farming the losses are low, 1-2.5%, which might be expected since the process is usually by hand and may be contained within jute bags so there is little spillage, whereas the large scale figure is 3.5% and may reflect the greater spillage associated with mechanical shelling. The available data attributes rather higher threshing losses to rice, a 6.5% measured estimate from Madagascar and 6% from questionnaire survey in Ethiopia for cereals (generally).

3.1.3 *Winnowing*

Winnowing losses are relevant to most grains except maize. There are virtually no loss figures available. Winnowing losses of rice in Madagascar were measured at 2.5% while questionnaire survey results relating to cereals in Ethiopia average 5%.

3.1.4 *Transport*

Losses incurred from transport from field to store are little known and are likely to be highly variable. For rice in Madagascar they have been measured at 2.25% whereas 'commonly applied' figures or those from questionnaire surveys for other cereals range from 1% to 3%. There is at least some consensus on the general magnitude. For transport to market there is only a single 'commonly applied' figures offered, 1% for maize (Table 1).

Table 1: % weight loss figures for different activities in the postharvest chain, from various East/Southern African countries

Country	Ethiopia	Ethiopia	Swaziland	Zambia	Zimbabwe	Zimbabwe	Uganda	Uganda	Uganda	Madagascar
Data source	1	2	3	4	5	6	7	7	7	8
Data quality	Questionnaire survey - multiple sources	Questionnaire survey	Measured	Old measured data and data from outside Zambia	Commonly applied figures, origin ?	Questionnaire survey	Measured ?	Measured ?	Measured ?	Measured
Harvesting and drying	Cereals	Cereals	Maize	Maize	Maize	Maize	Maize	Sorghum	Millet	Rice
Field drying Small-scale	2	5	16.3 ^R	13.5 ^P	9.5	5.8	17.4 ^T	11.3 ^T	12.2 ^T	6.85
Large scale	2	-	16.3 ^R	13.5 ^P						
Platform drying Small-scale	-	-	-	3.5	4.5	-	-	-	-	-
Large scale	-	-	-	3.5	-	-	-	-	-	-
Threshing/shelling										
Small-scale	1	6	-	-	1	2.5	-	-	-	6.5
Large scale	1	-	-	-	3.5	-	-	-	-	-
Winnowing										
Small-scale	0	5	-	-	-	-	-	-	-	2.5
Large scale	0	-	-	-	-	-	-	-	-	-
Transport to store										
Small-scale	2	3	-	-	1	-	-	-	-	2.25
Large scale	2	-	-	-	-	-	-	-	-	-
Transport to market										
Small-scale	-	-	-	-	1	-	-	-	-	-
Large scale	-	-	-	-	-	-	-	-	-	-
			^R rain at harvest	^P includes production losses?			^T includes threshing			
	Data sources									
	1. Boxall 1998			5. Odogola and Henriksson 1991						
	2. Vervroegen and Yehwola 1990			6. Mvumi et al. 1995						
	3. De Lima 1982			7. Silim et al. 1991						
	4. Lars-Ove Jonsson and Kashweka 1987			8. Repoblika Malagasy (1987)						

3.2 Storage losses

One of the earliest investigations of storage weight loss using modern methods was of maize cob storage in Malawi by Schulten and Westwood (1972). They followed the course of weight loss in local, improved and hybrid maize varieties stored in traditional structures (Fig. 2). This demonstrated big differences between hybrid and local/improved varieties and that very little loss occurs during the initial periods of storage. Subsequently, farmers have grown hybrids for grain sales, not their own consumption, and send this grain to market soon after harvest to keep losses low.

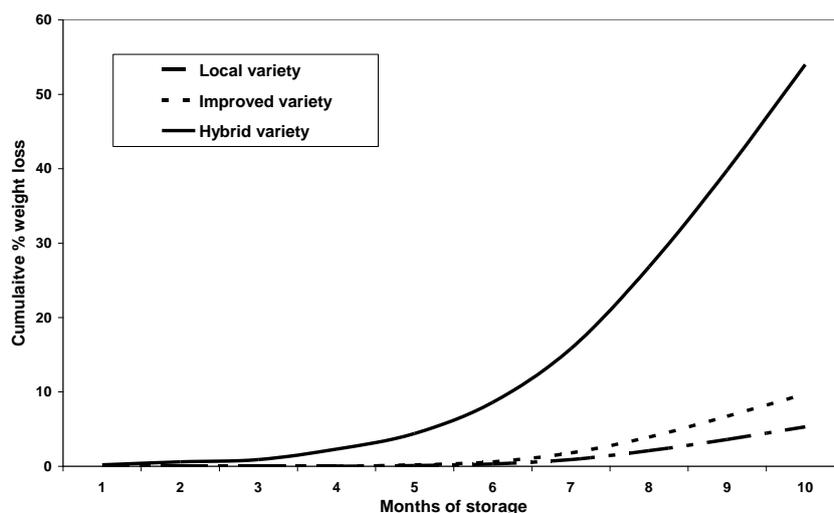


Figure 2: Cumulative % weight loss of different maize varieties in traditionally stores in Malawi - figure prepared from data presented in Schulten and Westwood (1972) - not corrected for household consumption

A good example of a storage loss study is the pioneering investigation of Adams and Harman (1977) who measured storage losses in Zambia using a variety of modern methods, offered an economic analysis of the observed losses and considered the costs and benefits of improvements to reduce losses. The losses they found (4-5%) and subsequent studies on maize, particularly in East Africa (Kenya – De Lima 1979; Malawi - Golob 1981 a&b), 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.

If the figures for storage loss available in the literature are either to be compared or combined, so that they can be used to estimate the losses suffered by future harvests, then they must be standardised. The original loss studies will have been undertaken over different time periods and may or may not have taken household consumption into account. Where necessary, for the purpose of this study, 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 period was adjusted by considering the shape of the curve of loss over time that is suggested by the results of the original study and

then by extrapolating or interpolating to infer the loss at 9 months. 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. In any case, the majority of storage studies are about 9 months, this is the length of a typical storage season. The resulting 75 adjusted, loss figures are presented in Annex 2 together with an indication of the original weight loss figure and quality of the source of data. The best quality is considered to be measured estimates using modern methods, other methods such as questionnaire surveys or guesstimates would generally 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 for which they are derived.

3.2.1 Clustering provinces to share loss data

A problem faced in seeking to use postharvest loss figures for cereals supply calculations is that for many locations there are no specific loss data. It is therefore inevitable that many different locations (provinces) will have to share the same data. This can be achieved by clustering together the provinces of many countries that are basically similar with respect to the factors that influence postharvest losses. Storage losses are known to vary according to crop type, climate and storage type. Climate is a key determinant of grain storage losses, since the biodeterioration factors that are the main agents of loss are dependant on conditions of temperature and humidity. Consequently, there is a close correlation between climate and store type. At one extreme, in hot humid climates farmers typically use very open storage structure to allow a substantial airflow and continuous drying and at the other extreme in hot dry climates farmers use sealed stores with no airflow since the crop enters store fully dried. Intermediate climates have stores designed with intermediate airflows. Examples of these stores types are shown in Annex 3. Crop type and climate may therefore offer a simple and easily understood approach to clustering provinces although cross checking by store type may be a useful way of judging cluster boundaries. Thus in Annex 2, storage loss estimates are grouped according to the climate classification codes of the Köppen system (Peel *et al.*, 2007) of the locations where the estimates were made.

To give a generalised loss figures for each loss category, under each climate code, the figures in Annex 2 were summarised by

1. removing outliers
2. avoiding the use of 'Q/G' data where there is sufficient 'M' data, and then averaging what data remained.

The 'general' loss figures derived are listed in Table 4.

Table 4: General % weight loss estimates in storage for various crops grouped by climate classification for the locations where estimates were made, adjusted to a 9-month storage period and an even household consumption pattern

(Aw - tropical savannah; BSh - arid steppe, hot; BWh - arid desert, hot; Cwa - temperate dry winter, hot summer; Cwb - temperate dry winter, warm summer)

Climate code	Small/large scale farming	Variety	Loss
Maize cobs with LGB infestation			
Aw	small	local	9.7
BSh	large	local	2.7
	small	local	13.3
Cwa/Aw	large	local	2.1
	small	local	10.0
Maize cobs no LGB			
Aw	small	local	5.3
BSh	small	local	4.3
Cwa	small	local	3.5
	small	HYV	9.5
Maize grain with LGB infestation			
Aw	small	local	5.4
BSh	small	local	3.3
Maize grain no LGB			
Aw	small	local	5.4
Cwa	small	local	4.2
Sorghum grain			
BSh/BWh	small	local	2.5
Cwa	small	local	3.9
Sorghum panicle			
Aw	small	local	2.8
	small	improved	11.0
Millet			
BSh	small	local	1.1
Cwa	small	local	1.3
Wheat			
BSh	small	local	3.1
Cwa	small	local	5.8
Barley			
Cwa/Cwb	small	local	0.8
Rice			
Aw	small	-	1.2

BSh	small	-	0.1
Cwa	small	-	0.4
Teff			
Cwa	small	local	0.3

The general figures show some variation by crop. Maize (without LGB infestation) as grain or cobs typically loses 4-5%, sorghum grain 2-4%, wheat 3-5%, millet 1%, barley, rice and teff 1% or less. Apart from maize and sorghum the actual number of individual figures contributing to the loss estimates for the other crops is low and so not much reliance can be placed on these generalisations. However, teff is an interesting case as it is well known to suffer few losses in store due to its very small grain size making it resistant to insect attack so the very low figure for storage loss is probably realistic even if the data source is poor. Indeed in Ethiopia one way to prevent infestation of maize grain is to admix teff, which fills the inter-granular spaces preventing insect pest damage (Haile, 2006).

The situation with maize is more complex since it may or may not be infested by LGB. If cobs or grain are infested by normal storage pests, not LGB, weight losses from range from 4-5% (Table 5). When cobs are infested by LGB losses are about doubled (although it should be noted that the figure for BSh is entirely guesstimate and may be on the high side). Others arrived at a similar conclusion, losses doubling from about 5% to about 10% (Hodges *et al.* 1983; Dick, 1989; Boxall, 2002). However, LGB infestation has little or no effect on the losses of maize when this is stored as grain. This is not surprising as it is well known that LGB is more damaging on stabilised grain, as it is found on the cob, than on shelled grain (Cowley *et al.* 1980). Shelling grain and storing in sacks (as well as addition of insecticide) are the standard recommendations to limit LGB losses.

Table 5: Comparison of the % weight losses estimates for maize stored as grain or as cobs with or without LGB infestation

Storage form	No LGB	LGB present	Climate code	Incremental increase due to LGB
Cobs	5.3	10.3	Aw	1.9
	4.3	13.3	BSh	3.1
	4.5	10.0	Cwa	2.2
Grain	5.4	5.4	Aw	1.0
	4.2	3.3	Cwa	0.8

In general the data on storage losses are too few to make comparisons between crops stored under different climates. Maize and sorghum offer modest data sets but with considerable variation between estimates in the method of data collection. In the case of maize there were no consistent differences between climate

classifications in the observed losses (Fig. 3). This may be due to the inadequacy of the data or could be interpreted as resulting from the appropriate adaption of farmers working under different conditions, where they have adjusted their postharvest technology to minimise grain losses. In the case of sorghum, losses might appear somewhat lower under hot dry conditions 2.5% (BSh) compared to temperate conditions 3.9 (Cwa) but the widely overlapping error bars for these two estimates suggest that the current data set are inadequate to confirm a genuine difference.

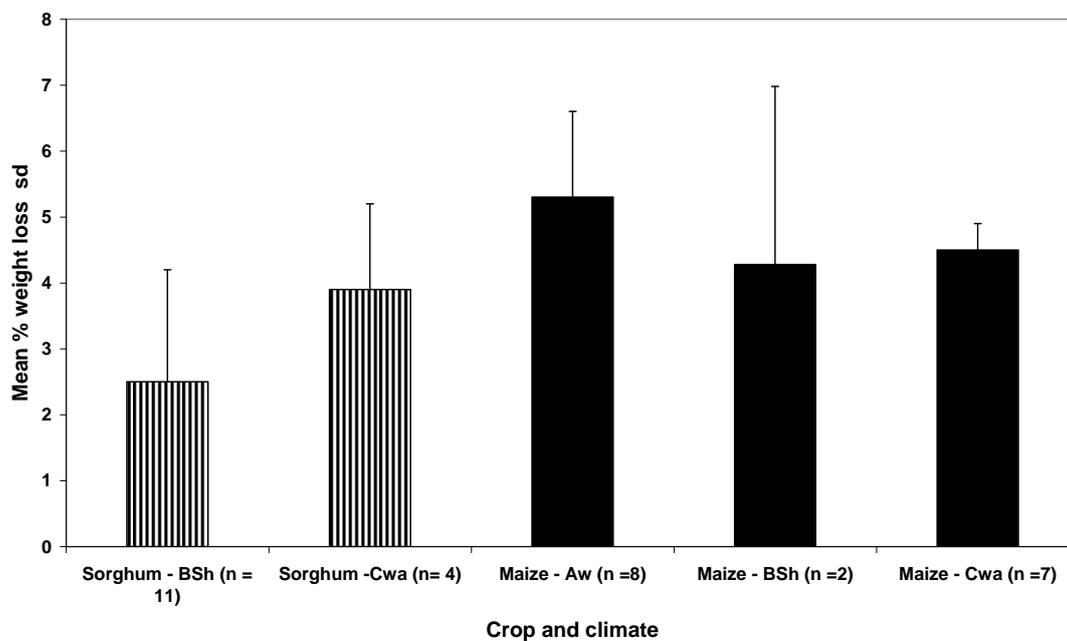


Figure 3: Mean % weight loss \pm sd of stored sorghum grain or maize cobs (not LGB infested) under different climate conditions

3.3 Losses for the whole postharvest chain

If the loss figures for each step in the postharvest chain of a particular crop are applied to the production estimates, it is possible to calculate a cumulative weight loss. The set of loss figures to do this is termed a 'PH loss profile'. Some examples of loss profiles for different crops and different climate clusters are shown in Table 6 together with the calculated total cumulative loss. Two potential cumulative losses are shown, one where it is assumed that the grain is retained in farm storage and not sent to market and the other where the 50% of the harvest is sent to market in the first three months after harvest and so although not subject to the losses associated with farm storage, losses are incurred in transport to market and market storage. However, it is important to point out that that the cumulative losses shown are not necessarily those that would be determined for a particular situation since other factors that would have a very significant bearing on the actual loss estimate that would have to be taken into account, such as -

- 1) whether or not the crop is harvested in one or two seasons

- 2) the proportions of grain produced by small scale and large scale farming,
- 3) whether or not there is bad weather at the time of any of the harvests,
- 4) the proportion of grain that is market directly so will not enter farm storage for any significant time,
- 5) in the case of maize, whether or not LGB is expected to be a significant pest.

Table 6: Examples of loss profiles for various crops in various climate clusters

Climate cluster	Aw	Cwa/Cwb	BSh/BWh	BSh/BWh	Aw
Crop	Maize	Maize	Sorghum	Millet	Rice
Scale of farming	Small scale	Large scale	Small scale	Small scale	Small scale
Harvesting/field drying	6.4	2	4.9	3.5	4.3
Drying	4	3.5	-	-	-
Shelling/threshing	1.2	2.3	4	2.5	2.6
Winnowing	-	-	-	-	2.5
Transport to store	2.3	1.9	2.1	2.5	1.3
Storage	5.3	2.1	2.2	1.1	1.2
Transport to market	1	1	1	1	1
Market storage	4	4	4	4	4
Cumulative % weight loss ¹	17.9	11.3	12.6	9.3	11.4
Cumulative % weight loss ²	16.5	11.2	12.0	9.3	11.9

¹Cumulative weight loss assuming all grain retained on farm, none marketed

²Cumulative weight loss assuming that in the first three months 50% of grain stock marketed not incurring farm storage losses

From the example it appears that when maize is subject to small-scale postharvest practice the losses are much higher than for large-scale farming of maize or of small-scale farming of sorghum, millet or rice. Further in these particular examples, marketing of 50% of the grain stock early in the season had little effect on total losses. However, it must be stressed that, generally these estimates have not been adjusted for the essential factors listed above which require local knowledge. The PHL Information System makes the same calculations but is designed to take these other factors into account.

4. Conclusions

To provide PHL estimates for a range of cereal crops, under a range of circumstances, requires a great deal of basic data on the losses occurring along the postharvest chain. The scientific literature has been searched in detail for PHL figures. In addition, local experts have been asked to find and submit relevant loss figures for their own countries. What is clear is that the volume of reliable data is much less than originally anticipated. Data on storage weight loss for the countries

of East and Southern Africa are limited to 73 estimates (Table 7), most of which are derived by direct measurement. However, these estimates are from only 38 different provinces, or about 15% of the provinces for which the project will seek to make loss estimations and the majority of the figures are for maize or sorghum; there are very few data for other crops and no measured storage loss data for rice.

Table 7 – Numbers of storage weight loss estimates that have been found for various grains and their condition in East and Southern Africa and the numbers of different provinces to which these figures apply

Grain and its condition	No. of storage loss estimates	No. different provinces
Maize cobs with LGB infestation	12	4
Maize cobs no LGB infestation	21	9
Maize grain with LGB infestation	2	2
Maize grain no LGB infestation	8	4
Sorghum unthreshed	1	1
Sorghum threshed	15	10
Millet - threshed	2	1
Wheat - threshed	6	2
Barley - threshed	2	1
Rice	3	3
Teff	1	1
Total	73	38

The problem is even more acute when considering losses for other links in the postharvest chain. The data are sparse (Table 8) and most are not derived by direct measurement but come instead from questionnaire surveys that may not be very reliable.

Table 8 – Total number of postharvest loss estimates for East and Southern Africa from various points in the post harvest chain (excluding storage losses)

Harvesting and drying losses	Total no. studies	Cereals generally	Maize	Millet	Sorghum	Rice
Field drying Small-scale farming	10	2	5	1	1	1
Large scale farming	3	1	2	0	0	0
Platform drying Small-scale farming	2	0	2	0	0	0
Large scale farming	1	0	1	0	0	0
Threshing/shelling loss						
Small-scale farming	5	2	2	0	0	1
Large scale farming	2	1	1	0	0	0
Winnowing loss						
Small-scale farming	2	1	0	0	0	1
Large scale farming	0	0	0	0	0	0
Transport to store loss						
Small-scale farming	4	2	1	0	0	1
Large scale farming	1	1	0	0	0	0

Transport to market loss						
Small-scale farming	1	0	1	0	0	0
Large scale farming	0	0	0	0	0	0

In the medium term, the PHL Information System would benefit greatly from the supply of additional loss figures. To strengthen the ability of target countries to collect relevant data, in the format needed by the system, requires suitable initiatives underpinned by modern rapid approaches to loss assessment.

In the future, the use of the PHL Information System is expected to benefit agricultural development and food security by

- 1) highlighting missing data and helping identify which gaps in our knowledge would be the most cost-effective ones to fill, and
- 2) acting as a model system to explore loss scenarios so that opportunities for loss reduction can be identified.

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.
- Ashimogo G. (1995) A case study of maize in Sumbawanga District (Tanzania). Verlag Dr. Koester, Berlin (Germany), pp. 360.
- Bengtsson L. (1991) Comparative study of storage techniques at household level, Tanzania. FAO-AGO--URT/86/016, pp. 33.
- Binder K.F., Masebo B. and K.F. Ngulbe (1994) Storage losses of maize under smallholders' conditions. Part1 Karonga Add, Northern Region. Malawi-German Biocontrol and Post-harvest Project (MGBPP)/ Lunyangwa Agricultural Research Station, Crop Storage Unit, pp. 18.
- Boxall R.A. (1986) A critical review of the methodology for assessing farm-level grain losses after-harvest
- Boxall RA (1998) Grains post-harvest loss assessment in Ethiopia. Final report NRI Report No 2377. Natural Resources Institute, Chatham, UK. pp. 44.
- Boxall R.A. (2001) Post-harvest losses to insects – a world overview. International Biodeterioration and Biodegradation 48 137-152)
- Boxall R.A. (2002) Damage and loss caused by the Larger Grain Borer *Prostephanus truncatus*. Integrated Pest management reviews 7: 105-121.
- Calverley D.J.B. (1996) A study of loss assessment in eleven projects in Asia concerned with rice. Rome, FAO ((PFL/INS/001).
- Compton J.A.F. and Sherington J. (1999) Rapid loss assessment methods for stored maize cobs: Weight loss due to insect pests. Journal of Stored Products Research 35, 77-87.
- Cowley R.J., Howard D.C. and Smith R.H. (1980) The effect of grain stability on damaged caused by *Prostephanus truncatus* (Horn) and three other pests of stored maize. Journal of Stored products Research 16, 75-80.
- De Lima C.P.F. (1979) The assessment of losses due to insects and rodents in maize stored for subsistence in Kenya. Tropical Stored Products Information 38, pp21-25.
- De Lima C.P.F. (1982) Strengthening the food conservation and crop storage section (Ministry of Agriculture and Co-operatives, Swaziland). Field documents and final technical report. Project PFL/SWA/002. Rome, FAO.
- Dick K. (1988) A review of insect infestation of maize in farm storage in Africa with special reference to the ecology and control of *Prostephanus truncatus*. Overseas Development Natural Resources Institute, Chatham, UK: Bulletin 18. pp. 42.
- FAO (1977) Analysis of an FAO survey of post-harvest crop losses in developing countries. AGPP MISC/27. pp.148.

- Giles P.H. (1986 a) Post-maturity grain losses in the field. In: Maize Conservation on the farm. Proceedings of a seminar at Kisumu, Kenya 21-23 January 1986. Ministry of Agriculture and Livestock Development, Kenya. pp 1-21.
- Giles P.H. (1986 b) Conservation of maize in various farm storage management systems. In: Maize Conservation on the farm. Proceedings of a seminar at Kisumu, Kenya 21-23 January 1986. Ministry of Agriculture and Livestock Development, Kenya. pp 94-113.
- Golob P. (1981a) 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. and Boag C. (1985) Report on field trials to control *Prostephanus truncatus* (Horn) (Coleoptera:Bostrichidae) in western Tanzania 1983/84 and 1984/85. Project No. A1074. (unpublished)
- Greeley M. (1982) Pinpointing post-harvest losses. Ceres 15 (1), 30-37.
- Grolleaud M. (1997) Post-Harvest Losses: Discovering the Full Story. UN Food and Agriculture Organization, Rome, 1997), pp. 34
(<http://www.fao.org/docrep/004/ac301e/AC301e04.htm#3.2.1%20Rice>)
- Haile A. (2006) On-farm studies on sorghum and chickpea in Eritrea. African Journal of Biotechnology 5 (17) 1537-1544.
- Harris, K.L. & C.J. Lindblad (1978) Postharvest Grain Loss Assessment Methods. Minnesota, America Association of Cereal Chemist, pp. 193.
- Henkes C. (1992) Investigations into insect population dynamics, damage and losses of stored maize - an approach to IPM in small farms in Tanzania with special reference to *Prostephanus truncatus* (Horn). GTZ, Pichhüben 4, D-2000 Hamburg 11, Germany. pp 124.
- Hodges R.J., Dunstan W.R., Magazini I. and Golob P. (1983) An outbreak of *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae) in East Africa. Protection Ecology, 5, 1983-194.
- Huq F. and Greeley M. (1980) Rice in Bangladesh: An empirical analysis of farm level food losses in five post-harvest operations. In: Grain quality improvement - Proceedings of the 3rd annual workshop on grains post-harvest technology. Kuala Lumpur, Malaysia, 29-31 January 1980. 245-262. - also see - Greeley M. (1982) Pinpointing post-harvest losses. Ceres 15 (1), 30-37.
- Katerere M. and Giga D. (1990) Grain Storage Losses in Zimbabwe. ISSN 0850856 97pp. Environmental Development Action, Occasional Paper series, 132.
- Kidane, Y. and Habteyes Y. (1989) Food grain losses in traditional storage facilities in three areas of Ethiopia. In: Proceedings of 'Towards a food and nutrition strategy for Ethiopia'. Alemaya University of Agriculture, 8-12 December 1986, Alemaya, Ethiopia.
- Lars-Ove Jonsson and Kashweka K. (1987) Relationship between drying, harvest and storage losses, production and consumption of maize for a rural household in Zambia. In: Holmes J.C. (editor) Improving food crop production on small farms in

- Africa. FAO/SIDA Seminar on increased Food Production through low-cost food crops technology, Harare (Zimbabwe), 2-17 March 1987.
- Mvumi B.M., Giga D.P. and Chiuswa D.V. (1995) The maize (*Zea mays* L.) post-production practices of smallholder farmers in Zimbabwe: findings from surveys. *Journal of Applied Science in Southern Africa* 1 (2), 115-130.
- National Academy of Sciences (1978a) Post-harvest Food Losses in Developing Countries. Washington, D.C., USA pp. 206
- National Academy of Sciences (1978b) Post-harvest Food Losses in Developing Countries: A bibliography. Washington, D.C., USA. pp. 356
- Odogola W.R. and Henriksson R. (1991) Post harvest management and storage of maize. UNDP/OPS Regional Programme, Harare, December 1991. pp. 35.
- Peel M.C., Finlayson B.L. and McMahon (2007) Updated world map of the Köppen-Geiger climate classification. *Hydrology and Earth Systems Science Discussions* 4, 439-473.
- Republika Malagasy (1987) Enquete sur les pertes de paddy apres recolte. Ministere de la production agricole et de la reforme agraire. Pp 17 + tables
- Schulten G.G.M. and Westwood D. (1972) Grain storage project Malawi. December 1969 - June 1972. Ministry of Agriculture, Malawi.
- Seifelnasr Y.E. (1992) Stored grain insects found in sorghum stored in the central production belt of Sudan and losses cause. *Tropical Science* 32, 223-230
- Singano C. (pers comm.) Principal Agricultural Research Scientist, Department of Agricultural Research Services, Malawi.
- SSEAD Consultancy (1997) Amhara national Regional State, Bureau of Agriculture, Regional Crop Pest Survey Report on Insect Pests. Addis Ababa (quoted in detail in Boxall 1998)
- Silim M.N., Odogola W. and Amenet J. (1991) Technical report of the post harvest loss prevention project 1987-1991. FAO (PFL/UGA/001), pp 131.
- Tyler P.S. (1982) Misconception of food losses. United Nations University <http://www.unu.edu/Unupress/food/8F042e/8F042E05.htm>
- Vervroegen D. and Yehwola F. (1990) Project for the identification of post-production grain losses and training on their education in Wollo Region, Ethiopia. FAO terminal report, Action Programme for the prevention of Food Losses. United Nations Food and Agriculture Organisation, pp. 17

Annex 1 - Postharvest losses database for better estimates of food availability

To give an early warning of any food insecurity, the MARS-Food Sec action (Joint Research Centre, EC) monitors crop production in developing countries. Crop production figures are adjusted for postharvest losses (PHL) in order to obtain the estimates of food availability on which any relief actions are based. To date, the origin and justification of figures used to make adjustments for PHLs have not been well founded. To remedy this situation, MARS-Food Sec, in association with AIDCO and FAO, commissioned a project to generate figures for the PHLs of cereal grains. In the initial stages the system may or may not produce loss figures that are different from those currently in use and if they are different there will be no solid evidence that they will be more accurate. However, the system has several advantages.

- 1) The method of calculation that is used will be fully transparent
- 2) It will be possible to see the figures used in the calculation, know their origin and their 'data quality' rating.
- 3) Each country in the PHL network will be responsible for its own data and will be in a position to supply recent data to improve the estimation of losses and query loss estimates.
- 4) New figures for loss can be entered into the system so that over time loss estimation can improve.

The project developed a database/information system to provide PHL estimates in East and Southern Africa (in particular IGAD and SADC countries); for grain staples by country and by province. The loss figures are the reduction in weight of ready to consume grain incurred during harvesting operations, farm storage, transport and market storage. The database responds to queries about the PHLs for countries, provinces, crops, agro-climatic areas, seasons and farming system. Alternative estimates are offered to take account of extreme climatic events, especially rain at time of harvest.

The PHL Information System was created with financial support from the European Commission within the work programme of its Joint Research Centre (Italy). Postharvest issues were managed by the Natural Resources Institute (UK) and database development and IT management undertaken by BLE/ISICAD (Germany). In Africa, the team included the regional research organisations ASARECA and SADC/FANR and their national experts contributed through the PHL Network. The project was overseen by a steering committee provided by the UN Food and Agriculture Organisation (FAO), Joint Research Centre (EC) and AIDCO (EC). Advice and feedback was also obtained from FAO's Global Information and Early Warning System (GIEWS).

Annex 2 - Weight loss % during storage of cereal crops

The table below shows original % storage weight loss estimates, estimates standardized for 9-month storage period and an even household consumption pattern, arranged by country and prevailing climate classification (Köppen code) and with an indication of the quality of the data source.

Country	Climate code	Farming scale	Original estimate	Standardized estimate	Quality rating	Authors
Cob storage with LGB						
Tanzania	Aw	small	34.0	11.6	M	Golob and Boag 1985
Tanzania	Aw	small	20.0	7.8	M	Hodges et al. 1983
Tanzania	Aw	small	31.0	11.6	M	Henkes 1992
Malawi	BSh/Aw	large	8.0	2.7	Q/G	Singano (pers. comm.)
Malawi	BSh/Aw	large	8.0	2.7	Q/G	Singano (pers. comm.)
Malawi	BSh/Aw	small	40.0	13.7	Q/G	Singano (pers. comm.)
Malawi	BSh/Aw	small	38.0	12.9	Q/G	Singano (pers. comm.)
Malawi	Cwa	large	5.0	1.7	Q/G	Singano (pers. comm.)
Malawi	Cwa	large	7.0	2.5	Q/G	Singano (pers. comm.)
Malawi	Cwa	small	41.0	13.8	Q/G	Singano (pers. comm.)
Malawi	Cwa	small	35.0	11.1	Q/G	Singano (pers. comm.)
Tanzania	Cwb/Aw	small	5.1	5.1*	M	Ashimogo 1995
Cob storage no LGB						
Ethiopia	Aw	small	8.0	5	Nk	SSEAD 1997
Kenya	Aw	small	5.2	4.6	M	Nyambo 1993
Kenya	Aw	small	7.3	7.3*	Mu	De Lima 1979
Kenya	Aw	small	6.2	6.2*	Mu	De Lima 1979
Kenya	Aw	small	15.0	6.1	M	Giles 1986b
Kenya	Aw	small	4.6	4.6*	Mu	De Lima 1979
Kenya	Aw	small	8.5	3.1	M	Giles 1986b
Kenya	Aw	small	5.2	5.2*	Mu	De Lima 1979
Tanzania	Aw	small	1.9	1.9*	M	Bengtsson et al. 1991
Kenya	BSh	small	6.2	6.2*	Mu	De Lima 1979
Malawi	BSh/Aw	small	4.5	2.4	M	Golob 1981 a
Malawi	Cwa	small	7.6	4.4	M	Binder et al 1994
Malawi	Cwa	small	7.7	4.3	M	Binder et al 1994
Malawi	Cwa	small	8.9	4.6	M	Binder et al 1994
Malawi	Cwa	¹ small	39.8	9.5	Mu	Schulten and Westwood 1972
Malawi	Cwa	² small	6.7	1.6	Mu	Schulten and Westwood 1972

Malawi	Cwa	³ small	3.6	0.9	Mu	Schulten and Westwood 1972
Malawi	Cwa	small	2.1	1.2	M	Golob 1981 b
Swaziland	Cwa	small	4.05	4.4	M	De Lima 1982
Zambia	Cwa	small	9.0	4.1	M	Adams 1977
Zambia	Cwa	small	13.0	5.4	M	Adams 1977
Varieties ¹ hybrid, ² improved ³ local * household consumption included in original estimate						
Maize grain with LGB						
Tanzania	Aw	small	19.7	7.6	M	Golob and Boag 1985
Tanzania	Aw	small	8.0	3.3	M	Henkes 1992
Maize grain no LGB						
Ethiopia	Aw	small	9.0	5.5	Nk	SSEAD 1997
Kenya	Aw	small	18.0	7.8	M	Giles 1986b
Kenya	Aw	small	14.1	5.4	M	Giles 1986b
Kenya	Aw	small	14.0	5.3	M	Giles 1986b
Zambia	Cwa	small	2.6	0.9	M	Adams 1977
Zimbabwe	Cwa	small	7.01	7.01*	M	Keterere & Giga 1990
Zimbabwe	Cwa	small	¹ 12.2	12.2*	M	Keterere & Giga 1990
Ethiopia	Cwa	small	2.6	0.8	Nk	Kidane and Habteyes 1989
Sorghum threshed						
Eritrea	BWh/BS h	small	14.9	5.5	M	Haile 2006a
Eritrea	BWh/BS h	small	13.0	5.7	M	Haile 2006a
Sudan	BWh/BS h	small	5.3	2.5	M	Seifelnasr 1992
Sudan	BWh/BS h	small	5	2.4	M	Seifelnasr 1992
Sudan	BWh/BS h	small	4.3	2	M	Seifelnasr 1992
Sudan	BWh/BS h	small	3.2	1.5	M	Seifelnasr 1992
Sudan	BWh/BS h	small	3.2	1.5	M	Seifelnasr 1992
Sudan	BWh/BS h	small	2.9	1.4	M	Seifelnasr 1992
Sudan	BWh/BS h	small	2.8	1.3	M	Seifelnasr 1992
Sudan	BWh/BS h	small	1.8	0.8	M	Seifelnasr 1992
Malawi	BSh/Aw	small	10.5	3.5	Q/G	Singano (pers. comm.)
Malawi	Cwa	small	7	2.5	Q/G	Singano (pers. comm.)
Malawi	Cwa	small	10	3.4	Q/G	Singano (pers. comm.)

Ethiopia	Cwa	small	11.0	4.3	Nk	Kidane and Habteyes 1989
Ethiopia	Cwa	small	15.4	5.5	Nk	Kidane and Habteyes 1990
Sorghum unthreshed						
Kenya	Aw	small	10.2	4.7	M	Nymabo 1993
Wheat						
Eritrea	BSh	small	6.5	3.1	M	Haile 2006a
Eritrea	BSh	small	0.7	0.1	M	Haile 2006a
Ethiopia	BSh	small	0.1	0.1	Nk	SSEAD 1997
Malawi	BSh/Aw	small	0.5	0.5	Q/G	Singano (pers. comm.)
Ethiopia	Cwa	small	2.1	0.7	Nk	Kidane and Habteyes 1989
Malawi	Cwa	small	15.0	5.8	Q/G	Singano (pers. comm.)
Barley						
Ethiopia	Cwa/Cw b	small	2.5	0.9	Nk	Kidane and Habteyes 1989
Ethiopia	Cwa/Cw b	small	2.0	0.7	Nk	Kidane and Habteyes 1989
Millet						
Namibia	BSh	small	1.5	0.7	M	Hodges et al. 2006
Malawi	BSh/Aw	small	5.0	2.4	Q/G	Singano (pers. comm.)
Malawi	Cwa	small	3.0	1.3	Q/G	Singano (pers. comm.)
Malawi	Cwa	small	3.0	1.3	Q/G	Singano (pers. comm.)
¹ Hybrid variety			* household consumption included in original estimate			
Rice						
Malawi	BSh/Aw	small	0.1	0.1	Q/G	Singano (pers. comm.)
Malawi	Cwa	small	2.0	0.6	Q/G	Singano (pers. comm.)
Malawi		small	0.2	0.2	Q/G	Singano (pers. comm.)
Teff						
Ethiopia	Cwa	small	0.3	0.3	Nk	Kidane and Habteyes 1989
Data quality rating			Köppen climate classification			
Measured, using modern methodology	- M	Aw	Tropical savannah			
Measured, methodology uncertain	- Mu	BSh	Arid steppe, hot			
Questionnaire	- Q	BWh	Arid desert, hot			
Guesstimate	- G	Cwa	temperate dry winter, hot summer			
Not known	- Nk	Cwb	temperate dry winter, warm summer			

Annex 3 - Store types

Traditional stores



Modern stores



High ventilation



Restricted airflow



Airtight stores