Participatory evaluation report. Improved design of indigenous grain stores (NRI report no. 2447)

NATURAL RESOURCES INSTITUTE

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Participatory Evaluation Report

Project R6685 (A0566)

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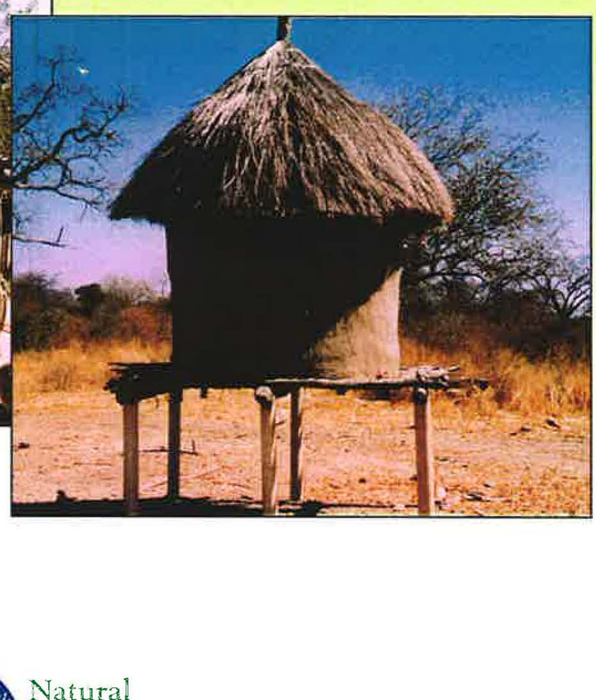

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Improved Design of Indigenous Grain Stores

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Natural Resources Institute

EXECUTIVE SUMMARY

The availability of suitable hardwoods for the construction of grain stores (and other traditional structures) is reasonable-to-low in the areas surveyed. Farmers appear to be having to travel further to source these materials and so the situation seems to be getting worse. Availability of hardwoods is indirectly proportional to the population and directly proportional to the area of woodland available. The suitability of the technology will therefore vary greatly from area to area - in the study area, hardwood species are more abundant than in other areas of Zimbabwe, where hardwood resources are already seriously depleted. The substitution technology developed through this project may therefore be a more effective strategy for hardwood conservation elsewhere in Zimbabwe.

The rate of traditional store replacement is one of the key factors in determining the appropriateness of the proposed technology. Mean rate of replacement was found to be at or below 10 years - the actual figure is invariably inversely proportional to the termite activity in the vicinity of the store.

The cost of replacement is the other key factor which determines whether the technology will be adopted. In the absence of significant cost reductions and/or credit arrangement, the technology would be most relevant to those households who are not cash constrained and who would normally expect to harvest enough grain to last well into the rainy season. Given the unpredictability of conditions placed on credit arrangements (should a farmer wish to borrow money to construct a modified store) it is difficult to predict its viability for cash-constrained farmers where credit is the only option. However, if the generally accepted view of farmers in that mopane is becoming more scarce is true, replacement costs for the traditional store may increase in the future, possibly reducing the price differential between the traditional and the modified stores.

Since mopane responds well to coppicing, improved management of woodland resources must be considered alongside the reduction of timber harvesting achieved through the introduction of this alternative technology.

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1. INTRODUCTION

1.1 Background

As part of the Department for International Development (DfID) Crop Post-Harvest Programme (CPHP) in Zimbabwe, a survey was conducted in 1996 to assess the grain storage practices and the general crop post-harvest situation in the Zambezi valley, including the use of hardwood in the construction of grain storage structures. The districts covered were Binga and Kariba. (Douglas *et al.* 1997)

In agro-ecological terms, Zimbabwe is divided into Natural Regions (NR) I-V, determined primarily by rainfall (Eicher and Rukuni, 1994), with the best and worst conditions found in NR I and V respectively. Binga and Kariba Districts fall mainly under NR V, with pockets of NR III and IV. The farmers in the Zambezi valley grow mainly drought-tolerant small grains such as pearl millet and sorghum. Maize is grown to a lesser extent, mostly in those areas with slightly higher rainfall (i.e. NR III and IV).

The main post-harvest problems identified in the 1996 survey were rodents, termites and storage insects, leading to grain losses:

> **Rodent** types, whether mice or rats, are unclear, however, significant rodent activity (and presumably losses) are reported in many villages.
>
> **Termites** were reported to cause grain losses directly or indirectly. The termites may find their way into the storage bin via the storage structure supporting posts, and attack the grain inside the store. Alternatively, the termites damage the supporting posts to the storage structure, rendering it structurally unstable. The instability creates cracks on the wall of the storage structure where insect pests or the eggs remain between storage seasons, thus becoming a source of residual insect infestation for the following season's stored grain. Termite damage to the storage structure also leads to excessive use of hardwoods as the store needs to be rebuilt more frequently.
>
> **Insect pests** infest stored grain: losses of up to 10% over one storage season in maize have been reported by Giga *et al.* (1991), elsewhere in Zimbabwe. No work has been done in Zimbabwe to establish the extent of millet and sorghum losses during storage. In Malawi sorghum losses of up to 3.4% have been recorded (Golob, 1981). The past decade has seen an introduction of new high-yielding sorghum varieties. Most of these were reported by the farmers to be highly susceptible to insect damage (Douglas *et al.* 1997). No technology to cope with the high losses associated with these varieties was introduced at the time.

In view of the information mentioned above, it was considered important that losses in small grains be reduced to promote household food security. To achieve a loss reduction it was considered essential that the extent of sorghum losses be understood. On-farm trials were therefore launched in Binga district to establish the grain losses suffered by smallholder farmers. Losses on threshed grain were compared to unthreshed grain. SV2, an improved open-pollinated sorghum variety, was selected for use in the trial. The traditional design of store was compared to a modified design (for both threshed and unthreshed sorghum grain), where the timber uprights were replaced with a plastic pipe filled with concrete. The purpose of these modifications were to reduce the excessive use of hardwood resources (reportedly depleted in other parts of Zimbabwe, Giga and Katerere, 1986, Tshuma 1989), and to reduce grain losses through the provision of a pest barrier. Results from the loss trial after the first storage season show a difference in grain losses between threshed and unthreshed sorghum: higher grain losses were observed in unthreshed grain and traditional stores. The trial showed minimum differences between traditional and modified stores.

Alongside this trial, a termite trial was conducted to establish the rate at which mopane (*Colophospermum mopane*), eucalyptus (*Eucalyptus spp.*) and PVC pipe filled with concrete are damaged by termites. Eucalyptus has shown significantly more termite damage, followed by mopane. There is no damage or signs of termites making tunnels on the PVC pipe filled with concrete.

1.2 Objectives

The main objectives of this participatory evaluation were as follows:

- to assess the financial, economic, social and environmental impacts of modified stores in the storage trial in Binga District;
- to examine farmer's perceptions of the effectiveness, affordability and acceptability of the modifications;
- to identify socio-economic constraints of store construction and management for both traditional and modified stores;
- to advise on future modifications to stores that are affordable and acceptable to farmers in Binga District.

The report is structured as follows:

Section 2: financial and economic analysis of modifications to reduce excessive use of hardwoods, from the farmer's perspective, including farmers' perceptions of the effectiveness, affordability and acceptability of the modifications;

Section 3: social analysis and identification of socio-economic constraints;

Section 4: discussion of the environmental issues, focusing on *Colophospermum mopane*;

Section 5: conclusions and an outline of possible future modifications.

1.3 Methodology

Data collection was based on a combination of the following:

- semi-structured interviews with trial farmers (both men and women);
- group discussions based on causal diagrams of post-harvest constraints (one dominated by men, the other by women);
- key informant interviews.

Analytical methodologies are described below.

2. FINANCIAL AND ECONOMIC ANALYSIS

2.1 Trial sites

Binga District falls mainly into the two poorest agro-ecological classifications in Zimbabwe: NR IV (suitable for semi-extensive farming) and NR V (suitable for extensive farming). Rainfall varies across the District, but mean annual rainfall generally falls between 450 mm and 800 mm. Rainfall is highly variable. (Majid, 1996)

Binga District is a food deficit area. Most households do not meet their annual food needs through their own crop production. The main crops cultivated are pearl millet (because of its drought tolerance), maize (on better, loamy soils), and sorghum (on certain soil types) (especially for brewing). Livestock ownership is particularly important as a buffer against food insecurity. Cattle are more important as a direct source of income for wealthier households, goats and chickens are relatively more important for poorer households. Other important components of food security strategies include wild foods, cash crops, beer-brewing, craft sales, thatch and firewood sales, and fishing. (Majid, 1996; Tokotore, pers. com.)

In general, the poorer agro-ecological areas of the District are populated by Tonga people resettled from the Zambezi river valley to the escarpment in 1958 on completion of the Kariba Dam. Historically, the Tonga people's livelihood systems have been based on fishing, hunting and riverine gardening, rather than the cultivation of field crops. The populations of the richer agro-ecological areas, on the other hand, have in general not been resettled and have a longer history of field-based agriculture. (Majid, 1996)

Within Binga District, the twelve trial sites for the modified stores are distributed across three main sites to ensure the representativeness of a range of conditions. Table 2.1 presents a brief summary of prevailing socio-economic and agro-ecological conditions in each of the three sites, with specific reference to grain storage.

Table 2.1: Summary of sites

Site	Agro-ecological	Socio-economic	Crop storage (from harvest)
Manjolo	poorest area; very limited crop production	Crop earnings very low; diverse range of alternative income-generating activities	low: ~ 3 mths; med: ~ 4-5 mths; high: ~ 8 mths.
Kariangwe	less poor; slightly higher crop production; irrigation scheme	Crop earnings low; higher livestock ownership; alternative income-generation also important	low: ~ 5-6 mths; med: ~6-7 mths; high: ~ 7-9 mths.
Siabuwa	similar to Kariangwe, but with a relatively fertile pocket; better production, including cotton and maize	Similar to Kariangwe, except for fertile pocket where crop sales important income source	low: ~ 5-6 mths; med: ~6-7 mths; high: ~ 7-9 mths.

Sources: Majid, 1996; Khupe, pers. com.

2.2 Store design

The most common type of store in the trial consisted of a basket-style storage bin, with a separate roof structure. The other main structure was a cylindrical storage bin directly supporting the roof. While the separate roof structure is more common in Binga District, the joint roof structure is more common in the Kariba District, and elsewhere in Zimbabwe.

All stores were raised off the ground - supports in the traditional stores being either of mopane or stone. Several homesteads used different materials on different stores.

Table 2.2: Storage structure by trial site

Site	Siabuwa				Kariangwe				Manjolo			
Store	1	2	3	4	5	6	7	8	9	10	11	12
Separate roof					x	x	x	x	x	x	x	x
Mopane	x	x	x	x		x	x	x				

2.3 Store construction: base structure

2.3.1 Mopane supports

Mopane suitable for constructing the main posts was available at a mean distance of 3.5 km (n = 7, range 0.5 to 5) from the site. Four respondents said that sources of suitable mopane were being depleted, while two respondents said there had been no significant change.

The complete process of finding, cutting, transporting, debarking and installing mopane posts takes an average of 6.5 days (7, 3 to 14). Farmers said that they would charge approximately Z$350 (4, 100 to 550) to undertake this task for the neighbour.[1] One farmer noted that he would usually collect mopane for other parts of the structure at the same time. Transport would normally be by oxen with or without a scotch cart or, if unavailable or inaccessible, by collective labour arranged through a beer-party.

The durability of mopane posts depends on the prevalence of termites. While the heartwood is resistant to termite attack, the surrounding sapwood is often destroyed at ground level and below, undermining the stability of the store. Farmers expected mopane-based stores to last an average of 22.5 years (4, 5 to 40). The oldest stores in use and considered still to be strong, in homesteads settled for more than 5 years, averaged 14.7 years (7, 7 to 29). In all but one case, these were the first stores built in new homesteads.

As well as consuming the sapwood and undermining the structure, termites can climb the mopane posts and attack the super-structure. Rodents can also climb mopane posts where there are no rat-guards, but should be prevented from entering the storage bin if it is well-sealed.

[1] Agricultural extension officers present at these interviews suggested that, for all cost figures, the lower end of the range was more realistic. Farmers might over-estimate the charge in the hope of receiving payment for constructing stores as part of future trials. The difference between farmers willingness-to-pay and willingness-to-accept was highlighted by one farmer who would charge $250 for the installation of stone posts but pay only $50.

2.3.2 Stone supports

Stone suitable for constructing the main posts was available at a mean distance of 4.5 km from the site (n = 2, range 4 to 5).

The complete process of collecting, transporting and installing stone posts takes an average of 4 days (4, 1 to 10). This is considered heavy work. Farmers said that they would charge approximately Z$230 (4, 75 to 500) to undertake this task for a neighbour.

Two respondents mentioned that stones might fall over or subside after heavy rainfall. Two other respondents, however, said that this could be prevented by placing the stones in contact with stable subsoil, allowing the mud to harden first, and ensuring that the roof overhang protects the base from rainfall.

Stones are more durable than mopane as they are not consumed by termites. The general consensus was that termites climb stones, but there was some debate about whether climbing termites are visible and can be brushed off. Rodents can jump onto the low platform, but should be prevented from entering the storage bin if it is well-sealed.

2.3.3 PVC pipe/concrete supports

The cost of materials (cement, wire, PVC pipe) to farmers is expected to be in the region of Z$580 per store.

Farmers said that cement and wire would be available in Binga, Gokwe or Hwange, although some dealers might deliver if there were sufficient demand. Transport would usually be by bus, at an average return fare of Z$66 (6, 14 to 45). Farmers considered the job of installing the concrete posts as relatively easy, and would charge an average of Z$53 (4, 30 to 80) to complete this task, excluding the cost of materials or transport.

Farmers expected concrete posts to last indefinitely.

Concrete posts have the advantage that termites can neither consume nor climb them. If termites managed to climb the posts, they would be clearly visible and could be knocked off. Rodents cannot climb the posts or jump onto the high platform. These advantages are offset by questions of the cost and availability of materials.

2.4 Store construction: superstructure

2.4.1 Platform

The durability of the cross-beams and platform depends on the prevalence of termites. Termite holes might start to appear within six months to a year, but most respondents replaced this part of the structure only every ten years.

It would be expected that the cross-beams and platform would need to be replaced less frequently in the modified store due to the reduction in termite access and therefore damage.

2.4.2 Storage Bin

The internal structure of the storage bin is usually replaced at the same time as the platform - about every ten years depending on the prevalence of termites. In most cases, farmers applied a fresh coat of plaster (inside and possibly outside) every year, but in others the bin was never replastered. One farmer said that he would charge $200 to make a storage bin (basket-style).

The storage bin structure is replaced on average every 10 years (2, 10). As with the platform, it would be expected that the storage bin's internal structure would need to be replaced less frequently in the modified store due to less termite damage.

2.4.3 Roof

Roofing practices diverged significantly. The durability of the roof structure itself (rather than the thatching material) depends on the prevalence of termites. For example, in one termite-infested homestead, the roof structure is replaced annually. Elsewhere, the roof structure was said to last 20 to 30 years if there were no termites. Two male farmers said that they would charge about $125 to construct a roof (2, 100 to 150).

The preferred thatching material is grass, but this is increasingly difficult to find, and so many households use pearl millet stalks. Thatching grass is sold for Z$4-5 a bundle, but the number of bundles used varied widely from 10 to 50. Where termites are rife, thatching grass may need to be replaced every year. Otherwise thatching grass needs to replaced on average every 12 years (6, 3 to 25) depending on the prevalence of termites. Thatching grass, where available, is found at an average distance of 5.5 km (2, 4 to 7).

Pearl millet straw is readily available, but is more susceptible to rot and termite damage. It is usually replaced annually. Where sold, one bundle may cost $2-3.

The thatching process takes an average of 20 days (5, 14 to 30). Most of this time is spent collecting thatching grass. Two female farmers jointly agreed on $120 for thatching only.

Where the roof structure is supported by separate posts from the storage bin, the modified store makes no difference. (This is because these posts run from the ground, by-passing the modified posts. Future designs would ensure that these posts are supported by the platform and not from the ground, thereby maintaining the integrity of the modified design.) Where the roof is supported directly by the bin, the roof structure would be expected to need replacing less frequently in the modified store. However, less difference would be expected with regards to the thatch, especially where straw is used - the straw is usually replaced annually due to rot from damp as much as due to termite damage. Where thatching grass is used, the modified store would be expected to reduce the need for replacement. Adoption of the modified store might lead to a shift from straw to thatching grass, as the investment would be more worthwhile in the expectation of limited termite damage.

2.5 Cost of capital

Formal lending institutions, such as the Agricultural Finance Corporation, are not active in the study area and their terms, including collateral, are unlikely to appeal to resource-poor farmers. It would seem that considerable informal lending takes place, generally for small amounts over short periods to finance immediate consumption needs. The nature of the transaction depends on the degree of trust and various ties between the lender and borrower, and no standard interest rate applies. (Khupe, pers. com.; Tokotore, pers. com.)

In group discussion, farmers said that larger amounts could be raised by borrowing from a number of different creditors. However, it was not possible to determine whether an expansion of informal lending to larger amounts over longer periods to finance small-scale investments would be a reasonable option for farmers from different wealth groups.

The cost of capital also depends on the availability of alternative investments to farmers, and on consumption needs. It was not possible to determine the range and viability of alternative investments available to farmers. In group discussion, farmers said that they usually construct stores in July or August. This is a period of fairly low cash expenditure, which starts to increase as food stocks run low in September building to a peak in December and January.

It is likely that a discontinuity exists between the cost of capital for cash-constrained and non-cash-constrained farmers because of imperfections in local capital markets.

2.6 Cost of labour

Store construction generally takes place in July or August, a time of year when labour demands are relatively low, especially for men who are generally responsible for the main supporting posts and basic frame, unless they are involved in opening up new fields. Women are usually responsible for plastering the storage bin and for collecting thatching grass and preparing the thatch mat. Women are involved in threshing in July, which is labour intensive, but are relatively free in August, if not involved in opening up new fields.

In non-cash-constrained households, labour constraints may be relieved by hiring additional labour.

2.7 Losses

The proposed technology is expected to reduce occasional catastrophic losses attributable to termites. These can be caused in two ways:

- termites undermine the structure so that it collapses and grain is spilt;
- termites enter the grain and cause up to 100% losses very rapidly.

The former is more likely, as termites tend to consume the timber components of storage structures before the grain. There is no information available on how common such catastrophic losses are in Zimbabwe, but it is thought to be rare (< 1%), and the extent of termite structural damage in stores is often difficult to detect. Most households would guard against such losses by replacing stores more frequently in termite infested areas. (Mitchell, pers. com.)

While farmers participating in the trials recognised differences in losses between modified and traditional stores, these were not clearly attributed to the concrete posts. For example, one farmer said that termites eat through dagga and invade the crop inside the traditional store, but then added that the difference in losses was mainly due to the failure to close the traditional store properly.

2.8 Effectiveness, acceptability and affordability

A majority of trial farmers found the proposed technology acceptable, and indicated that they would prefer it to existing alternatives (mopane or stone), because it is resistant to termites and would prevent termites climbing the posts. However, farmers expressed concern about the cost and the availability of materials. These are important considerations which could reduce adoption rates in the study area.

2.9 Cost-benefit analysis

The cost-benefit analysis is based on the assumption that the household has made the decision to construct a store and is comparing the modified store and a traditional store with the roof directly supported by the storage bin. This store design was chosen because it is more common in the Kariba Valley as a whole, and because the modification will affect the roof structure and so differences will be more significant than in the separate roof structure case. This should be taken into account when assessing the findings. A further assumption is that basic best practice is carried out in both traditional and modified stores, in particular that the storage bin is sealed and that the inside is replastered annually to prevent residual infestation. The cost-benefit analysis therefore focuses on the impacts of the concrete posts, and assumes that other low-cost modifications promoted during the storage trials (in particular, effective sealing of the storage bin) are implemented.

The range of conditions in the study area varied widely, and it was difficult to elicit a clear consensus on the value of non-marketed inputs. Sensitivity analysis was therefore undertaken based on an increase (in 25% increments) in the following factors:

- frequency of replacement of traditional store;
- replacement costs for traditional store.

In all cases, it was assumed that the basic structure of the modified store would not be replaced during the 20 year period, but that the (grass) thatch would be replaced after 10 years.

Results are presented based on benefit-cost ratios over 20 years for a range of discount rates. The technology is considered viable where the benefit-cost ratio is greater than 1:1.1.[2]

Table 2.9: Benefit:Cost ratios greater than 1:1.1 over 20 years

	Replacement cost	high				high-medium				low-medium				low			
	Discount rate	10%	15%	20%	25%	10%	15%	20%	25%	10%	15%	20%	25%	10%	15%	20%	25%
Freq-uency	5 years	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	10 years	x	x	x	x	x	x	x	x	x	x			x	x		
	15 years	x	x			x				x							
	20 years	x															

[2] Detailed calculations are presented in Appendix II.

2.10 Conclusions

2.10.1 Cost of capital

Financial and economic analysis suggests that the cost of capital is an extremely important factor in determining the viability of the proposed technology: it will be more attractive to non-cash constrained farmers.

2.10.2 Frequency of replacement

The attractiveness of the proposed technology is significantly higher where traditional stores are more frequently replaced due to termite damage. Frequency of replacement is also likely to be correlated with the probability of catastrophic grain losses attributable to termites, which was not included in the cost-benefit analysis directly. For trial farmers, the mean rate of expected replacement of storage structures was over 20 years.

2.10.3 Cost of replacement

The attractiveness of the proposed technology will also depend on the cost of building and maintaining the traditional store. This will depend on the availability of hardwoods or of local substitutes (such as stones) for post construction and the costs of labour. The availability of hardwoods is likely to vary with population density compared to woodland cover, which are probably inversely related. The availability of hardwoods or local substitutes may also be related inversely to the level of termite infestation. This suggests that the technology will have greater appeal in areas of high population density and/or low woodland cover, and possibly in areas of high termite infestation.

Due to the long life of the store, the proposed technology *may* also be preferred by labour-constrained households as it is less labour intensive than the alternatives. Store construction generally takes place in July or August, a time of year when labour demands are relatively low, especially for men. In non-cash-constrained households, labour constraints may also be relieved by hiring additional labour. However, it is unclear as to the costs of hiring labour - one farmer stated that whilst he would charge another farmer $250 per day to help construct a store, he would only be willing to pay $50 for somebody to do the same on his own store. Since stores are built in the slack season when alternative employment opportunities are low, labour costs (and opportunity costs for farmers constructing their own stores) could be low.

For trial farmers, the mean replacement costs, in terms of willingness-to-accept correspond with the low-medium category above, while willingness-to-pay probably corresponds with the low category of replacement costs. However, there was a general consensus that mopane is becoming more scarce. As the availability of construction materials becomes increasingly restricted, the costs of replacing the traditional store will rise. At some point, farmers will need to consider alternative approaches to improve the sustainability of hardwood use, two of which would be: to reduce harvesting rates through substitution, or: to increase regeneration rates through improved management.

The two crucial parameters from an economic point of view are therefore the frequency of replacement and the discount rate to farmers (the modified store only makes sense if the discount rate is 15% or below, and if the frequency of replacement is 15 years or less).

However, it is not possible within the constraints of this survey to make a judgement as to how the trial farmers feel about these. Further work would be required to clarify the situation.

3. SOCIAL ANALYSIS

The financial and economic analysis is undertaken in terms of a theoretical, generic farmer. In practice, various socio-economic factors will lead to different patterns of costs and benefits for different farmers under the same financial and economic conditions. The remainder of this section considers the role of wealth, livelihood strategies, and gender in shaping the impacts of the technology on farmers.

3.1 Wealth

3.1.1 Cost of capital

As indicated in the financial and economic analysis, due to imperfections in local capital markets, farmers from different wealth groups may face different costs of capital. *Ceteris paribus,* it may make sense for a wealthy farmer to invest in the proposed technology, but not for a poorer farmer, because they face different discount rates.

3.2 Livelihood strategies

3.2.1 Mobility

The traditional way of life of the Tonga people is fairly mobile (Khupe, pers. com.). The change in livelihood strategy implied by resettlement together with increasing population pressures is encouraging a shift towards more permanent homesteads (Tokotore, pers. com.). Households participating in the trial had settled in their current homesteads on average 14 years ago (9, 3 to 29). Households in Siabuwa, where populations have been longer established, have on average been settled for 20.5 years (4, 9 to 29), while those in Kariangwe, with a largely Tonga population resettled during the creation of Lake Kariba, have been settled in their current homestead for an average of 7.75 years (4, 3 to 13).

The acceptable pay-back period for more mobile households is likely to be lower. The pay-back period is highly dependent on the frequency of store replacement. Table 3.2.1 below presents expected pay-back periods under various conditions.

Table 3.2.1: Pay-back periods in years

	Replacement cost	high				high-medium				low-medium				low			
	Discount rate	10%	15%	20%	25%	10%	15%	20%	25%	10%	15%	20%	25%	10%	15%	20%	25%
Freq-uency	5 years	4	4	4	4	4	4	4	4	4	4	4	4	4	6	6	6
	10 years	6	6	6	6	6	6	6	11	6	6	11	16	11	11		
	15 years	8	8			8				16							
	20 years	11															

3.2.2 Storage

In the financial and economic analysis, it was assumed that the household had already decided to construct a store, and was comparing the costs of modified and traditional stores. In practice, for households in the study area, the decision to store is not given. It will be determined by yields, the duration of storage and the expected differences in loss rates between stores and alternative methods of storage (for example, in a sleeping hut).

In group discussion, farmers said that they made the decision on constructing a new store in July or August, once harvesting was complete and they could estimate the amount to be stored. Sorghum is generally harvested in April.

Within the study area, households adopt different livelihood strategies, in terms of the importance of crop production, depending on the agro-ecological potential of their land, their asset base, and the availability of alternatives, such as casual labour opportunities and crafts. Table 3.2.2 below presents the expected duration of grain storage for households with different livelihood strategies in terms of crop production, in different areas.

Table 3.2.2: Expected month of sorghum stock exhaustion

Site	Livelihood strategy	Month of stock exhaustion (harvested in April)
Manjolo	low	July
	medium	August/September
	high	December
Kariangwe	low	September/October
	medium	October/November
	high	November-January
Siabuwa	low	September/October
	medium	October/November
	high	November-January

Source: Khupe, pers. com.

Farmers may also consider the expected yields in future years, as they are unlikely to have successive years of good harvests over a long period (Khupe, pers. com.). For those households whose stocks are usually exhausted earlier, it may not make sense to construct either a traditional or modified store. This is a general point that refers to many storage projects (including this one), namely that the improved store may be of less relevance and therefore have less impact on the less well-off farmer when compared to those who are more affluent. Some farmers (not interviewed) purchase significant quantities of grain (up to 450 kg) shortly after harvest from surplus areas such as Gokwe, Lusulu and Lupane for storage. This is not considered to be a common occurrence (Khupe, pers. com.).

3.3 Gender

3.3.1 Store construction

In semi-structured interviews with both women and men, farmers agreed that the decision to construct a new store was taken by the head of household (usually male). Construction of the basic storage structure (supporting posts, platform, basket frame, roof structure and mounting the thatch) is usually the responsibility of male members of the household. Women are responsible for the finer weaving of the basket, plastering and preparing the thatch mat. Men are responsible for finding and collecting heavier materials, in particular supporting posts, whereas women are responsible for collecting lighter materials, in particular thatching grass which is extremely scarce.

In terms of store construction, heads of household (usually male) will be expected to make the decision on whether to construct the modified or traditional store. Both men and women will be expected to benefit from construction of the modified store in the long-term, in terms of the reduction of labour requirements for replacing the traditional store. For men, the main alternative activity in July and August is the opening of new fields, whereas women may also be involved in threshing in July.

3.3.2 Female headed households

Female headed households comprise about 20-30% of all households in Binga District (Majid, 1996). Where these households are female headed because the male *de jure* head is permanently absent but sending remittances, the decision to construct a store may still be taken by the absent male, although female advice may be more important. The household may be less cash-constrained than many male headed households. It may be labour-constrained but able to relieve these constraints through hiring labour, for example to assist with store construction.

Where these households are *de jure* female headed, or the absent male head is providing no support, the decision to construct a store is likely to rest with the female head. These households are likely to be both cash-constrained and labour-constrained. Labour constraints may be partially relieved through collective labour in return for a beer party, as beer brewing is primarily a female activity. (It should be noted that the Tonga people are traditionally polygamous, and this practice is still common (Majid, 1996). Widows who face severe constraints are more likely to have the option of remarriage than in monogamous societies.)

For these households the benefits for the proposed technology, in terms of reduction of labour requirements, may be greater, but the costs, in terms of capital outlay, may also be greater. These households are also likely to be more risk averse (because poor), less mobile (because of the high labour costs of resettlement), but may have low expected yields. Such households would benefit more than most from a reduction in the capital cost of the proposed technology, where expected yields are sufficiently high to justify the construction of a store in the first place.

3.4 Vulnerability

The vulnerability of households to catastrophic losses depends on a complex interplay of factors. Poor households may be more vulnerable, as their coping strategies are limited by a low asset base. Households whose livelihood strategies give low importance to crop production may be less vulnerable because of greater diversification. On the other hand, these same households may hold their entire harvest in a single storage structure, which would increase their vulnerability.

Female headed households with no support from permanently absent males are likely to be correlated with poor households and diversification may be limited by labour constraints (especially where female and male labour is non-substitutable). Where the combination of poverty and limited diversification implies a single storage structure and limited coping strategies, these households may be especially vulnerable. Furthermore, these households may replace traditional storage structures less frequently for a given level of termite infestation because of labour constraints.

4. ENVIRONMENTAL ANALYSIS

The main objective of the proposed technology is to reduce the use of hardwoods in store construction. In the study area, the main hardwood in question is *Colophospermum mopane*.

4.1 Species conservation

Mopane can thrive in a wide range of ecological conditions, and mopane dominated vegetation covers about 550,000 km^2 in southern Africa, including 101,000 km^2 in Zimbabwe (Timberlake, 1995). Mopane is not threatened as a species in Southern Africa or in Zimbabwe (Timberlake, pers. com.).

4.2 Conservation of vegetation types

"Cathedral" mopane, stands of mopane of more than 14 m in height, occurring in pockets of mopane woodland on old clay-rich alluvial soils, include a unique assemblage of species and therefore have preservation value. Generally, however, mopane woodland is species poor and includes no known endemics, but is a valuable habitat for wildlife. (Timberlake, 1995; Timberlake, pers. com.)

4.2.1 Conservation of an economic resource

Mopane provides a significant contribution to local rural livelihoods. Mature poles are used for the construction of houses, kraals, granaries, and drying structures and for fuelwood. Mopane is a favoured firewood because it burns slowly and produces much heat - mature poles are used for the brewing of beer (which requires a steady, continuous heat over a long period), smaller sticks and dead wood are used for lighter tasks. Mopane is also valuable as dry season browse for livestock, as well as wildlife (Timberlake, 1995; Mawire, pers. com.). Mopane bark can be used as a medicine (Mawire, pers. com.). Mopane worms are not found in the study area (Khupe, pers. com.)

4.3 Depletion of mopane

The main cause of the depletion of mopane woodland in the study area is conversion to agriculture. Mopane cleared for agriculture reverts to either mixed woodland or scrubland when abandoned, suggesting that conversion may be irreversible over 20 years (Pender *et al.*, 1997). The availability of construction poles, in particular, is also being affected by unsustainable harvesting for timber and fuelwood for brewing (Mawire, pers. com.) According to a simulation of household timber needs, granaries might account for approximately 20% of the demand for poles with a minimum diameter of 6 cm over a 100 year period (Lynam, 1996).

In 1993, Manjolo and Siabuwa Communal Lands both retained approximately 30% cover by mopane woodland. The rate of loss has decreased since 1990, to less than 0.5% in Manjolo and less than 1% in Siabuwa. This decrease has been linked to the reduction of tsetse control campaigns in 1989 and consequent reduction in the opening of new roads. (Pender *et al.*, 1997). This compares to a rate of human population growth of approximately 4% (1992 Census).

Table 4.3 below compares population densities for the study area from the 1992 Census with the estimates of mopane woodland cover based on 1993 remote sensing imagery (Pender *et al.*, 1997).

Table 4.3: Comparison of household needs with mopane woodland

Site	Total area (ha)	Mopane woodland (ha)	No of households	Average household size	Mopane woodland per household (ha)	Mopane woodland per hh in study sites (ha)
Manjolo Communal Land	257,882	77,365	6,072	5.0	12.74	4.97
Siabuwa Communal Land	179,122	53,737	4,003	4.2	13.42	4.79
Kariangwe Communal Land	309,895	92,969*	6,495	4.9	14.31	16.66

* Extrapolation of 30% from data on Manjolo and Siabuwa Communal Lands.

A simulation model of household needs for building and construction materials and for fuelwood in the Zambezi Valley estimated that each household would need about 7.5 ha of woodland to meet their needs sustainably, depending on the frequency of replacement of timber structures (Lynam, 1996). While the above figures compare favourably with these estimates at the macro-level, population density is uneven, as is demonstrated by the figures for the study sites. Furthermore, the distribution of households and mopane woodland is likely to be inversely related. In some areas therefore, households may meet their short-medium term needs only through unsustainable harvesting. If current population growth rates continue, an increasing proportion of the study area will fall into this category. Options to improve the sustainability of harvesting include increasing regeneration rates through improved management and reducing the harvesting rate through substitution.

At the *site level* therefore, the environmental argument appears to be strong in the Manjolo and Siabuwa sites, but weaker in the Kariangwe site. At the *communal lands* level however, the availability of woodlands in all three communal lands is almost double what Lynm estimates to be required for sustainability. The technology would therefore appear to be applicable on a local site level rather than a communal or regional level.

4.3.1 Improved management

A study in northern Botswana (Tietma *et al.*, 1989 cited in Timberlake, 1995) recommended coppicing of natural mopane woodland to meet high construction and fuelwood demands. Mopane coppices easily and production of poles from seedlings takes twice as long as production from coppice. In a model of mopane growth, basal diameters of 5-25 cm were produced in 5-10 years. However, other sources suggest that it might take 20-30 years to achieve the diameters necessary for supporting posts in storage structures.

In a group discussion in Manjolo as part of the present study, farmers said that coppicing when harvesting construction poles is a widespread practice. Poles take about 10-12 years to develop into useful construction timber. While customary regulations prohibit the felling of valued, indigenous fruit trees, such as baobab, tamarind and *Arkansia kirkiana* (*matoye*), offfarm mopane is still regarded as an open access resource. Farmers said that if mopane became scarce they would save and plant seeds. Planted trees would probably be regarded as private property. A potential approach to the sustainable management of mopane woodland might be coppicing with more defined usufruct rights.

The Zimbabwe Forestry Commission is promoting the regeneration of mopane woodland through coppicing by providing support to schools to fence small areas of woodland and manage trees for pole production. Constraints on the wider application of this programme are the relative abundance of mopane in the study area, and the communal nature of the resource. (Mawire, pers. com.) Slow growth rates would be an additional constraint to the coppicing of poles for support posts in storage structures.

4.3.2 Reducing harvesting rates

The present research project aims to investigate options for reducing harvesting rates by minimising the use of hardwoods in storage structures.

The current trial is examining the impacts of substituting mopane main supporting posts with concrete encased in PVC pipes. This technology is expected to reduce use directly through substitution, and indirectly by removing the need to replace the main posts, and reducing the replacement rate for the rest of the store by protecting it from termite damage. Substitution is likely to be particularly attractive in areas where mopane woodland is seriously depleted and where termite infestation is high. In the first case, alternative substitutes include stone, which is widely used in the study area, and other hardwood species. In the second case, it is generally agreed that termites climb over stones and hardwoods and attack the store superstructure. In environmental terms, the advantage of the concrete posts is therefore that they reduce consumption of hardwoods and other natural materials throughout the store.

4.3.3 Conclusions

The conservation values of mopane woodland in the study area are dominated by the species' economic role in local livelihoods. Options for conservation include increasing productivity through systematic coppicing and improved management, and reducing the harvesting rate through substitution. The success of improved management will depend on perceptions of scarcity and the effectiveness of the management framework. The success of the substitution approach will depend on scarcity, and the comparative costs of substitutes. It should be noted that the substitution approach implies reducing the local economic value of the species, which may constrain rather than promote its conservation (ODA, 1996).

In the study area, the main hardwood species used in store construction (mopane) responds well to management through coppicing. Improved management should therefore be considered as a complement or alternative to reducing harvesting rates through substitution. Elsewhere in Zimbabwe, the feasibility of this approach will depend on the responsiveness of hardwoods suitable for store construction to improved management. In the study area, hardwood species are still relatively abundant, while in other areas of Zimbabwe, hardwoods are already seriously depleted. The substitution technology developed through this project may therefore be a more effective strategy for hardwood conservation elsewhere in Zimbabwe.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

In conclusion, the financial and economic viability of this technology depends in particular on the following factors:

- frequency of traditional store replacement (level of termite infestation);
- replacement costs for traditional stores (availability of hardwoods or local substitutes, cost of labour);
- cost of capital (household wealth).

Trial farmers in Binga District have confirmed that the technology is both effective and acceptable, but have questioned its affordability. This study indicates the conditions under which the technology is most likely to be appropriate, and has discussed some of the possible socio-economic constraints and environmental issues. This should facilitate the identification of areas where the potential for adoption of this technology is high. Further evaluation, involving participatory rural appraisal techniques including participatory budgeting of store construction and management, should be undertaken prior to any extension of the project to new areas.

5.2 Post-harvest constraints

In two group discussions, held in Manjolo and Kariangwe, causal diagrams were used to examine farmers perceptions of post-harvest constraints. In both cases, post-harvest constraints led to hunger. The results are presented in the table below.

Additional comments:
In Manjolo:

- elephants cause damage in the fields and to crops in the drying structure;
- weevils are not considered a problem when there is a good surplus, but they attack SV2 in particular; people do not use grain protectants because they have no cash;
- termites are a problem from the fields through storage, and eat grain and stalks;
- rodents are a problem in the store and in the field;
- [quelea] birds and grasshoppers only occur in periodic outbreaks;
- rotting is not significant because grain can be sun-dried;
- poles which fall over cause unplanned labour;
- food insecurity causes forced livestock sales which cause no draft power which causes greatly reduced harvests.

Table 5.2: Post-harvest constraints

	Manjolo			Kariangwe	
constraint	reverse rank	cause (comments)	constraint	reverse rank	cause (comments)
elephants	14		rodents	10	
weevils	9		weevils	9	no chemical protectants because no money
termites	8		termites	8	
rodents	7	cracking due to poor thatching, termite damage, and incorrect mixing of grass with dagga	moths	7	
germination	6	rain	larval stage	6	
birds	5		birds	5	
rotting	4	rain	chickens	4	poor structure
grasshoppers	3		rotting	3	water
fire	2		discolouration	2	high temperatures
spillage	1	falling poles due poor installation and rain, and cracking	thieves	1	hunger
low yields	1	insufficient draft power			

Note: in Manjolo the rank of termites was raised after considerable probing.

In Kariangwe:

- rodents are a problem at all post-harvest stages;
- weevils come from the bush and may infest crops even in the field; black weevils are a particular problem when crops stay too long in the granary, and can reduce grain to dust;
- termites cause the collapse of temporary structures;
- discolouration causes poor germination and low yields;
- cracking is caused by inappropriate mixing of grass and dagga.

In semi-structured interviews, trial farmers suggested the following further structural modifications:

- two additional concrete posts to prevent the platform sagging;
- cement poles for roof, where this is separate;
- asbestos instead of thatch, because it is neater and more durable;

- constructing the platform and even storage bin out of cement (but the farmer considered this would not be affordable).

5.3 Future areas for research

Based on the group discussions and semi-structured interviews, the following areas may be considered for future research:

Storage structures:

- investigation of alternative locally-used approaches to termite control;
- impact of using a larger number of smaller diameter poles (from coppicing) in store construction;
- reduction of replacement rates for thatch and roof structure by decreasing termite attack on separate roof structure through concrete posts;
- investigation of the effectiveness, affordability and acceptability of further low-cost modifications, such as rat guards;
- investigation of the viability of concrete support posts in areas with greater hardwood shortages;
- introduction of alternative storage structures (such as brick) in high crop production areas.

Other:

- investigation of effectiveness of indigenous grain treatment methods, and adaptability of indigenous grain treatment methods from elsewhere in the region to conditions in Binga District;
- investigation of options for reducing post-harvest losses pre-storage due to insect infestation;
- comparison of loss differences across varieties and recommendation of appropriate varieties for different end-uses;
- investigation of constraints to correct application of commercial grain protectants.

APPENDIX I: REFERENCES

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APPENDIX II: COST-BENEFIT ANALYSIS

This appendix presents detailed calculations for the cost-benefit analysis, based on the following assumptions.

Frequency of replacement:

Calculations are presented where the traditional store is replaced every 5, 10, 15 or 20 years.

- In the 5 year case, the entire traditional store is replaced after 5 years. The superstructure (including thatch) in the traditional store is replaced after 3 years. Thatch is replaced after 10 years in the modified store.
- In the 10 year case, the entire traditional store is replaced after 10 years. The superstructure (including thatch) in the traditional store is replaced after 5 years. Thatch is replaced after 10 years in the modified store.
- In the 15 year case, the entire traditional store is replaced after 15 years. The superstructure (including thatch) in the traditional store is replaced after 7 years. Thatch is replaced after 10 years in the modified store.
- In the 20 year case, it is assumed that the superstructure in the traditional store is replaced after 10 years. Thatch is replaced after 10 years regardless of store design.

Replacement costs:

Low costs for the traditional store are:

	Z$
Construction of main posts:	
Labour	250
Maintenance:	
Platform	200
Storage bin	200
Roof structure	100
Thatch	100

Sensitivity analysis is based on 25% increments on these low cost estimates.

Construction of the modified store implies:

Increased cash costs	Z$620
Reduced labour costs	25%