Supplement to ODNRI Bulletin No. 10 - An evaluation of structures suitable for emergency storage in tropical countries 2. Bumper crop storage (ODNRI Bulletin No. 24)

Bulletin No. 24

ODNRI

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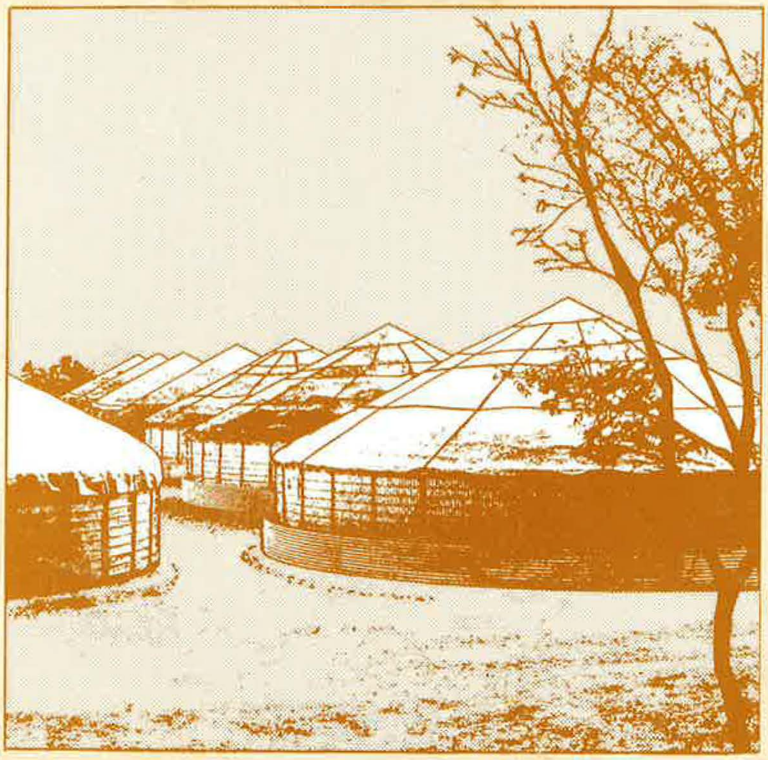
An evaluation of structures suitable for
emergency storage in tropical countries

2. BUMPER CROP STORAGE



OVERSEAS DEVELOPMENT
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2. BUMPER CROP STORAGE

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Contents

VALEDICTORY

Sadly, the author of this bulletin, Tate O'Dowd, died just before the manuscript went to press. Tate O'Dowd was a storage engineer of many years' experience, who contributed greatly to the knowledge and application of storage technology, particularly in the developing world.

ACKNOWLEDGEMENTS

I wish to acknowledge the help given me by commercial firms and by colleagues at ODNRI; I should like to thank Derek Caley for providing me with an account of the bunker storage trials in Zimbabwe with kind permission of the Zimbabwe Grain Marketing Board, but any errors are my responsibility.

NOTE

This bulletin, and its companion, *ODNRI Bulletin* No. 23, form supplements to *ODNRI Bulletin* No. 10 (1987) An evaluation of structures suitable for emergency storage in tropical countries, by E. T. O'Dowd, J. H. New, A. J. K. Bisbrown, J. A. Hallam and Corinne Joy.

Summaries

SUMMARY

The supplement distinguishes between emergency storage for relief food and bumper crop storage: it critically examines and compares the different systems including traditional methods, cover and plinth (CAP), flexible silos, pits and bunkers. To help users choose the system appropriate to their unique needs, the supplement provides a qualitative method for system selection and indicative costs.

RÉSUMÉ

Ce supplément établit une distinction entre stockage d'urgence de produits alimentaires de secours et stockage de récoltes exceptionnelles; il y est fait un examen et une comparaison critiques des différents systèmes, à savoir: méthodes traditionnelles, couverture et socle (CAP – 'cover and plinth'), silos flexibles, fosses et soutes. En vue d'aider l'utilisateur à choisir le système qui répond le mieux à son propre besoin, ce supplément propose une méthode qualitative de sélection de système, ainsi qu'une indication des coûts.

RESUMEN

En este suplemento se distingue entre almacenamiento provisional para productos alimenticios de ayuda y almacenamiento de cosechas récord, realizándose un estudio y comparación críticos de los distintos sistemas existentes, tales como métodos tradicionales, cubierta y plinto (CAP), silos flexibles, fosas y depósitos subterráneos. Con objecto de asistir a los usuarios en la selección del sistema más apropiado a sus necesidades específicas, el suplemento proporciona un método cualitativo de selección de sistema, junto con costes aproximados.

2. Bumper crop storage

INTRODUCTION

Grain storage capacity in a country is planned, or develops, according to requirements in a year of average harvests (Mitchell, 1988; Baker, 1988; FAO, 1983). Many tropical and semi-tropical countries have great variations in yearly or biannual harvests of cereals (FAO, 1986a). When the harvest is seriously deficient there may be a need for emergency storage for relief food as discussed in *ODNRI Bulletin* No. 10. A harvest significantly greater than average, described in this bulletin as a bumper crop, will also present difficulties if the quantity of grain is more than can be accommodated by the existing transport and storage system. Severe losses are often associated with bumper harvests (Friendship, 1988; FAO 1986a) because without adequate storage facilities in warm/humid conditions deterioration and/or pest attack are unavoidable. The cereal excess over available storage capacity requires protection through provision of rapidly erected, low capital cost, easily manageable facilities. Such facilities may also be appropriate in the early stages of a rising trend in cereal production while the long-term storage requirements are not clearly defined. Typically, a bumper cereal harvest is associated with lower-than-average cereal prices immediately post harvest. From the nutritional and economic standpoint therefore it is important to prevent cereal losses by providing safe storage until such time as prices rise or alternative uses for the bumper crop can be found. For example the crop might be exported to a country which has a deficit.

In some circumstances it may be possible to provide the additional storage capacity by utilizing as grain stores buildings constructed for other purposes. More often, some new facility will be required. While this may be regarded as temporary, it may be required to store the bumper crop for an extended period, until markets are found or alternative storage is constructed. The temporary facility must therefore permit all measures necessary to control grain quality and minimize losses. Storage systems suitable for bumper crops can consequently become cost-effective components of the regular storage system in some countries. In others, bumper storage may be truly temporary, occurring once every eight or nine years. This supplement to *ODNRI Bulletin* No. 10 aims to provide a framework for deciding between available proven methods of bumper crop storage. These include a traditional system for bulk paddy used in Burma, cover and plinth (CAP) bag storage used in India, flexible silos used in Africa, pit storage as used in Sudan and Argentina, and its close relative bunker storage used in Australia, Israel, Turkey, the United States and recently tested in Zimbabwe.

The requirements for bumper crop storage differ from those for relief food storage in a number of respects. The bumper crop does not materialize unexpectedly; there are usually two or three months' warning that harvests will be above average (FAO, 1986b). The grain flow is in the normal direction so bumper store location will be near to permanent stores. It is less likely that donor funds will be available for store construction, placing greater emphasis on available local resources. Only one crop need be considered (for seasonal storage or longer) rather than a mix of food commodities distributed in an emergency. Single structures with high capacity are therefore acceptable.

TYPES OF STORAGE

Traditional

In Burma in 1986 success in national paddy production and increase in government procurement was such that the harvest was greater than could be accommodated in existing Agricultural Food Produce and Trade Corporation (AFPTC) stores. This presented a situation akin to bumper storage, where 12% of the total harvested, or more than 290,000 tonnes, had to be stored in temporary facilities.

As a temporary measure, about half of the total harvested was stored for 4-6 weeks on bamboo mats out of doors in pyramid-shaped heaps sloped at the angle of repose. Tarpaulins were sometimes used for protection against showers and dew. Security was achieved by spreading paddy husk ash around the perimeter. If the paddy was disturbed it would roll down over the ash and signal pilferage.

At the approach of the rains the paddy was moved by basket to be stored in bulk, in permanent, semi-permanent and temporary/bumper crop stores. Temporary/bumper stores are of three main types:

- 'kyi' rectangular structures, capacity 200-300 tonnes. These stores have bamboo or wooden frames, woven bamboo matting for flooring and walls and leaf thatch roofing. The floors are from 250 mm to 900 mm above ground, providing protection from water vapour and some natural aeration for the stored paddy;
- 'pokes' are small circular woven bamboo mat bins, of 0.5-1 tonne capacity, rendered with earth, straw and cow dung. The bins are protected by a thatch roof and are also elevated 250-900 mm above the ground. Kyis and pokes are traditional methods of storing paddy in bulk. AFPTC now use kyis in preference to the smaller pokes;
- temporary sheds have a capacity of 200-400 tonnes and are constructed with a bamboo frame and low-quality thatch cladding. Paddy is laid on a bamboo mat floor resting on a layer of paddy husk on the ground and is therefore not naturally aerated and can only be stored for a maximum of one season. (Giles, 1988).

In Burma all paddy is stored in bulk. The procedure is to first check the roofs of temporary/bumper stores and then to admit only paddy of below 14% moisture content. Paddy is loaded manually in baskets, 10% being checked for weight and tally sticks used for checking the numbers of baskets. Paddy is stored to enable 'first in, first out' procedures with store doors at each end of the structure.

During the course of storage signs of rodent and bird damage are checked daily. Quality is assessed by sampling with 2 m probes and moisture content is measured with a moisture meter. The samples are also examined for discolouration and damage, including insect damage. Hot spots are sought manually and with thermometer probes. Fumigation is carried out if necessary. These temporary stores can be upgraded to include a strengthened frame, raised floor and improved cladding. Another indigenous system for bagged rather than bulk grain is considered next.

Cover and plinth (CAP)

Outdoor stacks of bagged grain, covered with a waterproof material, have been used in many countries. A standardized system, cover and plinth (CAP), has been adopted in India. Bumper crop storage in India, like that in Burma, relies in the main on local resources and techniques. CAP storage was born of necessity as Indian harvests increased faster than storage capacity (Garg, 1985). About 20 million tonnes of storage capacity has been provided at a fraction of the capital cost using CAP rather than conventional godowns.

Construction of a CAP bag stack is described in *ODNRI Bulletin* No. 10, Appendix 5. Operational details of the CAP method are also included in the bulletin, but briefly construction is as follows: a plinth, with hooks to provide purchase for the ropes lashing the stack, is constructed on a suitable site. Dunnage is provided and the covers are made of black polyethylene 250 microns thick, shaped to suit the stack. The covers are held down by nets and nylon lashing. Condensation is prevented by placing a layer of paddy husk-filled sacks on top of the stack under the polyethylene.

CAP storage is vulnerable to wind damage and the covers should be inspected frequently to detect damage. The system requires careful management if severe losses are to be avoided. For example, only sound stock should be accepted at the plinth with a maximum of 14% moisture content at 25°C ambient temperature, and regular opening of covers is necessary to allow some aeration. Careful quality control is achieved with regular sampling. The advantage of CAP is its low establishment cost which is only one quarter the cost of godown storage (*see* Table 1), but security is a problem and extra fencing together with an extra watchman have been allowed for in the cost calculations in Table 2.

Garg (1985) also suggests that operating costs are 10% lower for CAP than for godown storage. His calculations make no allowance for the extra labour required although he states that CAP is labour intensive. Similarly no allowance is made for extra fencing and an extra watchman, although the need for extra security is recognized. Finally no allowance is made for the faster deterioration of CAP materials which are exposed to the elements and vehicle traffic. With these amendments CAP annual costs appear 21% higher per tonne year than godown costs (*see* Table 2). This is analogous to the calculated higher annual costs for tarpaulin storage *vis-à-vis* warehousing for relief food emergencies (*see ODNRI Bulletin* No. 10, Table 5). The costs of chemicals are excluded but are assumed to be the same for both systems.

These costs are the annual payment to pay back the capital in the assumed lifetime with compound interest at 10% interest on the unpaid balance. Labour costs are based on handling 5,000 tonnes in and out, when labour handles 5 tonnes/day at a $ 2/day charge. CAP labour charges are 15% higher to allow

Table 1

Comparison of establishment costs for 5,000 tonnes grain storage by CAP and godown in US $, 1985 prices

Element	CAP	Godown
Construction*	20,000	200,000
Extra fencing*	10,000	—
Polyethylene covers	5,760	—
Cover tops	1,152	—
Cover nets	1,440	—
Nylon ropes	1,440	—
Fumigation sheets*	—	4,000
Sand snakes	128	128
Sprayers	240	240
Dunnage*	12,489	12,489
Fire-fighting equipment	480	480
Total	53,129	217,337
Total/tonne	$US 10.63	$US 43.47

Source: Adapted from Garg (1985)

Notes: Extra fencing for security has been included, 400 m at US$25/m. Items marked with an asterisk are capital, the remainder are strictly operating costs.

Table 2

Comparison of annual costs for 5,000 tonnes' grain storage by CAP and godown in US$ 1985 prices (with assumed working life in years)

Element	Annual cost $* (assumed life in years)			
	CAP		Godown	
Construction	8,042 (3)		23,492 (20)	
Fencing	1,627 (10)		—	
Polyethylene cover	12,672 (0.5)		—	
Cover top	2,534 (0.5)		—	
Cover net	1,584 (1)		—	
Nylon ropes	1,584 (1)		—	
Fumigation sheet	—		2,305 (2)	
Sand snakes	141 (1)		74 (2)	
Sprayers	264 (1)		138 (2)	
Dunnage	7,196 (2)		3,940 (4)	
Fire-fighting equipment	528 (1)		277 (2)	
		36,172		30,226
Extra watchman		700		—
Labour		4,600		4,000
		41,472		34,226
Costs per tonne per annum	US$ 8.29		US$ 6.85	

Source: Adapted from Garg (1985)

Note: * Capital recovery factor based on 10% interest on unpaid balance and assumed years of life shown in brackets for each item.

for cover removal for aeration, etc. Bumper crop storage may only be required infrequently and therefore this method of annual costing is discussed below. Another type of bag stack is the flexible silo described in the following section.

Flexible silos

Flexible silos can be used for bag or bulk storage (*see* Plates 1 and 2). Early types employed butyl rubber sheeting as the membrane and had capacities of up to 1,000 tonnes. Currently available silos use PVC-coated polyester fabric and are usually of 500 tonne capacity for bag storage. They require a level site free from debris. The silos consist of a PVC cup-shaped liner supported by a circular welded steel mesh wall, made up of segments. Bags are loaded into the liner by hand until level with the top of the welded mesh and are then methodically built into a cone. This can be covered with an insulating blanket to combat condensation. A white conical PVC cover is fitted over the sacks (and blanket), rolled into and clamped against the liner at the rim of the 'cup'. This forms a waterproof hermetic container. The conical cover is secured against wind with a net and the silos are protected from rodents with an exterior wall, buried below ground, made with curved corrugated galvanized steel sheets, approximately 1 m high. The silos require little site preparation, can be delivered rapidly by air if need be, are easy to erect and are relocatable. The silos require no mechanical equipment. In 1980 a survey concluded that such silos were well suited to store overflow stocks from a bumper harvest with the proviso that the silos and stock were well cared for, regularly inspected and effectively maintained. (Kenneford and O'Dowd, 1981). Capital costs are US$ 50-60 per tonne (*see* Table 3).

Plate 1

Flexible silos in Karonga, Malawi, 1986

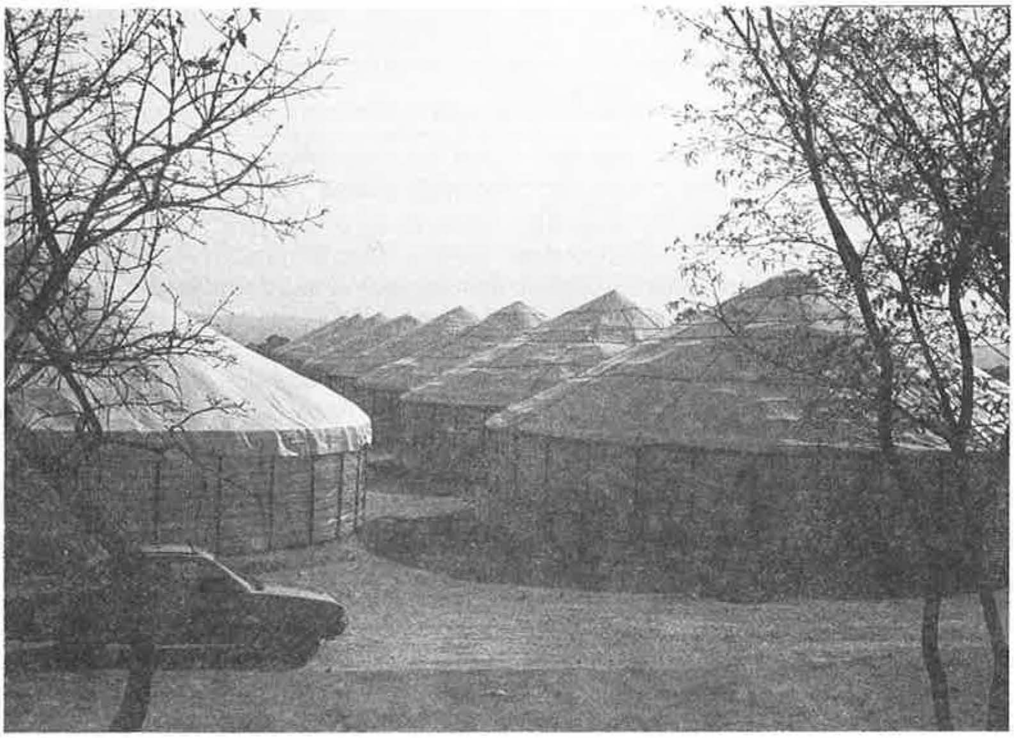


Photo courtesy Gerhard Meyer

Plate 2

Unloading maize bags; Karonga, Malawi, 1986

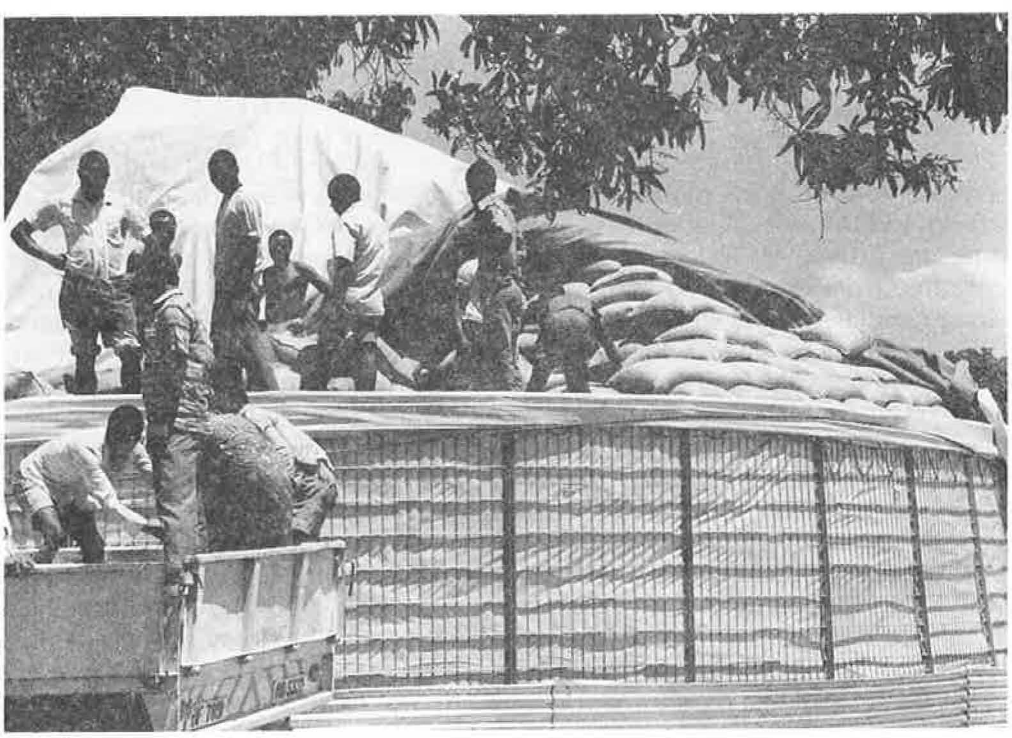


Photo courtesy Gerhard Meyer

When applicable (see below) operating costs vary with the life of the silo (*see* Table 4) and local labour costs. It is assumed that a labourer can move 4 tonnes/day against 5 tonnes/day with CAP because flexible silos require special stacking; this is supported by evidence from West Africa that the silos were unpopular with labour gangs because they were slower to work and therefore penalized labour on piece rates (O'Dowd and Kenneford, 1983). Operating costs for silos are about US$ 12/tonne (excluding fumigation chemicals as for CAP). Flexible silos are now readily transportable and can be relocated, although such wear and tear could increase operating costs by reducing working life.

Some owners of bag systems are under management pressure to change over to bulk storage. Flexible silos have been successfully used for bulk storage, if care is taken to load the silo exactly in the middle to prevent uneven loading of the walls. Bulk storage for bumper crops started in underground pits, which are described in the following section.

Pit storage

After World War II underground pits (of 500 tonne capacity) were successfully employed for hermetic storage of bumper crops harvested in Argentina. (Turtle, 1949; FAO, 1973). Sites with a low water-table were selected and large trenches dug in the ground to a depth of 2 m. With the earliest pits, the earth removed whilst excavating was later heaped on top of the grain-filled (and straw-covered) pit. Later this practice was discontinued because the covers were damaged by the earth during unloading and consequently the grain was adulterated. Instead the earth was used to increase the surrounding ground level, decreasing the depth to which the trench need be dug. The walls and

Table 3

Indicative capital costs for a 500 tonne capacity flexible silo in US$, 1988 prices

	$
Ex-works price for 500 t silo	23,625
Air freight at $1.00/kg 2500 kg	2,500
Local transport	750
Erection	400
Miscellaneous	100
Total	27,375
Total/tonne	US$ 54.75

Source: Manufacturers' quotations and ODNRI estimates.

Table 4

Indicative operating costs for 500 tonne capacity flexible silos at 8-year and 12-year lives in US$, 1988 prices

Element	Annual cost $ 12-year life	8-year life
Silo complete	4,018	5,131
Maintenance	300	300
Labour for 500 t in and out charged at $2 day	500	500*
Watchmen	700	700
Total	5,518	6,631
Total/tonne	US$ 11.04	US$ 13.26

Source: Table 3 and ONDRI estimates **Note:** * Equivalent to handling 4 tonnes/day.

floor of the pit were lined with 150 mm of a cement-stabilized soil mix. The walls were next painted with bituminous paint, dusted with fine sand when tacky and painted with gloss paint when dry. When filling, the pit, heaped with grain, was covered with bituminized paper sheeting supported with hessian or cane matting for strength and painted white to reduce solar heating. Grain was delivered in bulk from waggons and outloaded by bucket elevators. Allowable moisture content at intake was 13% (wet basis).

'Sunken' silos as these pits were known used a single PVC liner to replace bitumen covers and wall/floor treatments in 1966. In 1973 flexible covers were reported to have been replaced by a permanent roof (FAO, 1973). Lower grain losses were reported from these pits than from conventional silos because the liner provided hermetic control of insects (Anon., 1966). Hall and Hyde (1954) had drawn attention to the potential for this method and Darling (1959) reported its successful use in traditional storage pits in the Sudan. Such pits are still in use for bumper crop storage of sorghum (Hassan Shazali, 1986). Although effective, pit storage has been superseded by bunker storage in several countries.

Bunker storage

Modern bunker storage in Australia derives from pit storage developed by the Commonwealth Industrial and Scientific Research Organisation (Yates and Sticka, 1984). McCabe and Champ (1981) relate that with earth-covered bunkers local rodent problems were of two types: mice and rabbits. They state:

> 'Siting of bunkers at locations with histories of rodent activity should be avoided unless positive rodent control measures are taken. Susceptibility of a bunker to rodent attack will depend in part on soil types including liability of soils to cracking. Care must be taken to ensure that the full cover of soil is placed over the bunker to prevent mouse damage to sheets. Rabbit activity should preferably be countered by eradication and if this fails, then rabbit-proof fences should be constructed.'

Under Australian conditions pit storage was too labour intensive and working conditions too severe, therefore research moved to above-ground bunker storage. As in Argentina the earth-covering operation was discarded and furthermore where earth had been employed to build banks, concrete or steel was substituted. This prevented contamination of the grain with earth and stones. The cambered floor was surfaced with asphalt, initially to allow lorries to tip directly onto it, which increased intake rate in the early stages. Now grain is loaded into the bunkers using mobile elevators or grain throwers, after laying PVC sheet on the floor and bunker walls. When the grain is heaped, PVC covers are laid on top. These are stitched together and to the PVC sheets at the wall, and sealant applied, forming an airtight envelope. This bonding method follows failure of adhesive alone to do the job. A mobile grain thrower, the Lobstar, has been developed which can load and outload 2,000 tonnes each day into and from rail waggons. Loading with the thrower is only a problem in high wind. Bunker capacity is now 50,000 tonnes each and PVC covers are moved mechanically using cables and a capstan. With careful management it is claimed that hermetic conditions can be achieved in these bunkers which, combined with their smaller depth (relative to grain silos) are suitable for fumigation with phosphine tablets. These are laid under the bunker covers through resealable ports at the ridge. If the system is airtight, lower dosages than those used in silos can be employed. Even so, Robinson (1987) claims that operating costs for these bunkers are higher than for steel/concrete silo complexes but capital costs are much lower. Few operational problems remain and should soon be overcome; these are:

- damage to PVC cover from birds and large hailstones;
- vandalism of stores not protected by fencing;
- rain and high wind during loading and unloading.

Bunker storage capacity is considered appropriate where a permanent facility might not be fully used. Similar storage bunkers are employed in the United States (*see* Plates 3 and 4) where Johnson (1988) claims that when mechanical-handling plant is shared between bunker operators, operating costs are lower than conventional costs. Grain loaded with more than 12% moisture content requires mechanical aeration to avoid moisture migration and accompanying mould and stack burn. An experimental 15,000 tonne non-aerated bunker in Israel, where oxygen fell sufficiently to contain insect development, experienced isolated mould damage at the surface, caused by moisture migration; the average moisture content in the bulk was 11.4%, but at one point at the surface the grain was at 12.6% moisture content. By the process of moisture migration this increased to 14% in three months and moisture condensed on the inside of the covers causing mould damage to the surface grain when surface temperatures fell to 16°C while bulk temperatures remained *circa* 30°C (Navarro *et al.*, 1984). The bunker site measured 50 m × 150 m, walled on three sides with ramps made up with earth from the floor and outside the site, and the fourth side left open for loading grain. The ramps were 2 m high and 8 m wide at their base, with slopes sufficient for drainage. Before loading, the floor and ramps were lined using 250 micron polyethylene sheet with an overlap to ensure a continuous liner. The cover was a white 830 micron PVC sheet with UV-inhibitor which was folded into the polyethylene liner at the ramp and covered at the joint with earth to provide a hermetic seal. The bunker was loaded with wheat and the bulk was 8.5 m high at the apex. Thermocouples and gas sampling tubes were installed and measurements taken every 2 weeks. Sixty grain samples were taken throughout the bulk 10 times during the 15-month storage period and examined for moisture content and damage (see above). High germination and baking quality were preserved for most of the bulk, but 30 tonnes had reduced quality and 9 tonnes of this were discarded. The PVC liner's elasticity and wear resistance were unimpaired after exposure for 15 months, and although rodents were active around the bunker, no rodent damage occurred. Total damage after 15 months from insects and mould was 0·21%. Oxygen levels fell to 5·1% and CO_2 rose to 9.8% providing, it was claimed, adequate insect control without fumigation.

Plate 3

Loading large bunker, United States, 1988

Photo courtesy Commodity Storage Ltd

Plate 4

Sealed bunkers, United States, 1988

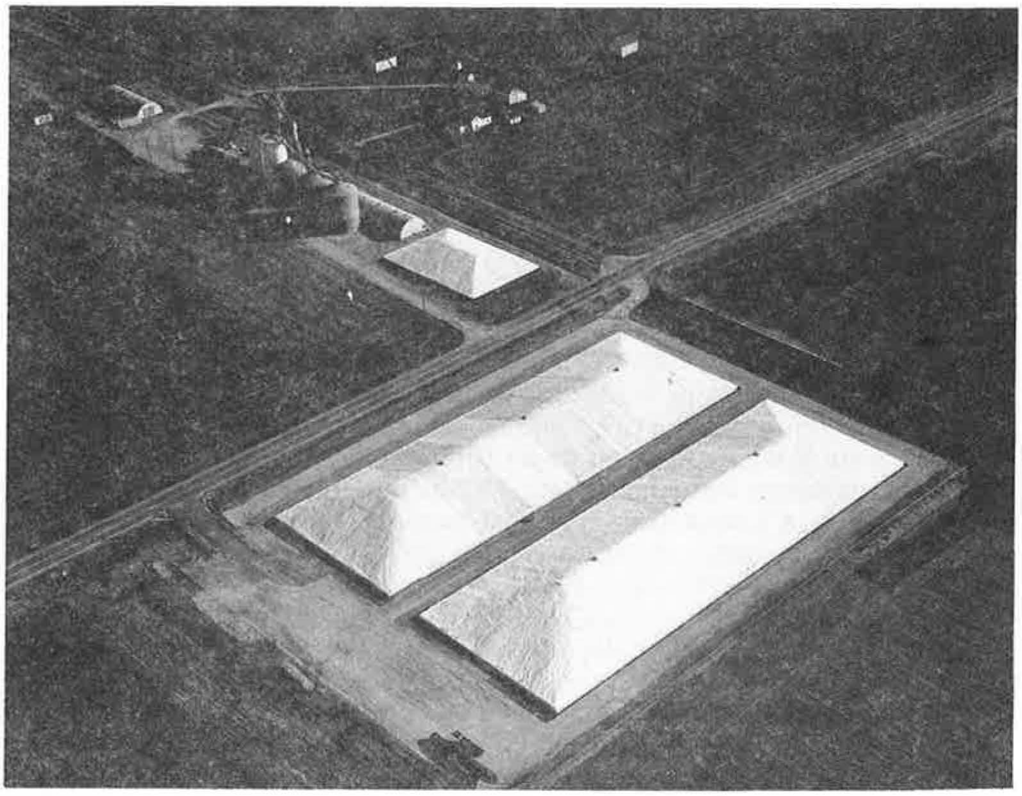


Photo courtesy Commodity Storage Ltd

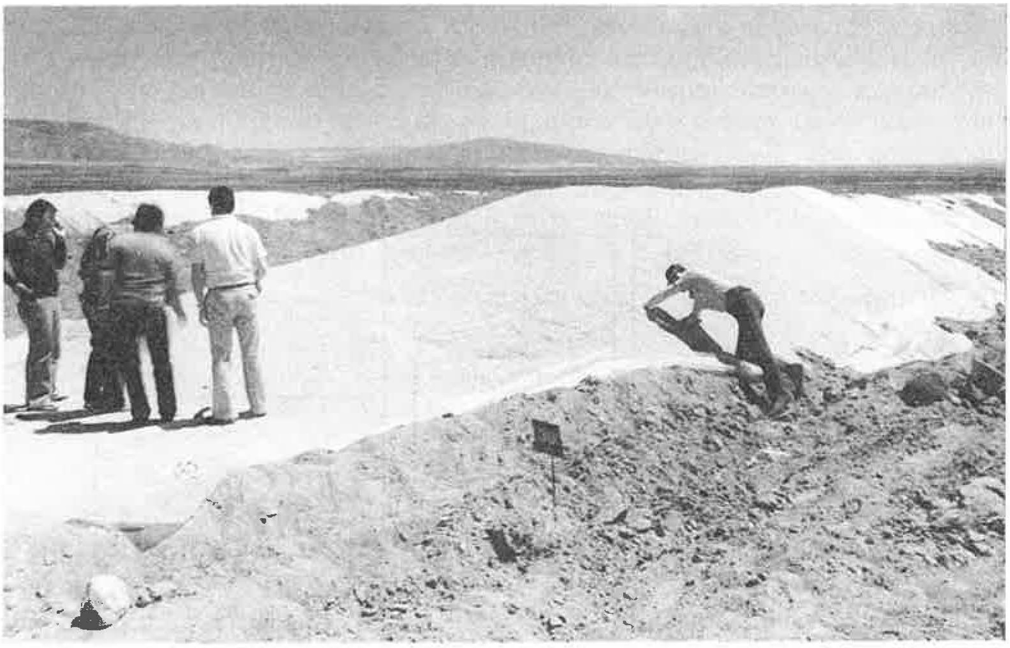
In Turkey, small bunkers or mounds of 600 tonne capacity are employed when silos and buildings are full (*see* Plate 5). These can be regarded as temporary or bumper crop stores. The features required of the site are:

- the site should have a low water table;
- the site should slope between 1% and 5%;
- the soil should be well-drained sandy loam, but with sufficient clay to enable soil to cover bunkers;
- the site should be on sufficiently high ground to prevent water accumulating on it;
- the site should be clear of flash floods;
- the site should not be on filled land;
- the site should be well away from nearby building drains, etc.;
- the site should be protected from strong winds.

There are several types of bunker in use. Tarpaulin-covered bunkers are used only for short periods, just for cereals and only when it is not possible to cover with soil. Soil- and straw-covered bunkers use about 40-50 kg of straw per tonne of grain. Straw is laid 200-300 mm thick over the grain pile (see below) and then covered with soil. After rain this is checked and maintained. Polyethylene- and earth-covered bunkers are prepared by rolling stubble flat or by scraping off grass and vegetation on measured strips. Shallow drainage ditches are ploughed between them. A polyethylene ground sheet 250 microns thick measuring 70 m × 8 m is unrolled down the straw covered strip as grain from delivery trailers is shovelled off onto the polyethylene (*see* Figure 1). A similar polyethylene cover is laid transversely over the heaped grain in sections with a 1 m overlap formed to shed water 'downhill'. To close the bunker as filling proceeds the sides of the groundsheet are folded under

Plate 5

Loading small bunker, Turkey, 1987



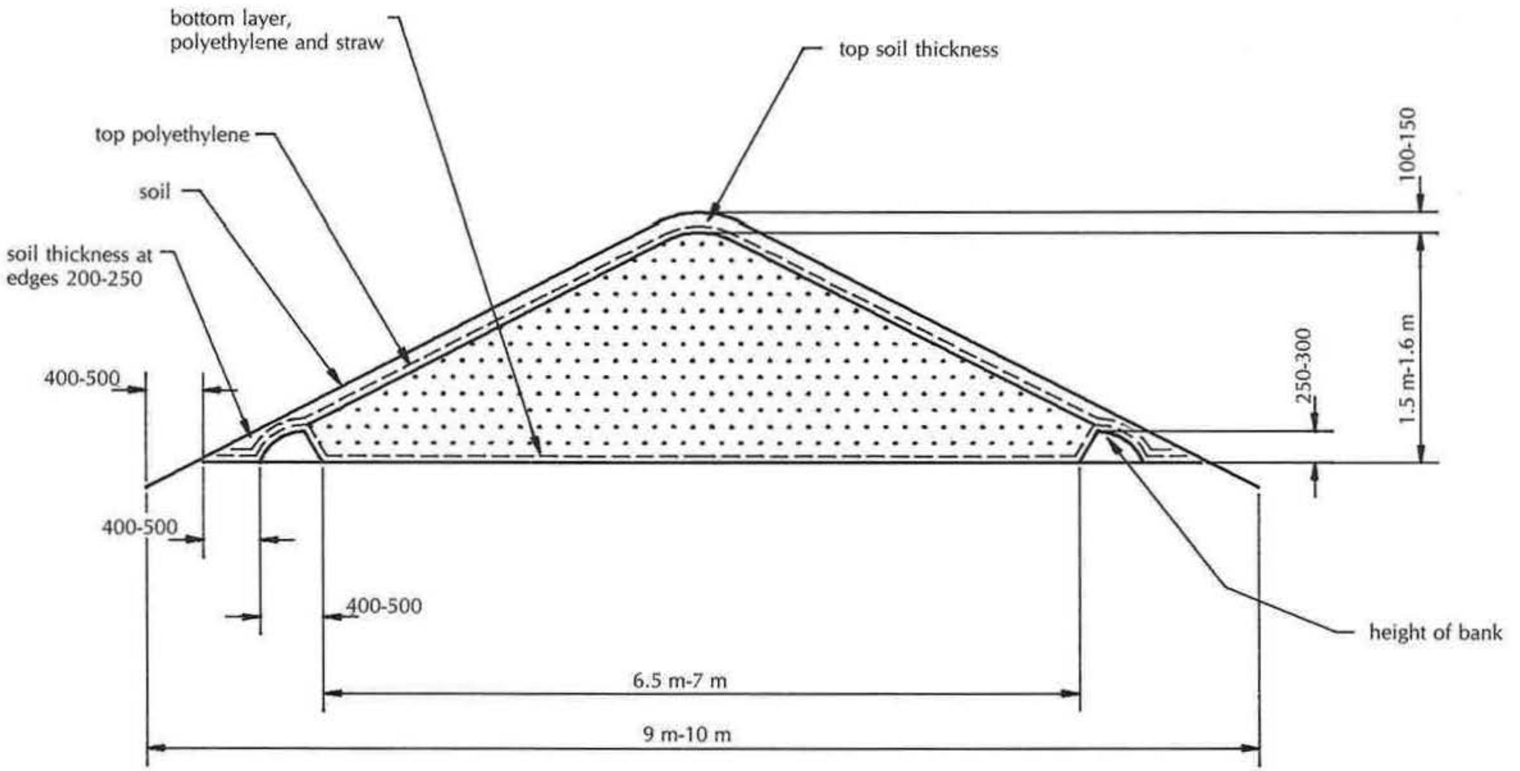
Note top sheet in distance, ground sheet in foreground *Crown copyright*

the cover sheet and held down with clods. Loose soil is shovelled overall, thinly at first, to prevent wind flapping the cover sheet, and later to a soil depth of 10 cm at the ridge, thicker at the toe. The maximum grain moisture allowed at intake is 13%. No matter what the covering material is, all types of bunker are inspected frequently, but not in rainy weather. Grain samples to detect any deterioration are extracted every fortnight during the storage season by carefully spear-sampling along transverse joints at the ridge.

Out-loading is by auger direct into trailers or trucks; difficulties with vehicles bogging down in wet soil have been experienced but overcome with the help of tractors. The cover sheets have no adhesive or stitching at the overlap and some losses – less than 1% over 12 months – caused by water penetration can occur, but no damage from condensation is experienced, even though grain moisture content is greater than 12%, because the soil cover insulates the surface grain. Fumigation with phosphine tablets is routine, although a cold winter also helps control pests. Polyethylene sheeting deteriorates with exposure and is renewed annually. Security fences and watchmen are supplied. The total capital cost is low, in the region of US$ 4/tonne at 1986 prices including land preparation, but the system relies on careful management with regular inspection. Operating costs are probably higher than conventional silo/ horizontal storage costs (Gracey, 1988). In Zimbabwe, 5,000-tonne capacity bunkers are being tested for the first time in Africa. In 1985 the Grain Marketing Board was faced with the task of storing 250,000 tonnes of maize surplus to available silo capacity. The problem was exacerbated by a steep rise in the cost of imported jute sacks which made sheeted bag stacks – the main method of crop storage – more costly. The bunkers tested have an earth floor and earth walls (sometimes substituted by maize-filled bags) which are covered with polyethylene sheet before filling with (bulk) maize mechanically. The heaped bunker is then covered with bituminized tarpaulins which overlap. Mechanical loading and unloading is being tested with combinations of tipper trucks, pneumatic conveyors and fore-end-loaders. So far, compared with the rate of loading/unloading the traditional sheeted bag stacks using a labour gang supported by a bag elevator, loading/unloading the bunker takes slightly longer. This endangers stock in rainy weather and has contributed to the most

Figure 1

Small-scale bunker, Turkey



Section, polyethylene and soil-covered bunker

All dimensions in mm unless stated

serious problem encountered. This is wetting of stock, mainly from rain penetration at the tarpaulin overlap, but also from condensation with cold diurnal temperatures. Combined with sweating of stock under black tarpaulins in hot weather these factors caused stackburn and concomitant grain spoilage and adulteration despite frequent removal of the covers to provide aeration. This poses the question of whether a single light-coloured PVC instead of bituminized tarpaulins would eliminate mould/moisture damage to grain or whether the combination of moisture and appreciable oxygen levels under the PVC would cause damage like that encountered in Israel. The additional insulation of straw-filled sacks or insulation blanket used in flexible silos may be compulsory if moisture migration is to be ameliorated. This harks back to the original concept of earth cover.

Annual costs/tonne for bunker versus bag stack storage are shown in Table 5 (Caley, 1988).

Table 5

Comparison of annual operating costs for bunker with bagstack stores in US$/tonne in Zimbabwe

Bag stack with elevator	11.64
Bunker	
with bituminized tarpaulin	8.12
with PVC cover	5.99

Source: Caley (1988)

These costs include a figure for a bunker with PVC cover. Bunker handling costs are low because it is assumed that pneumatic conveyors, etc. can be fully utilized when not employed at the bunker. Capital costs for bunker storage are comparable to bagstack costs when sack costs are included in the latter.

DISCUSSION

The bumper crop storage systems described provide alternatives to traditional systems: bag warehouses are replaced by flexible silos or cover and plinth and for bulk grain, aerated concrete/steel silos are replaced by various types of bunker. The bumper crop stores are usually uniquely suitable for one location; what works in Turkey may not be suitable for Zimbabwe and vice versa. (Most of the systems described were managed by marketing boards but could equally well be privately managed). Where choice of site with history of rodent activity is unavoidable, anti-rodent measures are essential.

Bumper storage methods should not be evaluated in isolation because they are part of an existing marketing system whether they are in bag or in bulk. The latter is usually more capital intensive and requires a technically skilled type of management, while bag storage requires constant but relatively unskilled attention. Analysis of bumper storage systems raises questions for management.

- Can local skills and resources be mobilized as in Burma and India? These resources are often quicker to procure locally and also save foreign exchange. If local resources are inadequate, flexible silos provide a tested alternative for bag storage.
- If, as in Zimbabwe, bags must be imported, are bunker stores practical, economic alternatives to bag storage?

- If bunkers are economic, what aeration/moisture management will they require? Mechanical aeration is needed for bunkers in parts of the United States when moisture content is more than 12%. This question of moisture management requires immediate research and development if grain losses and connected delays in removing damaged grain are to be avoided.
- If bunker storage is adopted, has the agency the necessary engineering expertise to manufacture solutions to local problems like the Australian 'Lobstar'? Total dependence on outside skills complicates maintenance and prevents innovation.
- Bulk storage may be adopted because of a coincidence of circumstances. In Zimbabwe there was need for reserve stocks in a year which simultaneously produced a bumper harvest and in which bag prices doubled. In these circumstances a sense of urgency may dominate evaluation. For example annual costs may be calculated and employed for evaluation purposes, but bumper storage may occur infrequently and use of capital costs may be more appropriate because the store is employed for only one season. Morley (1988) has recognized this point and has advocated the hire of tarpaulins rather than purchase where possible (see below).
- When the need for bumper crop storage is intermittent there remains the problem of caring for the equipment and sheeting when it is unused and therefore vulnerable to damage (O'Dowd and Kenneford, 1983). It has been suggested that hiring tarpaulins weekly, where practicable, ensures their quick return and low wear and tear (Morley, 1988).
- When bumper storage is intermittent, purchase of high capital cost handling and bulk transport equipment may be uneconomic. If therefore a bag handling system is considered, is sufficient labour available? Alternatively if bunker/bulk storage is adopted will the decision to handle in bulk rather than in bag cause problems locally?

In an attempt to resolve some of these questions and provide a guide to bumper store selection a performance profile may be used. The performance profile is a concept derived from a management interview technique (Ansty, 1987). In this instance the profile is divided into three parts covering different sectors of performance.

1. **Resources**, capital costs, management and local resources.
2. **Operations** include five standard operations as a guide; these can include relocation, and speed of procurement can include speed of obtaining sacks.
3. **Quality control** includes ease/effectiveness of pest control, aeration and inspection required. In addition, ease of storm proofing is included because this embraces features such as the likelihood of strong winds and storms bringing rain into contact with the grain.

Management specify the level of resources, the ease of operations and the degree of quality control required. This step requires mangement to have detailed knowledge of local requirements. For example, a local requirement might be for a system with average (medium) cost, below average technical management, ample local labour (resource), fast loading, good pest control, but below average storm proofing (*see* Figure 2). When these have been pencilled in, the characteristics of the alternative systems are marked with hatching over the requirement profile, when they can be compared. In Figure 3, CAP storage has lower capital cost/tonne, lower management demands than required but uses local resources (labour and materials). All operations are more than up to requirement but CAP is under requirements for pest control, aeration, inspection and storm proofing. Flexible silos (*see* Figure 4) cost more, demand more technical management than CAP, but use fewer local resources. They are easier to site/erect than required, though slower to load than required.

Figure 2

Field performance profile local requirement

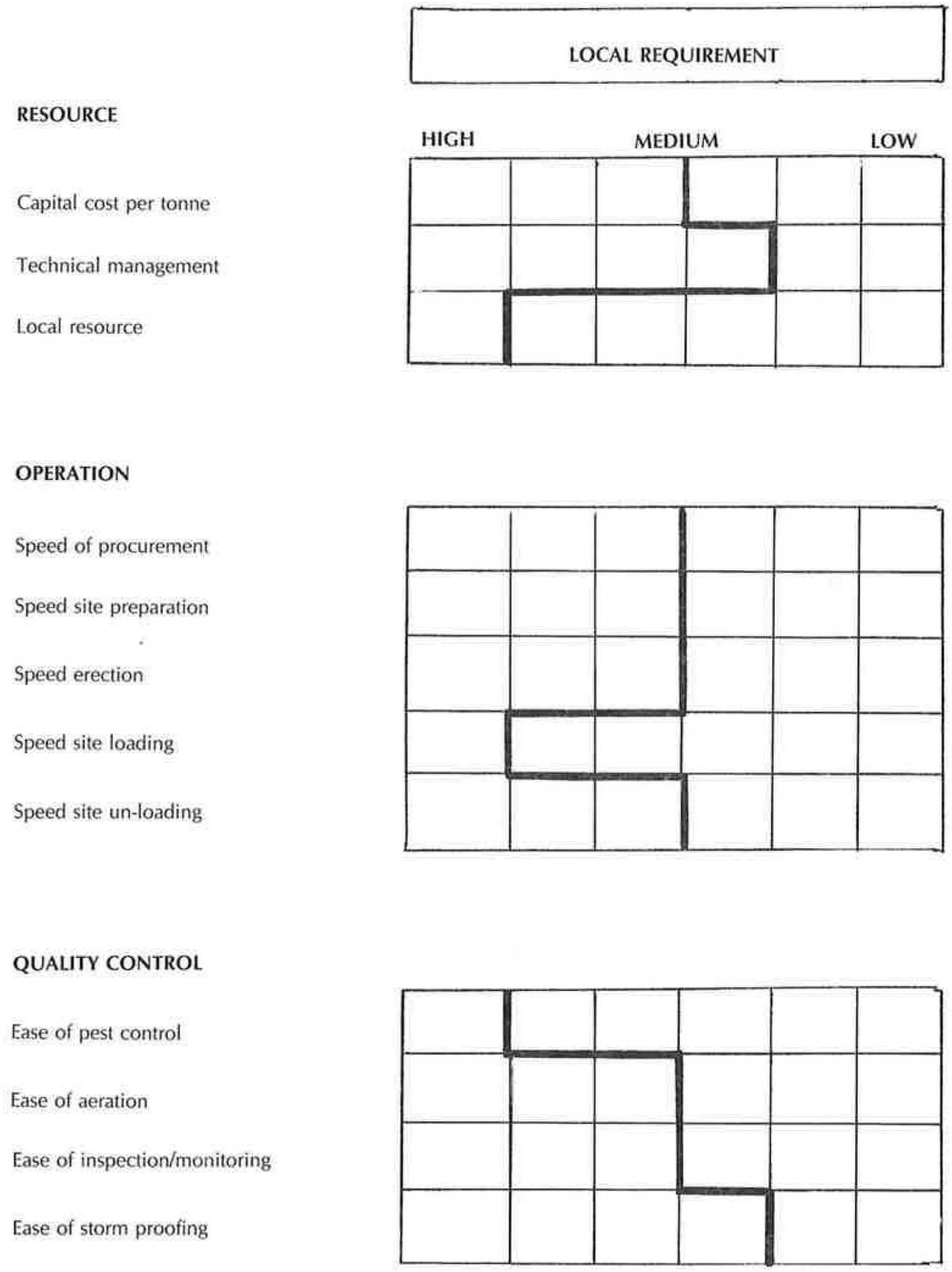


Figure 3

Field performance profile, cover and plinth storage

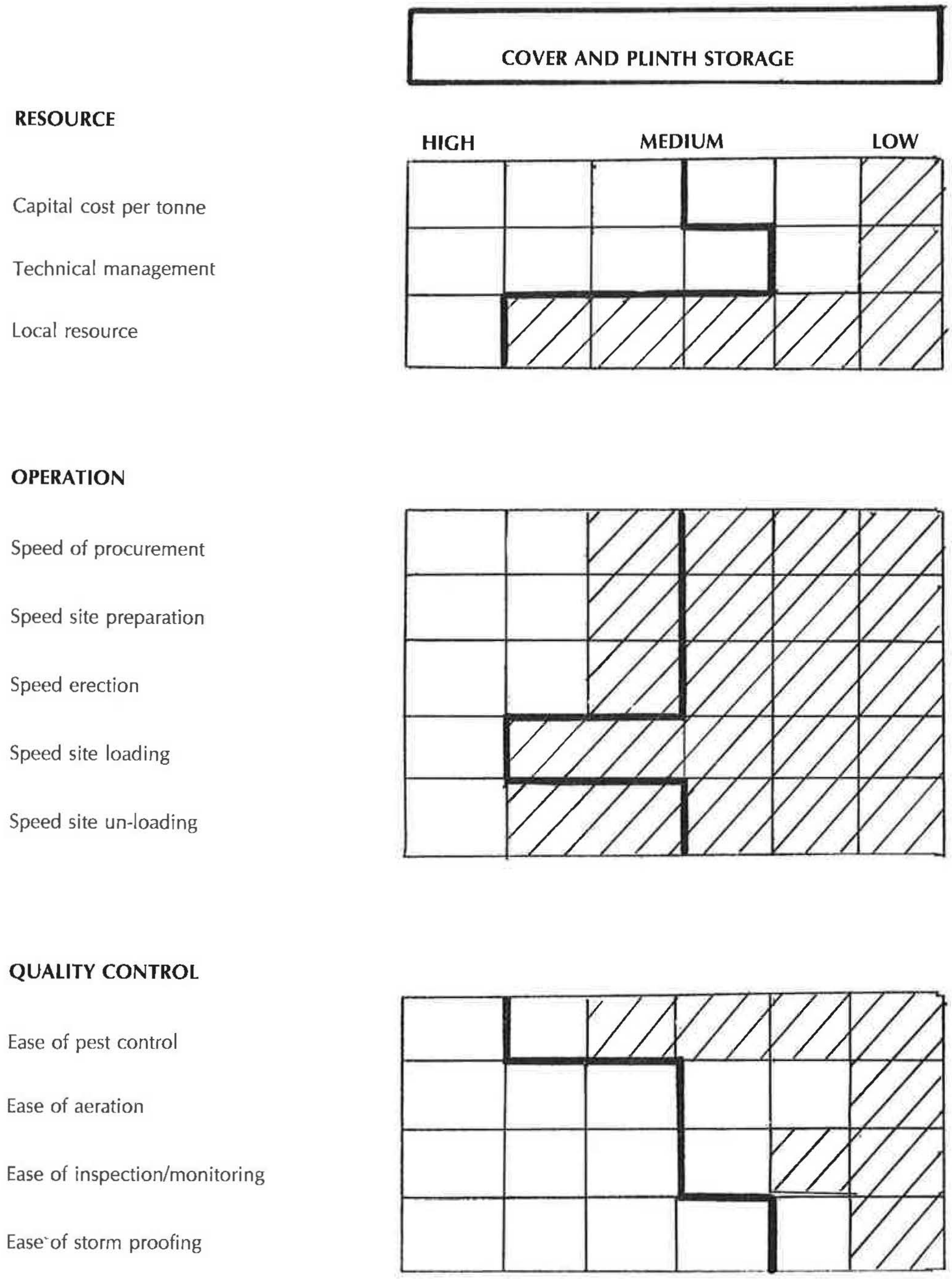
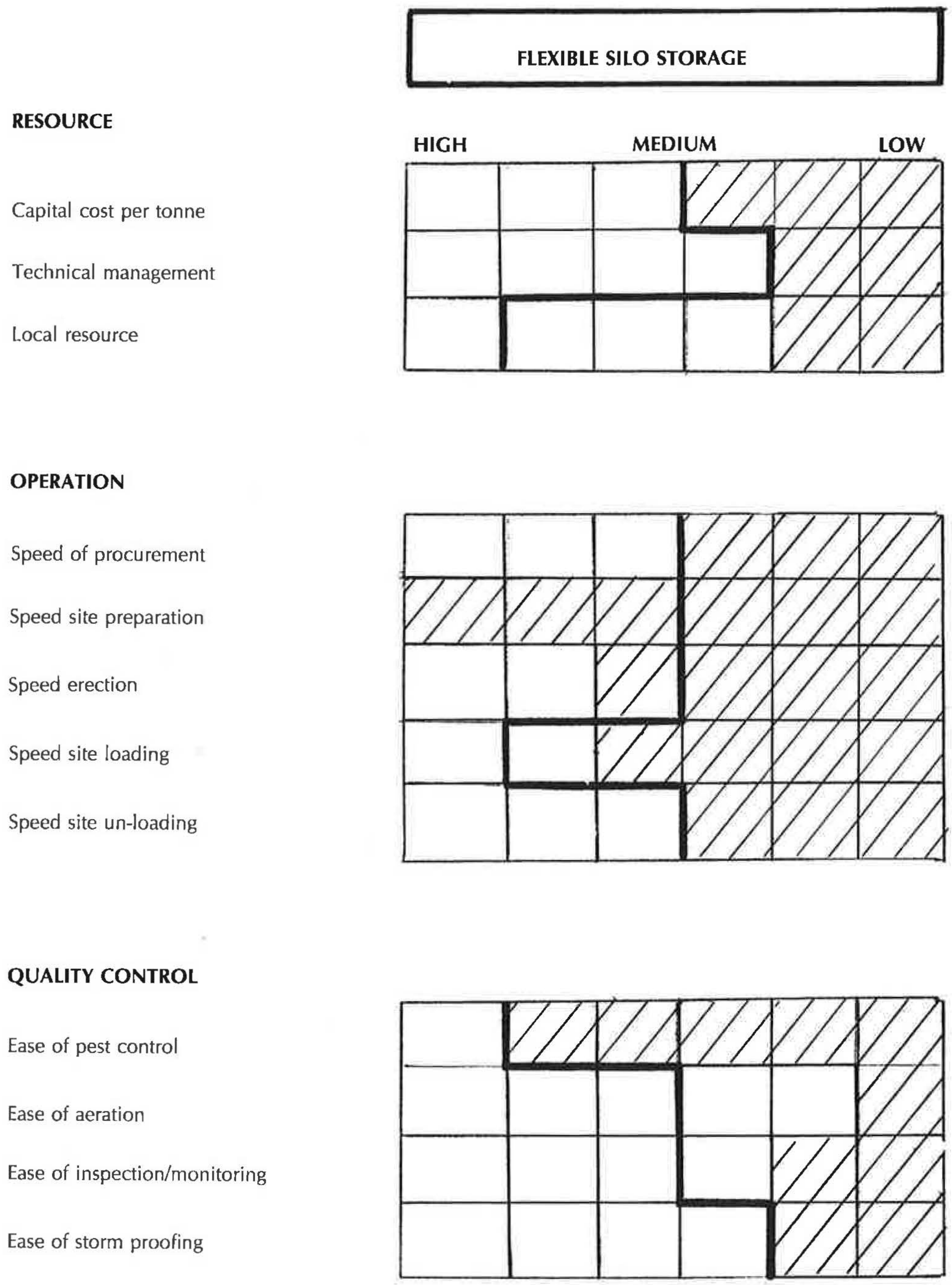


Figure 4

Field performance profile, flexible silo storage



The silos are superior on pest control and are more storm proof, but are below requirements on aeration and inspection.

The field performance profile enables any number of relevant factors to be considered. Final choice could be assisted with cost-benefit analysis and depends on the local priorities. In this example, where cost is not limiting, flexible silos have the edge with more effective pest control, but both systems have aeration problems. The profile is a searching technique which is deliberately qualitative rather than quantitative, and seeks to reveal qualitative aspects in system comparison which will then have quantitative effects in cost-benefit analysis. It requires a sound assessment of the attributes of a system and is therefore best applied with established techniques.

CONCLUSION

Proven techniques for bumper crop storage include bag and bulk systems. Traditional systems for bulk grain include above-ground storage in Burma, using baskets for handling, and underground pits in Sudan. Bunker storage (for bulk) has been developed in a number of countries. Bagged grain can be stored under tarpaulins on plinths (CAP) or in flexible silos. All bumper crop storage systems are more vulnerable to damage and therefore require more careful management than conventional system.

Field performance profiles can be helpful in system selection for established techniques as a qualitative adjunct to cost-benefit analysis.

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Appendix

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