NATURAL RESOURCES INSTITUTE

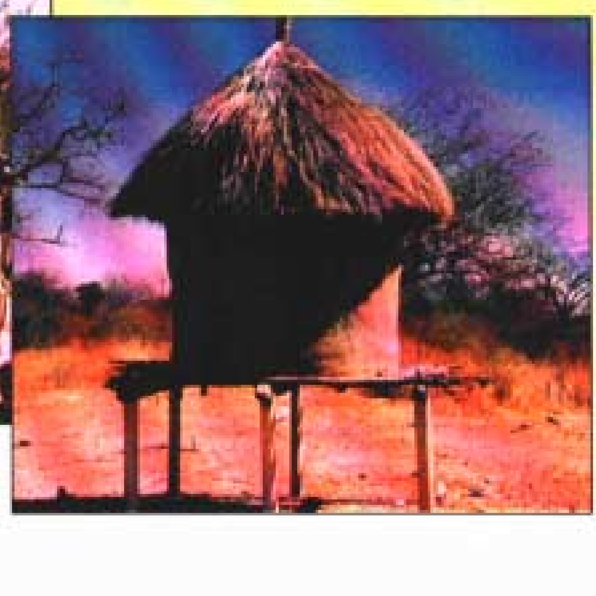
NRI Report No. 2446

Grain Storage Design and Practices in Zimbabwe's Zambezi Valley: A Survey of Binga and Kariba Districts

Project R6685 (A0566)

Improved Design of Indigenous Grain Stores

1997



Natural Resources Institute

NATURAL RESOURCES INSTITUTE

NRI Report No. 2446

Grain Storage Design and Practices in Zimbabwe's Zambezi Valley: A Survey of Binga and Kariba Districts

Project R6685 (A0566)

Improved Design of Indigenous Grain Stores

1997

Douglass, M.P.[1], **Mvumi, B.M.**[2]

Chigariro, J.[2], **Mitchell, M.**[3]

Stevens, S.[4]

[1]Postharvest Technology Department, Silsoe College, Cranfield University, Silsoe, Bedford, MK45 4DT, UK

[2]Institute of Agricultural Engineering, PO Box BW 330, Borrowdale, Harare, Zimbabwe

[3]Termite Graphics, PO Box GD728, Greendale, Harare, Zimbabwe

[4]Overseas Development Institute (ODI), Regents College, Inner Circle, Regents Park, London NW1 4NS, UK

Natural Resources Institute

EXECUTIVE SUMMARY

This study is part of the ODA-funded Crop Post-Harvest Programme covering both aspects of grain storage practices and grain store design in the Zambezi Valley of Zimababwe. In addition, the study was concerned with investigating the use of hardwoods in the construction of the grain stores and possible shortages of timber.

The study used participatory rural appraisal techniques making use of focus group meetings with farmers (male and female), Chiefs and Headmen as well as discussions with many AGRITEX staff. Around 20 focus group meetings were held in a number of villages and centres throughout the Binga and Kariba areas of the Zambezi Valley.

The principle types of storage container are described and illustrated together with the construction; in general, these are constructed on a platform supported by either posts or rocks, with a round or rectangular container on the platform. The containers are either of small section round timber or woven basket types; in most cases these are plastered with mud on the inside or outside - occasionally both. In addition to the storage structures, drying structures are also used. In most cases these are open-topped platforms. Termite damage is a problem with the structures although the most commonly used posts, *Colophospernum mopane*, feature a heart that is reasonably resistant to attack. Trees used should therefore be mature enough to provide a heart of sufficient diameter to carry the loads.

Although the focus groups did not consider shortage of suitable timber a problem, it was clear that there is a shortage of suitably mature timber within the distances that it could previously be obtained from. Farmers now need to travel up to 10 km to cut suitable sized timber.

Storage practices were also considered including the responsibilities for both construction and day-to-day management of the stores. The circumstances of the survey did not allow for definitive assessments of the levels of loss in storage; however this point, was covered by the focus groups. The estimates given by different groups in different areas were reasonably consistent at around 15 - 20%. The use of protectants was also considered and although man-made protectants are used, this is not at a high level, and natural protectants, such as 'soswe' *(Maerua edulis)*, are more commonly used. The threatened arrival of the Larger Grain Borer (LGB; *Prostephanus truncatus)* in the area was also identified.

A cost-benefit analysis (CBA) was carried out in order to identify the level of store improvements that would be acceptable.

A range of possible improvements were identified together with recommendations for a series of trials to be carried out in the area.

CONTENTS

ACKNOWLEDGEMENTS

The authors would like to thank the Director of AGRITEX for allowing staff to participate in this collaborative research project. The co-operation of AGRITEX extension staff in the field is gratefully acknowledged and we have tried to include all of those who assisted in Appendix 1 of this report.

Advice on Participatory Rural Appraisal was given by Di Auret of Save the Children Fund, which proved invaluable for the conduct of the survey. Steve Chipika also offered an input into the design of future participatory work.

The staff of the National Herbarium, Harare, especially Stephen Mavi and R. B. Drummond who kindly identified botanical specimens. The staff of the Katete Lodge in Kariba District were also very helpful in identifying local tree species and translating their Tonga names.

Lastly, we would like to thank Tim Donaldson of the Natural Resources Institute (NRI) for his input into project design and implementation, and his logistical support, and Tanya Stathers of NRI for her time spent editing and finishing off this report.

GLOSSARY OF ABBREVIATIONS

AEW	Agricultural Extension Worker
AGRITEX	Department of Agricultural Technical and Extension Services
CBA	Cost-Benefit analysis
CCA	Copper-chrome arsenate
DR&SS	Department of Research and Specialist Services
FGM	Focus Group Meeting/s
GMB	Grain Marketing Board
LGB	Larger Grain Borer (*Prostephanus truncatus*)
NR	Natural Region/s
ODA	Overseas Development Administration
PRA	Participatory Rural Appraisal
ppm	parts per million
RIRR	Required Internal Rate of Return

Chapter 1

INTRODUCTION

The study was undertaken as part of the ODA-funded Crop Post-Harvest Programme. The focus here is specifically on grain storage practices, although information is also given on post-harvest practices more generally.

In agro-ecological terms, Zimbabwe is divided into Natural Regions (NR I-V), determined primarily by rainfall. The best conditions are found in NR I, constituting only 1.8% of the total land area of the country (Eicher and Rukuni, 1994). Conditions deteriorate through NR II (15%), III (18.6%), IV (37.8%) and V (26.7 %). This survey concentrated on land in the Zambezi Valley area, comprising primarily NR V conditions, but also some land in NR III and IV.

The survey investigated post-harvest technologies and practices of the occupants of the Zambezi Valley with a view to promoting household food security by reducing cereal grain losses. A necessary component of the study was therefore to approximate existing grain losses, not only through observation but also soliciting the views and estimates of the farmers themselves. In addition to concentrating on some 'traditional' pests, such as rodents and weevils, the survey also sought to ascertain the degree of protection provided by existing practices against possible infestation by the LGB (*Prostephanus truncatus*). The LGB has been reported in neighbouring Zambia and Malawi and there is a strong likelihood that the pest will eventually spread further south, into Zimbabwe. In other sub-Saharan countries (e.g. Ghana and Tanzania), stores and storage practices have been modified following the introduction of the LGB. The survey has thus sought to recommend post-harvest practices and storage structures that might offer increased protection against existing pests and pre-empt the likely introduction of the LGB.

An additional objective of the survey was to investigate ways in which the use of hardwood resources might be minimised. The shortage of timber used for constructing stores has been recognised in other reports (Giga and Katerere, 1986; Tshuma, 1989), and some substitution of other materials such as brick, is expected. The survey sought confirmation of the hardwood shortage and information on alternatives that have been tried.

The remainder of this report is set out as follows. First a brief description outlines the methodology used, laying particular emphasis on the extent of participation. The succeeding chapters use the information gained through the survey to assess the post-harvest practices of farmers in the areas studied, to describe the range of traditional stores and cribs found in the Zambezi Valley, and to suggest alternative materials for store construction available locally. The final section tackles storage issues for the future, with recommendations for a series of possible options for the conduct of on-farm field trials and suggested areas for future research.

Chapter 2

METHODOLOGY

In order to be able to assess the current situation both of the quality of the indigenous storage and the level of usage of hardwood in the stores, an initial survey was carried out in two areas of the Zambezi Valley in northern Zimbabwe from 9 - 20 December 1996. A multi-disciplinary team was employed, comprising an Agricultural Structures Engineer, a Forest Entomologist, a Socio-Economist and two Post-harvest Technology Specialists, in collaboration with local AGRITEX field staff.

The selection of areas (Wards) to be studied followed discussions with district AGRITEX staff. The criteria used included:

- wide crop spectrum and a range of levels of production
- a range of styles of granary covering the most predominant types
- available population data
- historical background of the people to determine the influence of settlers from other parts of the country on local traditional grain post-harvest practices.
- proximity to the Zambian border, the most likely LGB entry route into Zimbabwe.

The Wards selected using these criteria are shown in Appendix 1.

An objective of the survey methodology was to introduce participatory rural appraisal (PRA) techniques as a tool for eliciting more accurate and more useful information.[1] The extent to which a full PRA could be conducted was limited by the time available. Since this was a particularly rapid appraisal of grain storage practices in a number of Wards, with the aim of selecting areas for future field trials, the choice of PRA methodology was severely time-bound. The PRA methodology adopted consequently was two-pronged: firstly, the concept of participation and its advantages were discussed within the team and agreed; secondly, participation was designed around a series of focus group meetings (FGMs), with village members divided according to the conditions in each location. While single FGMs have their drawbacks, these are mitigated to the extent that issues raised but not answered can be pursued in greater detail during later phases of the project (Magrath *et al*, 1997).

The criteria for determining the composition of FGMs were primarily the number of villagers attending the meeting, the number of women attending, the presence of the Chief and/or Headmen and Councillors, and the number of Tonga/Shona-speaking members of the team at any one time. Where enough team members were available, villagers were split into groups of between five and ten people. Where more villagers attended than could be supported in groups of this size, the numbers in each group were extended. The groups were split primarily by gender and position. Thus in most cases it proved possible to have a separate group of women

---

[1] We are grateful to Di Auret of Save the Children Fund, Harare, for assisting us in appraising the options for PRA in this study.

and at least one of men, with perhaps a mixed group also. Where the Chief and/or Headmen and Councillor attended, they were placed in a separate group. The maximum number of groups in any village was three. The team split between the groups, and where possible a local extension worker was also assigned to each group, to introduce the team to the villagers and explain the objective of the study. Emphasis was placed in these introductions on the participatory nature of the survey. The team each carried a common checklist for reference, but the FGMs were allowed to take their own course rather than following a structure determined by the checklist. Following the meetings, the team compared notes.

The time constraint limited any more sophisticated method of village division. For example, separation by wealth, which might have revealed some useful insights, was not feasible without considerably more time spent gaining trust. Villagers in this region do not flaunt wealth, although it is likely that most are aware of the wealth ranking amongst them. Separation by gender and position nevertheless revealed some interesting differences in perception. The separation of Headmen and Councillors from the rest also to some extent divided the village by age. The total number of FGMs thus held was around 20.

Extensive use was made of diagrams drawn in the earth to illustrate storage structures and to highlight the main areas of weakness. In addition, there was considerable consultation with villagers in order to identify tree species, combining local knowledge with published arboreal information. Where appropriate, simple ranking exercises were also carried out.

Following the interviews, the local extension workers assisted further in selecting sites for farm visits in order to physically observe the storage facilities available in the area and examine the designs, analyse the construction material and discuss the management and socio-economic aspects of storage with the granary owner.

Photographs and slides of the storage and drying structures completed the description of the designs available in the area.

Chapter 3

POST-HARVEST PRACTICES OF FARMERS IN THE STUDY AREAS

General post-harvest practices

It can frequently take between two and four months from initial harvesting of grain to its storage. The following sub-sections briefly detail the main stages involved. These practices are generalised and may not be followed consistently by individual farmers. Closer observation may reveal that each stage comprises a 'decision situation', characterised by actions that are influenced by particular constraints existing at that time (Compton, 1997).

Drying

The crop is dried both before and after harvesting. Once the crop is harvested, it is put onto drying platforms, either at the fields or homestead, for further drying. Drying structures may also be used as temporary storage facilities, particularly when the field is a considerable distance from the homestead. In such cases, the entire crop may be gathered first and only then transported to the homestead. This process may take several weeks. Drying may take up to four months depending on the work pressure and availability of labour for subsequent processing. Inadequate drying has been identified as a problem in past studies (Giga and Katerere, 1986), due to the resultant mould growth. This potential problem was neither observed in the current survey, nor mentioned in the FGMs.

Threshing

Threshing is carried out between June and August when all the crops have been harvested and the wind conditions are right for winnowing. A common method of threshing small grains is by beating. The beating is done either with a straight stick or an 'Ipubila' stick with both ends widened. Threshing usually takes place on compacted ground surface coated with cow dung or on a rock surface. In some cases maize threshing is carried out on a wooden platform in front of the storage cribs. However, these platforms are rarely used for small grains.

Cleaning and Sorting

Cleaning of the grain is by manual removal of waste material and by winnowing. Ears with grain intended for seed are separated prior to threshing. The ears are then stored separately under the roof eaves of either the store or kitchen. In some cases, grain is stored in portable pot-type storage structures.

Storage Practices

About 85% of farmers in the Nabusenga ward (Binga district) store their grain on the ear, through fear that leaving the stored grain in bulk form will lead to excessive consumption (Chirove, 1997). Therefore grain is often only threshed in these areas as the need arises, either for family consumption or for other uses, such as barter or beer-brewing. Most farmers around Siabuwa area (Kariba district) also store their grain unthreshed. In other areas visited by the team most of the grain is stored threshed, although even in these areas a significant number of farmers store unthreshed grain. The reasons for not threshing grain in these areas varied from a shortage of labour and transport to cultural preferences.

Processing

Traditionally, small grains, particularly sorghum, are roasted to improve flavour, pounded with water by mortar and pestle to remove the pericarp, winnowed and then stone ground. Increasingly, hammer mills are being used to grind all grains without prior roasting or removal of the pericarp.

Grain Sale

Although very few of the farmers surveyed grew sufficient grain to generate a surplus, there are examples of households in most areas whose crop exceeds personal consumption. There are at least three ways in which these farmers might sell surplus grain: directly to wholesalers, usually the Grain Marketing Board (GMB); to dealers, who might come from as far as Bulawayo; or to other people in the village. Depending upon which of these routes is taken, grain might be sold for cash or in exchange for goods (e.g. goats or chickens) or labour. There was some evidence of speculation, i.e. farmers keeping their grain for longer in order to wait for a higher price.

Store Construction

Stores are erected according to the likely size of the harvest in the year of building. If the prospects for harvest are particularly poor, a structure may not be built. Rather, the grain will be stored in sacks at the homestead. Thus, structures are to some degree adapted to requirements. However, building a storage structure is not an annual event, therefore the decision on what size store to construct affects more than simply the current year. Should the harvest look as if it might exceed current storage capacity, another store will be constructed. Compton *et al* (1993) point out that it is inaccurate to assume a store is also used to its full capacity. Harvests are sufficiently variable that it is possible to witness a store half-full one year and overflowing the next. It would seem to be a fair assumption therefore that the very first store constructed for a homestead is built after consideration of the size of the current harvest (especially if the current harvest is unexpectedly poor) as well as expected future yields. Further research would be necessary to determine whether capacity is determined by some estimate of average harvest, above-average harvest, or perhaps maximum conceivable yield and also the extent to which traditional shapes and sizes influence continued adherence to similar stores.

Labour inputs into storage construction vary. There appear to be three main determinants of construction time: the distance from the homestead to the nearest source of construction materials; the size of the structure to be built; and the design of the structure, particularly the time needed to cut and prepare the timber. Thus construction of a structure may take anything between one person-week and a person-month. Thus February is the most likely construction time, given that harvest may occur any time between March and May.

In terms of the gender division of the labour involved in store construction, it appears that the men cut and collect the timber and construct the frame of the store. Women are often responsible for thatching and for plastering stores. For the woven-basket structures, women also complete the weaving, and in at least one case women collected stones, where these were used in place of wooden posts, to raise the structure from the ground.

Chapter 4

TRADITIONAL STORES AND CRIBS

Existing Storage Structures

Several traditional structures were identified in the two districts visited by the team. Figure 1 shows a representative example of the most common stores encountered. See also Plate i. Some of the stores were reminiscent of stores described in Tyler and Harding; although in no case was there any attempt at providing rat-guards on the upright supports of the stores.

Among the traditional structures were:

(a) The Shona type store found in parts of Siabuwa, Lusulu and Mola. A rectangular store, often with several compartments, built of poles plastered with clay. The structure is supported by stones or posts (Figure 2 and Plate ii).

(b) The elevated Chitula store found in Siabuwa, Sinampande, Mulindi and parts of Manjolo. The wall of the structure is made of poles, and usually plastered inside, the bin is raised more than 1m above ground, with the space below often used as a kitchen (Plate iii).

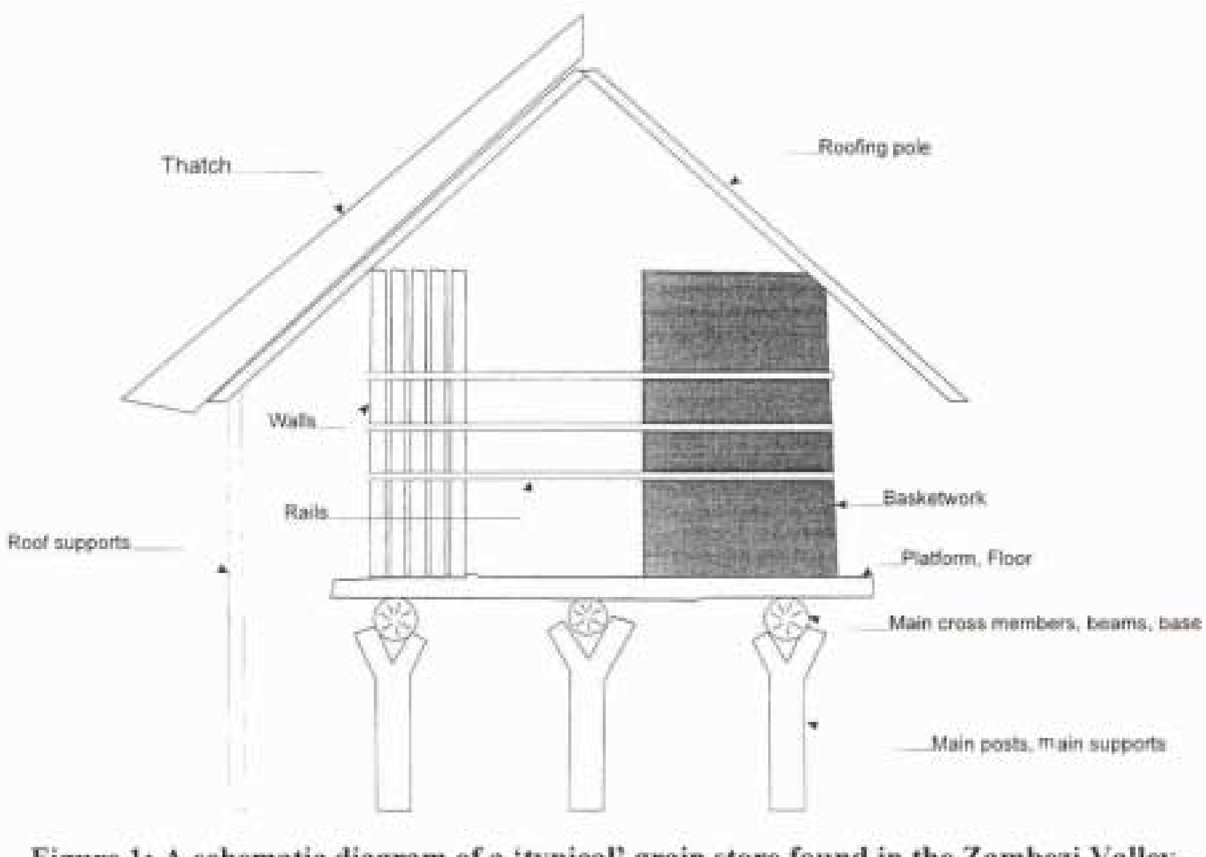


Figure 1: A schematic diagram of a 'typical' grain store found in the Zambezi Valley, Zimbabwe, giving the terminology used.

(c) The Katala store, common in Mulindi. A pot-like structure, the bin is constructed from clay that is sometimes reinforced with chopped dry grass. Small ones may be used as portable seed stores (Plate iv).

(d) The Katula store, most common in the Mulindi, Manjolo and Siansundu areas. This is a larger, bottle-shaped store, with a basketwork frame, supported by stones or posts. (Fig. 3 and Plate v)

(e) The woven-basket type store common in the Siansundu, Sinampande, Negande, Nebiri and Mola areas. Basically cylindrical bins, very variable in size, where the roof rests directly on the top of the bin, either detachable or with separate supports (Plates vi and vii).

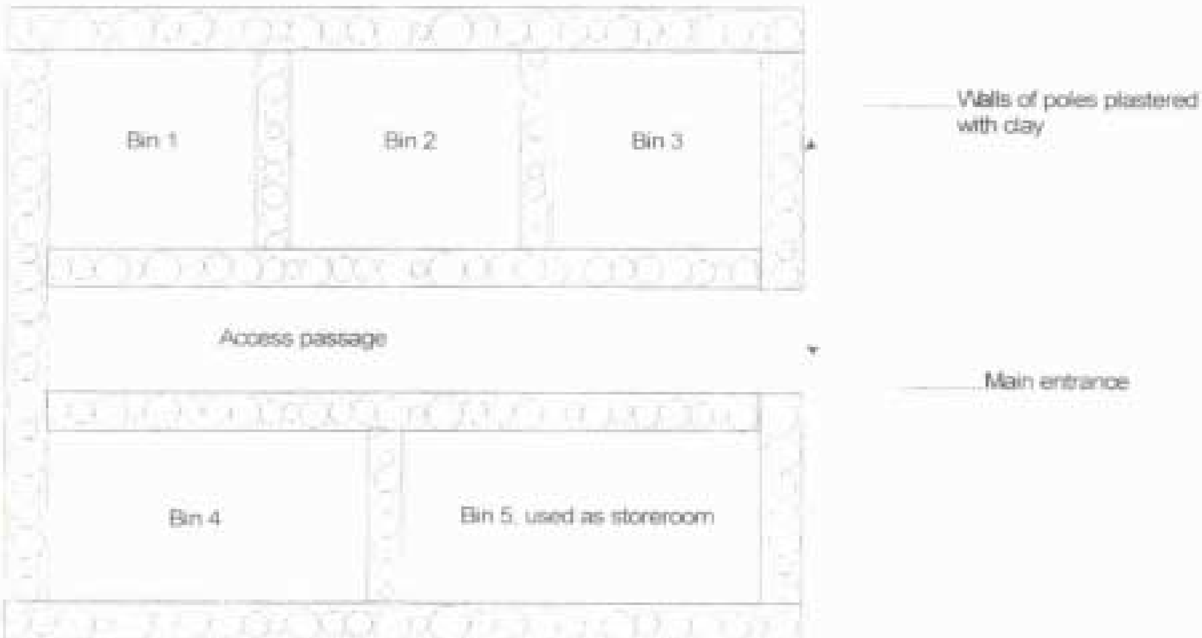


Figure 2: Floor plan of traditional, multi-compartmental Shona store

Plate i. Typical grain store of the region **(see page 7)**

Plate ii. Shona type of rectangular grain store **(see page 7)**

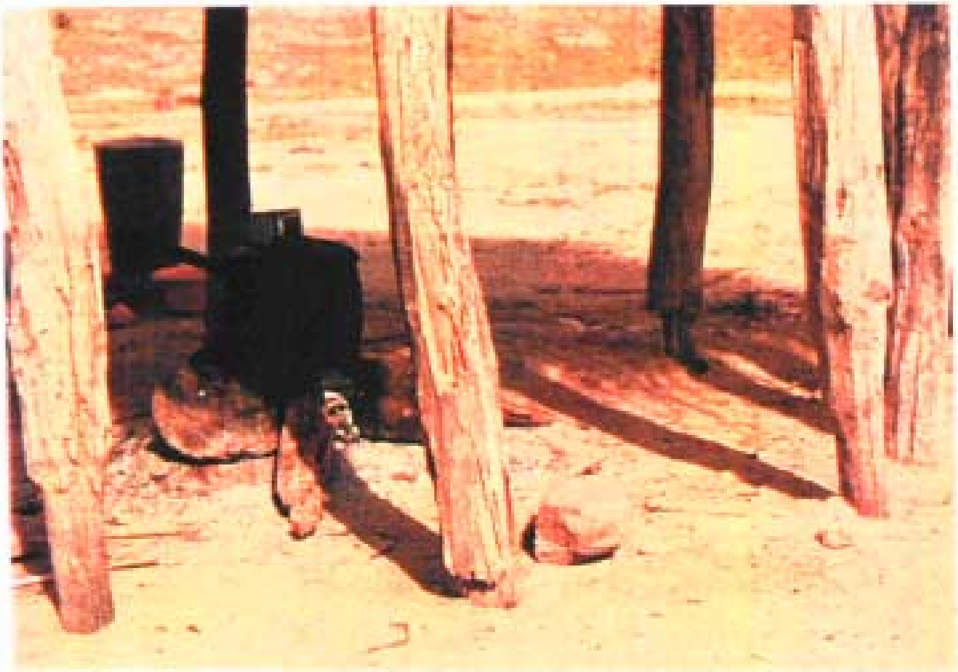


Plate iii. Chitula store in Sinampande raised to allow cooking beneath; smoke may deter storage pests. Note termite damage to sapwood of the *mopane* poles (see page 7)

Plate iv. Katala stores in Mulindi; the small pot stores may be used for seed (see page 8)

In addition, some improved brick structures with multiple compartments were found in the upper parts of Siabuwa, adjacent to Gokwe communal area where cotton is grown as a cash crop, contrary to the traditional structures which mainly utilised indigenous hardwood as construction materials (Figure 4 and Plate viii). This design is similar to the traditional Shona store observed in Lusulu where most stores had compartments, and where the capacities of the stores were far higher than those in the other areas of the district.

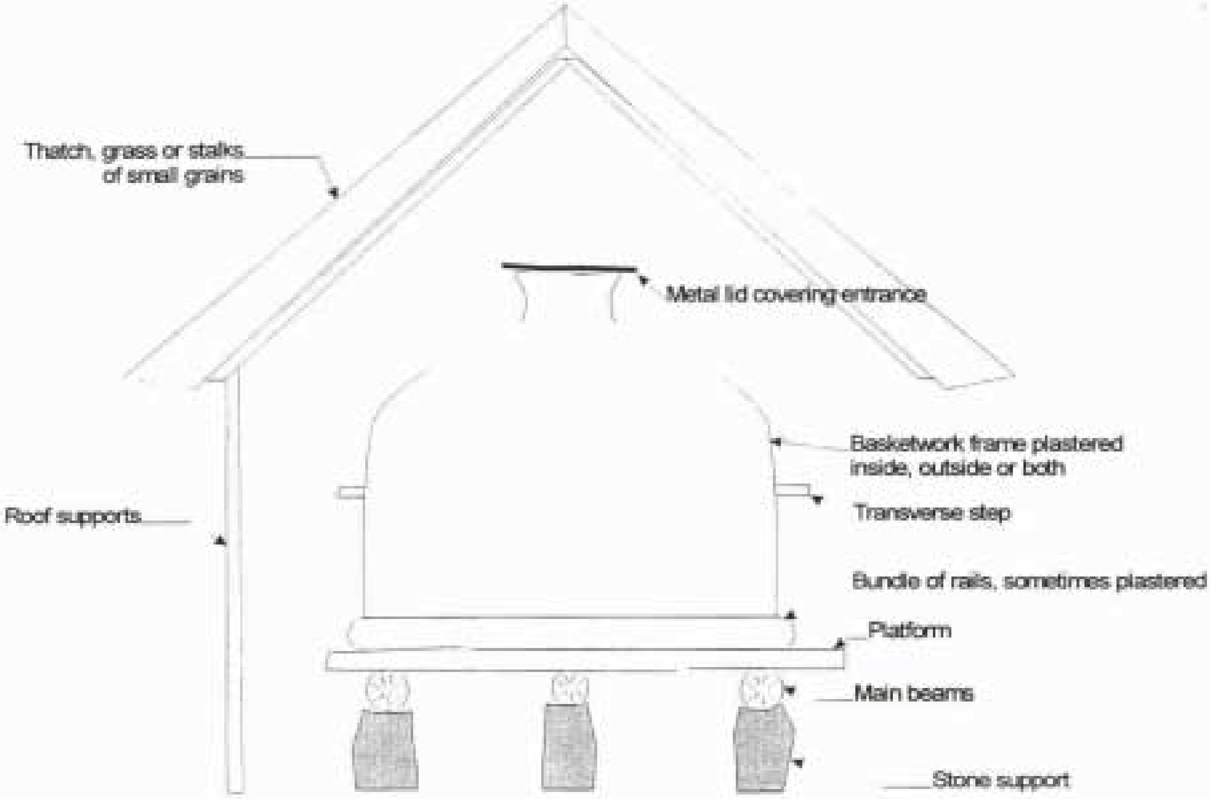


Figure 3: Traditional Tonga 'Katala' type of store, common in Binga district.

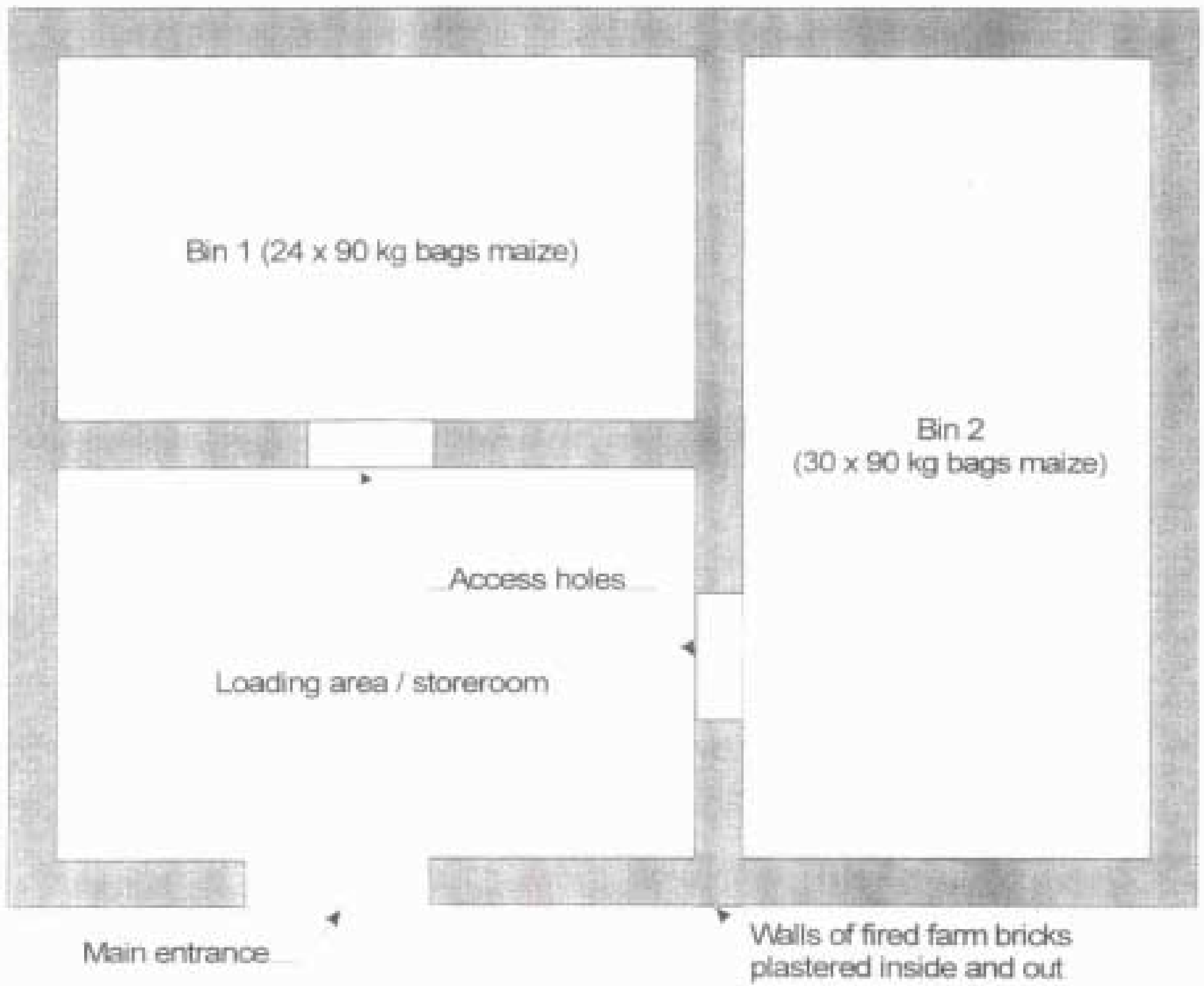


Figure 4 Floor plan of improved, multi-compartmental Shona store (note brick walls and fewer compartments)

Plate v. Katula store in Mulindi; large bottle-shaped pot stores (see page 8).

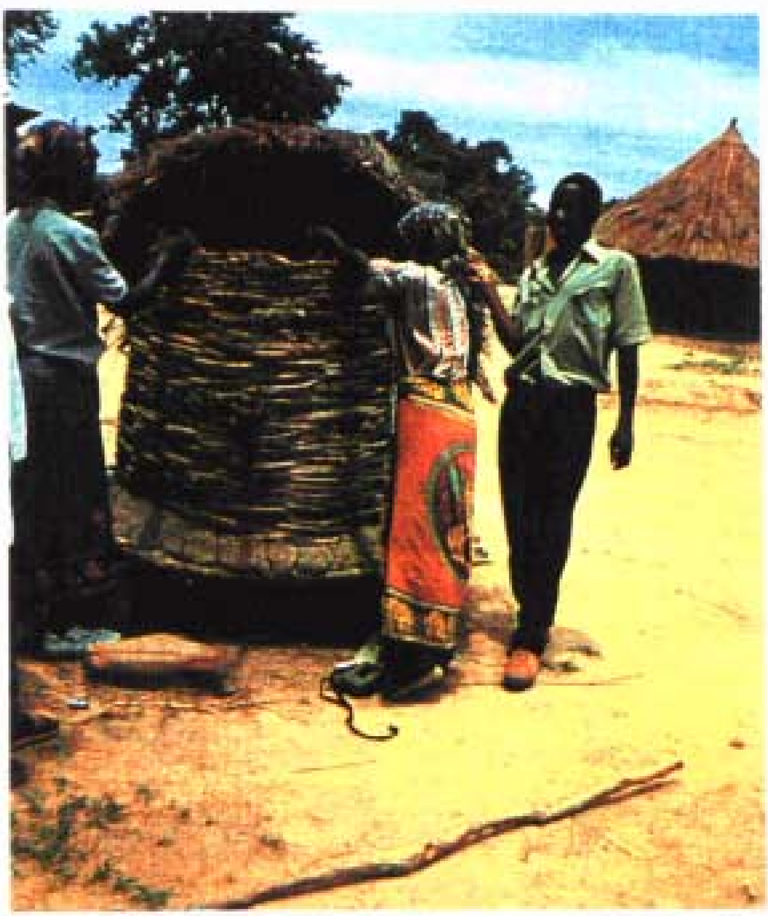


Plate vi. A woven basket store plastered on the inside only (see page 8)

Plate vii. Basket store showing internal plastering (see page 8)

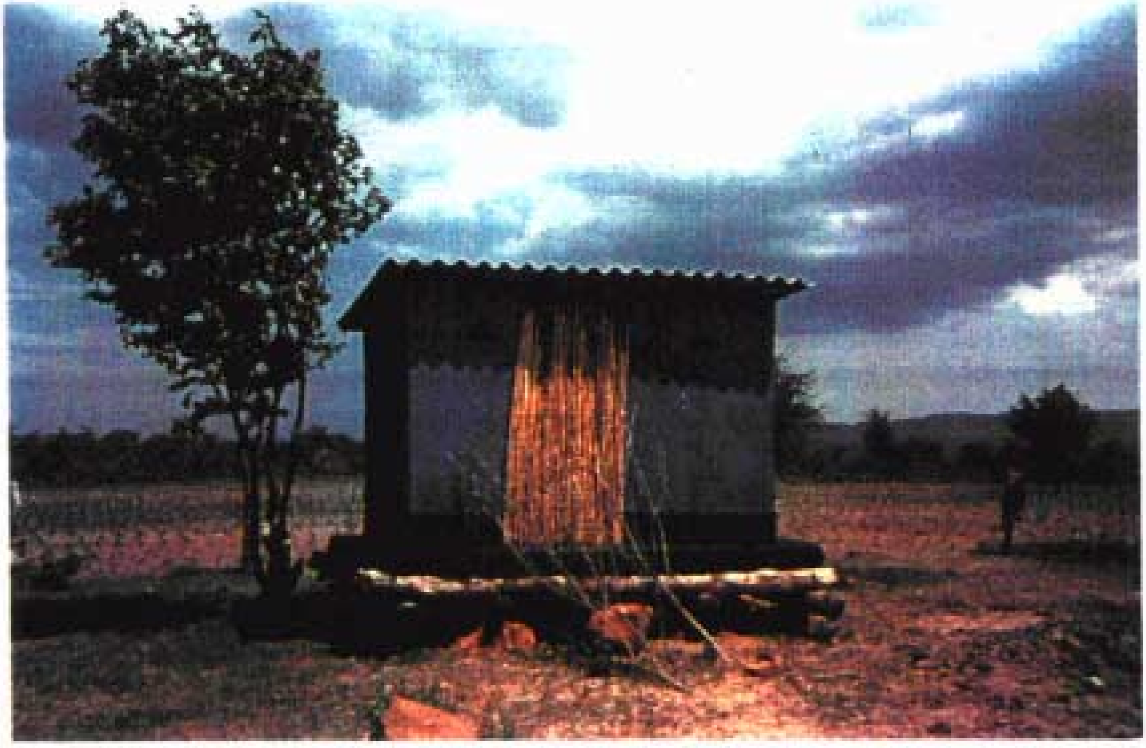


Plate viii. Recently built brick construction store plastered with cement mortar and asbestos-cement roof sheets (see page 11)

General Construction Details

Platforms

In general stores are built on a platform off the ground. Broadly, the platforms are either supported by stones with the platform height at about 0.5 m, or by posts with the platform height at about 1 to 1.5 m. The former was often found to be a response to termite problems, though there is some evidence of termites building tunnels across the stones to the timber platforms when the termite tracks were not regularly removed by the farmers (Plate ix).

Plaster

Three types of dagga plaster were found: one purely clay, taken from termite mounds; a second consisting of clay, mixed with chopped straw as reinforcement; and the third, generally for the inside of the structure, clay, mixed with cow manure as an insecticide.

Life-span and maintenance

There was a considerable amount of broad agreement regarding the life of stores. In general, the average life ranges from 10 to 20 years. Repairs are required periodically including re-thatching every 3 to 4 years and repairing dagga-plastering periodically, occasionally knocking off all dagga and re-plastering completely. More often, the plaster is simply re-skimmed annually.

Timbers Used in Grain Store Construction

The areas visited varied in both altitude and vegetation type, resulting in different timber species being available for the construction of storage structures in different areas.

A total of 32 tree species are used in the construction of stores, of which 27 were identified to species name, either by the identification of botanical specimens or by consulting the literature for the local names given. The tree species identified are given in Appendix 3. There is a recent publication listing the Tonga names for plant species (Reynolds and Crawford Cousins, 1993), others in existence (Thomas, 1970; Wild, 1972; Goldsmith and Carter, 1981) are by no means complete. The situation has been further complicated by the influx of Shona and Ndebele speakers into the area, resulting in many different names for the same species. A further complication was that no members of the team were native Tonga speakers resulting in problems with the spelling and transliteration of names.

The summaries below indicate the different uses of the timber in the grain store structures. For each different use, the species are listed in Appendix 3 with the species recorded in order of general preference. Due to differences in vegetation type between the different areas visited several species are not available in certain areas. For example *Julbernardia globiflora*, *Brachystegia boehmii* and *Burkea africana* are not commonly found north of the Zambezi escarpment.

Main posts

Storage structures were either supported on timber posts or on stones. Since stone give some protection against termites, stone supports are preferred, if suitable stones are locally available or there is access to transport.

Strength and resistance to termite attack are the main considerations during selection of tree species for the timber main posts. A major requirement of these main supports is that they are cut from a tree which is forked at a suitable height above the ground, so that the main cross members rest on the top of the posts (Plate x). Such trees may be hard to locate, requiring more time for timber collection. There may be considerable wastage when the tree is cut, with the parts of the tree not needed for posts left on site rather than being utilised, especially if the felling site is a considerable distance from the construction site.

The portion of main supports above ground varies from about 0.5 m to about 1.5 m in length, and the basal diameter from 10 cm to 25 cm.

Main cross members

Main beams vary from about 1.5 m to about 2.5 m in length, and their basal diameter from 5 cm to 20 cm, depending on the size of the store. Strength and straightness are the major considerations in the selection of species of tree to be used.

Timbers used for platform

Platform timbers vary from about 1.5 m to about 2.5 m in length, and their basal diameter from 3 cm to 10 cm, depending on the size of the store. Strength and straightness are the major considerations in species choice.

Rails and basket-work

Flexibility when the wood is green is the most important consideration in choice of species. Many of the species listed are scramblers with long flexible branches, with little taper, which can be easily woven.

Walls and basket uprights

The platform timbers vary from about 1.5 m to about 2.5 m in length, and their basal diameter from 3 cm to 10 cm, depending on the size of the store. Strength and straightness are the major considerations in choice of species.

Roof and crib supports

The platform timbers vary from about 1.5 m to about 3 m in length, and their basal diameter from 10 cm to 20 cm. Strength and straightness are again the major considerations in choice of species. One farmer in Mola A has built three stores: the first is a traditional store with heavy roof supports. The second structure has smaller diameter timbers (+/- 10 cm basal diameter) which can easily be replaced by lifting the roof by hand. Any kinks in the poles are notched to straighten them. In the third structure, the roof rests on the top of the storage bin, with no supporting poles (see Plates xi and xii for the second and third stores).

Roofing poles

Roofing timbers vary from about 1.5 m to about 2.5 m in length, and their basal diameter from 5 cm to 10 cm. Straightness and length are the major considerations in the choice of species to be used.

Additional uses for timber: these include bark for tying timbers together or tying thatch to roofing poles and wood for doors (Plates xiii and xiv).

Desirable Store Features

The survey also attempted to discover which features of existing stores make them attractive and convenient to use. Many of these reasons are common to other tropical regions (see Compton *et al*, 1993), including:

- convenience of access, either by adults or by small children;
- ease of adding and removing grain;
- protection against theft, sometimes necessitating a locked door to the store itself, or a secure fence surrounding the store;
- ease of visual assessment and monitoring of the level of grain stocks;
- whether store can be used for other purposes, such as use of area below for cooking, or as shade, or as storage space for agricultural equipment;
- in isolated cases, portability.

These features of store design should be given proper consideration when devising modifications. A new design that radically reduces storage losses, may nevertheless be unacceptable to farmers for its failure to take into account other desirable design aspects.

Historical Perspective

None of the FGMs reported a change in the traditional design of the stores. All participants commented that stores were built to the same designs and patterns which had been taught to them by their ancestors. In one group, the choice between round and rectangular stores was described as a matter of personal taste.

However, it was reported that although the designs of the stores had not changed, the distances travelled to obtain the appropriate size and type of timber (mainly *mopane*) for the main posts and beams, have increased considerably over the years. Whereas the timbers could be found within a relatively short distance in the past, sources are now located seven to ten kilometres away from the storage site. This is not symptomatic of an overall shortage of material, rather that although the material is available, farmers now have to travel much further to obtain it.

There is an indication, therefore, that there has been an overall depletion in the appropriate timber growing near the homestead. Although there was a considerable amount of young *mopane* coppice growing, often within a very short distance from the homesteads, this all appeared to be too immature for use as construction timber for the grain stores. The shortage does not appear to be related to the number of *mopane* trees, but to the number that are sufficiently mature. Only the more mature trees that will have developed heartwood thick enough to make the timber effectively resistant to termites and to carry the required loads are used in store construction. Moreover, mature trees are more likely to have developed strong forks that may be used as supports.

It is questionable whether the young *mopane* trees currently growing near homesteads will be allowed to grow to full maturity without more explicit protection. The use of the trees as firewood might precede their use as construction timber. Even if they were allowed to mature, estimates were given of between four and five generations for a tree to fully develop.

Despite the problems in finding timber, the scarcest material in general was thatching grass. Not only is thatching grass scarce, implying that long distances may be travelled to collect new grass, but the thatching itself (depending on the extent of the termite problem for the timber) is the part of the store needing most frequent maintenance. In any ten year period, thatching grass will be replaced once, but there may be no other repairs carried out to the store. In response to the thatching shortage, in one homestead dried millet stalk are mixed with the grass.

Drying Structures

In addition to the storage buildings, many farmers use structures to provide a drying platform to raise the crop off the ground and allow air circulation around it. The crops are dried on the platforms after harvest and before storage. In a few cases, there are drying platforms in the fields but in most cases, the drying platforms are found at a close proximity to the stores. Four types of drying structures were identified in Binga and Kariba districts. These include:

a. Platform type: a platform mounted on four or more *mopane* tree posts. The platform does not have raised sides (Plate xv).

b. Triangular type (Dumba): a platform with a triangular-shaped bin on top. The top is normally constructed of crop residue and poles (Plate xvi).

c. An unsheltered crib mounted on a platform (Sanza) with walls constructed out of crop residue and/or poles and/or chicken wire (Plate xvii).

d. A roofed hut on a platform with walls; sometimes the roof is made of crop residues.

A maximum of two types of drying structures were observed per ward or Agricultural Extension Worker (AEW) area.

Plate ix. Rock support in a grain store showing termite track up the rock and on the surface of the horizontal timber bearer (see page 15)

Plate x. *Mopane* main posts showing the use of forked trunks to support the main horizontal floor bearers (see page 16)

Plate xi. Mola farmer's modified store - 1; note the use of more slender than normal vertical posts to support the roof (see page 16)

Plate xii. Mola farmer's modified store - 2; note the absence posts to support the roof which rests entirely on the wall of the store (see page 16)

Termites

The most common cause of structure deterioration seen was termite damage, principally of the sapwood of main posts. The denser heartwood, particularly of *Mopane*, tends to be resistent to termite attack. However, since the sapwood is vulnerable, this inevitably requires timber for posts which is of heartwood of sufficient diameter to carry the loads required. This can be seen in Plate xviii. It should be pointed out that this deterioration in turn requires the continued use of hardwood for maintenance and replacement of posts in addition to the construction of new stores. The survey therefore also studied the types of termites found and the particular problems that the prevalent species presented for current and future store construction.

There are two dominant termite species in the districts visited: *Ancistrotermes latinotus* which does not build mounds and *Macrotermes michaelseni* and, at higher altitudes *M. falciger*, which are large mound building species. *A. latinotus* is the most destructive termite species in Zimbabwe and is found in all soil types except sand.

Macrotermes are relatively simple to deal with: mounds can be destroyed by digging out the queen, but only immediately after all the alate (winged) termites have flown, otherwise supplementary reproductives will be produced from nymphs of alates remaining in the nest. The alternative of mound poisoning is both unreliable and expensive. The mounds of these species were found to be important to the local people as the alates are a source of protein and the mounds are the sole source of clay for plastering and brick-making.

In contrast, as the nests of *A. latinotus* are small scattered subterranean structures, killing the queen is impossible, and the only certain ways of preventing damage by this species are:

- to raise the structure as high as possible above the ground on stone or concrete pillars, ensuring that the humidity beneath the structure is kept low and that light is allowed in. Termites do not commonly cross stone or concrete unless the humidity is high and the area is dark. There is however evidence that termites will build runs over stones if left undisturbed (Plate xviii); these need to be brushed off by the farmers in order to keep the termites from the timber platforms.
- use termite-immune timbers, such as *Mopane* heartwood for poles in ground contact.
- use timber commercially treated with Copper-chrome arsenate (CCA) or creosote.
- treat the soil around the buried part of the pole and the base of the pole itself with commercial insecticides.

Storage structures should never be erected on or near termite mounds. The best site is on bare rock, otherwise deep, sandy soil is preferable to soil with a high clay content as *A. latinotus* cannot nest in pure sand.

The following methods of termite control were used in the areas visited:

- *soswe* (*Maerua edulis*) pounded and smeared on the timber - limited effectiveness.
- *siila* (*Cucumis metuliferus*) pulp smeared on the timber - limited effectiveness.

- *Mopane* ash applied to the hole before the support pole was inserted and then sprinkled on the soil surface around the base of the pole. Maize cob ash can be applied in the same way.

- used engine oil, where the base of the pole is dipped in old oil before being put in position. Further applications are poured onto the pole as required (Plate xix).

- charring the base of the pole where it is in contact with the ground.

- soaking the area in goat urine - an extreme case.

The efficacy of the above should be tested in field graveyard tests.

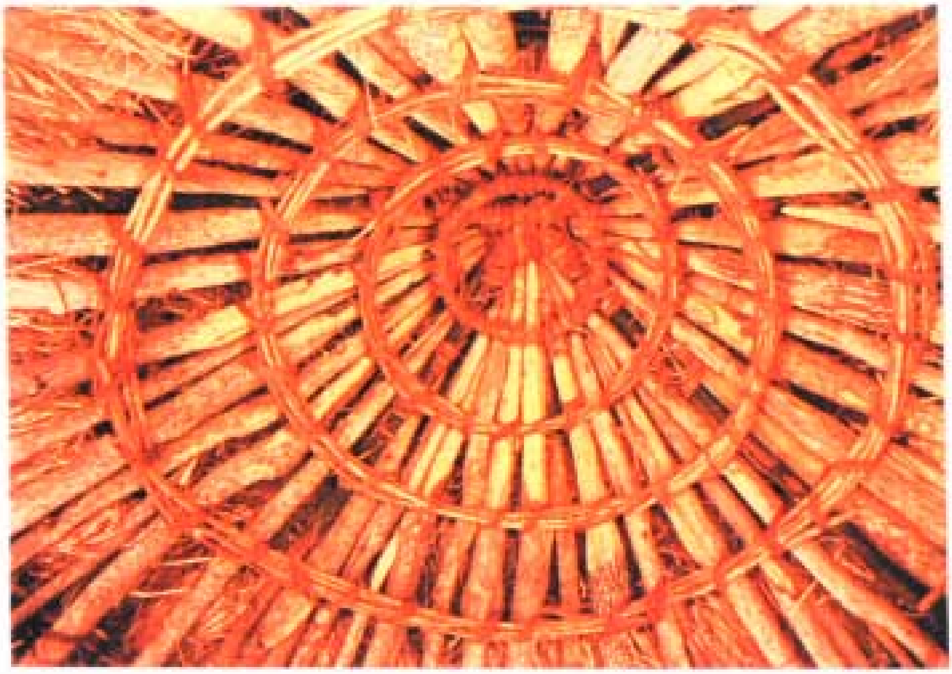


Plate xiii. Inside of roof structure showing timbers tied together (see page 16)

Plate xiv. Sticks used for a doorway on a store (see page 16)

Plate xv. Open-sided drying platform (see page 18)

Plate xvi. Triangular shaped shelter on drying platform (Dumba); shelter built using crop residue and poles (see page 18)

Plate xvii. Unroofed crib for maize (Sanza); tree in foreground is *C. mopane* (see page 18)

Plate xviii. Termite damage to the sapwood of *mopane* posts; note the resistance of the heartwood (see page 21)

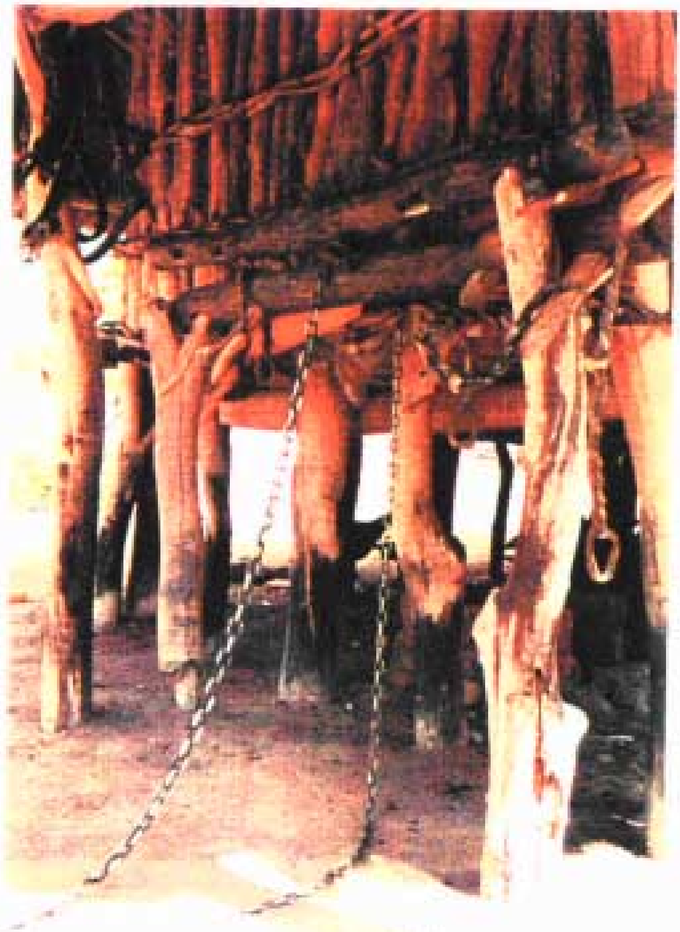


Plate xix. Posts treated with old engine oil; note also damaged posts (see page 22) (timbers with chains are yokes for oxen)

Cost-Benefit Analysis of Traditional Stores

A cost-benefit analysis (CBA) of traditional stores is a worthwhile exercise for at least three reasons: first, it may give an insight into why grain stores are built; second, by developing a framework of costs and benefits, it simplifies the analysis of store modifications; and third, it offers some information for a preliminary assessment of the acceptability of improved store designs.

The nature of the subject of this study unfortunately makes a detailed CBA particularly difficult. The absence of markets in many of the relevant inputs means that estimates of prices must be made. Benefits (such as food security) may be largely unmeasurable. Inappropriate valuation of costs and benefits can lead to poor recommendations for modified stores (Compton *et al*, 1993).

Nevertheless, this survey has attempted to gather information on costs and benefits where possible, and the analysis below provides the resulting framework. The participatory nature of the survey has been aimed, *inter alia*, at discovering exactly what the costs and benefits of grain storage might be from the point of view of the villagers. The results strongly supported the hypothesis that the villagers are indeed aware of costs of structures, even where no transactions, financial or otherwise, are involved in their construction outside the household. It also showed an acute awareness of relative costs and benefits, expressed by the 'pointlessness' of building a large and sophisticated store when the harvest would last at most six months. There is a general increased sophistication in storage methods - from storage sacks, to small and large baskets, to compartmentalised 'houses' - with the increased size of harvest.

The 'worth' of a larger or more sophisticated store is also tied up with its affordability. A relatively poor household will need to spend more time in the months approaching the next harvest in finding food, given that their own stores are exhausted. The major input into store construction is time, which is a commodity found in greater abundance amongst wealthier farmers, with enough grain to last the year and perhaps even to sell to others, than amongst poor farmers.

With this in mind, the approach used here is two-fold: the descriptive approach that follows details some of the costs and benefits identified during the survey which are considered of relevance to the design of modified stores; in Appendix 4, a simplified example based on the survey is presented, in which the decision to store is taken as given, and some additional costs from constructing a store (as opposed to storing it untreated in the home) are provided. Although some concrete and stone stores were noted, they were rare and will not be covered in this analysis.

Costs

For the costs, the general structure of the approach has been taken from Compton *et al* (1993). This breaks costs into the following categories: materials; labour; store capacity; the life of the store; operating cost; storage duration; opportunity cost of grain; and storage losses. While this section will attempt to generalise about costs, the reader should be aware that practices in specific regions may not conform exactly to the picture presented here.

Cost of material: the bulk of structures observed in the Zambezi Valley, as shown above, use timber, mud, dried grass, thatching grass, millet stalks and stones. There is no local market in these materials; rather the (generally male) farmers collect the materials themselves. Consequently there is no simple way to value them.

As shown above, the scarcest material is thatching grass, followed by timber. Collection of both, depending upon the location of the village can take some time. The preparation of wood into building timber was also frequently mentioned as a relatively time-consuming activity. The demand for wood for building structures is highly inelastic, i.e. there is no evidence that the use of wood varies with the distance required to collect it. Timber is an essential part of building the shelter and platform in some cases, or the entire structure in others. Thatching grass, on the other hand, may be mixed with or replaced with millet stalks. There was also some limited evidence of thatching grass being farmed.

The collection of mud was not mentioned as a time-consuming activity. Mixing the mud with dried grass for reinforcement may require slightly more time: one farmer in Siansundu explained the lack of mud covering for the outside of his basket container and the absence of dried grass in the mixture by the fact that the homestead had only been built that year and in haste.

Stones are also locally available, and generally only used as a termite-proof method to raise the structure from the ground.

Cost of labour: the separation of costs between materials and labour was often made by the farmers. For example, in asking the time taken to construct one structure in Siabuwa, the farmer said that it had taken 4 men just 3 days. However, it transpired that this was only the time for putting the materials together; adding the cost of gathering and preparing materials more than doubled the time cost. It was clear from discussions with other farmers that they also separate the time taken to gather materials from construction time.

However, in common with the cost of materials, the cost of construction is mainly the cost of time. More specifically, it is the cost of the men's time. Women are sometimes involved in plastering the structure, but rarely in other tasks. The gender distinction is important, because at the time of store construction the costs of men's and women's time are quite different. Time is valued here by opportunity cost, i.e. a valuation of the task that the person would be performing were s/he not occupied in constructing the store. The store is constructed when the crop is in the field and the farmer has some idea of the likely size of the harvest, either from his own field or that of his wife/wives. If any of these harvests are likely to exceed the capacity of the related store, then a new store will be built. At this time in the crop cycle, the main task for men appears to be to guard the crop against such hazards as elephants, birds, green locusts, grasshoppers, stalk-borers, baboons and other monkeys. This does not occupy them full-time. Women, on the other hand, are employed weeding mainly their own and their husband's field, or sometimes a neighbour's field in return for some grain. Women described weeding as the most onerous task, with the weeds often reappearing at their starting point before they had reached the finishing point. In addition, women prepare food. Thus the opportunity cost of women's time seems to exceed that of the men.

Where outside labour is used to assist in store construction, a common method of payment is with locally brewed beer. Beer-brewing in all areas appeared to be considered as women's work.

Store capacity: the capacities of the grain stores varied considerably. As mentioned above, the store is constructed once the likely size of the harvest has been assessed. The poorest farmers will have small stores, if they have any store at all. Where the harvest leaves little surplus, it is likely to be stored in bags in the home rather than in a purpose-built store. Store capacities ranged from the small pots holding as little as about 50 kg up to the largest stores - such as the improved Shona stores which may hold up to about 5 tonnes.

Life of the store: estimating the life of a store is not a straightforward problem, because to some extent it is dependent on maintenance. Where the store is susceptible to termites, it might also need regular and effective treatment of the timbers. Moreover, to what extent should a store that is still standing and in use, but whose walls are crumbling and where insect infestation is widespread, be considered a store?

Operating costs: these costs may be separated between maintenance and treatments. In terms of maintenance, the more traditional woven-basket construction appears to be the easiest of the low-cost structures to use, mainly due to its size. Should the shelter deteriorate beyond repair, the plaster may be knocked out of the basket work, the basket removed from its platform, and the platform and shelter rebuilt. Replacing crumbling plaster should also be relatively easy. For the elevated 'chitula' structures, replacement of plaster would require more work, simply due to the greater surface area. Moreover, extensive termite damage for a pole and dagga structure is more likely to necessitate complete replacement.

To the extent that local plants, ash or manure is used as a grain protectant, costs are fairly low. The use of chemical treatments is more expensive, though treatment of 500 kg of grain with pirimiphos-methyl 2% should only cost around Z$10 (about US$0.90), with treatment remaining effective for nine months.

Storage duration: the length of time over which the farmer wishes to store grain is another important feature of costs, particularly when considering likely grain losses. The majority of farmers exhaust their grain supplies before the next harvest and need to sell goats and chickens to raise money to survive during the rest of the year, or sometimes offer to weed for a neighbouring farmer who has surplus stocks.

Opportunity cost of storage: like the opportunity cost of labour, the opportunity cost of grain storage is the value of the next-best alternative use of the stored grain. The simplest assumption to make is that the farmer sells the grain and invests the proceeds. However, there was no evidence from this study of easy access to financial institutions in remote areas. It is likely that the return from this alternative would therefore be very low. First, the savings rate itself would not reflect the number and cost of trips the farmer would need to make to the nearest bank to deposit funds, and withdraw them when the need arose to purchase food[2]. Second, the farmer will not be able to purchase grain at the same price at which it was sold at the beginning of the season. For example, the price of a 15 kg tin of maize in Manjola ward was reported to be Z$20 in September 1996, but Z$30 in December the same year. A farmer investing over these 3 months would therefore need in the first instance to receive a nominal interest rate on savings in excess of 50% in order to be better off in terms of the ability to feed himself/herself and his/her

---

[2] The nearest Post Office Savings Bank is in Binga, and the nearest Commercial Banks are in Gokwe and Hwange

family. This assumes that the farmer would receive Z$20 in September; this would only be the case if it was sold to another local farmer. Otherwise it would need to be sold to a trader, who would charge for transporting the maize to a market or processing centre.

Losses: grain losses are the key to the design of an improved grain store. Reducing losses enables a household to feed itself on its own grain for longer, perhaps keep some grain as security against poor seasons, and therefore to sell less of its livestock. It may also lead to a vicious circle in areas where women earn extra grain through weeding in neighbours' fields. By hiring out their labour, they may neglect weeding their own fields. Less grain losses should therefore enable more time to be dedicated to the household's own plots and lead to increased yields.

Benefits

Storage benefits can be divided between price and non-price factors. Price benefits are fairly straightforward, though they vary slightly between different farmers. Non-price benefits are more difficult both to identify and to quantify.

Price benefits: the price of grains will vary seasonally as well as between years depending upon supply levels and sources. For most of the farmers in the communal areas of the Zambezi Valley, both types of price variation increase the importance of storage. Most areas have grain deficits in aggregate, although there may be individual households with surpluses. The relevant price of grain is therefore the sale price, which varies between seasons and between regions. For maize (the grain for which a price was most often quoted), the sale price might vary during the year between Z$20 and Z$40 for a 20 litre (15 kg) tin. When households exhaust their food stocks, in addition to finding other sources of food (such as wild fruits), they sell livestock to purchase more grain. Purchases are made first from other farmers, then from local shops where they exist, and lastly from traders. All areas reported the presence of traders that regularly visit to assess the current state of supply. Grain from traders is the most expensive option, no doubt partly due to transport costs.

Therefore, from the point of view of individual households, the longer they can store grain for in any year, the more valuable that store becomes to them. From the point of view of the entire village, it is better that at least one household has a surplus which can be sold to the others. Local AGRITEX officers indicated that grain surplus households often sell their grain at a higher price to neighbours than to outside traders. This was confirmed by a farmer near Lusulu who claimed to sell a 20 litre tin of maize to traders from Bulawayo for only between Z$10 and Z$13 depending on the time of year. In FGMs, it was suggested that for grain deficit households, the grain surplus households are the cheapest source of extra supplies. Therefore it appears to benefit the entire village if at least one member is able to store grain over most of the year.

For the grain surplus households, it is clearly profitable to store grain for longer when it might fetch a higher price. There are indications of some grain price speculation on the part of these households. At the time of the study, grain was in plentiful supply and grain surplus households were said to be holding on to their stocks in expectation of higher prices in the future.

More work needs to be done in this area, especially with respect to grain deficit households. What may be important to them is not the absolute rise in the price of grain in Zimbabwe dollars, but the relative (or real) price rise. For grain deficit households and food security, the two most important relative prices are between grain and goats or chickens, and between grain and local wage labour. Future work might reveal how these relative prices change, in addition to the shifts in absolute grain prices.[3]

Non-price benefits: the major non-price benefit is food security, i.e. the assurance of food supplies now and in the future. In fragile environments, households can never be certain of the next harvest, or of their ability to purchase food in the future. Storage allows more attention to be given to producing the next crop and more livestock to be retained between seasons

Another non-price benefit of grain stores is that some seem to be multipurpose. A walled store, made of wood and dagga or of brick and cement, often contains a small corridor that is used as storage space. Other structures are raised high off the ground, providing an area underneath which can be used for cooking or as a cool sheltered place during the summer.

Discounting

Discounting the stream of future benefits is a controversial practice, though it is beyond the scope of this paper to enter into the various arguments for and against. The approach used in Appendix 4 was to look at the storage construction decision by taking a representative harvest and comparing this with an annual cost figure. The alternative would be to compare the entire initial cost of construction with the stream of future discounted benefits; or for modified stores, to compare the extra cost of construction with the stream of future discounted additional benefits. Moreover, any future maintenance costs would also need to be discounted. Such an exercise would be highly complex. It would assume not only that farmers value the future less than the present (the principle behind discounting) but also that a figure or percentage can be assigned to this 'time preference' (the discount rate). In addition, an assumption about likely future benefits would be needed, which given the variability in harvests would require the assignment of probabilities to possible yields. Approximations for all of these values can be made through participatory research, but would require a considerable amount more time than was available for this survey.

Alternative Available Materials for Store/Crib Construction

Few alternative materials were found locally to improve the construction of grain stores in terms of their defence against infestation or, more particularly, their resistance to termite damage. Stone pillars are more effective than timber pillars, but only if care is taken to regularly check the stones for termite trails. Where these are found, they can simply be brushed away. This in itself would considerably reduce the need to replace timbers.

The absence of an immediately available alternative is partly shown by the fact that the stores themselves have often not been adapted to the shortage of timber. There was considerable evidence of adaptation in other areas on individual homesteads. For example as noted earlier, in the section on 'Timbers Used in Grain Store Construction' on one homestead in Mola A, a farmer showed three 'generations' of store, each one an improvement on the last in terms of its

---

[3] The values used in Appendix 4 have not been deflated. The use of appropriate price indices for deflating nominal values is an area of much debate. It is felt here that any general price index (such as the consumer price index) is not appropriate for areas where the range of relevant goods is relatively narrow, where a large part of production is for subsistence, and where barter exchange is common. A general price index, based on recorded prices collected nationally, is unlikely to reflect sufficiently movements in local absolute and relative prices.

timber usage (Plates xi and xii). The first was a very traditional woven-basket sheltered under thatch, with both store and shelter supported on thick poles. The second store type used more numerous but thinner poles to support the shelter, the argument being that these could individually be easily removed and replaced once damaged without the collapse of the entire structure. The third store type used no poles for roof support, but rested the roof on the store.

Thus some farmers do modify the designs of their stores. Nevertheless, they continue to use a considerable amount of mature hardwood timber, in particular to support the storage platform.

Chapter 5

THE MANAGEMENT OF GRAIN STORES

The effectiveness of grain stores in maintaining grain quality is an essential feature, which is determined not only by the quality of the structure design, but also by the management of the store. This section covers some of the management practices found, including estimates of existing storage losses, the use of grain protectants and the threat posed by the LGB.

Assessment of Storage Losses

This phase of the project sought to gain only an approximation of actual storage losses, largely on a subjective basis. Within the constraints of the time and facilities available, it was not possible to conduct controlled sampling to enable quantitative loss assessments. Since there was no record of the quality of grain entering the store at harvest, it would also not have been possible to carry out a volumetric assessment. In one or two cases a gravimetric (count and weigh) assessment might have been carried out, although it would have been of dubious value without more satisfactory sampling.

The survey also sought to gain estimates on losses from the perspective of the farmers themselves. More sophisticated loss estimates for Zimbabwean communal areas have been conducted by other researchers (Giga and Katerere, 1986; Giga *et al*, 1988), and loss rates of around 10% have been found. However, these studies also recognise that grain that has deteriorated may also be fed to domestic animals, such as chickens; and may therefore not be perceived of as a loss by farmers.

The estimates of grain losses gained through the FGMs mainly exceed the values calculated in the studies quoted above. Loss estimates were reasonably consistent and although a maximum level of around 40% was noted, the majority were in the range of between 15% and 20% of total stocks. However, it should be added that some groups of farmers found it difficult to estimate losses.[4] It is important that a more rigorous assessment of losses is undertaken to allow more detailed interpretation of these estimates. At first sight these estimates suggest, that contrary to other research findings (Giga and Katerere, 1986), farmers do recognise the considerable size of storage losses. Many of the loss estimates were given by men, despite the fact that in some areas the men stated that the women informed them when the grain stores were nearly exhausted. Since men are generally not involved in management after the grain has been loaded into the store, their estimates of losses may not be very reliable.

The ability to produce and store enough grain to last a whole year was variable. Some farmers produced a surplus, and in a few cases small grains had been stored for three years or more. For example, local cultivars of pearl millet, were reported to remain fit for human consumption after periods of more than five years. Some sorghum that had been stored for four years was encountered, but it was severely infested with insects resulting in almost 100% of grains showing damage.

---

[4] Losses were often expressed in numbers of bags (50kg or 90kg) per season.

Cases of such long storage were in the minority; most families exhausted their grain stocks after an average of between three and six months. Consequently in many cases the grain may not be stored for long enough to allow a serious level of insect infestation to develop.

In general, the principal causes of losses were identified as rats, termites and insects. It should be noted that the identification of rats was not always clear when talking to the farmers and could include mice. Identification of the insects similarly was not usually specific however there was reference to insects with beaks - evidently *Sitophilus* spp. *Rhizopertha dominica* was also observed. In one bin where grain had been held for four years, there was considerable evidence of webbing in the sample inspected and *Sitotroga cerealella* (Angoumois grain moth) was present. Insect attack was confirmed in a number of samples, particularly those retained for over a year, where many grains had insect holes.

In terms of crops stored, it was felt that maize was the most susceptible to storage insect pests, followed by sorghum and lastly pearl millet. Generally the modern cultivars of either crop were less resistant, with PNR473, out of all maize hybrids, identified as the most susceptible to infestation. Plate xx shows a hybrid maize cob with visible insect holes in a number of the grains whilst the cob reverting to the original stock shows very little infestation. Both cobs were from the same store.

Store Management

Store management is the responsibility of women, and often the participants in all male FGMs showed a distinct lack of enthusiasm when issues of store management were raised for discussion. In some settings, where the husband and wife (or wives, and possibly the husband's mother) each had separate stores, the women were also responsible for management of the husband's store. Despite this, there were individual cases, revealed in homestead visits, where the husband clearly took a more active role in store management. In these cases, the husband may determine the storage practices, including attention to hygiene, while the wife/wives would be expected to implement these instructions. Similarly, it is impossible to generalise about the application of grain protectants: this may be a task undertaken by men or by women.

In cases where there are multiple stores, which are each identified with particular members of the household, it is always the women's stores that are emptied first. Although this was not confirmed in the survey, it is possible that this affects the type of grain stored in different structures. For example, consistency with other findings would suggest that women's stores are more likely to hold maize, while there is a greater probability that the men's stores hold pearl millet or sorghum.

Many examples of poor store management practice were encountered. Several crop types might be stored in the same structure (Plate xxi); treated grain might also be stored in the same store; and old crops are sometimes stored together with the new crop. Where the structures had multiple compartments, these were not sealed, leading to a high chance of cross-infestation. In the woven-basket or pot-type structures, the timber support passing through the centre of the structure (also used as a step or platform when entering or exiting) was in fact a source of structural weakness. The support also provided easy access for pests, including rodents, into the structure (Plate xxii). The interior of most of the structures except the pot-type, were disorderly and hygiene was often poor. Many structures were also open at the top. In other instances, where stores were equipped with doors, they were often ill-fitting as can be seen in Plate xxiii and in addition, there was often a poor state of repair of both the outer structure - roof and supports - and of the containers themselves (Plates xxiv and xxv). Badly cracked clay covering on walls can harbour continuing infestation (Plate xxvi).

Use of Grain Protectants

Contrary to a past national survey which found that more than 75% of communal farmers used synthetic insecticides, and 7% traditional methods (Tshuma, 1989; Mvumi *et al.* 1995), in the Zambezi Valley, it appears that grain protection using synthetic insecticides is not very common. The main inhibiting factors are the general non-availability of chemicals in local retail outlets and the high cost of chemicals where sold. Mvumi *et al.* (1995), also found that 50% of the retail outlets in Matabeleland North did not stock insecticides. There appears to be a general reluctance among retailers to stock chemicals due to low demand. Among the small proportion of farmers who did apply synthetic treatments, the most popular substance was pirimiphos-methyl 2% dust (Shumba), followed by malathion 1% dust and methacrifos 2% dust (Damfin).

There was also a reluctance to use synthetic treatments among some farmers due to their low perceived effectiveness; however, both the FGM and homestead visits revealed a widespread misapplication of chemicals. For example, pirimiphos-methyl, the most commonly used insecticide, was being under-applied in more than half the cases. The dosages ranged from 1.8 ppm to 3.3 ppm instead of the recommended 4 ppm, another consequence of this misapplication, was that farmers often kept chemicals beyond their expiry date without realising the importance of this factor. In the remaining cases, farmers were over-applying by up to 2.5 times the recommended dose.

Zimbabwe Farmers Union (ZFU) is planning to open a warehouse at Mola Centre and orders for grain protectants have already been made to alleviate the supply problem. A chemical expiring within first half of 1997 was noticed on the shelves of one of the local shops. Such a chemical should not be used on a crop harvested in 1997.

Some of the chemicals are packaged with small cups to facilitate measurement of a known quantity of insecticide. However, the cups are rarely used to measure the correct quantities of chemical. Each chemical is supplied with a cup of specific capacity; yet sometimes these cups are interchanged between insecticides and between farmers. Similar cups, with a range of capacities are also used for fertiliser application by cotton farmers, increasing the likelihood of confusion due to different cups in areas where cotton is grown.

The most common application method involves sprinkling of the chemical between 'layers' of two-to-six 90kg bags as the grain is loaded into the store. Insecticide dust may also applied by either sprinkling on grain at the bottom and top of the store or dusting the walls. Despite not following the recommended application techniques (of admixing insecticides thoroughly with grain), farmers expressed satisfaction with the efficacy of pirimiphos-methyl 2% dust.

Some variation in insecticide use was observed by grain type. For example, synthetic insecticides are commonly applied to maize, but rarely to sorghum and never to pearl millet. A lower application rate is used with sorghum than maize, because sorghum is believed to be less susceptible to storage insect pests. If there is a positive correlation between the wealth of the farmer and the proportion of land allocated to maize (through the prospect of selling surplus maize to GMB or to dealers), this factor may also partly explain their greater use of synthetic insecticides. The fact that chemicals are usually applied only on maize stored for about a year; maize intended for shorter-term storage (i.e. 6 months or less) is not treated supports this theory.

In stores where grain was kept for periods in excess of one year, periodic removal of the grain, store cleaning and re-treatment with fresh natural insecticides or with commercial insecticides was not practised. Although the use of insecticide materials may be accepted and practised by farmers, there is considerable potential to improve the methods of usage.

Traditional grain protection is still being used in most areas of the Zambezi Valley, as in other parts of Matabeleland North (Mvumi *et al*., 1995) with application of a leaf referred to as 'sozwe' (*Maerua edulis*) being the most common method (see Appendix 2). The fresh leaves are often applied directly to the grain (Plate xxvii), or are pounded with a little water and then smeared on the inner walls of the storage structure prior to loading new grain. The fresh leaves may also be crushed, dried and then mixed with the grain in layers. Locally grown tobacco was also used for grain protection as a repellent. In addition, wood ash (from trees such as *Mopane* or 'mubimba' (*Combretum hereroense* or *C. imberbe*)), or maize cob ash is widely used for grain protection. *Mopane* ash is the most commonly used, followed by maize cob ash.

Younger farmers were found to have comparatively little knowledge about the identification of 'sozwe' and the methods of its application. Although they were aware of natural grain protectants, they had little confidence in their efficacy, which suggests that the use of natural grain protectants may be on the decline.

Some farmers who previously applied 'sozwe' have now abandoned this practise. The following explanations were among those given:

- the shrub is becoming scarce in some areas;
- large quantities must be applied before it becomes effective;
- if applied as a powder, the leaf residue left in the grain adds an unpleasant taste, therefore more winnowing than normal is needed prior to consumption.

Some cases of integrated control were also encountered with pirimiphos-methyl 2% dust being used simultaneously with either tobacco lumps or fresh 'sozwe'. In one instance the farmer only applied Pirimiphos-methyl 2% dust after observing that the 'sozwe' leaves, which had been sprinkled on top of the maize in the previous year, were not effective.

The Neem tree, *Azadirachta indica*, and the Syringa tree, *Melia azedarach*, were found in isolated cases at homesteads. The trees had been primarily planted for shade and their insecticidal properties against stored product insect pests were unknown to the farmers. Distribution of information on the potential use of these trees as grain protectants, may lead to more widespread planting of these species.

Plate xx. Hybrid maize (lower) showing infestation with maize reverting to original type (upper) showing minimal infestation; both cobs were from the same store (see page 34)

Plate xxi. Several crops - millet, sorghum and maize - of different ages in the same store (see page 34)

Plate xxii. Pole running through a store to form a step externally and internally; note the gap around the pole providing access for pests and vermin (see page 34)

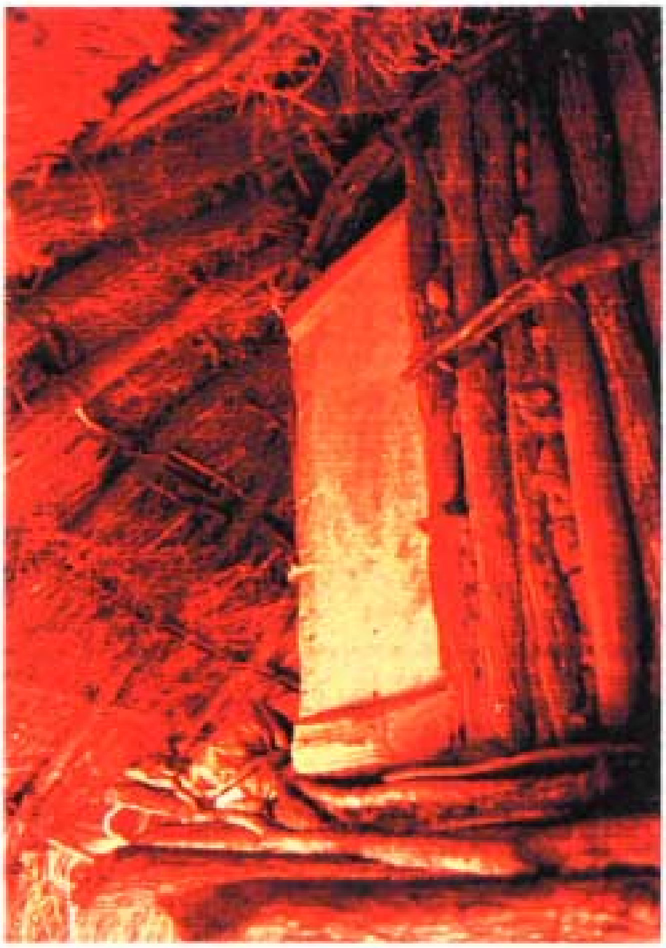


Plate xxiii. Ill fitting store door allowing access for infestation and vermin (see page 34)

Plate xxiv. Poorly maintained store; note the poor hygiene with bird droppings around the top of the left-hand container (see page 35)

Plate xxv. Poorly maintained store; note the failed external plastering (see page 35)

Plate xxvi. Cracked mud walls harbour infestation which is difficult to eradicate (see page 35)

Plate xxvii. 'Soswe' leaves on grain as a protectant (see page 36)

The Threat Posed by LGB

Current post-harvest practices will have a significant bearing on the spread of the LGB should it be introduced into Zimbabwe. The presence of the LGB in Zambia has been confirmed (Sumani and Ngolwe, 1996). There is a high risk of the pest accidentally crossing the border, as it can fly for relatively long distances, and the legal or illegal cross-border movement of grain presents a constant danger. Most residents of areas close to the Zambezi River have relatives staying across the border in Zambia and visits are frequent, especially during the off-season period. Shoppers/traders also travel between the two countries to supply the Zambezi fishermen with basic necessities. Therefore there is an ever present possibility that infested material may be unknowingly brought into the country, which would serve as the catalyst for its more general spread through Zimbabwe. Consequently, there is an urgent need to identify which storage practices or facilities favour the spread and proliferation of the LGB at farm level.

Both maize and cassava are attacked by the LGB. When it is considered that maize is the second or third most important crop in the Binga District and the first or second in the Kariba District, the potential harm that might be caused by the LGB is substantial. Cassava is not an important crop in the areas surveyed. The limited amount of cassava that is grown is often consumed fresh rather than as dried chips, while it is the latter that is attacked by the LGB.

The LGB is more damaging to maize cobs than to loose grain, a fact which should give some indication of its likely impact in these regions. In some areas, especially the cotton growing areas, up to 4 months may elapse before shelling, while the maize is left in the field or temporarily on a holding structure. (This is because maize and cotton compete for labour, and cotton being a cash crop, is often given first priority). The long period during which the corn remains on the cob following physiological maturity increases the risk of infestation by the LGB. Moreover, contamination often begins in the field.

In the survey area there were also pockets of farmers practising cob storage. This was more often the case where only small quantities of maize were harvested. The practice of cob storage can clearly promote infestation by LGB. However, in areas where maize is stored shelled, the remaining maize cores can harbour LGB, burning of the cobs, either for reasons of hygiene or production of ash for use as a grain protectant, can help to contain the spread of this pest.

Another reason why the Zambezi Valley region is conducive to spread of the LGB is that post-harvest grain structures (drying cribs and stores) are built primarily from timber. As well as infesting maize and cassava, the LGB is also known to occur in natural wooded habitats away from maize growing areas. Being a member of the family Bostrichidae, the pest has a wood-boring habit and traditionally affects trees and dressed timber. Minimisation of the use of timber during construction of farm structures may assist in containment of this pest. Effective pest control measures must prevent transfer of residual infestation harboured in the wood. It will be useful in future research to test different locally-available tree species for resistance to the pest.

Chapter 6

RECOMMENDATIONS FOR ON-FARM FIELD TRIALS

The next stage of this project is to conduct on-farm field trials of grain storage. This involves not only testing the durability of alternative store designs, but also looking at ways of improving store management and the use of grain protectants, and introducing practices that may better guard against infestation by the LGB.

The Store Structure

The major problems identified that need to be tackled are:

- excessive use of timber
- serious timber damage by termites; further increasing the timber demand
- pest control

There are a range of possible design improvements which can be applied, to allow modified stores to be adapted to accord more closely with the different traditional designs in each area. However, many of the suggestions can be applied to all the structures observed in most wards. The improvements can range from relatively simple alterations in the traditional structures, using the natural materials and traditional construction techniques, to modified structures using man-made materials.

There follow seven possibilities, the first two involving the most simple modifications in construction and maintenance, and the subsequent suggestions increasing in complexity. Most of them entail some cost, and future work should include an estimation of the cost implications of the different alternatives (see Appendix 4).

a) Many stores did not contain a ceiling, making the grain more susceptible to damage from insects and pests. One improvement is therefore to spread the practice of sealing stores, or sealing the compartments within stores.

b) The walls of stores are either plastered on the inside or the outside, or in some cases, not plastered at all. The unplastered type can only be used to store grain on the ear and will inevitably allow greater infestation and higher losses than plastered stores. Those with plaster only on the outside of the wicker or stick framework allow the harbouring of insects on the inside of the containers and are very difficult to clean effectively. Those plastered on the inside are more easily cleaned and, in areas where cow dung is available, it is sometimes the practice to re-skim the inside walls each year as part of store preparation. It is recommended therefore that all stores should be plastered on the inside surface at least. If plastered on the outside face as well, this will help to minimise the harbouring of insects and make entry for rodents more difficult, however plastering the inside surface and re-skimming annually will have the greatest effect.

c) None of the existing stores were fitted with rat guards. The use of rat guards on the uprights of the stores with timber posts will help to minimise losses due to rodents. The rat guard may be either a casing of truncated cone shaped around the posts, or simply a piece of tin or other metal wrapped round the posts. One problem, however, may be the availability of tin sheets; therefore it may be necessary to introduce this to local stores, extension workers or AGRITEX offices to make the material more readily available to farmers. If *Mopane* supports are to be used with a rat guard, all the termite susceptible sapwood must be removed before the rat guard is attached to sound heartwood.

d) Both stone bases and timber posts are used in the Zambezi Valley to support the platforms for the stores. Whilst the timber posts raise the platforms between 1 m and 1.5 m above the ground, the stone bases are only approximately 0.5 m high. Although they are not vulnerable to termite damage, they are nonetheless too short to stop rats, which can jump on to the platform. Burnt brick bases can be used as an alternative to stone bases. Burnt brick bases of at least a metre high will both protect the structure against termite damage and prevent rats from jumping onto the platform. However, rat guards as described in c) above may still be required to prevent the rats climbing the pillars.

e) Concrete posts would be another alternative to burnt brick pillars. Asbestos-cement pipes that could be used as a framework, were seen in the area. If the pipes were placed upright on a foundation and filled with concrete, they would form a post which would be termite-resistant (a clay filling is not) and may in addition be smooth enough to prevent rats from climbing, otherwise rat guards as in c) above could be used.

f) With the depletion of suitable sized timber for use as the main supports in the stores, a further step in the modification would be the replacement of the timber beams with reinforced concrete beams. Suitable beams have been seen used as seats at bus stops and would appear to have been originally intended for another purpose. Beams of this type would form both a rat- and termite-proof base on which to build the platform.

g) A further alteration, although likely to be prohibitive in cost, could consist of posts and base beams constructed as in e) above, with a storage bin made from ferro-cement - chicken wire plastered with cement mortar. Using a frame made of wood to support the chicken wire initially, the construction technique would be similar to those used to build the traditional stores. In practice, these stores would still need a thatched roof on the outside for weather protection and shade, but the main container could be easily cleaned, would be stable and less likely to crack, would protect against rodents, and could be constructed to be essentially airtight.

If any of the above possible store design improvements were considered for a trial, a minimum of three replicates would be needed in each case. Each improved store should be tested with a freshly built, unimproved store of the same basic design on the same site. If the farmer did not have sufficient grain for both stores, either grain should be purchased locally and mixed with the farmers own crop in both stores, or both stores should be filled with grain purchased from the GMB.

Trial Site Selection

There are a number of criteria affecting site selection.

a) Uncertainty over the land tenure situation; many of the farmers in the area are relative newcomers, having moved as a result of the construction of the Kariba Dam. A project in the area currently being undertaken, with the support of the European Union, is assessing current land use with a view to placing some farmers on more suitable land. It was mentioned in some FGMs, especially in the Kariba district, that the farmers were uncertain about their future on current land and the prospect for moving.

Wards where the farmers are likely to be moved would be clearly unsuitable for conducting storage field trials, as the trials themselves may be disrupted. It was not possible in the survey to ascertain from which Wards farmers are likely to be moved. The only certain message so far is that the Wards of Mola A and Mola B will not be affected.

b) The project should concentrate on the less affluent farmers in each area. A village may contain farmers with varying capabilities, with both basic pole-and-dagga and brick built structures co-existing in a relatively small area. Moreover, the emphasis of the project should be on food security rather than allowing greater commercial sale of grain. This probably rules out Lusulu, which straddles land falling into Natural Regions III and IV, and where cotton appears to be widely grown.

The main justification for using wealthier farmers for the trial would be so-called contact-farming, i.e. the belief that adoption of new techniques by certain farmers will be observed and imitated by others. The likely success of such an approach in the Zambezi Valley would need to be established first, before concentrating on these farmers.

An alternative would be to use the stores for village food security, possibly sited at the chief's or headman's home although this may require the purchase of grain and then putting the store under the management of someone other than the owner.

c) The types of structures used in those areas should be generally transferable to other areas. The types of structures observed were fairly location-specific, but there are nevertheless some broad categories of store that can include types from more than one Ward.

d) The areas chosen should have a local extension officer as actively supportive of the project procedures and objectives as possible. It would add unnecessary difficulties to a project if the extension officer either opposed the project or was apathetic about it.

e) The area should be exposed to some of the major and most common problems identified in the FGMs, in particular termites and rats.

On this basis, the following sites are recommended for field trials:

Mola A
Mola B
Mulindi
Negande B
Siansundu

Participation

The benefits of participatory methods of project appraisal and implementation are widely accepted, if difficult to quantify (see Magrath *et al*, 1997). The success of the next phase of this project will be considerably enhanced, by paying close attention to the involvement of local farmers. The field trials will include the construction of modified stores alongside traditional structures, and the monitoring of the conditions within each. This phase should include:

a) the active involvement where possible of local farmers in the construction of stores;

b) the input of farmers into store design, with modifications made where appropriate;

c) the active involvement of farmers in monitoring the progress of the project, including:
   - the selection of key performance criteria
   - inclusion in observing the results and/or implications of the fieldwork
   - involvement in developing simple methods of ranking the level of grain damage
   - consultation in developing conclusions from the fieldwork;

d) the input of farmers into the viability of different modifications and/or into other possible alterations to the basic design;

e) the provision of advice to farmers where appropriate in improved store management techniques.

It is also essential that the rights and responsibilities of men, women and children are considered at all stages. While this study has broadly referred to 'the farmer' it has also recognised at various points the difference in responsibilities between men and women. For example, store management, as elsewhere in tropical areas (Compton *et al*, 1993), is the responsibility of women (although men may adopt a more or less active role in monitoring management performance). Advice on store management must therefore recognise this feature, and target the advice appropriately. It is not necessarily the case that groups of women should be gathered and store management issues discussed directly and exclusively with them. The field trial manager will need to assess the appropriate strategy to relay information to the appropriate people in each area.

In addition to gender-sensitivity in implementation of the field trials, the assessment of the results will also require a gender analysis. Any modifications in store design and/or management are likely to affect men and women disproportionately. It is important that such considerations are taken on board in evaluating the performance of the trials. A similar argument can also be made for judging the potential impact of modifications on children.

LGB Containment

There are a number of further studies that should be undertaken in the future, both to prevent the introduction of LGB and to contain it should it appear.

a) A survey should be conducted to determine cross border grain movement by, both traders and fishermen (at their fishing camps) in Zimbabwe and Zambia.

b) A grain loss assessment should be undertaken to establish the impact of LGB should it appear in the country.

c) A study to test the survival and breeding success of LGB on hardwoods commonly used for construction of post-harvest structures (to be carried out in an LGB infested country)

Grain Protection

The following are some recommendations for future research into the efficacy and use of grain protectants.

a) A baseline survey should be conducted to identify the spectrum of stored product arthropoda in the Zambezi Valley.

b) The use of natural protectants in the Zambezi Valley is widespread but their efficacy and safety are unknown. Therefore there is need to:

- screen the natural substances in laboratory bioassays
- test promising candidates on-farm and determine the effective application rates
- determine effect of smoke on chemically treated and untreated grain

c) Most of the farmers do not treat their grain with any protectant. There is need to assess loss on untreated maize, sorghum and pearl millet due to insect pests using the traditional storage structures.

d) Conduct adaptive research on neem and syringa trees as grain protectants and determine the feasibility of producing the trees on a sustainable basis.

Other Research Areas

Two other areas of post-harvest practice would benefit considerably from future research. First, there needs to be a comparison of the effect of management practices on grain damage. To what extent would greater concentration on grain store management reduce loss rates? Secondly, it would be very useful to determine the susceptibility of the different hardwoods commonly used for construction of grain post-harvest structures, to termites. The use of those least susceptible to termite damage could then be encouraged, and the use of hardwoods in general consequently reduced.

REFERENCES

Chirove (1997) pers. com. Acting Agricultural Extension Supervisor, Siabuwa.

Compton, J.A.F., Tyler, P.S., Hindmarsh, P.S., Golob, P., Boxall, R.A., and Haines, C.P. (1993). *Reducing Losses in Small Farm Grain Storage in the Tropics*. Tropical Science, 33: 283-318.

Compton, J. (1997). *Managing Applied Research: Experiences from a Post-Harvest Pest Control Project in Ghana*, AGREN Network Paper No. 74a. ODI: London, U.K.

Eicher C.K. and Rukuni M. (1994). *Zimbabwe's Agricultural Revolution*. University of Zimbabwe Publications: Harare, Zimbabwe.

Giga, D.P. and Katerere, Y. (1986). *Rural Grain Storage in Zimbabwe: Problems, Loss Assessment and Prevention*. African Environment, ENDA, Harare, Zimbabwe.

Giga, D.P., Tembo, E., Nehumai, I., and Matarirano, L. (1988). *Grain Storage in Communal Areas of Zimbabwe: Results from a Survey*. The Zimbabwe Science News. 22, 3/4: 40-44.

Goldsmith, B. and Carter, D.T. (1981). The indigenous timbers of Zimbabwe. *The Zimbabwe Bulletin of Forest Research* No. 9. 406 pp.

Little, I. and Mirrlees, J. (1974). Project Appraisal and Planning for Developing Countries, New York: Basic Books.

Magrath, P., Compton, J., Ofosu, A. and Motte, F. (1997). *Cost-Benefit Analysis of Client Participation in Agricultural Research: A Case Study from Ghana*. AGREN Network Paper No. 74b. ODI: London, U.K.

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 Applired Science in Southern Africa 1(2): 115-130

Reynolds, P. and Crawford Cousins, C. (1993). *Lwaano Lwanyika* – Tonga Book of the Earth, London: Panos Publications.

Sumani, A.J and Ngolwe, A.R.K. (1996). The status of the Larger Grain Borer in Zambia. In: Farrell, G., Greathead, A.H., Hill, M.G., and Kibata, G.N. (Editors) *Management of farm storage pests in East and Central Africa*. Proceedings of the East and Central African Storage Pest Management Workshop. 14 - 19 April 1996 Naivasha, Kenya, IIBC, UK 255 pp

Thomas, P.J. (1970). A Chitonga - Botanical dictionary of some species occurring in the vicinity of the Mwenda estuary, Lake Kariba, Rhodesia. *Kirkia* 7(2): 269-284.

Timberlake, J.R., Nobanda, N and Mapaure, I. (1993). Vegetation survey of the communal lands - Northern and Western Zimbabwe. *Kirkia* 14(2): 171-270.

Tshuma, J. (1989). *A National Survey of Grain Storage Practices in Zimbabwe*. PPRI, Harare. DR&SS/Agritex: Harare, Zimbabwe.

Tyler, P. and Harding, S. (undated). *A Guide to Appropriate Technologies for Small-Scale Storage of Grain in Sub-Saharan Africa*. NRI: Chatham Maritime, U.K.

Wild, H. (1972). *A Rhodesian botanical dictionary of African and English plant names*. 2nd edition. Government Printer, Salisbury. 281 pp.

Appendix 1: BACKGROUND INFORMATION

Site	Altitude	Vegetation type (Timberlake *et al.*, 1993)
Binga District		
Siabuwa (Malube)	660 m	*Colophospermum* woodland (single dominance)
Sinampande	620 m	*Colophospermum* woodland (single dominance)
Mulindi	850 m	*Guibourtia conjugata* - *Colophospermum* woodland catena
Lusulu (Chilibi)	970 m	*Julbernardia* - *Colophospermum* woodland catena
Siansundu	580 m	*Guibourtia conjugata* woodland thicket
Manjolo	600 m	*Guibourtia conjugata* woodland thicket
Kariba District		
Mola A (Chief Mola) Mola B (Marembera)	550 m	*Colophospermum* and *Diospyros kirkii* open woodland mosic with areas of *Colophospermum* woodland (single dominance) and *Julbernardia* - *Colophospermum* woodland catena
Negande B	580 m	*Colophospermum* and *Diospyros kirkii* open woodland mosic with areas of *Colophospermum* woodland (single dominance)
Nebiri A	580 m	*Colophospermum* woodland (single dominance)
Nebiri B (Kasisva)	710 m	*Julbernardia* - *Colophospermum* woodland catena
Msampakaruma	700 m	*Julbernardia* - *Colophospermum* woodland catena

It is unwise to generalise about practices in any of the communal areas of Zimbabwe. However, there are some common factors between areas that might be highlighted, although there is also considerable diversity in the ranking of different activities. Factors such as rainfall, land quality, and proximity to major urban centres, and the extent of the termite problem would appear to be very important. Even within particular areas, there are wide differences in conditions facing households with different incomes.

The main food crops grown in the areas surveyed are maize, millet and sorghum, while there is some planting of cotton and, to a lesser extent, groundnuts. The type of crop planted depends, *inter alia*, on the quality of farming land, rainfall patterns and the seeds available[5]. There may be a number of other sources of income for food. Livestock is clearly very important: the sale of goats and chickens was frequently mentioned as a means of supplementing inadequate food reserves particularly amongst poorer households where the main source of food is often not own food production, but rather food purchase, wild foods and gifts or relief. It is also possible that the poorer households produce more millet and sorghum, for reasons of both taste and their perceived superior storage properties. Among richer households, cattle, sheep and guinea fowl may also feature in their assets. Local employment such as working on the field of a wealthier farmer in exchange for grain, was mentioned as a source of supplementary income. In some areas it is common for the male household head to fish in Lake Kariba. Gifts and relief may be

[5] It was found, for example, that some farmers had switched to planting hybrid maize after these were supplied in emergency seed packs during the recent drought.

provided, usually from outside the area rather than from wealthier neighbours. Employment in urban centres, such as Binga or Victoria Falls, as a source of remittance income is rare.

Non-food income frequently appears to be generated from beer brewing. Sometimes local crafts may also be important, and in one case the sale of grass and thatch to tourist lodges was found to be an additional source of extra income.

Poor households do not generate sufficient income to save in any form, and also hold no assets. Some richer households may save in cattle or possibly in Post Office savings accounts, while they also own some tools and have access to animal or mechanical traction.

The assistance of the following AGRITEX staff is gratefully acknowledged.

Mr. Tokotore (District Agricultural Extension Officer, Binga District)

Mr. Gomo (Senior Agricultural Extension Officer, Binga District)

Mr. Tshuma (Agricultural Extension Officer, Binga District)

Mr. Chirove (Acting Agricultural Extension Supervisor, Siabuwa)

Mr. Mapuranga (Agricultural Extension Worker, Siabuwa)

Mr. Ncube (Agricultural Extension Worker, Binga District)

Mr. Moyo (Agricultural Extension Worker, Dobola)

Mr. Mlilo (Agricultural Extension Worker, Siansundu)

Mrs Nkala (Agricultural Extension Worker, Manjolo)

Mr. Sithole (Agricultural Extension Supervisor, Kariba District, Omay)

Mr. Anderson (Agricultural Extension Officer, Kariba District)

Mr. Nekati (Agricultural Extension Specialist, Mashonaland West Province)

Mr. Mhuri (Agricultural Extension Worker, Kariba District, Omay)

Mr. Ngoshe (Agricultural Extension Worker, Mola)

Mr. Jazire (Agricultural Extension Worker, Mola)

Appendix 2: PROTECTANT SUBSTANCES AND METHODS, IN ORDER OF PREFERRED USE

Substance/Method	Botanic Name	Remarks
A. Substance		
1. Soswe	*Maerua edulis*	Used as fresh leaves or as paste mixed with water and smeared on the structure walls or as a powder; short term efficacy (2 weeks) against storage insect pests, unsatisfactory effectiveness.
2. Ashes - *mopane*, muvimba, *mopane* fruits, maize cobs	*Colophospermum mopane*, *Combretum hereroense* or *C. imberbe*, *Zea mays*	When properly applied, effectiveness can last a year or more if the structure is not frequently opened and if the grain is fully mature at harvesting.
3. Tobacco	*Nicotiana* spp.	Used as a powder or a lump put on top of grain.
4. Millet chaff	N/A	Considered very effective for the whole year if applied every year
5. Animal droppings/urine	N/A	-cow dung plastered on the inside walls of the structure, seals insects into crevices. -droppings/urine to repel insects, rodents & termites
6. Mugake, Siila	*Cucumis metuliferus*	crushed, pulp mixed with water and smeared on inside walls of structure
7. Muntiri	*Boscia salicifolia*	
B: Methods		
1. Smoking	N/A	grain for consumption stored in elevated timber structures above fire place; grain for seed stored on heads in kitchen huts
2. Unwinnowed maize	N/A	no other protectant applied
3. Physical	N/A	withdraw all grain and winnow then reload into store

Note: "N/A" = not applicable; "-" = unknown

Appendix 3: TIMBERS USED IN GRAIN STORE CONSTRUCTION

The areas visited varied in both altitude and vegetation type resulting in different species being available for the construction of storage structures in different areas.

A total of 32 tree species are used in the construction of stores, of which 27 were identified to species, either by the identification of botanical specimens or by consulting the literature for the local names given. There is a recent publication listing the Tonga names for plant species (Reynolds and Crawford Cousins, 1993), others in existence (Thomas, 1970; Wild, 1972; Goldsmith and Carter, 1981) are by no means complete. The situation has been further complicated by the influx of Shona and Ndebele speakers into the area, resulting in many different names for the same species. A further complication was that no members of the team were native Tonga speakers resulting in problems with the spelling and transliteration of names.

In the lists below, the species have been recorded in order of general preference, but due to differences in vegetation type between the different areas visited several species are not available in certain areas. For example *Julbernardia globiflora*, *Brachystegia boehmii* and *Burkea africana* are not commonly found north of the Zambezi escarpment.

Species named as being used for main posts

Storage structures were either supported on timber posts or on stones. Stone supports are preferred if suitable stones are locally available or transport can be used, as they give some protection against termite attack.

A major requirement for the timber main supports is that they be cut from a tree which is forked at a suitable height above the ground, so that the main cross members rest on the top of the posts. Such trees may be hard to find, requiring more time for timber collection, and there may be considerable wastage when the tree is cut, with unneeded parts of the tree left on site rather than being used, especially if the felling site is a considerable distance from the construction site.

Strength and resistance to termite attack are the main considerations in species choice.

The above ground portion of the main supports varies from about 0.5 m to about 1.5 m in length, and the basal diameter from 10 cm to 25 cm.

Species

- *Colophospermum mopane* was used in all areas visited and was the preferred species in most. It is important that the pole used has a high proportion of heartwood, as this is virtually immune to termite attack and no heart-rot, as this is as liable to termite attack as the sapwood.
- *Afzelia quanzensis* was also commonly used and was reported to be the preferred species by headmen in Mulindi.

- *Pericopsis angolensis*
- *Pterocarpus antunesii*
- *Erythroxylon zambesiacum*
- *Combretum* sp. probably *apiculatum* It is not clear whether these refer to a single species or several *Combretum* spp.
- *Dichrostachys cinerea*
- *Burkea africana*
- *Diospyros mespiliformis*
- *Monotes engleri*

Species named as being used for main cross members

The main supports vary from about 1.5 m to about 2.5 m in length, and their basal diameter from 5 cm to 20 cm, depending on the size of the store. Strength and straightness are the major considerations in species choice.

Species

- *Colophospermum mopane*
- *Afzelia quanzensis*
- *Pericopsis angolensis*
- *Pterocarpus antunesii*
- *Erythroxylon zambesiacum*
- *Combretum* sp. probably *apiculatum*
- *Terminalia sericea* - crib main beams
- *Julbernardia globiflora*
- *Burkea africana*
- *Pterocarpus angolensis* - as main crib cross members
- *Diospyros mespiliformis*
- *Monotes engleri*
- *Dichrostachys cinerea*

Species named as being used for platform

The platform timbers vary from about 1.5 m to about 2.5 m in length, and their basal diameter from 3 cm to 10 cm, depending on the size of the store. Strength and straightness are the major considerations in species choice.

Species

- *Diospyros quiloensis*
- *Colophospermum mopane*
- *Julbernardia globiflora*
- *Maytenus senegalensis*
- *'Mutidoro'* see Note 1 below.

Species named as being used for rails and basket-work

Flexibility when green is the most important consideration in species choice. Many of the species listed are scramblers that have long flexible branches, with little taper, which are easily woven.

Species

- *Friesodielsia obovata*
- *Combretum elaeaginoides*
- *Combretum* sp. probably *apiculatum*
- *Dalbergia martinii*
- *Crossopteryx febrifuga*
- *Dichrostachys cinerea*
- *Gardenia ternifolia*
- *Bauhinia petersiana*
- 'Musakamwenje' see Note 1 below.

Species named as being used for walls and basket uprights

The platform timbers vary from about 1.5 m to about 2.5 m in length, and their basal diameter from 3 cm to 10 cm, depending on the size of the store. Strength and straightness are the major considerations in species choice.

Species

- *Colophospermum mopane*
- *Diospyros quiloensis*
- *Combretum elaeaginoides*
- *Julbernardia globiflora*

Species named as being used for roof and crib supports

The platform timbers vary from about 1.5 m to about 3 m in length, and their basal diameter from 10 cm to 20 cm. Strength and straightness are again the major considerations in species choice. One farmer in Mola A has built three stores: the first with heavy roof supports, the second with smaller diameter timbers (+/- 10 cm basal diameter) which could easily be replaced by lifting the roof by hand. If the poles were not straight, they were notched at kinks to straighten them. In the third structure the roof rested on the top of the storage bin, with no supporting poles.

Species

- *Colophospermum mopane*
- *Diospyros quiloensis*
- *Strychnos madagascariensis*
- *Diospyros mespiliformis*
- *Terminalia sericea* - crib
- *Combretum elaeaginoides* - crib

Species named as being used for roofing poles

Roofing timbers vary from about 1.5 m to about 2.5 m in length, and their basal diameter from 5 cm to 10 cm. Straightness and length are the major considerations in species choice. *D. quiloensis* is the species of choice in most areas, as coppice shoots are long and straight.

Species

- *Diospyros quiloensis*
- *Colophospermum mopane*
- *Diospyros mespiliformis*
- 'Mufumbu' possibly *Canthium huillense* - see Note 1 below.

Species named as being used tying timbers together or tying thatch to roofing poles

- *Colophospermum mopane* (bark)
- *Hyphaene benguellensis* (leaves)
- *Julbernardia globiflora* (bark)
- *Adansonia digitata* (bark)
- *Brachystegia boehmii* (bark)
- *Acacia nigrescens* (bark)
- *B. boehmii* was considered to produce the best rope in areas where it is available, otherwise
- *C. mopane* bark and *H. benguellensis* leaves were preferred, the former being used to tie timbers together and the latter to tie thatch to the roofing poles.
- *nigrescens* is the only species used in the construction of storage structures which is armed with thorns.

Species named as being used for doors

- *Diospyros mespiliformis*
- *Oxytenanthera abyssinica*

Note 1

Three species could not be identified:

- 'Musakamwenje' used for rails in Mola B.
- 'Mufumbu' used for roofing poles in Mulindi - possibly 'Mufumbu' = *Canthium huillense* Hiern.
- 'Mutidoro' used for the floors of structures in Nebiri A

Appendix 4: THE MARGINAL COST OF GRAIN STORE CONSTRUCTION

Traditional Stores

The decision to construct a grain store is separate from that of storing grain. Grain is stored in order to spread consumption, just as in urban areas money might be saved in bank accounts.[6] The primary consideration is therefore how to store the grain. In the following simplified example, based on actual figures given in FGMs, the additional costs involved in building a store, as opposed to piling grain on the floor in the house, are given. It is assumed that stores are constructed chiefly for the purpose of reducing grain losses, therefore a lower loss rate is the only additional benefit. Other benefits are also relevant, such as higher food security, additional time spent on own fields rather than hiring out labour, improved quality of stored grain, or the use of stores to shelter kitchens or to store agricultural equipment. These benefits are difficult to estimate; to the extent that they are positive, they reduce the necessary improvement in losses.[7] An internal rate of return approach is used (see Little and Mirrlees, 1974), where the rate of return equating additional benefits with costs is measured as the reduction in grain losses, valued at the price of grain quoted for the end of the calendar year, when it is most scarce. This is referred to here as the *required* internal rate of return (RIRR), or the minimum percentage fall in losses necessary to make store construction worthwhile. It differs from the internal rate or return concept in the sense that it is not a comparison with another return on the capital investment. The opportunity cost of capital is mainly time (see main text): estimating the value of time would be problematic; moreover, the value of men's time is probably considerably less than that of women's, and men's time is the main capital input.

In the table below, the figures for construction costs represent a range of values quoted in FGMs. The approach used was to ask farmers what they would charge to build a store.[8] This is assumed therefore to include the opportunity cost of farmers' time (see main text for considerations relevant to the opportunity cost of time). All stores are assumed to last 10 years. This is very much an estimate; some stores last less than this time, and some (with appropriate maintenance) last considerably longer. To the extent that the actual storage duration is longer, the costs per year over the lifetime of the store are reduced. It is also assumed that grain is only treated when it is stored. Using this assumption allows grain treatment to be viewed explicitly, while removing it would not significantly affect the overall results. For small stores, the table assumes that only traditional methods are used, examples of which are given in the main text. Traditional methods are assumed to take half a day of labour, with a full day of labour valued at a tin of maize, or Z$45 when most stores have been exhausted, which is a rate commonly quoted for weeding. For large stores, holding maize surplus to household annual requirements, it is assumed that commercial protectant is used, namely 'shumba' (pirimiphos-methyl 2%). For five metric tonnes of grain, 55.5 measures of 'shumba' would be the recommended

---

[6] An analogy with keeping money under a mattress might be considered more appropriate. However, effectively stored grain will increase in monetary value during the year, and perhaps between years, hence the comparison with interest-bearing bank accounts.

[7] To the extent that they exceed the annual costs of building a store, then store construction is justifiable regardless of the reduction in grain losses.

[8] We are grateful to Paul Nekati for pointing out this approach.

dosage, each measure weighing 18g. Total treatment would therefore require 1kg of 'shumba'. In one store in Mola, 500g of 'shumba' was seen on sale for Z$54. Annual maintenance costs are taken as 5% of the annual construction cost, or 25% of the construction cost every five years for both stores.

The net result of this exercise is to show the relatively low cost of using grain stores relative to storing in the home, and the associated low rate of return in terms of reduced grain losses required for the store construction to be worthwhile. It is lower for the large store due to economies of scale in construction: a store with ten times more capacity in this example costs only three times as much. The RIRR is sensitive, however, to the value of grain assumed. For example, if the grain were valued at Z$30, the required reduction in losses for a small store would rise to 6%, and for a large store to 1.8%.

Costs (z$)	Small store[a]	Large store[b]
Construction Cost	250	500
Duration (in years)	10	10
Capital cost per year	25	50
Annual grain treatment	22.5	108
Annual maintenance	12.5	25
Total annual costs	60	183
Required Internal Rate of Return	4.0%	1.2%

Notes
[a] Used for harvests of around 0.5 metric tonnes.
[b] Used for harvests of around 5 metric tonnes.

It should also be noted that this approach adds some support to the oft-stated view that it was not worthwhile building a store for, say, two 90kg bags of grain. If Z$250 is considered the minimum construction cost of a basic store, then storing 180kgs of grain in a new structure would imply a RIRR of 11.1%, i.e. considerably higher than for a larger harvest. While these figures should not be considered very accurate, there is evidence to support the assumption that farmers carry out similar calculations to these.

Modified Stores

A similar exercise may be carried out for modified stores, where the comparison of costs and benefits would need to be made with traditional stores. The possible permutations are too numerous to tabulate at this stage. Nonetheless, this structure allows some of the main cost-benefit issues of modification to be flagged.

All of the recommended store improvements require some additional capital and/or labour cost to be incurred. These need to be clearly outweighed by improvements in at least the following areas: the durability of the store; maintenance costs; and loss rates. It is beyond the scope of this survey to estimate how the recommended modifications will affect each of these aspects of grain storage. However, a qualitative appraisal would suggest that modifications should improve durability (for example through reducing or eliminating termite damage) and reduce loss rates (through greater pest-resistance and improved management). While having an ambiguous effect on maintenance costs (reducing costs to the extent that termite damage is successfully tackled, increasing costs through recommended management improvements

Natural Resources Institute

Natural Resources Institute
Central Avenue
Chatham Maritime
Kent ME4 4TB
UK

Tel: + 44 (0) 1634 883797
Fax: + 44 (0) 1634 883567
Internet: http://www.nri.org
E-mail: J.R.Brice@gre.ac.uk