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NATURAL RESOURCES INSTITUTE

Farmer Coping Strategies against the Larger Grain Borer in East Africa

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INTRODUCTION TO THE REPORT

The Larger Grain Borer (LGB), *Prostephanus truncatus* (Horn), was first reported in Africa in 1981 (Dunstan and Magazini, 1981). The beetle, a severe pest of farm-stored maize and dried cassava was initially a major problem to farmers in western Tanzania. The devastation caused by the beetle was sufficient to induce those suffering its ravages to make a 1,000 km journey to Dar Es Salaam to pressurise the Government of Tanzania into taking action to counteract the problem. Thereafter, more than £10 million has been expended by various donors on research and control of this pest. By 1983 LGB had become established in the Taveta district of Kenya, in an area bordering the infested Kilimanjaro Region of Tanzania.

During the first decade after its initial establishment in Africa a very effective method was developed for its control. This involved the treatment of maize with a mixture of synthetic insecticides and although the efficient use of the chemical required a change in traditional storage practices, it became the template of control strategies across Africa.

During the last twenty years, LGB has spread to a number of countries throughout West and East/Central Africa. Research has continued to examine the biology and ecology of the pest and to devise methods of control, which are 'safer' and less environmentally sensitive than conventional chemicals. Workshops and conferences have been held throughout the period to evaluate progress and identify future needs. However, progress has always been regarded as the potential to control the pest rather than as a measure of the farmer's ability to alleviate the pest problem. However, at an East and Central Africa Storage Pest Management Workshop, held in Naivasha, Kenya in 1996 the general synopsis was that there was a need to evaluate how farmers had coped with the LGB problem during the past two decades in order to justify any proposals for further research. Accordingly it was recommended that a study be undertaken to evaluate farmers' reactions to LGB, to identify coping strategies and to ascertain whether the beetle should still be regarded as a major pest of primary importance.

The DFID Crop Post Harvest Programme (CPHP) co-funded the study with the Rockefeller Foundation. In practice, the CPHP funded activities in Tanzania, which were co-ordinated by NRI, and Rockefeller funded activities in Kenya that were co-ordinated by CABI Bioscience. Initially, two training workshops were conducted to introduce staff to the loss assessment and RRA methodology, and to develop the design of the main surveys and questionnaires to be used. Thereafter, three teams conducted interviews with groups and individuals; two teams operated in Tanzania and another in Kenya. Each team spent a minimum of six weeks in the field, the period being extended as a result of adverse weather conditions due to El Ninõ effects. After data collation, a final technical workshop to discuss the results was held in Nairobi.

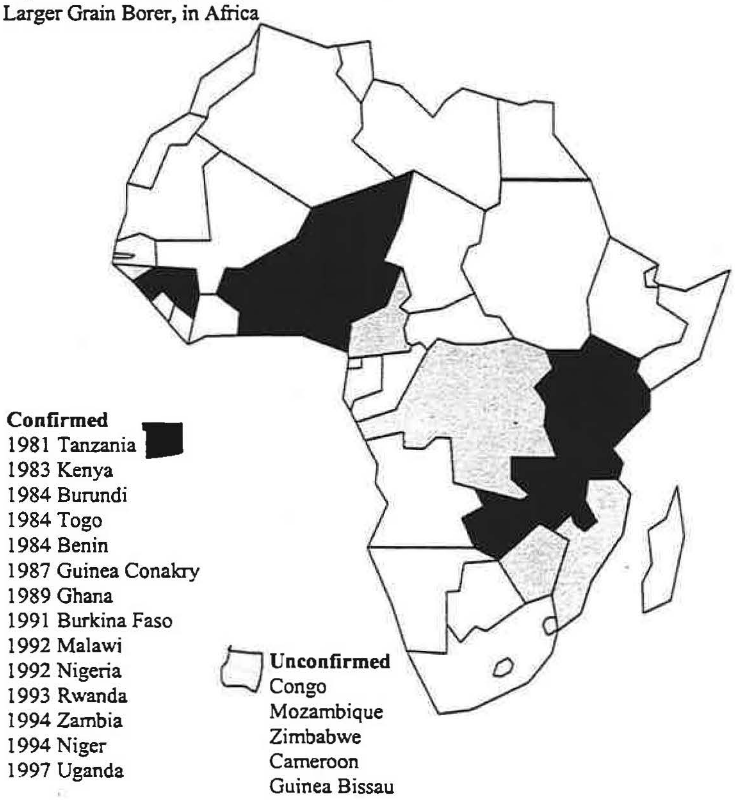
The Tanzanian survey was conducted only in villages that had suffered from LGB infestation. As most villages had experienced problems with this pest the villages, which were selected at random, were representative of the localities from which they were drawn. However, in Kenya the survey was mostly conducted in those areas that had been included in the Maize Database Project (MDP). This project grouped maize production areas into different agroclimatic zones and for the purposes of this study one site in each zone that had been surveyed in the MDP was selected. However, this method of selection eliminated all areas where LGB has been found on farms. Therefore, farmers from LGB-infested areas in Taita Hills and Taita-Taveta were included even though these areas were not part of the MDP.

The following report presents in detail the observations and conclusion gathered from the Tanzania study, a summary of results from the Kenya study and a summary of the conclusions of the final workshop.

I. GENERAL INTRODUCTION

The current African distribution of LGB is shown in figure 1.

Figure 1 Current distribution of *Prostephanus truncatus*(Horn), the Larger Grain Borer, in Africa



P. truncatus is a major pest of stored maize, the primary food staple of most of sub-Saharan Africa. The beetle is able to develop and reproduce in maize and dried cassava and, because of its boring activities, it is capable of damaging a large variety other food commodities, wooden objects and drying timber, and leather. This pest can cause more than twice the weight loss in maize as would be expected from infestation by indigenous insect pests such as *Sitophilus zeamais* (Motsch.) (Dick, 1988).

Estimates of on-farm weight loss of unprotected grain which take into account withdrawals over the course of a storage season are surprisingly elusive in Tanzania. Those estimates which have been made generally overstate the problem because they do not take into account the effect of withdrawals from granaries during the season (e.g. Hodges et. al 1983, Keil 1988, Henkes 1994). The real losses to unprotected maize during the course of a storage season lie somewhere between 10% and 30% by weight, significantly more than the 2-3% which is normally lost as a result of attack by indigenous insect pests (Tyler and Boxall, 1984).

These levels of loss contrast with what occurs when farmers apply protective measures to prevent insect infestation. During a FAO extension and control campaign conducted in western Tanzania between 1984 and 1987 to help farmers cope with *P. truncatus,* losses sustained by 105 farmers in three villages were assessed during a storage season. When food removals for home consumption were taken into account the real food loss over a period of 7-9 months was less than 2% (Golob, 1988). These low levels were the result of farmers taking action to control *P. truncatus* by applying insecticide immediately they saw the beetle in their maize, preventing the build up of pest populations.

There have been no studies on farm losses in stored cassava in Tanzania because the areas of major surplus, Mtwara and Lindi Regions, have only recently become infested with *P. truncatus*. Those localities in East Africa where dried cassava is stored for extended periods would be expected to suffer losses similar to those recorded in Togo where it was found that 25 farmers, in five villages, sustained average cumulative losses of 10% after three months storage, rising to 20% after seven months (Wright *et al.,* 1993) [1].

When Tanzanian farmers first became aware of the magnitude of the problem caused by *P. truncatus* they tried very many procedures to control it, including spreading grain in a thin layer to use the heat from the sun to drive away or kill the beetles, subjecting infested cobs to heat and smoke above the kitchen fire, and spraying cobs with DDT or endosulphan. None of these methods were effective and when it was demonstrated that the pyrethroid, permethrin, would control *P. truncatus* very easily

[1] Studies conducted using experimental cribs shown that weight loss could rise to as much as 70% after four months storage when there were no food removals (Hodges *et al*, 1985).

farmers readily adopted the recommended method of shelling their grain and applying permethrin 0.5% dust to the grain (Golob, 1991). This method (later modified by replacing the insecticide with a cocktail containing permethrin and pirimiphos-methyl) represented a major change to traditional storage practice because maize was normally stored on the cob. In West Africa, farmers were much more reluctant to shell their maize and methods were devised to enable them to treat maize on the cob (Boxall and Compton, 1996), including: sprinkling water based insecticide solutions on to the husk leaves; subjecting the wooden storage platform to intense heat; replacing infested timbers used in the store; raising the temperature of the cobs in the store by covering them with polythene sheeting; and removing any infested cobs, grain or other crop residues. Similar suggestions for treating both cobs and grain were produced in Kenya (Giles *et al.*, 1995) and the application of permethrin sprays to husked cobs in Tanzania was found to be very effective in preventing *P. truncatus* damage as long as the treatments were applied soon after harvest, before the pest becomes established in the maize (Golob and Hanks, 1990).

Biological control of *P. truncatus* by releasing a natural enemy, the histerid beetle *Teretrius nigrescens*, was first attempted in Togo, West Africa (Biliwa *et al.*, 1992) and subsequently in Kenya (Giles *et al.*, 1996). This method does not require intervention by farmers and so its effectiveness is independent of such problems related to misuse of chemicals during application, non-availability of chemicals when most required and incorrect timing of treatments. However, the impact of the predator is not apparent for about five seasons. In those circumstances where farmers have a serious LGB problem, they will continue to use whatever means they can to control the pest, including pesticides. This poses potentially damaging effects on the predator control method as, in some circumstances *Teretrius nigrescens* is more susceptible to the chemicals used to control *P. truncatus* than the pest itself (Golob *et al.*, 1994). *T. nigrescens* has not yet been released in Tanzania though there are plans to do so (it would not be surprising if the beetle had already become established from Kenya). Initial studies on the impact of the predator have concentrated on observing its spread and the effects on loss reduction in experimental maize stores (Borgemeister *et al.*, 1997). It is too soon to evaluate impact on farms.

Despite these alternative strategies, in East Africa in particular, the extension services have concentrated on the simple recommendation of shelling maize, treating it with Actellic Super Dust (ASD) and storing it in an appropriate container such as mud plastered cylindrical woven baskets *(kihenge)*, sacks, metal drums and cylindrical bark containers *(kilindo)* (e.g. Golob, 1991). At the time *P. truncatus* became established in Tanzania, maize was mostly stored for home consumption, on-the-cob and husked. The exception to this occurred in Arusha Region where maize has long been regarded both as a food and cash crop.

There have been no specific recommendations developed to control infestations in stored dry cassava. Farmers have been encouraged to leave their crop in the field as long as possible to circumvent damage during storage.

There has been only one other survey to assess farmers' reaction to this pest. This was conducted during the FAO control campaign between 1986 and 1987 (Golob, 1991), a period when control recommendations were being actively promoted. That survey, in which 3,200 farmers were interviewed each year, found that more than 60% of those who had seen *P. truncatus* carried out the prescribed actions to control the pest, including the application of the recommended insecticide, and that 90% of these obtained good control. There was an indication, however, that farmers were reluctant to take prophylactic action probably because the treatments required major change to traditional methods of storing maize: from storage on-the-cob to storage of shelled grain. Since that time, the extension services in Tanzania have been under severe financial constraint and the effort to promote good storage practice has declined markedly.

II. THE TANZANIA STUDY

METHODS

Sample frame selection and representativeness

The study was conducted in seven districts spread over six regions. In each district, between two and five villages were visited (Table 1).

Table 1. Study villages with district and region locations.

Region	District	Villages
Iringa	Iringa	Kiwere; Mgera; Nzihi; Chamdindi
Rukwa	Mpanda	Songambele; Mnyaki; Ikologo
Morogoro	Kilosa	Rubeho, Msingisi, Ukwmani, Ihenje
Arusha	Babati	Mamire; Chasimba; Singe; Dareda; Riroda
Kilimanjaro	Mwanga	Lembeni; Mwembe.
	Hai	Rundugai; Magadani
Tabora	Tabora Rural	Isikizya; Magiri; Inala; Itonjanda

Note: In Rukwa Region severe local flooding prevented access to many villages and only three could be visited during the survey.

Before 1984, *P. truncatus* was reported on farms throughout Tabora Region and in the trading towns of Shinyanga and Mwanza. Thereafter, the beetle gradually spread

East and South throughout the country until in the mid 1990s it was reported as being established in the last two regions to be infested, Lindi and Mtwara. The occurrence of the beetle has been sporadic from one region to the next. For example, in Tabora, Shinyanga and Mwanza Regions almost all villages have been infested whereas in Iringa, Ruvuma and Mbeya there have been very restricted foci of infestation, mainly concentrated around major towns or trading centres.

In designing the survey, care was taken to visit both types of area: those heavily infested with the pest and those where the infestation has been more sporadic. In addition, whilst some difficulties were experienced in gaining access to certain originally selected districts, the districts actually visited still provide a cross-section of the agro-ecological environments found in Tanzania, with the exception of the most arid zones which occur in Dodoma and Singida Regions. The districts also illustrate the cultural and ethnic diversity across the country.

Profile of Districts selected for the survey

- In **Rukwa**, Mpanda district is the only one that has suffered significant *P. truncatus* in both maize and cassava. The highlands of Sumbawanga district are major producers of maize but this area has not been infested. The lakeshore littoral of this district is much poorer, relatively lightly populated and produces a lot of cassava that has been heavily infested with the beetle in the past. However, access to this area is extremely difficult even under normal weather conditions and was impossible during this survey.

- **Iringa** Region, around Iringa town, has very sporadic, light infestations which intensive control campaigns during the 1980s kept very much under control.

- Kilosa district, close to Ilonga village, was one of two initial focii of *P. truncatus* infestation in **Morogoro Region** (the other being Morogoro town) and the area surveyed is representative of the other infested sections of the region.

- *P. truncatus* first occurred in Africa in **Tabora Region**. By the time the presence of the pest was acknowledged, it had already become established throughout the region. Tabora was the main focus of the initial campaigns to control the pest (see above, Golob,1991). Tabora Rural district is a major tobacco producing area and, climatically, is similar to much of central-west Tanzania. The survey was intended to be carried out in Urambo district but extensive flooding prevented this happening. Urambo is also a tobacco producing area but is more lightly populated than Tabora Rural. The other district that is heavily infested, Nzega, relies on cotton as its cash crop. For all three districts, Tabora is the major commercial and trading centre. Up until the onset of *P. truncatus*, storage practices were fairly uniform throughout the region: maize storage on-the-cob, on a variety of platforms or in cribs, and with an absence of pest control.

- In **Arusha region** the survey was to have been conducted in two adjacent, similar districts, Babati and Hanang, but the latter had to be omitted because of adverse weather conditions. *P. truncatus* has been established in these areas for 15 years. These districts, as well as the other areas in the region that are infested such as southern Arumeru, are semi-arid and support a significant population of pastoralists, Maasai and Barabaig.

- There are three districts in **Kilimanjaro Region**, Hai and Mwanga are close to Mt Kilimanjaro and experience high rainfall, and Same district. Hai and Mwanga were chosen for the survey as they have experienced significantly higher levels of infestation compared to Same.

Village selection and methods

Villages were chosen on the basis of known *P. truncatus* infestation. Each survey team of four enumerators spent two days in each village. In each village, rapid rural appraisal (RRA) techniques were used to understand farmers' perceptions of post-harvest problems, within a more general context of livelihood and food security strategies. This was complemented by a market trader's checklist and a sample survey administered to 390 individual farmers (between 47-79 farmers per district). Sample survey questions focused on both maize and dried cassava production, storage and sale. One of the key areas was an investigation of the impact of *P. truncatus* on production, storage and marketing outcomes, and the impact of extension messages on how to deal with the pest. This was assessed by comparing the situation today with the situation at the time when *P. truncatus* first became established in villages (around 15 years ago).

FOCUS OF THE STUDY

Objectives:

(i) To assess the role played by *P. truncatus* in determining changes in production, storage and marketing of the maize and cassava crop during the period between the time of the establishment of the beetle (mid to late 1980's) and today.

(ii) To assess the factors determining the role played by *P. truncatus* in these stages of the maize and cassava commodity systems, in particular the impact of insecticide treatment.

Hypotheses:

(a) The role of crop production in household food security strategies has reduced during the period between the establishment of *P. truncatus* and today.

(b) Farmers feel that the role of maize and cassava in household food security has reduced during the period between the establishment of *P. truncatus* and today.

(c) Quantity of maize and cassava harvested has decreased, and farmers' perceptions of the importance of these crops has fallen because *P. truncatus* is forcing farmers to switch out of the crop.

(d) Uptake of hybrid maize varieties has been adversely affected due to increased susceptibility of these varieties to *P. truncatus* in comparison with traditional varieties.

(e) The length of time that maize and dried cassava is stored has fallen, as farmers sell early to avoid *P. truncatus* damage.

(f) *P. truncatus* represents a major problem for farmers and they are unable to cope with it.

(g) Owing to problems with insecticides and sacks, the problems caused by *P. truncatus* are likely to increase in future.

RESULTS AND DISCUSSION

Role of Crop Production in Household Food Security Strategies

In each village visited, farmer groups were asked to rank household food security strategies in order of importance. This was done in order to place the importance of *P. truncatus* damage to maize and cassava in context. If it was clear that crop production was much less important in certain areas than 15 years ago, then this would clearly have an implication for the impact of *P. truncatus* on food security and level of well-being: i.e. *P. truncatus* would be relatively much less important than 15 years ago.

Farmers came up with several categories, which have been grouped for the purposes of analysis. The groups are as shown in figure 2 : crop production; livestock; trading activities; unskilled income generating activities (IGAs) and skilled IGAs. The figure indicates that there have been no major changes in livelihood strategies at an aggregated level (i.e. all 24 villages taken together). At the district level, the picture is much the same: whilst in some areas, off-farm IGAs have become more important (e.g. in the Morogoro villages), crop production remains the most important livelihood activity, followed by livestock in almost every case. In the light of this, hypothesis (a) is rejected: on the evidence collected it looks like crop production is no less important to household food security than it was 15 years ago.

Farmers perceptions of importance of maize and cassava.

Whilst crop production in general may be as important to household food security as it was in the past, what of the importance of maize and cassava within this? Has the importance of these crops decreased? If it has, then this is an *a priori* indication that the potential impact of *P. truncatus* on livelihoods will have fallen. In order to investigate this, farmer groups were asked to rank the importance of these crops relative to other crops and to compare these rankings with the situation 15 years ago. Figures 3(a) and 3(b) present the results on a region by region basis.

Figure 3(a) indicates that only a very small proportion of the groups (one group each in Iringa and Morogoro) felt that maize had fallen in importance. Figure 3(b) indicates that the picture is quite different for cassava. Here, out of a total of 47 farmer groups interviewed, 13 stated that cassava had decreased in importance and 11 felt that it had increased. Of the districts surveyed, cassava has only ever been important in Tabora Rural and Mpanda (Rukwa).

In the light of these findings, hypothesis (b) is also rejected: on the evidence collected it appears that both maize and cassava – in those areas where this has historically been an important food security crop - are as important to household food security as they were 15 years ago.

Influence of *P. truncatus* on Production, Storage and Marketing Outcomes

Context:

The period since *P. truncatus* became established in Tanzania has seen major changes in the provision of agricultural services. Since agricultural market liberalisation was introduced, government subsidies for agricultural inputs have been removed and insecticides, including ASD, have risen in price. In addition, the reduced role of government control over agricultural marketing has placed increased emphasis on the quality of on-farm storage of grains (Tyler and Bennet, 1993) [2]. During the 1990s, production of maize has been particularly influenced by adverse climatic conditions,

[2] The key point here is the loss of the guaranteed market for grain surplus shortly after harvest due to the closure of rural primary buying points, which had previously relieved the producer of storage and quality maintenance problems (Tyler and Bennet, 1993). One of the implications of such changes is that methods of conserving grain safely on the farm take on a new importance.

mostly drought. The impact of *P. truncatus* on the maize commodity system in Tanzania has been conditioned by these factors.

Production levels:

Farmers interviewed individually were asked to give estimates of maize production in recent years in both "normal" years (i.e. when the crop was not affected by drought) and in years when rainfall has been lacking (figures 4a and b). In drought years almost all of this maize is stored for home consumption (figure 5b). Not surprisingly, in "normal" years a greater proportion of maize is sold immediately after harvest. At the district level, in Babati district (Arusha) the mean number of bags sold immediately was estimated to be over 40% of grain harvested. In villages in the other districts the mean proportion of sales to stored grain is lower, though hybrid sales appear to be equal to upwards of 40% of hybrid volumes in the Kilimanjaro, Morogoro and Iringa districts (figure 6a).

Only in the Tabora and Rukwa districts did more than 12 farmers from the sample cultivate cassava (figure 7). Although cassava is generally regarded as a drought resistant crop, during drought years production decreases significantly (figure 8a). In Tabora Rural, equal quantities are both stored and sold in "normal" years but in drought years it is mostly retained for home consumption (figures 8b and 8c). In Mpanda district in Rukwa, cassava is only produced for home use whatever the quantity produced.

Role of P. truncatus in maize and cassava harvests

In villages in Mpanda district (Rukwa) and Kilosa district (Morogoro), very high percentages of farmers stated that there had been a significant reduction in the quantity of maize harvested, however, this has *not* been induced by *P. truncatus*. Indeed, very few farmers in any of the districts visited mentioned that production had been influenced by the pest (figure 9). Most farmers interviewed said either that there had been no change in quantity of maize harvested in comparison to 15 years ago (Arusha, Kilimanjaro, Tabora) or that harvest had reduced but this had been due to factors other than *P. truncatus* (Morogoro and Rukwa). In Iringa district, the picture was more complicated with roughly 40% of farmers saying that there had been no change, 30% saying that there had been a decrease (not due to *P. truncatus*) and the remainder stating that there had been an increase.

In Tabora Rural, 70% of farmers said their cassava production had not changed since *P. truncatus* was first introduced (figure 10). However, in Mpanda more than three quarters of farmers had decreased production during this period, primarily because of a decline in soil fertility (44%) but also because of perceived damage by insects (17%)

(in this example 'insects' probably includes damage by other pests and diseases, particularly CMV).

Role of P. truncatus in the choice of maize and cassava varieties

The majority of farmers are currently cultivating the same maize varieties now as they were 15 years ago (figure 11). Those farmers who are using different varieties, especially in Morogoro, are doing so because improved varieties have become available. There are now several international seed companies developing and distributing maize seed in Tanzania, whereas before 1990 seed was only available through the Tanzanian Seed Company, a parastatal organisation. New varieties, particularly hybrids, have been developed especially for the high potential areas of the Southern Highlands (Iringa, Rukwa, Mbeya and Ruvuma Regions) and Arusha, though opportunistic farmers in other areas, where rainfall is adequate, also cultivate them as a cash crop. HYVs are more susceptible to insects, including *P. truncatus* during storage, but this has not induced farmers to change varieties except in Kilimanjaro.

Most farmers in the Tabora and Rukwa districts, the main cassava producing areas within this survey, have not changed varieties (figure 12a). The minority of farmers who have changed varieties have done so for reasons other than pest damage. Farmers in Tabora Rural cultivate more sweet cassava varieties - which are just boiled before cooking, whereas in Mpanda more bitter varieties - which have to be fermented before cooking, are grown (figure 12b).

Role of P. truncatus in duration of storage and volume of sales at farm level

Figures 13(a) and (b) indicate the length of time after harvest that farmers have maize in storage on farm. Looking across all districts, figure 13(b) shows that farmers exhaust stocks of maize between 8 and 10 months after harvest in a "normal" year. In a drought year this reduces to between 5 and 6 months.

Figure 14 shows that at least 50% of farmers stated that there had been no change in the duration of maize storage in comparison with the time of *P. truncatus* establishment. In Babati (Arusha) and Iringa districts, 80% of farmers stated "no change", in Mwanga and Hai taken together (Kilimanjaro), 65%, and in the remainder, around 50%. In Kilosa (Morogoro) and Mpanda (Rukwa), 30 - 40% of farmers stated that there had been a decrease due to non-*P. truncatus* reasons (most commonly a reduction in production). It was only really in the Tabora and Kilimanjaro that a significant minority of farmers attempted to avoid the effects of *P. truncatus* by reducing storage and so curtailing the potential period of exposure of maize to the pest: 25% of farmers in Tabora rural and 15% of farmers in Hai and Babati had taken such action. Unsurprisingly, also in these districts some farmers had increased the quantity of maize sold due to *P. truncatus* (figure 15). Lower percentages of farmers in other districts had also taken this action (less than 10%).

The average duration of storage for cassava is less than one month, very few farmers store for longer (figure 16a,b). Most farmers have not changed the duration of storage except in Tabora Rural (figure 17). In the Tabora villages, 25% of farmers interviewed said the period had been reduced because of the presence of *P. truncatus*.

Summary

In all the villages surveyed, *P. truncatus* has had no real impact on maize production outcomes at farm level. Impact on storage and marketing outcomes has been more evident, but even here behavioural change has been restricted to a minority of farmers in the three districts in Tabora and Kilimanjaro.

Cassava production has been relatively low during the period under question and *P. truncatus* appears to have had no impact on production levels. As is the case for maize, there has been some impact on storage and marketing outcomes for a minority of farmers: a quarter of the farmers interviewed in Tabora rural have reduced the duration of storage - although this is usually short (less than one month) in any case.

Taking all districts together, then, hypotheses (c), (d) and (e) are unsupported by the survey evidence. This poses the question: do farmers actually regard the pest as a major problem, and if so, are they able to deal with it (hypothesis f)?

Is P. truncatus Still Regarded as a Problem?

P. truncatus in the context of major agricultural problems

In order to put the importance of *P. truncatus* in context, farmers in groups were asked to rank the main agricultural problems they faced, comparing the current situation to that when *P. truncatus* first became established. Figure 18 presents the results.

Figure 19 indicates that at the aggregate level (i.e. all districts taken together) the number of times that a specific mention of *P. truncatus* was ranked first [most important] is considerably lower for the present time than for the time of *P. truncatus* establishment. In fact, the position of *P. truncatus* as the first ranked problem fell in all districts except those in Kilimanjaro - where it remained high and Morogoro - where it remained low. At the same time, the number of times that *P. truncatus* was ranked as second or third most important agricultural problem has risen somewhat, so that the number of times that *P. truncatus* has been ranked as one of the top three most important agricultural problems has reduced only modestly. In comparison to other agricultural problems however, the importance of *P. truncatus* (as measured by the number of "top three" rank scores) has reduced considerably when compared to 15 years ago.

P. truncatus in the context of other storage problems

Taking all villages together, farmers perceive *P. truncatus* to be almost as important a problem today as when the pest first became established. Figure 19 illustrates this by showing the number of times that *P. truncatus* is ranked first second or third most important storage problem today by farmer groups, and comparing this with the ranks for time of establishment.

Disaggregating, Figures 20 and 21 show the importance of *P. truncatus* in surveyed districts. Figure 21 shows that at least 50% of farmers in districts surveyed still regard *P. truncatus*, as being the main storage problem for maize stored for own consumption - and in Tabora and Kilimanjaro the figures are much higher: 85% and 92% respectively. In relation to cassava, *P. truncatus* is the main storage problem for more than 60% of farmers in the two main producing districts surveyed (figure 22) and in Kilimanjaro districts.

It thus appears that P. truncatus is perceived as a major problem in relation to stored maize and dried cassava (hypothesis f). The next question is: to what extent are farmers dealing with the pest?

Coping Strategies for P. truncatus

ASD is regarded as the main method of protecting maize during storage in all districts surveyed except for Kilosa (figure 23), where less than half the farmers use this chemical through choice. In fact, it is known that many in Morogoro region spray diluted Actellic emulsifiable concentrate. This chemical is similar to ASD but it does not contain the pyrethroid component, permethrin. Although *P. truncatus* is particularly susceptible to permethrin it will also succumb to Actellic (pirimiphos-methyl) particularly during the first months after grain is treated. In Morogoro there has been a decline in the duration of storage (figure 14) and it is likely that application of Actellic alone will be sufficient to provide protection against insect pests, including *P. truncatus*. Other chemicals are used as storage protectants particularly where there is a need to apply insecticide to cash crops such as cotton and tobacco during the production period. These chemicals are often very cheap or even provided free by companies buying the harvested product. However, the chemicals, which include thiodan and DDT, are, without exception, all far too toxic to apply to grain which is to be consumed. Some farmers still subject their maize to heat and smoke by placing cobs in layers or heaps above the kitchen fire. This is an established traditional practice which is effective in controlling most storage pests but has very limited effect against *P. truncatus*. Other traditional methods are also still used, including mixing maize with leaves of various plants such as tobacco, applying ash from the kitchen fire or from burnt animal dung. None of these methods effectively controls *P. truncatus* by itself.

Actellic Super Dust (ASD) perceptions

Whilst ASD is used widely, several farmers expressed concerns about cost, availability and quality.

Efficacy

In discussions with farmers it became clear that concerns about the efficacy of ASD were not uncommon. To some extent, this is due to improper application, either by reducing the dosage or by treating maize on-the-cob rather than grain. There is also, however, a real problem in some areas with adulteration. Furthermore, in Kilimanjaro much of the ASD has, in recent years, been imported from Kenya. Kenyan ASD is formulated on a locally-available filler, which has led to the Actellic component of ASD being degraded rapidly causing it to be ineffective against all insect pests other than *P. truncatus.*

Table 1. Farmers' perceptions of the efficacy of Actellic Super Dust*

	Total number of farmers using ASD	**% of farmers saying that ASD is effective**	**% of farmers saying ASD is not effective against *P. truncatus* but effective against other insects**	**% of farmers saying that ASD is not effective against *P. truncatus* or other insects**
Tabora	46	70%	6%	24%
Kilimanjaro	53	63%	15%	22%
Arusha	73	71%	2%	27%
Rukwa	30	74%	2%	24%
Morogoro	24	54%	2%	44%
Iringa	56	82%	0	18%

Cost

When asked to list strengths and weaknesses of the methods used to control *P. truncatus* all farmers in the southern districts (Rukwa, Morogoro and Iringa) believed ASD was too expensive. Feelings were not as strong in the northern districts though the majority of those farmers who responded to the question also felt ASD was too expensive. To some extent the difference in response between the two groups may have been due to the emphasis in the way the question was posed by the two teams of enumerators. It is undeniable that the cost of ASD has risen substantially since price controls were lifted. In 1987/88 100g of ASD was retailing at 60 shillings whilst farmers were able to realise 3000 shillings for 100kgs of maize, a ratio of 1 to 50. In October 1998, the respective prices are 750 shillings plus and 13,000 shillings, a ratio of 1 to 17.

Table 2. Farmers perceptions of the cost of using Actellic Super Dust*

	Total number of farmers using ASD	Number that say method is cheap	Number that say method is expensive	Number with no expressed opinion on cost
Tabora	46	8 (17)	25 (54)	13(29)
Kilimanjaro	53	10 (19)	26 (49)	17(32)
Arusha	73	25 (34)	29 (40)	19(26)
Rukwa	30	0 (0)	28 (93)	2(5)
Morogoro	24	0 (0)	19 (79)	5(21)
Iringa	56	0 (0)	54 (96)	2(4)

Note: Figures in parentheses denote the percentage of total farmers

Availability

Although only a small proportion of farmers considered the availability of ASD as a criterion for assessing the strength or weakness of the method of insecticide use, of those who did more than half believed it was not readily available. It has always been difficult to get ASD, the degree of difficulty increases the further from Dar Es Salaam and the more remote the village (Golob, 1988). However, the data set is too small to make further assumptions regarding farmers' perceptions.

Table 3. Farmers' perceptions of the availability of Actellic Super Dust

	Total number of farmers using ASD	Number that say ASD is available	Number that say ASD is not available	Number with no expressed opinion on availability
Tabora	46	4 (9)	2 (4)	40(87)
Kilimanjaro	53	4 (8)	5 (9)	44(83)
Arusha	73	12 (16)	10 (14)	51(70)
Rukwa	30	6 (20)	8 (27)	16(53)
Morogoro	24	1 (4)	5 (21)	18(75)
Iringa	56	6 (11)	9 (16)	41(73)

Note: Figures in parentheses denote the percentage of total farmers

Storage operations and structures

In order to use ASD effectively, maize must be shelled before treatment. As shelling was never a traditional practice in most regions of Tanzania this activity necessitates a change in the type of storage container used. The survey found evidence that storage structures in some areas have changed since the time *P*.

truncatus was established. At the time of establishment, most families stored maize cobs in cylindrical cribs located outside the house or on platforms in the roof eaves above the kitchen fire or outside the house, the latter being used for drying as well as for storage (figure 24a). In Iringa district and Kilosa district (Rukwa), many farmers have since switched to storing in sacks made from jute, hessian or woven polypropylene (figure 24b).

In the Tabora, Kilimanjaro and Arusha districts, however, there are still many farmers who use platforms and who therefore mainly store maize on the cob. There appear to be two reasons for this. First, there has always been some reluctance to take action to prevent *P. truncatus* problems by shelling and treating, until insects are actually seen in the maize (Golob,1991). Thus many families store maize on-the-cob on platforms before shelling later in the year and putting the grain into sacks, when the insect becomes apparent. Second, improved methods i.e. Kihenges, steel drums or sacks are expensive. Sacks and drums may in addition be difficult to obtain. As an illustration of cost for sacks, in October 1998, a new 100kg capacity gunny sack will cost between 850 and 1000 shillings, giving a ratio of 1 to 13 - 15 in comparison to the selling price of maize (13,000 shillings). This compares with costs of around 100 shillings for a bag in 1987/88, giving a ratio of 1 to 30 in comparison to the selling price of maize (3,000 shillings). The cost of constructing a Kihenge will be a major financial outlay. It has been estimated that this can be as much as 130,000 shillings. In situations when maize stocks run out early in the season, a common occurrence especially in the frequent drought years of the 1990s, farmers may fail to see the cost-effectiveness of such measures.

CONCLUSIONS FROM THE TANZANIA STUDY

Clearly, rural communities in Tanzania still depend on local agricultural production to provide household food security. The positions of maize and cassava within the system remain as important now as they were fifteen years ago. There have been changes in production and marketing of these two crops but these have been induced by factors such as the introduction of new varieties, long periods of recurring drought and by the decline in soil fertility.

With the exception of a minority of farmers in the Tabora and Kilimanjaro survey districts, *P. truncatus* does not appear to have influenced production, storage and marketing outcomes to any significant degree in any of the districts surveyed. However, farmers still regard *P. truncatus* as the post-harvest problem with greatest potential. To ensure *P. truncatus* is unable to exploit this potential, that is to avoid significant weight loss in storage or loss of income at sale, farmers have changed their storage practices. The key behavioural changes have been:

- a much more widespread use of ASD and, in Kilosa district, Morogoro, Actellic EC
- a concomitant increase in the storage of shelled maize (with the exception of Kilosa)
- a decrease in crib and platform storage.

These changes were recommended when the pest first became established in the country some 20 years ago, and their implementation bears out the robustness of the procedures. However, the use of ASD is accompanied by the same problems that occurred when it was first introduced, in particular poor access to sales points in remote areas and irregular availability. Since market liberalisation, the absolute price of the dust has increased ten-fold and it is now regarded as being very expensive. Furthermore, the quality of the product has declined significantly, partly as a result of poor formulation but more probably because of adulteration by insecticide traders. The changes in storage practices, therefore, have by no means been universal, and there are significant concerns particularly about the cost of ASD and its efficacy against the spectrum of storage pests found on the farm. Although the composition of the recommended insecticide has changed since it was first introduced in order to improve efficacy, there are fewer farmers now who believe it is effective, 70%, than there were in 1985, 85%.

In these circumstances, it is legitimate to wonder why *P. truncatus*, in association with other storage insects, has not had more of an impact on production, storage and marketing outcomes. One possible answer is that farmers have been overestimating the difficulties that they are encountering with pesticides and bags, though this is unlikely. Another possible answer is that a combination of good protection measures in the past, together with the effects of the droughts of the last decade, have prevented the build up of *P. truncatus* in the villages so that it no longer causes significant damage even to poorly protected grain. This implies that:

- environmental contamination of ASD is significant and residues should be detectable in storage structures and possibly in the soil

- populations in the wider environment are being maintained at a sufficiently low level to prevent significant top-up of in-store populations

Neither of these factors has been monitored in Tanzania, so it is not possible to draw conclusions regarding these hypotheses. It should be incumbent on the Government of Tanzania to initiate such measurements, as this knowledge could provide guidance for other countries where the pest is now established.

Nevertheless, there have to be legitimate concerns over the prospects for the future as, if adequate protection measures are not taken, *P. truncatus* populations may well increase, and losses will rise. When farmers have access to reliable insecticides and adequate storage facilities, the indications are that they will use them if they can afford to. The implication is, therefore, that measures be taken to tighten up the regulation of pesticides and ensure that they are more widely available. In addition, the question of cost should be considered, and if it is not tenable to reduce cost then this argues for an increased emphasis on low cost (perhaps botanical) protectants and on integrating other, less effective control measures to achieve adequate control. These issues merit further investigation.

III. THE KENYA STUDY

Farmers were interviewed at one site in each of the six agroclimatic zones which are the main maize production areas, as well as in two maize marginal area where LGB has been established for more than 15 years. The selected districts were:

- Kirinyaga
- Kitui
- Kwale
- Nyandarua
- Taita-Taveta
- Teso
- Trans Nzoia

At each site, 20 farmers were selected for a structured interview by using a transect walk.

Farmers' current practices in relation to those of 15 years ago

The average maize production now is approximately 10 bags (200 kg) per family per year except in Trans Nzoia where the average exceeds 100 bags. In this district, almost 90% of the maize is sold though in the other districts almost all is kept for home consumption and stored on the farm. There has been some change in production levels but these have been a result of changing weather conditions and the wider availability of hybrids rather than because of pest problems.

Farmers generally store maize as loose grain though in Kwale more than 80% of those interviewed stored cobs with the husk intact. In Taita-Taveta, where LGB is well known, there has been a shift away from storage on the cob to storage of loose grain, although a third of farmers still store husked cobs. In this district, more than 60% of farmers said they stored maize for shorter periods compared with 15 years ago though it is not clear why this was so.

Storage problems

Insect pests are regarded as the main post-harvest problem facing maize farmers and where LGB is established (Taita-Taveta and Kitui districts) it causes the most concern (table 4). Insect pest damage also has the most influence in affecting grain prices.

Table 4. Maize farmers' perceptions of storage problems (mean rank)

District	LGB	Other insects	Rodents	Mould	Variety	Moisture
Kirinyaga		1.1	2.1	3.3	6.0	2.8
Kitui	1.6	1.4	2.7	3.3	5.0	2.6
Kwale		1.2	1.9	3.2	4.0	2.8
Nyandarua		1.9	1.5	3.0	3.8	3.0
Taita-Taveta	1.1	1.2	2.5	3.1	5.3	3.9
Teso		1.6	2.2	2.7		
Trans Nzoia		1.6	1.7	3.3		

Control of storage pests

The number of farmers using synthetic chemicals to control storage insect pests has doubled in the last 15 years, now more than 80% use chemicals. For controlling LGB, specifically, nearly 75% of farmers in Taita-Taveta use chemicals though only 45% in Kitui; other methods include admixing ashes or botanicals, subjecting maize to smoke and simply drying. In general, the use of traditional control methods has declined in favour of chemical control. Approximately 90% of those using chemicals believed them to be effective. However, there were concerns over the cost of chemicals and regarding the hazards to health.

IV SUMMARY OF WORKSHOP

The workshop was attended by 21 participants. Of these three represented the Ministry of Agriculture in Tanzania, three represented donor organisations, three were from NRI, three from CABI Bioscience and the remainder were from government departments in Kenya.

The results of the surveys were presented in the morning sessions and during the afternoon the participants divided into three groups to consider different aspects of the data. The subjects discussed were:

- Sustainability of control methods and IPM
- Research requirements
- Chemical control

The following summarises the conclusions of the discussions.

Sustainability

There was general agreement among the group that although chemicals were very effective in controlling LGB it is necessary to develop alternative strategies that were more environmentally sustainable and inherently safer. This meant reducing insecticide use, not necessarily eliminating it altogether.

Particular effort should be expended on devising methods for protecting dried cassava for which there is a dearth of information.

Chiefly, packages of recommendations should be evaluated through PRA methods, and uptake pathways using agricultural knowledge information systems (AKIS) should be developed and utilised.

Alternative methods for maize protection which still need to be researched include, in particular, the development of LGB resistant varieties of which none exist at present.

Research

Several researchable areas were identified, for which key activities are as follows:

1. Pest risk assessment
    - Trap data and the relationship with store infestation levels
    - The effect of moving infested grain on marketing in Kenya and on exports
    - The relationship between insecticide use and the effectiveness of the predator

2. Botanicals and inert materials
    - Chemical constituents of candidate materials
    - Validation of efficacy of botanicals and ash

3. Microbials
    - Continued research into efficacy against storage pest complex

4. Control of LGB in dried cassava

5. Plugging gaps in coping strategies in Kenya and Tanzania

6. Economic impact on stakeholders through the marketing chain

Chemical control

Even though the use of chemicals (Actellic Super Dust) is a very effective method for preventing LGB damage there are aspects of their use which still require to be improved.

1. *Cost*

   Issues
   - Do not use where not required
   - Blanket subsidy not recommended (except to promote initial use)
   - If cost continues to increase then the use will decline and alternatives will be needed

   Actions
   - Increase awareness of decision tree approaches (i.e. promote alternatives and IPM)
   - Continue and strengthen research into low cost control methods
   - Resolve disparity in recommended dosage rates

2. *Availability*

   Issues
   - Generally available and packaging is adequate
   - More feedback is required from extension staff to chemical stockists to ensure supplies
   - Method for predicting demand for chemical required
   - General infrastructure problems (e.g. poor roads)
   - Possible phase out of organophosphates so other contact insecticides will be required to control indigenous storage pests

3. *Quality of the formulation*

   Issues
   - Fake ASD on the market
   - Insufficient staff to check and monitor quality
   - New law in Tanzania allows extension staff to check quality (inoperative in practice)

   Actions
   - Manufacturers should apply a seal
   - Increase checking and prosecute offenders
   - Educate stockists on quality issues; only purchase from known dealers with good reputations
   - Manufacturers should guarantee quality by issuing batch quality certificates.

The consensus of the workshop was that whilst farmers are coping with LGB, problems concerning the availability, cost and quality of ASD must be resolved if this pest is to remain of limited economic significance. Furthermore, it is desirable to develop more environmentally sustainable control procedures so that the reliance on conventional chemicals can be reduced. This will require much greater interaction with the farming communities and the development of IPM and improved methods of technology uptake.

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FIGURES

Figure 2a Household food security strategies (past)

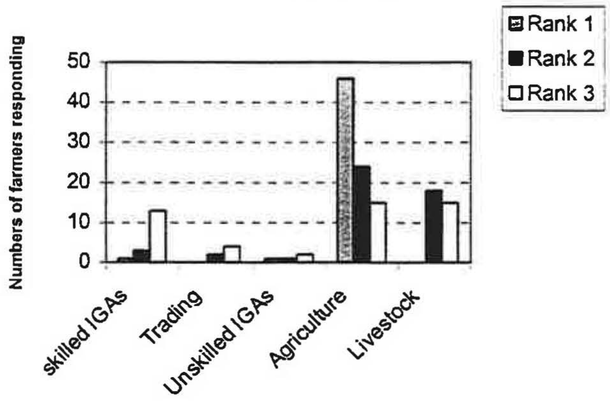
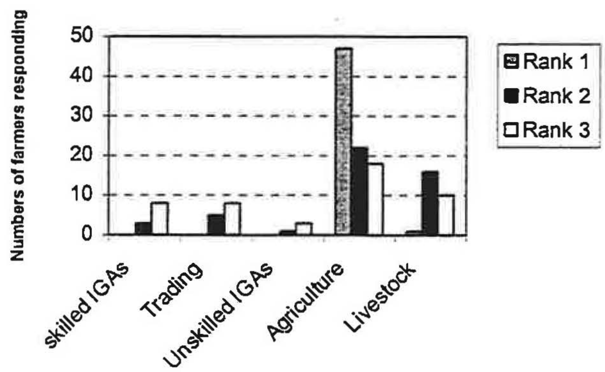


Figure 2b. Household food security strategies (present)



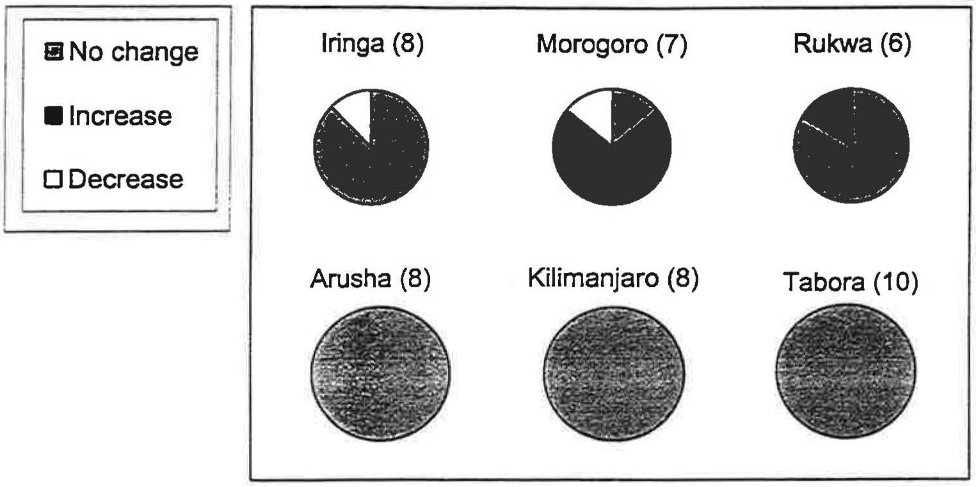


Figure 3a: Perception of the importance of maize to household food securit in relation to other crops
(number in brackets denotes the number of farmer groups per region)

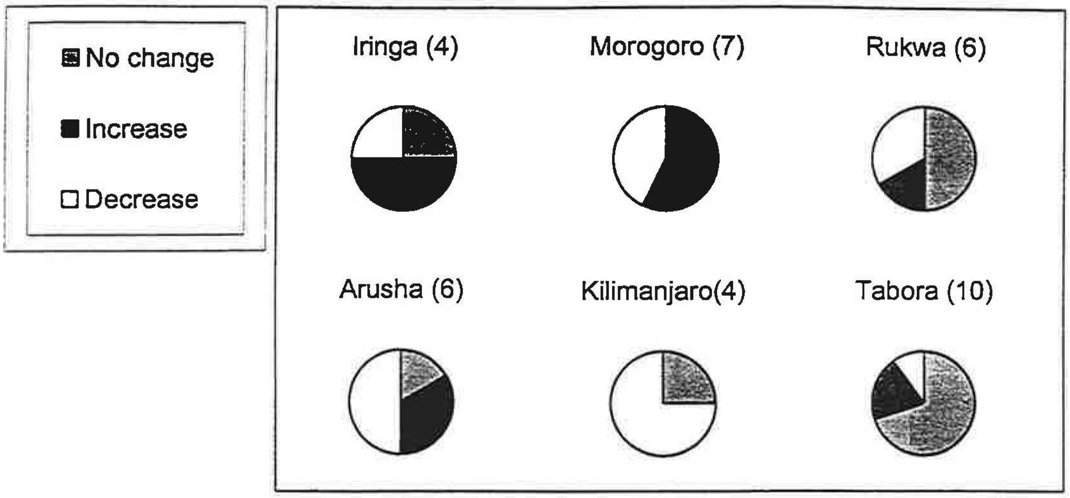


Figure 3b: Perception of the importance of cassava to household food security in relation to other crops.
(number in brackets denotes the number of farmer groups per region)

Figure 4a. Quantity of maize harvested in a normal year

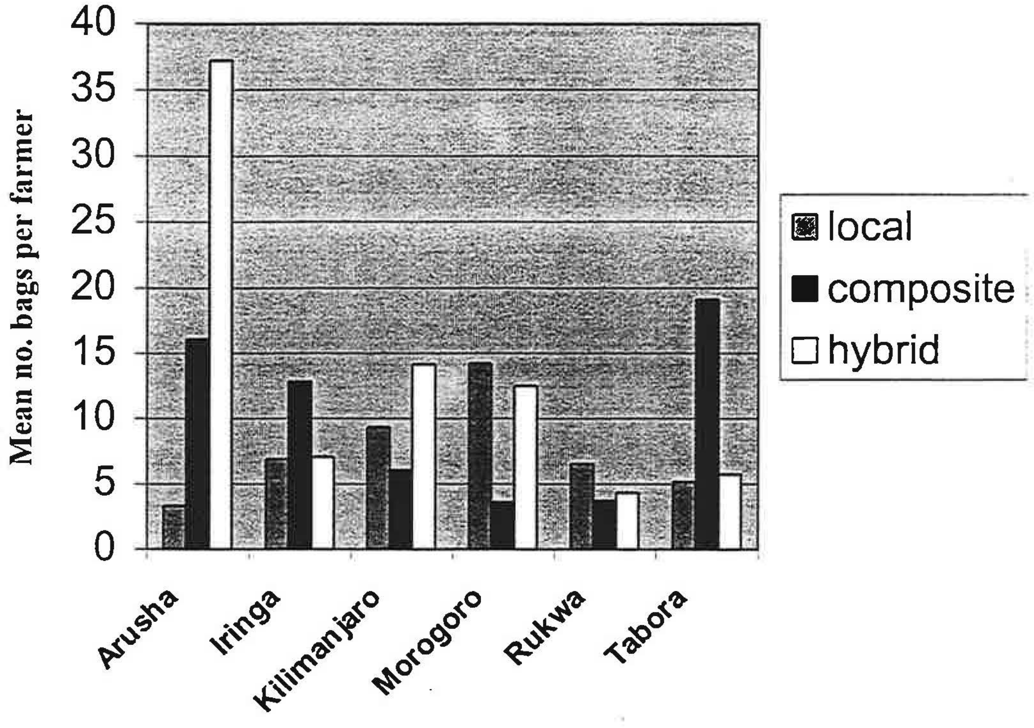


Figure 4b. Quantity of maize harvested in a drought year

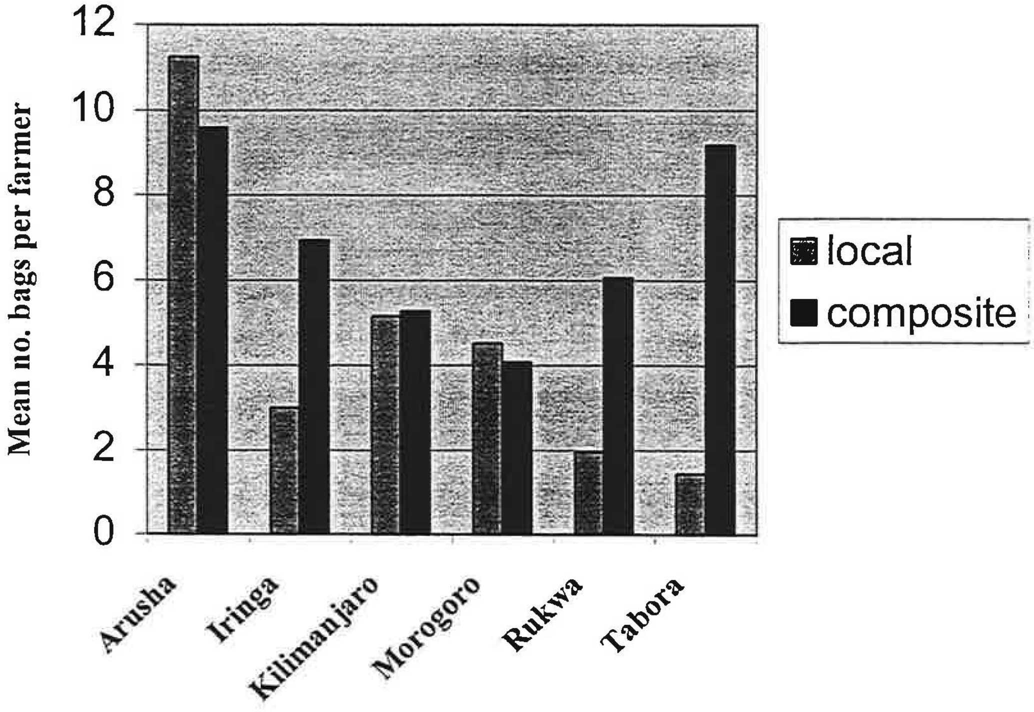


Figure 5a. Quantity of maize stored in a normal year

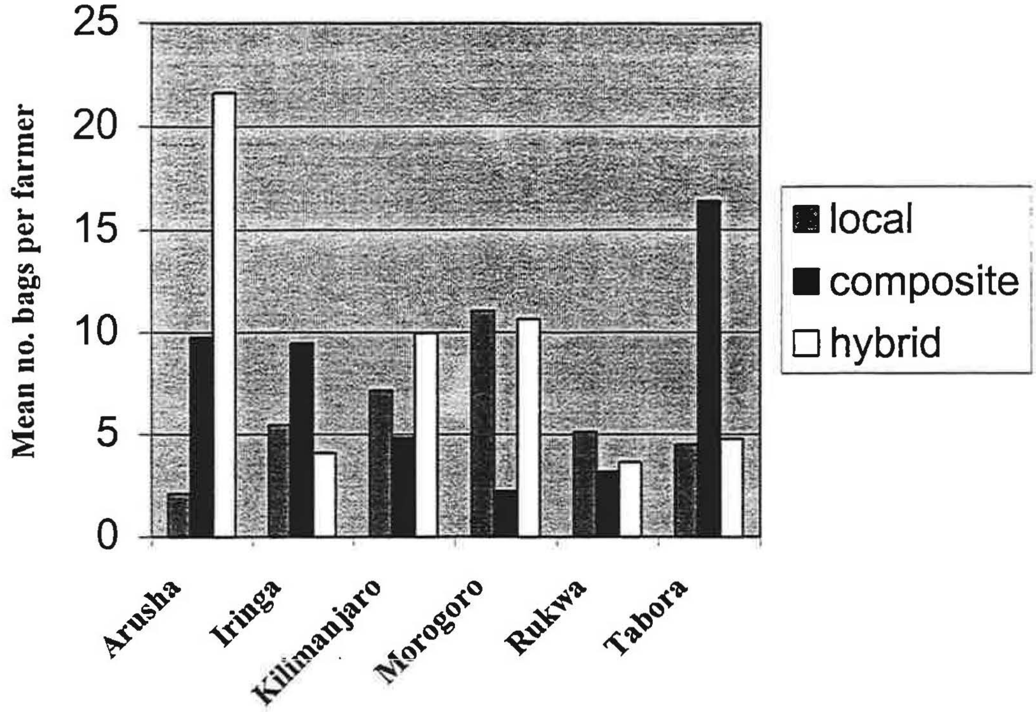


Figure 5b. Quantity of maize stored in a drought year

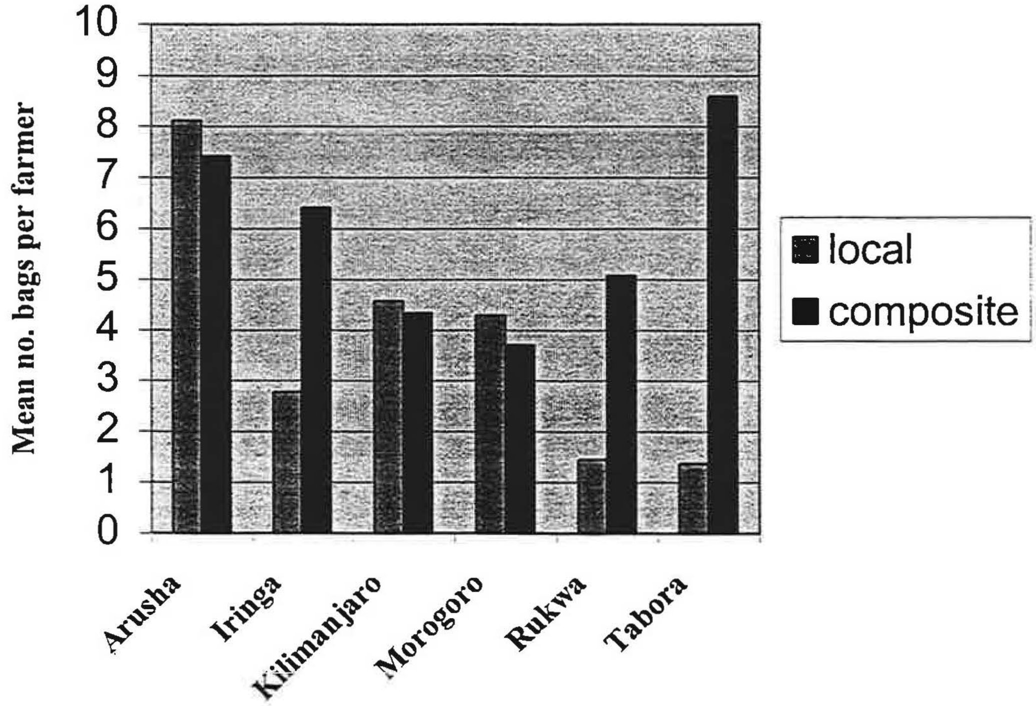


Figure 6a Quantity of maize sold immediately in a normal year

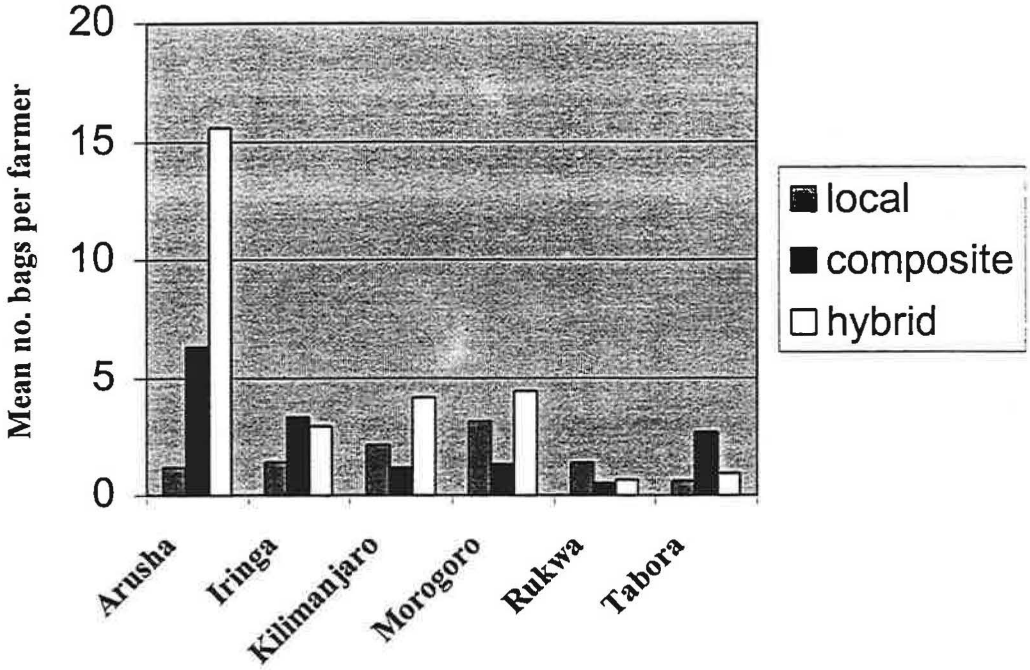


Figure 6b. Quantity of maize sold immediately in a drought year

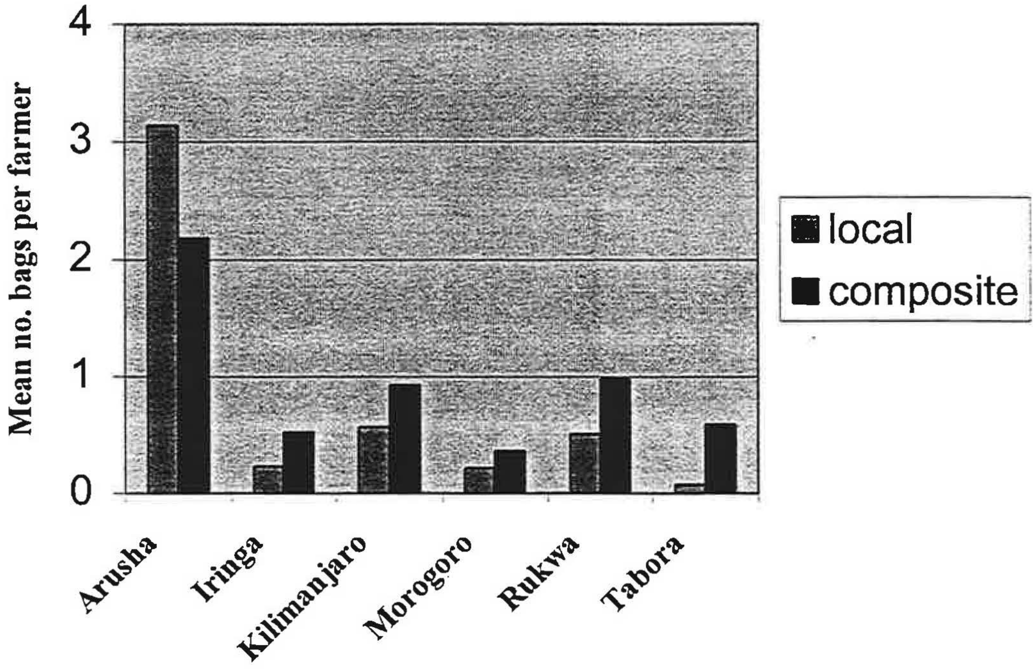


Figure 7. Number of farmers in each region who cultivate cassava

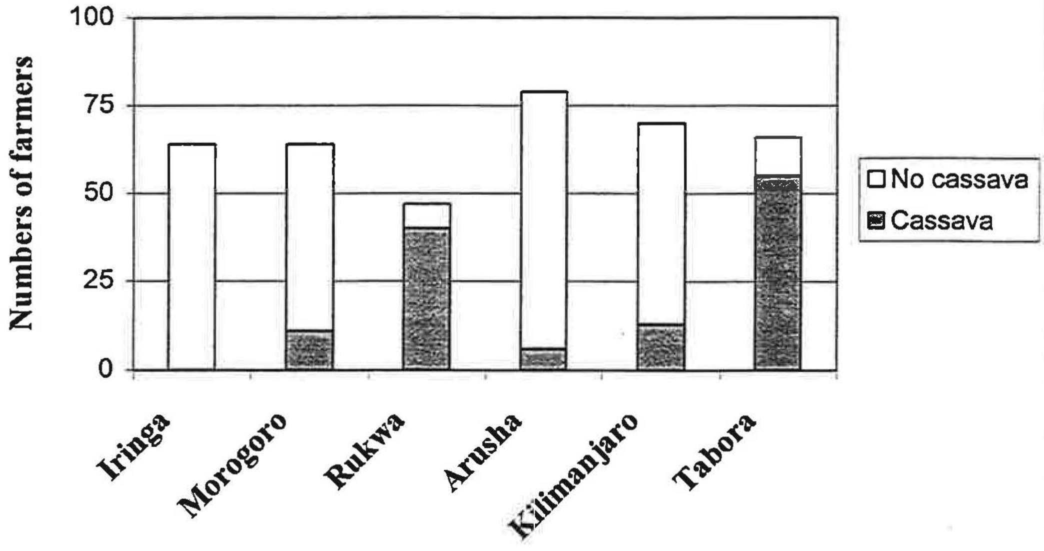


Figure 8. Quantity of cassava harvested, sold and stored in main producing regions in normal and drought years (no. of cassava growers is shown in histogram)

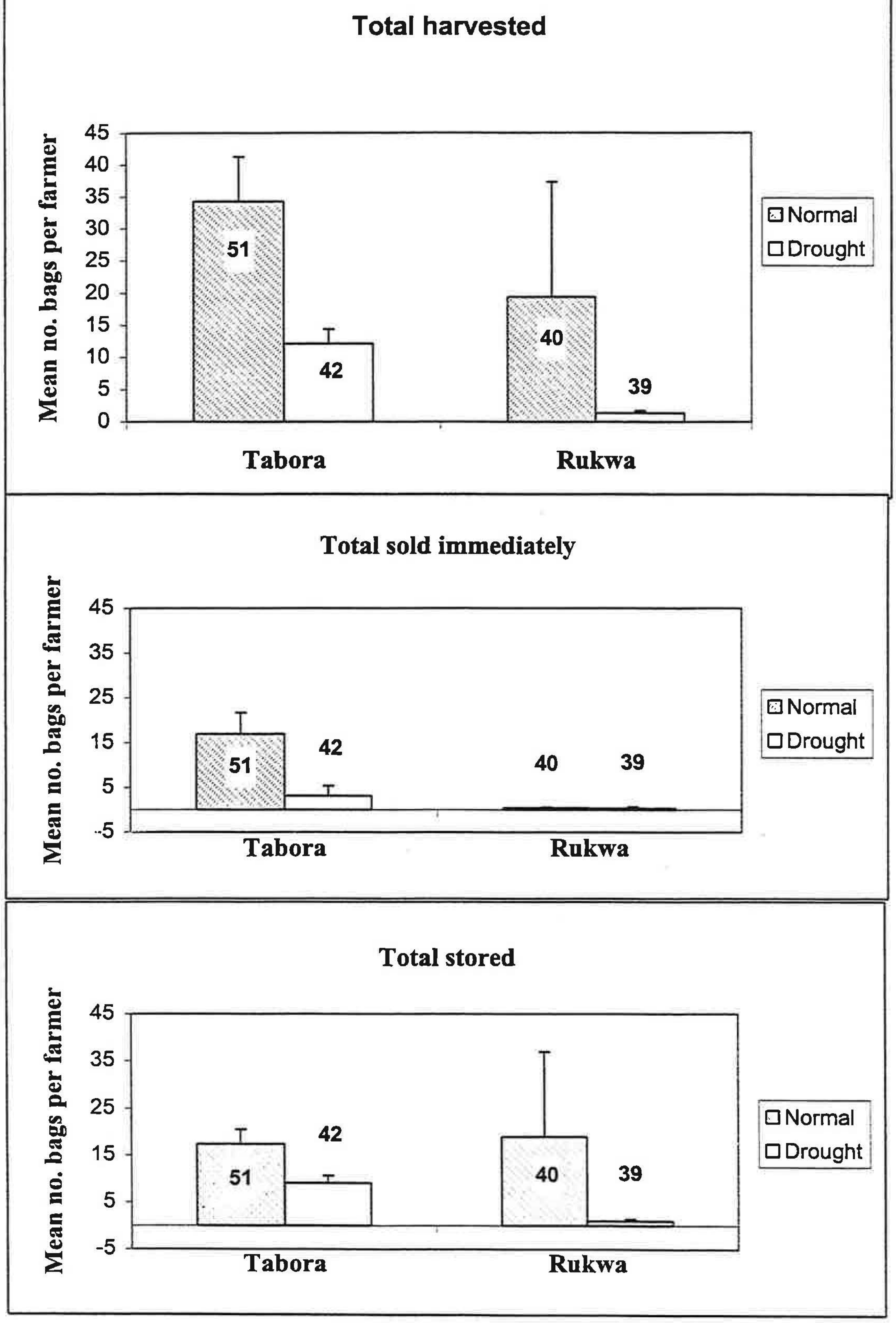


Figure 9. Reasons for change in the quantity of maize harvested at present compared with fifteen years ago

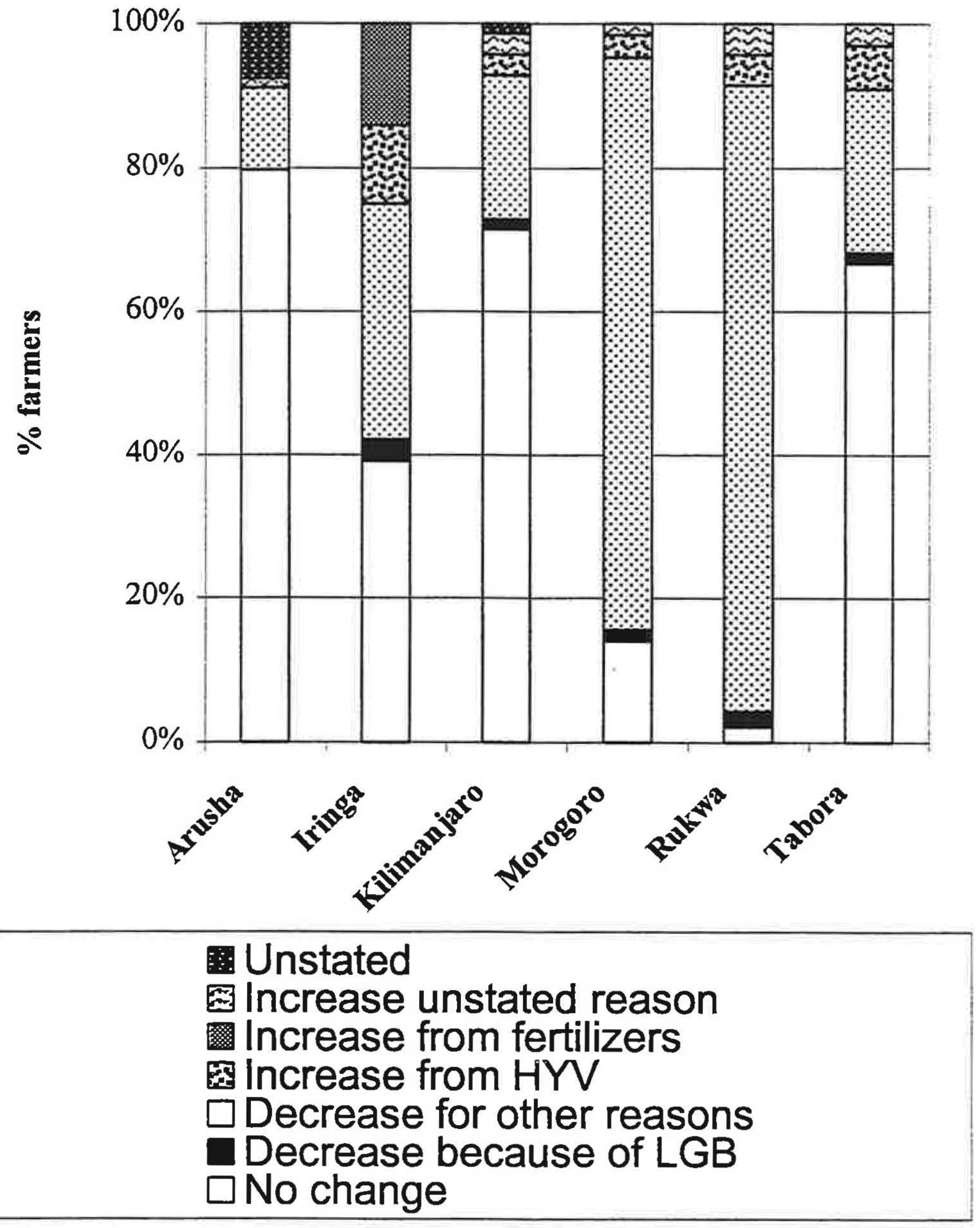


Figure 10. Reasons for the change in the quantity of cassava harvested at present compared with fifteen years ago

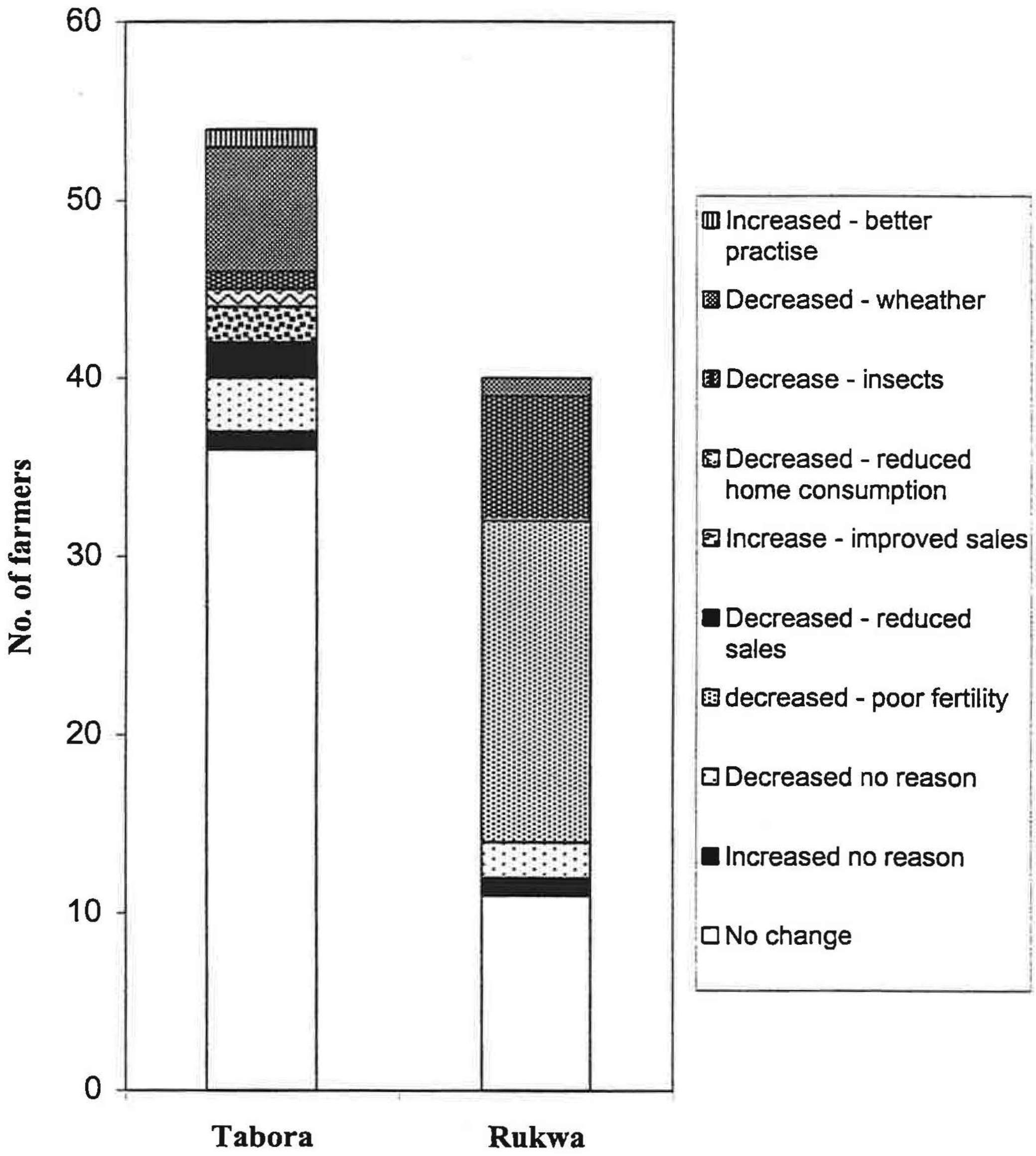


Figure 11. Reasons for the change in the varieties of maize cultivated at present compared with fifteen years ago

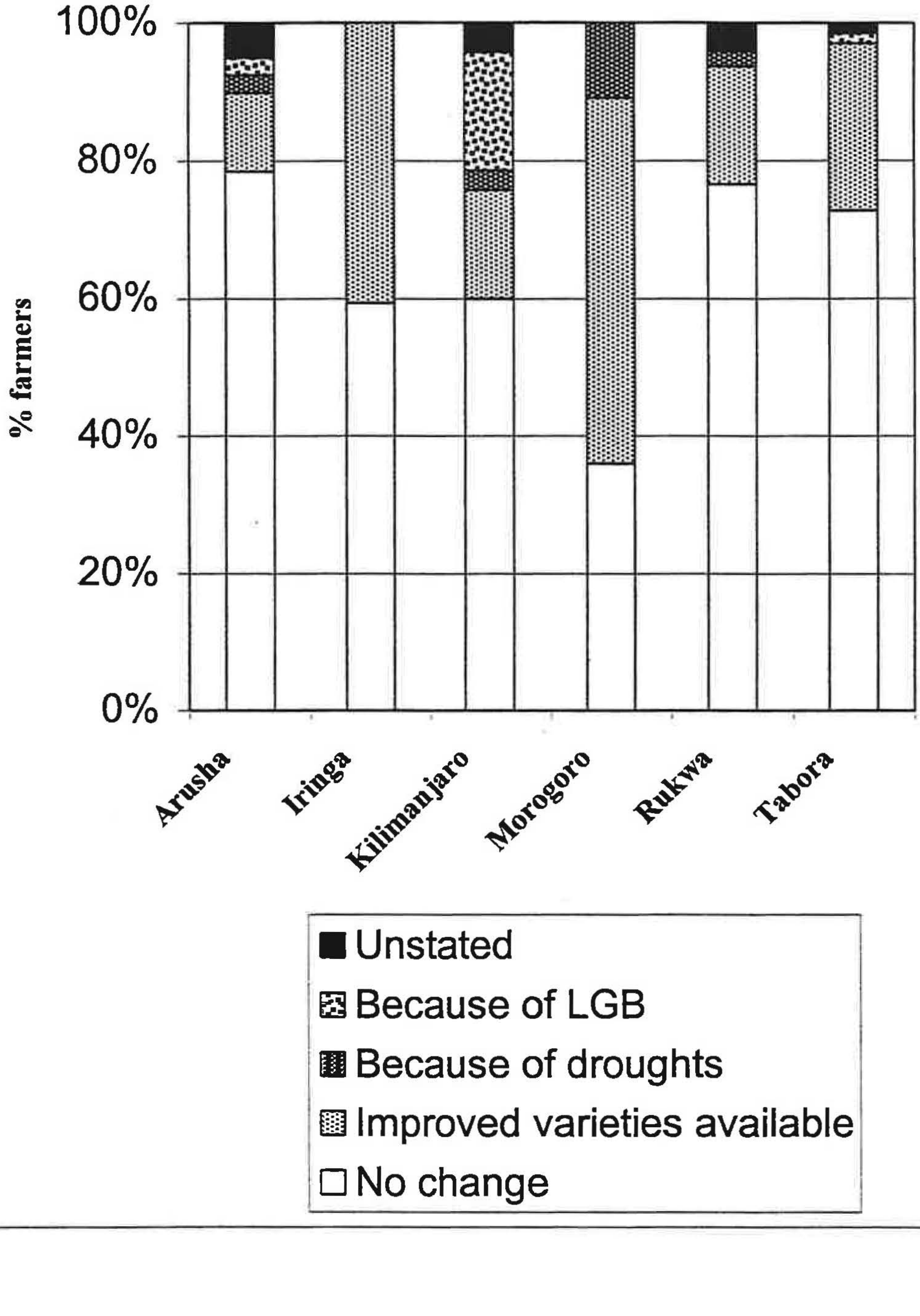


Figure 12a. Reasons for the change in the varieties of cassava cultivated at present compared with fifteen years ago

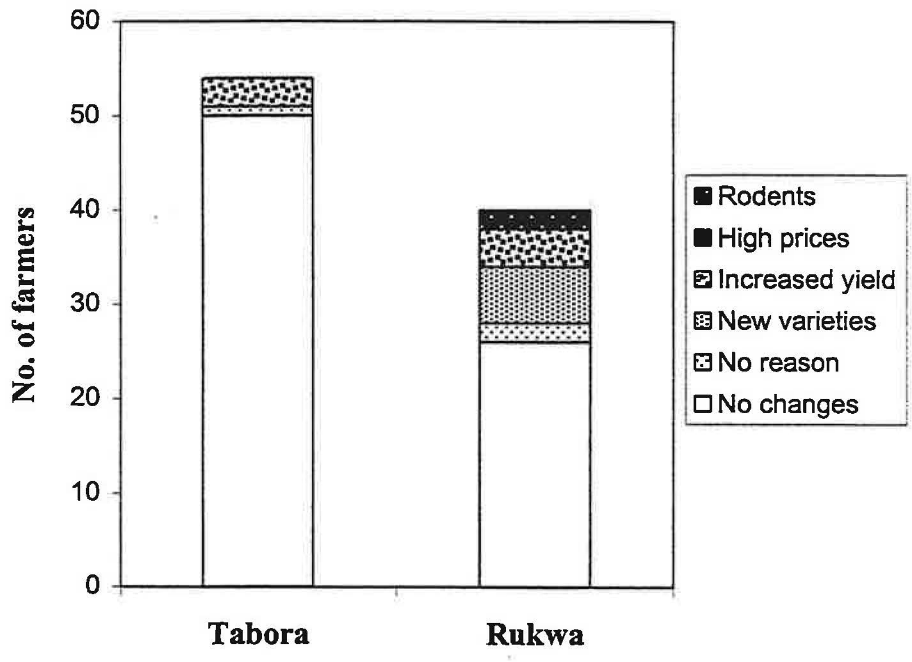


Figure 12b Types of varieties grown

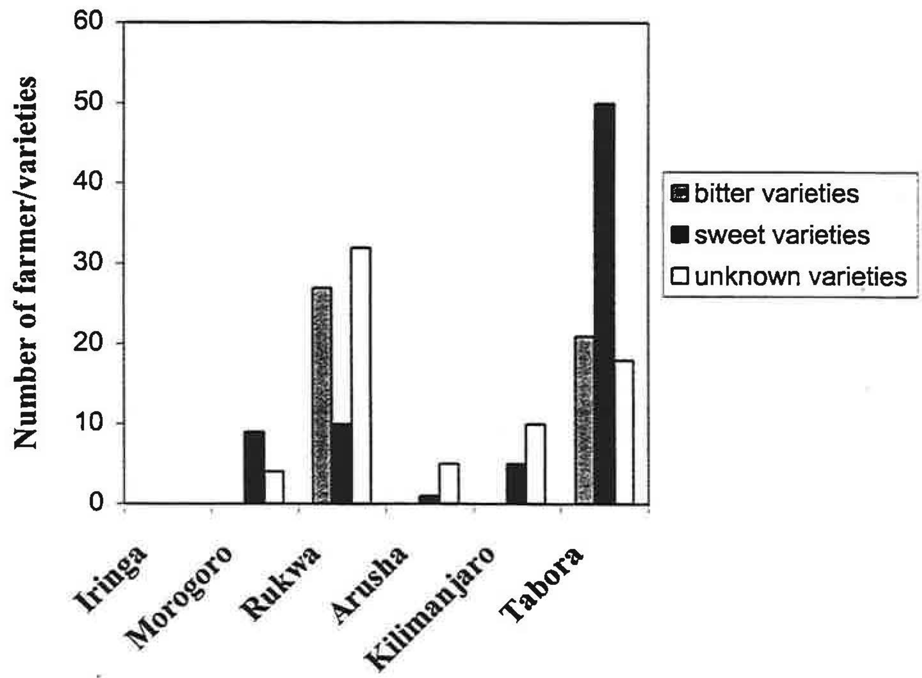


Figure 13a. Duration of maize storage (aggregate for six regions)

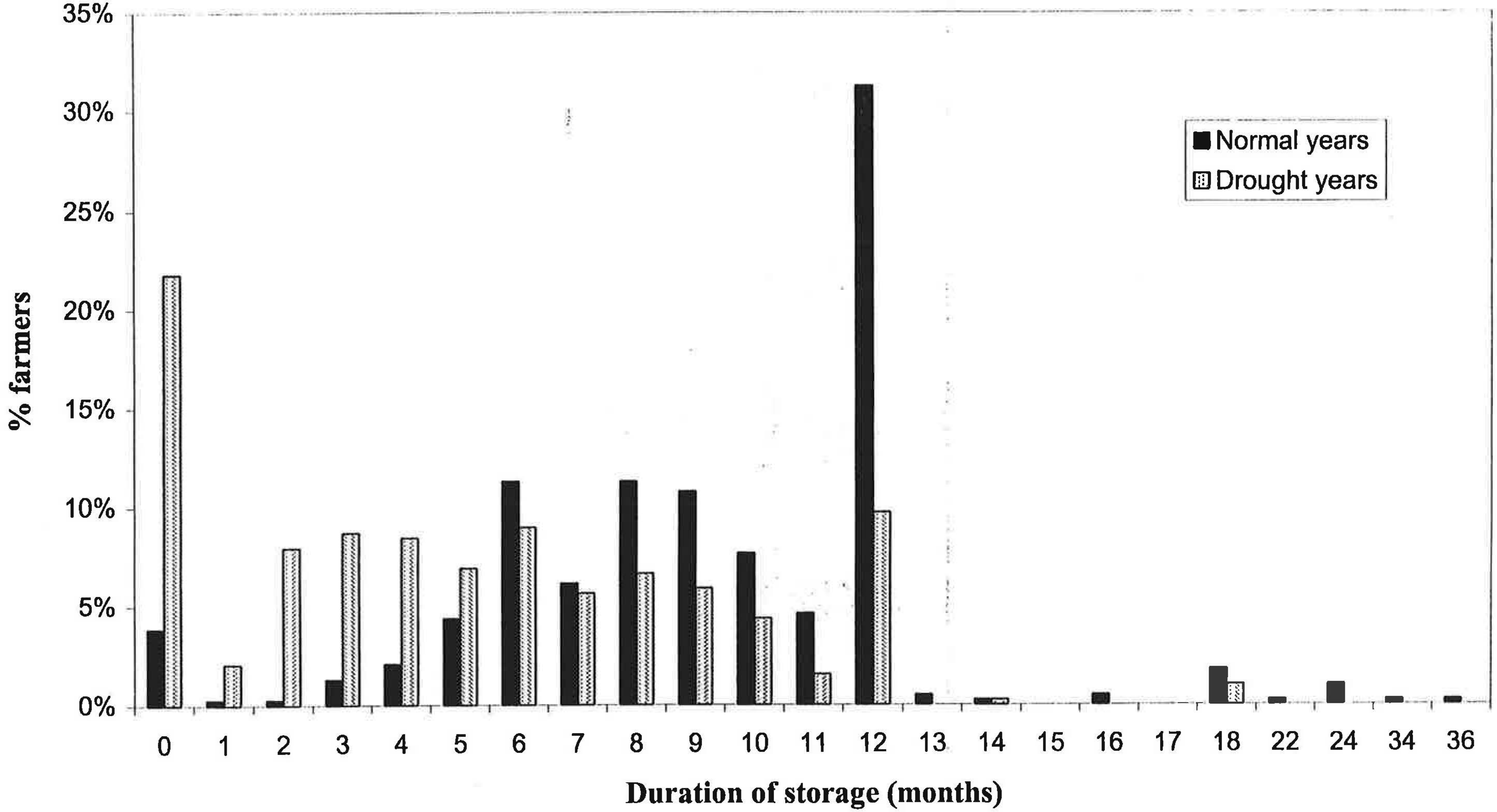


Fig13 b: Average duration of storage of maize (with SEM), by region

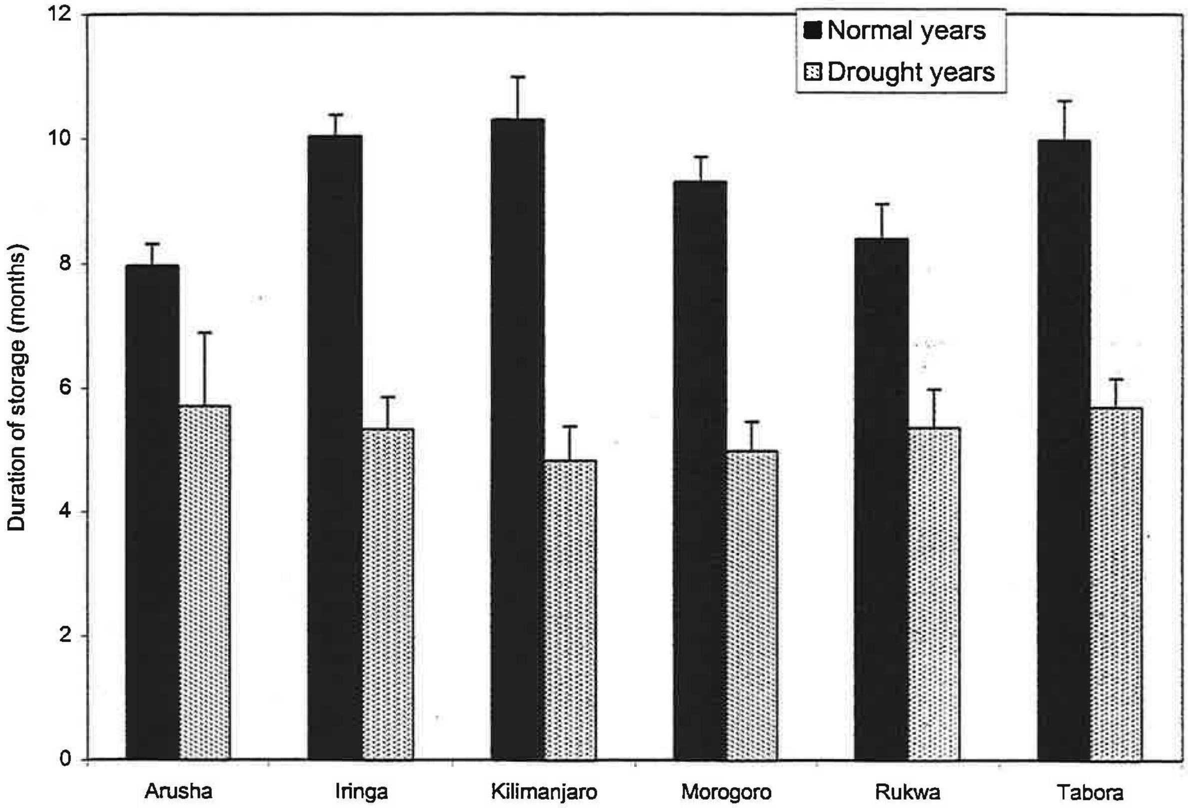


Figure 13c. Frequencies of storage duration by regions (weeks)

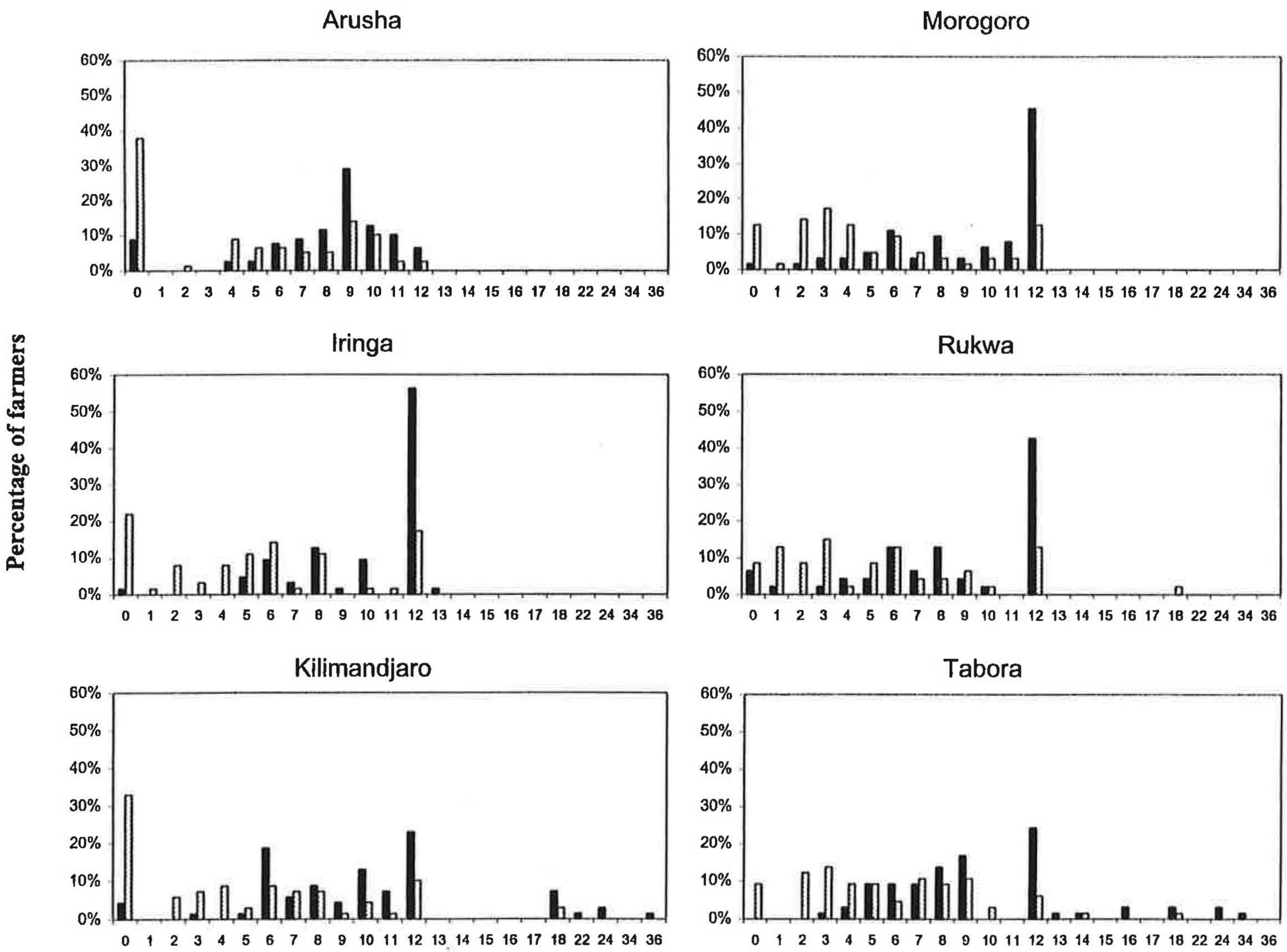


Figure 14. Reasons for the change in the duration of storage at present compared with fifteen years ago

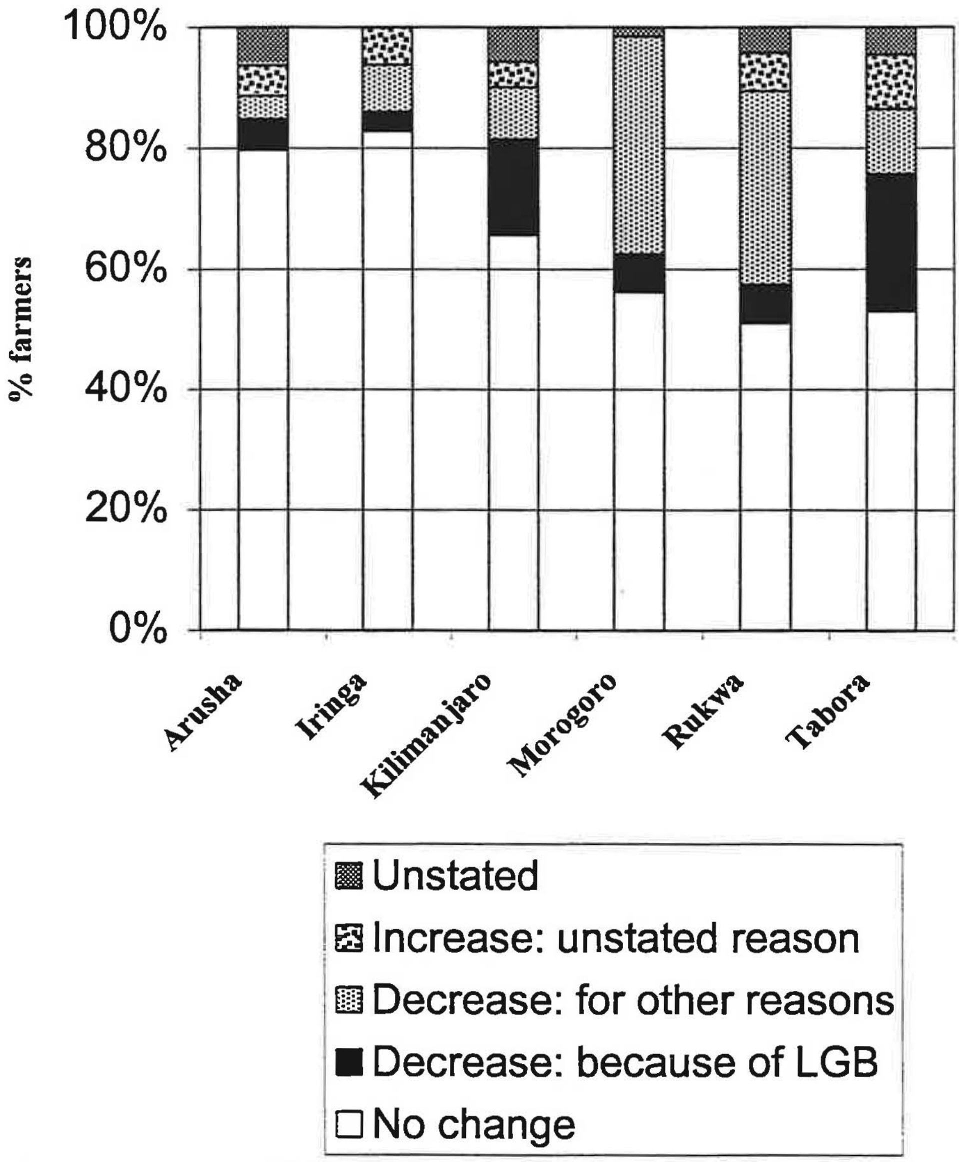


Figure 15. Reasons for the change in quantity of maize sold at present compared with fifteen years ago

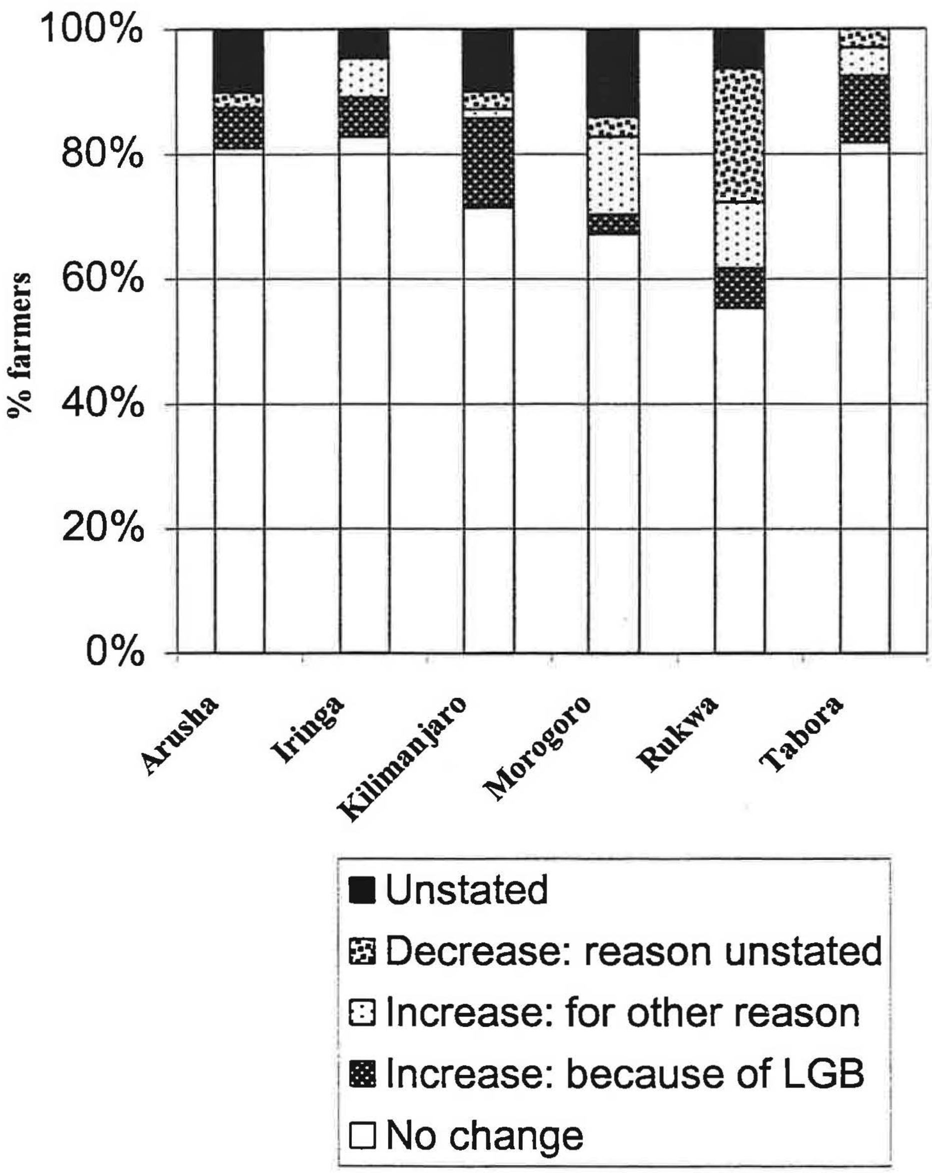


Figure 16a. Duration of cassava storage: aggregate of all districts

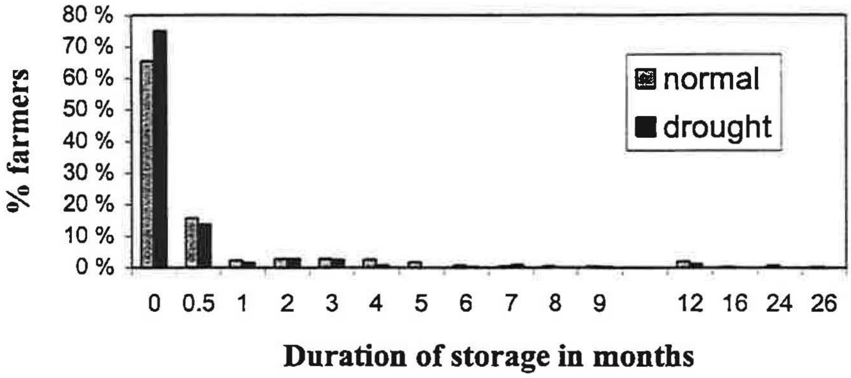


Figure 16b. Mean duration of cassava storage (with SEM) in Tabora and Rukwa

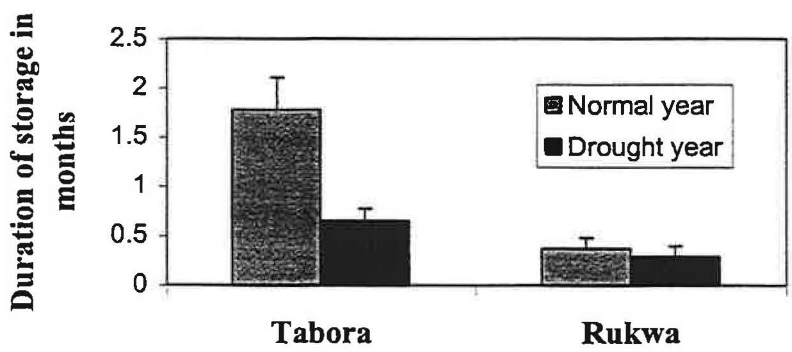


Figure 17. Reasons for the change in the duration of cassava storage at present compared with fifteen years ago

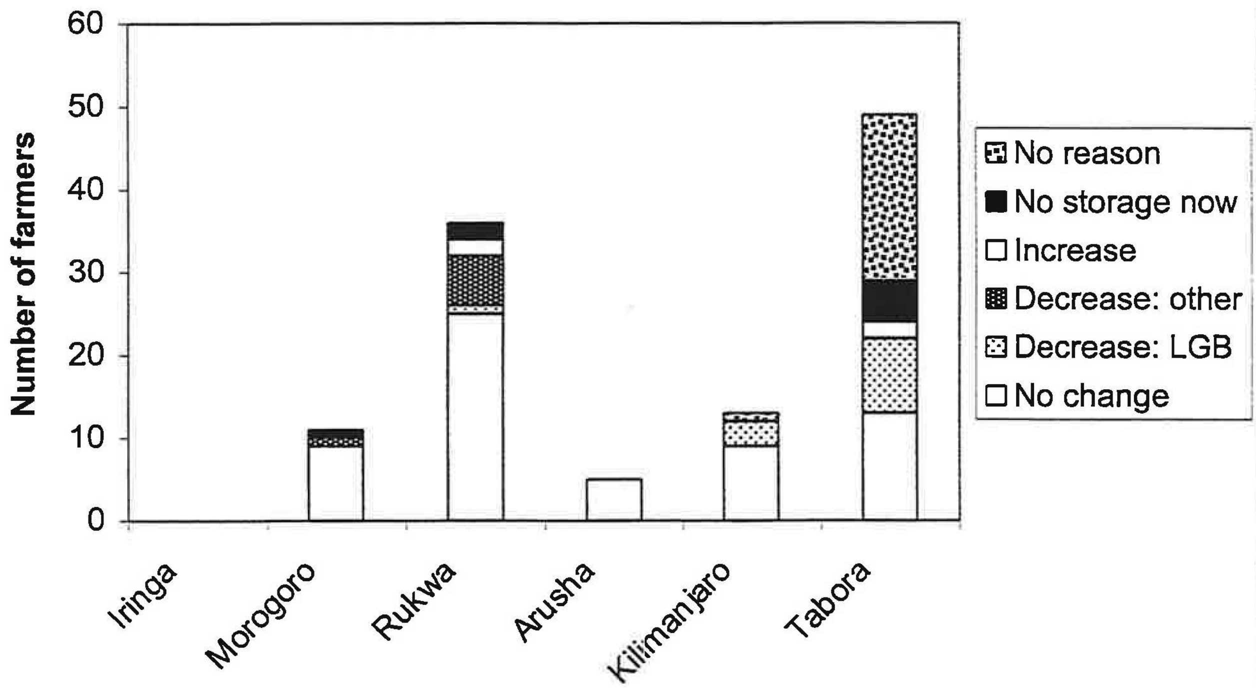


Figure 18a Farmers' rankings of agricultural problems: 15 years ago

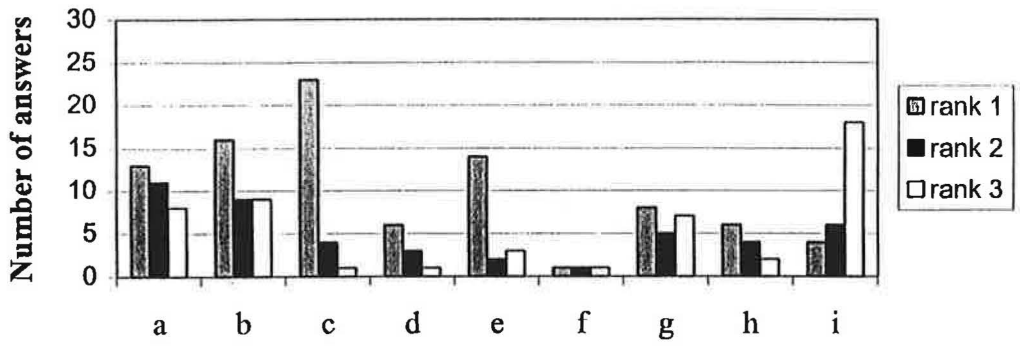
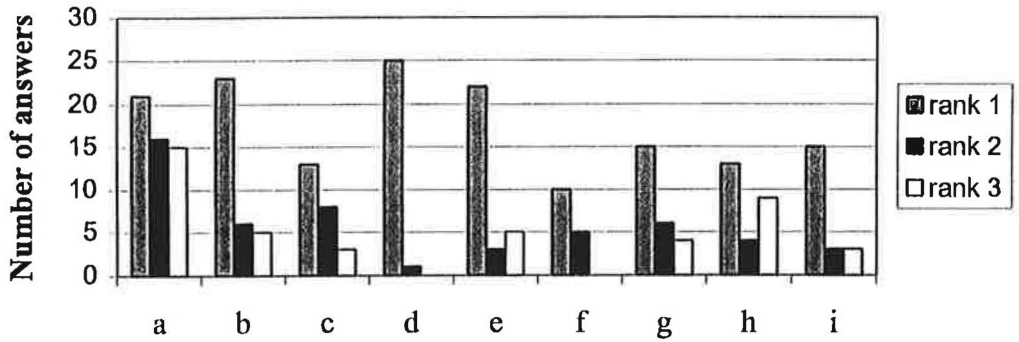


Figure 18b. Farmers' ranking of agricultural problems: Today



Categories:

a: Agricultural services
b: Storage related problems
c: Specific mention of LGB
d: On farm crop processing and handling
e: Market ??? and output ??? problems
f: Land productivity and ??? problems
g: Field pests and diseases
h: Water problems
i: Other

Figure 19a. Farmers' perception of the importance of LGB: Past

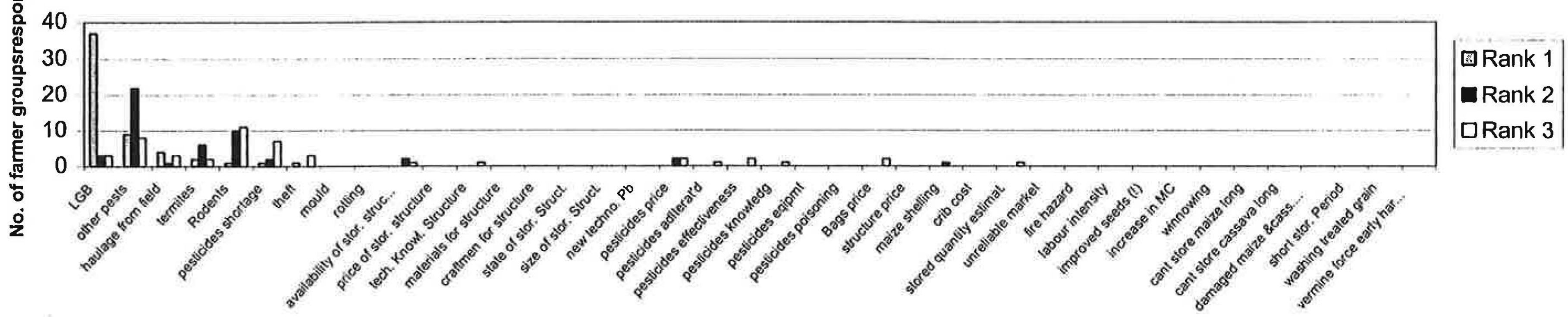


Figure 19b. Farmers' perception of the importance of LGB: Now

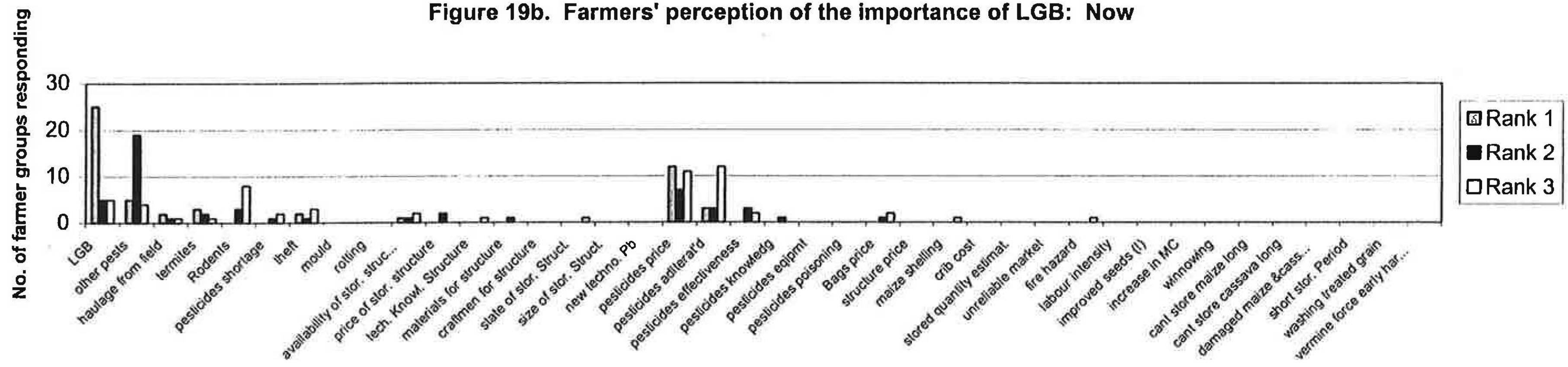


Figure 20. Problems associated with maize stored for home consumption

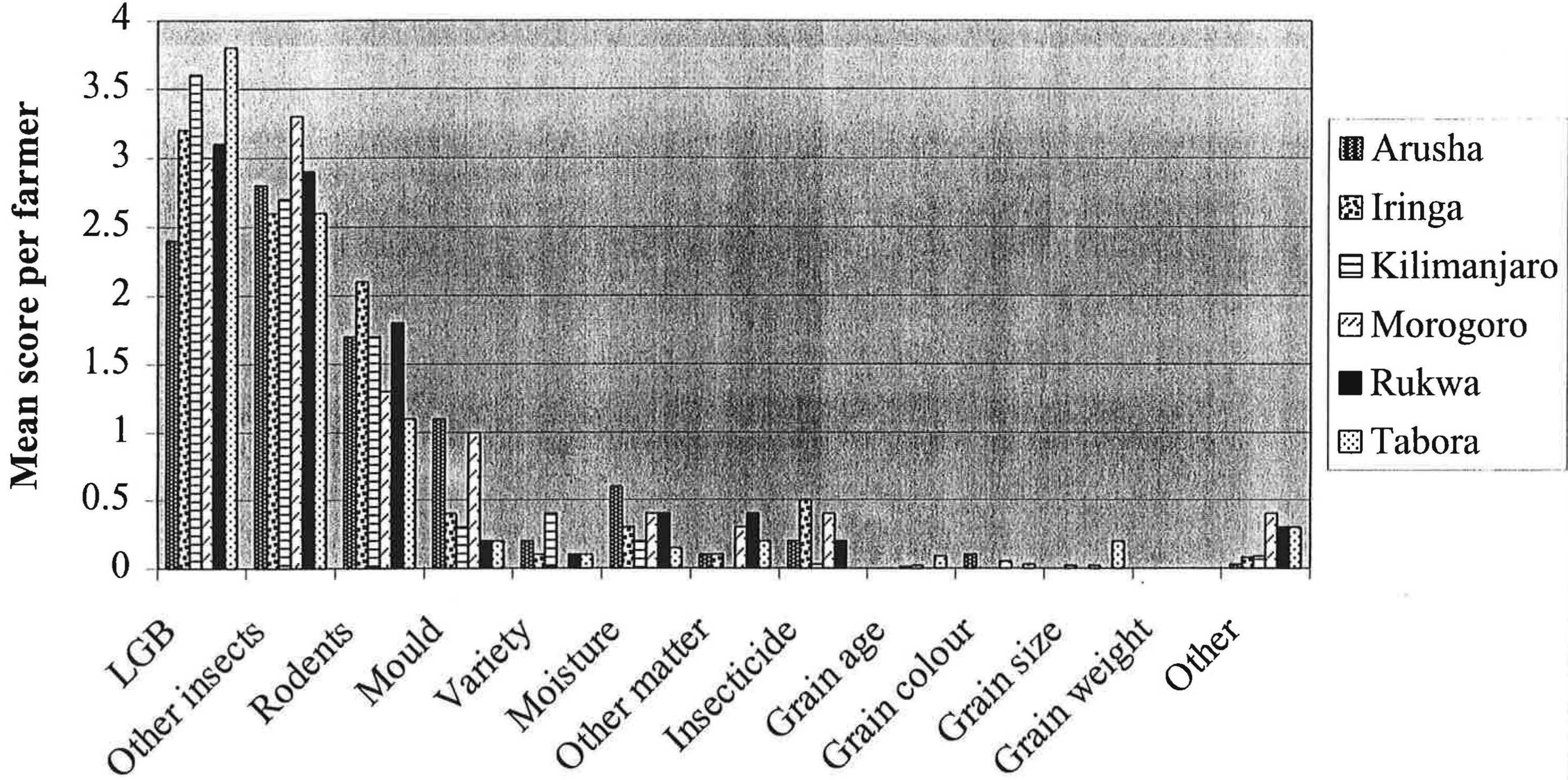
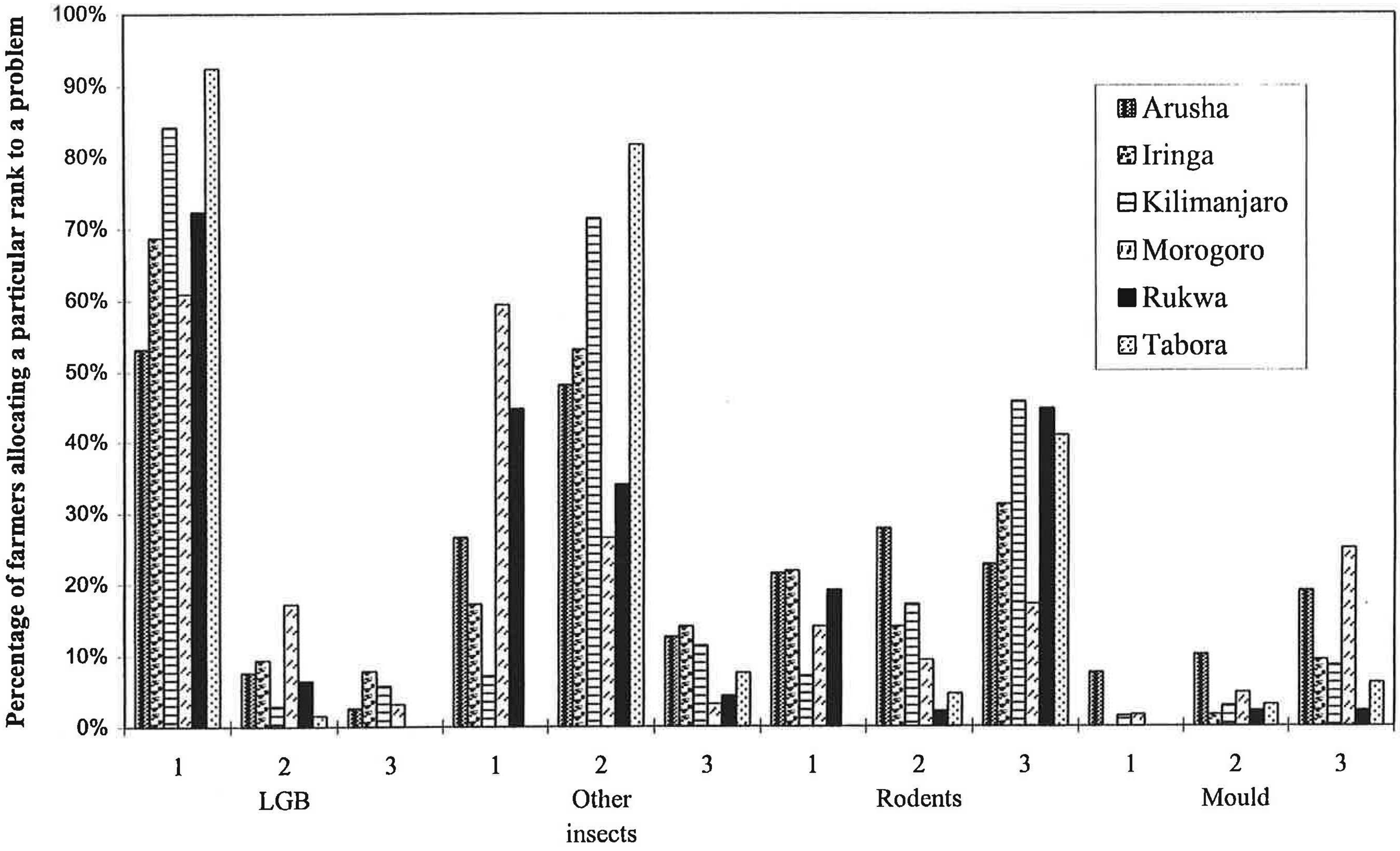


Figure 21 Ranking given by farmers to the four main problems associated with maize stored for food



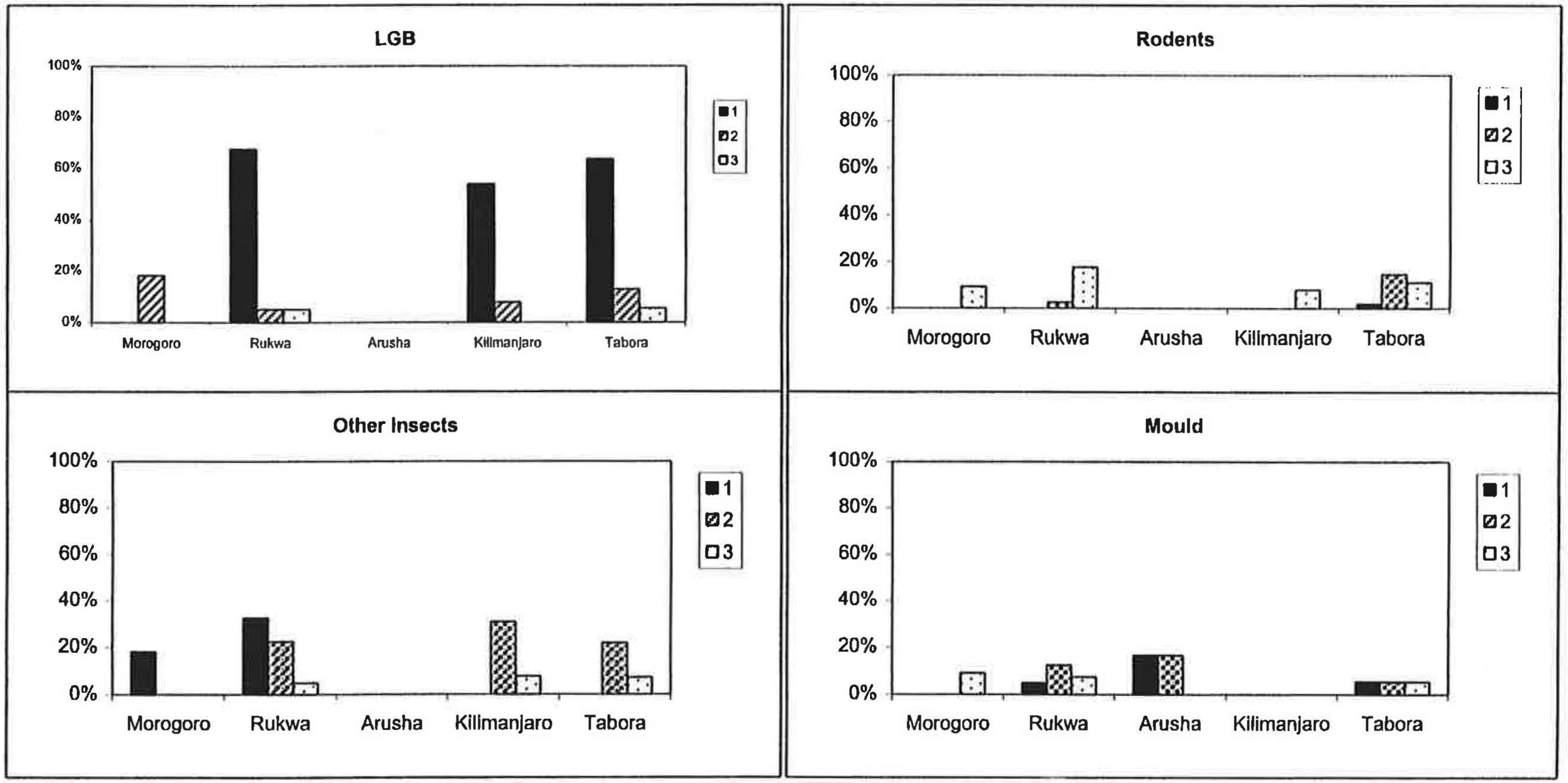


Figure 22. Ranking given by farmers to the four main problems associated with stored cassava

(Percentage of farmers growing cassava, allocating a particular rank to a problem)

Figure 23 Use of different methods of protecting maize against insect pests during storage

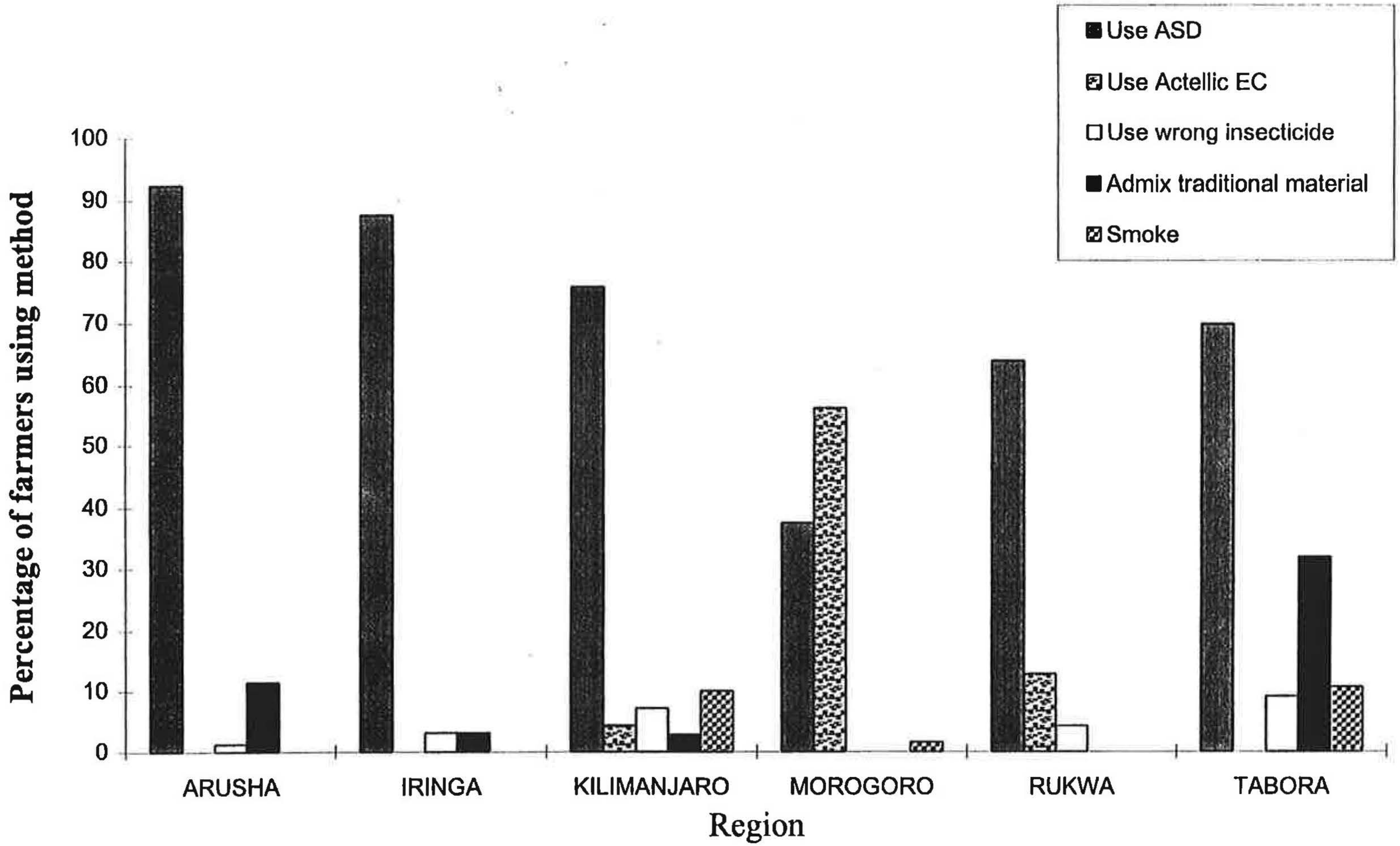


Figure 24a Structures used for maize storage: current use

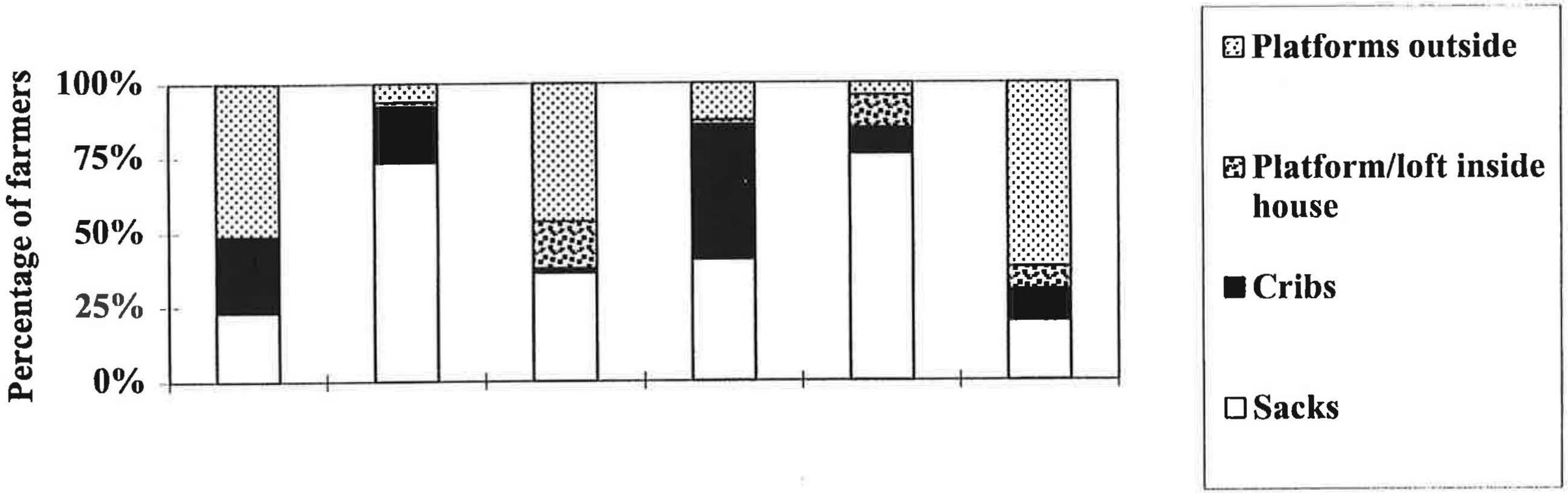


Figure 24b. Structures used for maize storage: 15 years ago