CROP PROTECTION PROGRAMME

Weed management options for seasonally inundated land in semi-arid Zimbabwe.

R7473 (ZA 0338)

FINAL TECHNICAL REPORT

Start and End dates
(October 1999 to December 2002)

Project Leaders
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Acronyms

AREX	Department of Agricultural Research and Extension
AGRITEX	Former Department Agricultural Extension
BPGs	Best practice guidelines
COTTCO	Cotton Company of Zimbabwe
CPP	Crop Protection Programme
DRSS	Former Department of Research and Specialist Services
DAP	Draft animal power
FAO	Food and Agriculture Organisation of the United Nations
OPV	Open pollinated varieties
NGO	Non Government Organisation
NRI	Natural Resources Institute
SRI	Silsoe Research Institute
UZ	University of Zimbabwe
WARDA	West Africa Rice Development Association
wace	weeks after crop establishment
WAE	weeks after establishment

The currency used in this report is Zimbabwe dollars (Z$). Current exchange rates are:

Official	**Parallel market**
US $1=Z$ 55	US $1=Z$ 600
£ 1=Z$ 88	£1=Z$ 1500

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FINAL TECHNICAL REPORT

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CONTENTS

EXECUTIVE SUMMARY

A very brief summary of the purpose of the project the research activities, the outputs of the project and the contribution of the project towards DFID's development goals. (Up to 500 words).

Project Purpose

Low cost, labour efficient weed management systems, in seasonally inundated land in savannah cropping system, developed and promoted.

Outputs and activities

Understanding of the impact of weeds in seasonally inundated semi-arid wetlands in Zimbabwe and of the opportunities for and constraints to improved weed management.

An initial planning meeting with project partners and stakeholders clarified issues relating to wetlands (*vleis* and a detailed programme for the project to be finalised. Areas of operation included a small-scale commercial, two communal areas and a resettlement area in Masvingo Province. Community workshops reinforced with a formal survey provided detailed information on farmers' knowledge and practices in *vlei* utilisation. Major constraints to improving productivity were weed, water and soil management. *Vleis* have multiple uses including year round cropping, with winter wheat and vegetables planted on residual moisture in the dry season and maize, rice, groundnuts and beans grown in the rainy season.. Most important is the ability to plant maize-rice inter-crops some 4 months before the rains, by utilising residual moisture. In many years, especially when rainfall is above average, weeds become an impossible burden, waterlogging occurs and whole fields are abandoned. Although *vleis* are widely cultivated legislation prohibits their cultivation, so little previous research has been undertaken on alleviating these constraints and no guidance has been given to smallholder farmers on appropriate farming practices.

Evaluation of innovative options for crop and weed management identified using a combination of traditional and scientific knowledge.

A nine-month period of characterisation and learning from farmers, led to two seasons of on-farm experimentation of researcher-farmer-extension selected options. These included a variety of maize-rice cropping practices, either as sole crops or as inter-crops, in conjunction with hand weeding, low-cost safe herbicides or a combination of the two. Additionally, to address the problem of water control, a number of soil management practices were tested including broad beds, pre- and post-plant ridges and drainage furrow systems constructed with existing resources. Improved OPV rice varieties provided by WARDA in West Africa were also evaluated through on-farm trials. Mid and end of season evaluations of trial plots were undertaken by all partners. Results indicate that the bed system offers most potential for improved soil and water management, herbicides offer potential for weed control and introduced rice varieties can provide higher yields than local varieties. Following the on-farm trials, there has been some adoption of the bed systems and rice trials are continuing, with bulking up of preferred varieties by local farmers with support from AREX, the extension service. Although some farmers are keen to use herbicides, the deteriorating political and macro-economic situation in Zimbabwe has led to rapid price increases and non-availability of many inputs. Inter-cropping of maize and rice (in alternate rows) provides an ideal risk minimisation strategy with rice doing best in wet years and maize in drier years. Even during the serious drought conditions of 2002, when there was widespread failure of maize crops, farmers were able to harvest above average rice yields due to heavy rains received at the end of 2001.

Promotion and development of findings

Research findings have been promoted through field days and annual workshops at which results were reported and discussed. Papers detailing project outputs were presented at a CIMMYT sponsored conference in Nairobi during 2002. The project required close collaboration of partners in a participatory process. This improved each institution's capacity to participate with rural communities (including women) in the identification of local constraints, testing and evaluation of potential solutions.

The project has prepared "Best Practice Guidelines" aimed at extension workers on, soil and water management, weed management and safe use of knapsack sprayers for use in further dissemination activities.

Contribution of Outputs to Project Goal:

The project identified three options for reducing the impact of weeds in the crop production cycle, through 1) improving soil and water management and improving crop stands better able to compete with weeds, 2) using herbicides and 3) through improved inter-cropping techniques, with higher yielding rice varieties. Option 3 remains the lowest cost and most likely to be adopted by even the poorest farmers. Option 1 requires an increase in labour and draft animal power at land preparation time, options confined to those with access to draft animals. Option 2, although best suited to those with least labour, requires herbicides to be available, cash investment and training in the use of herbicide technology. It is therefore likely to be used initially by those who can access and afford the appropriate chemical.

BACKGROUND

Information should include a description of the importance of the researchable constraint(s) that the project sought to address and a summary of any significant research previously carried out. Also some reference to how the demand for the project was identified.

Importance of the researchable constraint

Over 80,000 ha of cultivable *vleis* (wetlands) are currently under utilised in the communal areas of Zimbabwe. If they were properly managed, they could make a major contribution to food security, alleviate poverty and help stabilise rural household's economies. This has proved particularly relevant in recent seasons, as drought conditions have gripped large areas of Sub-Saharan Africa and dryland crops largely failed. The major problems facing farmers cultivating wetlands, not only in Zimbabwe, but also in other areas of sub-Saharan Africa, are weed control and soil water management, particularly in wet years. This can lead to crops being totally abandoned and resources directed to drier, potentially less productive topland soils.

Demand for the project

Vleis are recognised by rural Zimbabweans as a potentially valuable resource that play an important role in the stabilisation of rural household economies and make a major contribution to food security during times of drought (Kundhlande *et al.,*1995; Adams *et al.,* 1997). Although *vleis* are widely cultivated, current legislation in Zimbabwe attempts to conserve *vleis* by restricting their use, which has meant that little work has been carried out to understand and alleviate the production problems faced by farmers to ensure that the *vleis* are used in a sustainable manner. Adams *et al*., 1997 highlights that weeds and weed control, and soil and water management are major constraints to *vlei* production not only in Zimbabwe, but also in Zambia and Malawi where traditional management practices are labour intensive. More recently, FAO (Frenken and Mharapara, 2002) stated that wetland cultivation holds the potential to bring about a sustainable agricultural revolution in the region over a relatively short period. However, at the same time cultivation of wetlands has the potential for high environmental impact and ultimately a negative effect on the livelihoods of poor people.

Previous research

Much of the erosion that led to the current legislation ((Water Act, originally passed in 1927, updated in 1976 (Government of Rhodesia, 1976); Natural Resources Act, 1941 (Government of Rhodesia, 1941 and subsequent amendments, the most recent being 1996); Stream Bank Protection Regulations, originally passed in 1952, updated in 1975 (Government of Rhodesia, 1975)) has been attributed to inappropriate agrarian reforms and growing population pressures in Communal Land Areas (Bullock, 1995; McFarlene, 1995). At the same time studies using sequential air photographs revealed a strong relationship between variations of rainfall and livestock numbers, rather than an increase in cultivation since the 1950s. This is in contradiction to conventional wisdom (Whitlow, 1989; McFarlene and Whitlow, 1991). Of the 240,000 ha of *vleis* found in Zimbabwe's' Communal Lands, there is a potential of some 80,000 ha of cultivable *vlei*. A safe limit on the extent of *vlei* cultivation is considered to be 10% of the catchment area or 30% of the *vlei*, whichever is the smaller (Bullock, 1995). Therefore, alleviating the weeding constraint in *vlei* areas should contribute to stabilising yields, reducing pressures for cropping on the drier, often more fragile topland areas of the soil catena. This will contribute to enhanced food security and will alleviate poverty, particularly for poorer households.

Previous research in Zimbabwe has shown weed growth within the crop is a reflection of land preparation, tillage and planting practices (Mabasa *et al.,* 1998). At the same time soil moisture available to the crop can be enhanced by careful manipulation of tillage, and conserved by timely weeding (Mashavira *et al.,*1997; Twomlow *et al.,* 1997b; Twomlow *et* *al.,* 1998). In the wetland environment weeding with a mouldboard plough can have certain advantages if this is done early enough. The resulting ridge and furrow land form can promote improved drainage in wet years and conserve moisture in years of low rainfall resulting in yield increases in the order of 30 to 40% over normal farmer practice. This could represent an additional 500 to 750 kg/ha in smallholder systems in Masvingo District (Twomlow *et al*., 1998).

Grant (1995) demonstrated that commercial maize yields in excess of 7 t/ha could be achieved from *vleis* in both the wet and dry season, when fertility issues and weed control are properly addressed. In the commercial sector the weed problem on *vlei* soils has been overcome through early applications of herbicides.

However in the small-scale sector, the problem of weed control in *vlei* cultivation, still remains a serious problem, especially in wet years (Mabasa *et al*., 1998). The current practice is to plant *vleis* early, so that the crop can establish on residual moisture, before weeds emerge with the first rains. Unfortunately, the majority of farmers rarely have the necessary resources available at the ideal planting time. Consequently, late planting and poor cultivation practices mean that most households do not have the crop well established ahead of first rains and rising groundwater levels, which impairs crop growth and prevents access for weeding. On-farm trials to assess weed management options were undertaken at a limited number of *vlei* sites by previous CPP project R6655. This work documented that sedges, including *Cyperus esculentus, Cyperus pelophilus, Pycreus macrostachyos, Scleria foliosa* are particularly difficult to control and suppress crop growth if early weeding is not carried out. For instance, by February in many seasons, late planted *vlei* crops are overgrown by weeds forcing many farmers to abandon lower lying fields in Zimuto communal area (Chatizwa *et al.,* 1998). In addition, the perennial rhizomatous grass *Panicum repens* is also difficult to control. Detailed studies (Riches *et al.,* 1997; Riches *et al.*, 1998; Twomlow *et al.*, 1997a) on freely draining soils indicated the importance of studying tillage/crop establishment and the development of appropriate weed control practices within an Integrated Crop Management context.

A number of options, such as open plough furrow planting, ripping and post emergent ridging, were tested in *vleis* by farmers within project R6655 (Mashavira *et al.,*1997; Twomlow *et al.,* 1997b; Twomlow *et al.,* 1998). However it was concluded that to successfully produce summer crops in *vlei* areas it would be necessary to modify existing cultivation practice in order to alleviate both waterlogging and weed constraints.

PROJECT PURPOSE

The purpose of the project and how it addressed the identified development opportunity or identified constraint to development.

This project purpose, which has contributed to the CPP Semi-Arid Systems Output is:-

"Low cost, labour efficient weed management systems which conserve moisture in savannah cropping systems developed and promoted".

As such the project was designed to optimise crop production in the wetland *vlei* ecology which provides an opportunity to improve food security in otherwise risky rainfed savannah areas. Using participatory methodologies farmers, working with the extension service and NGOs were encouraged to select from available and novel tillage and weed management technologies and to test those options they considered best suit their circumstances.

RESEARCH ACTIVITIES

This section should include detailed descriptions of all the research activities (research studies surveys etc.) conducted to achieve the outputs of the project. Information on any facilities expertise and special resources used to implement the project should also be included. Indicate any modification to the proposed research activities and whether planned inputs were achieved.

Assessing existing farming systems

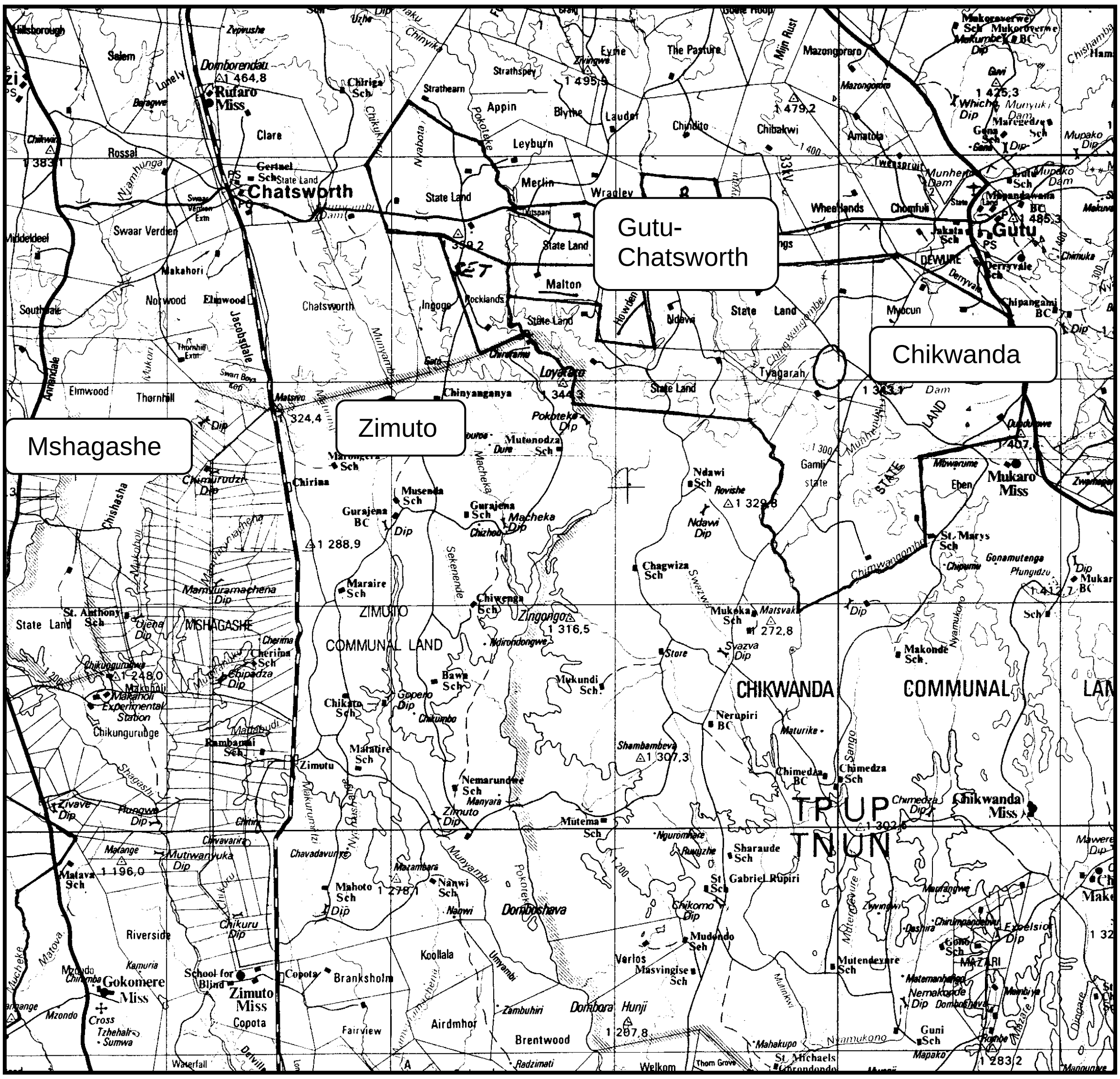
Planning meeting including identification of participating farmers

Project activities were initiated at a planning meeting involving project stakeholders during November 1999 (Twomlow *et al*., 1999). This meeting involved representatives from Agritex (the extension service) and DRSS (the research service) now amalgamated as AREX, University of Zimbabwe, Zimbabwe Farmers Union, Natural Resources Board, and a number of NGOs, including CARE, and representatives from local farmers groups. The meeting identified communities in small scale commercial, communal and resettlement areas, where the project was to be implemented, defined the roles and responsibilities of stakeholders and collaborators and finalised a detailed work programme.

Characterisation of farming systems

<u>Community workshops</u>
Four community workshops were held to ensure full participation and involvement of local farmers and gain an understanding of their perceptions and knowledge of *vleis* in general and weed management and crop production techniques in particular (Mutambikwa *et al*., 2000). These workshops provided opportunity for the project team and other stakeholders to learn from Communal, Resettlement and Small-Scale Commercial farmers. Participatory approaches were used to obtain information on: household access to *vleis* and the roles *vleis* play in people's livelihoods; farmer characterisation of *vleis*, their past and present day use, cropping calendars, protection measures, utilisation problems including soil, water, weed and crop management.

The areas selected for the community workshops were based on ensuring that a cross section of farming communities who carry out *vlei* cultivation in Masvingo Province was covered and included Communal, Resettlement and Small Scale Commercial Farming areas. They also comprised recently settled and older settled areas. The areas selected and the main characteristics of each are shown in Map 1 and Table 1.



Map 1: Location of research sites

Table 1: Areas Selected and main Characteristics

	Mshagashe	Chikwanda	Zimuto	Gutu-Chatsworth
Type	***Small scale commercial***	***Communal***	***Communal***	***Resettlement***
Soils	Granitic sands	Granitic sands	Granitic sands	Granitic sands
Natural Region	III/IV	IV	IV	III
Date settled	1930s	Before 1920s (demarcated in the 1950s)	Prior to 1950s	Mid 1980s
Land Tenure	Freehold title	Right to cultivate	Right to cultivate	Certificate of right to occupy
Typical arable land holding per household	15 to 30 ha	2 to 5 ha	2 to 5 ha	5 to 6 ha

Gender and length of settlement played an important role in the characterisation of *vleis* with many of the female respondents using the term *Matoro* as a generic name for all *vleis*. However, more detailed discussions with each group revealed that most farmers recognised two types of *vleis*, *Doro* and *Nhorobvukwa,* according to soil texture, degree of wetness, drainage and vegetation.

Nhorobvukwa are sandier textured *vleis* located on the valley sides that receive water as runoff from the upland areas. Although the surface may appear dry during the dry season, the water table remains high so crops can be planted on residual moisture in October just prior to the first rains, with yields assured regardless of the amount of rainfall. The smallscale commercial farmers of Mshagashe recognise *Gakata* as a sub-division of *Nhorobvukwa*. These soils have a slightly heavier texture and are more difficult to manage.

Doro are heavier textured *vleis* found on the lower end of the granite catena close to the valley bottoms, which hold water for a long time. The soils are typically black in colour, sticky to the touch (*chidhaka/chinamwe*) and are waterlogged for much of the rainy season. These soils are the first to be planted with maize in late August, September and early October prior to the onset of the rains so that the crop can become established before water logging occurs. In particularly wet seasons the crop may be abandoned as waterlogging prevents access for weed control. If resources and soil water conditions are favourable a dry season crop of wheat or beans may be grown.

It is apparent that the majority of farmers recognise the different management opportunities offered by the different *vleis*, and manage their fields accordingly, if resources allow. There were a number of differences in perception of the importance of use between the genders. Whilst the men concentrated very much on the major crops for food and income generation, the women's view was from a much wider perspective, in terms of household nutrition and other requirements including firewood and sacred uses.

<u>Maize, groundnuts, rice, beans, *nyimo* (bamabara nuts), and sugar cane are the main summer crops.</u> In Zimuto and Mshagashe some farmers also grow finger millet (rapoko), while a few farmers from Chikwanda indicated that "*tsenza*" (a traditional tuber crop) was also grown in the *vleis*. Ploughing is undertaken from April onwards with soil moisture conditions controlling timing and quality of operations. Until recently the majority of farmers purchased certified hybrid maize seed but presently retained seed is increasingly being used. Other crops are grown from home saved seed or are purchased from neighbours. Some farmers use compound 'D' fertiliser at planting, but its use is diminishing as the fertiliser price increases. Many people use compost or cattle manure at planting (if available) spread just before ploughing in August/September. Low rates of ammonium nitrate are applied on a small proportion of the total cropped area when maize is at knee height and again at tasselling.

Rice is broadcast prior to an overall shallow ploughing with maize planted simultaneously in every third furrow. If groundnuts are planted, then seed is dropped in every furrow behind the plough, or the crop is planted by hand. As maize is planted from August through to December depending on soil moisture conditions, early-planted crops reach maturity during December or January when drying and storage is a problem. Rice is harvested over a longer period, as grain is available from tillers of various ages.

Weeding is continuous for all *vlei* crops. Sole cropped maize is often weeded with either the plough (body removed) or cultivator if soil moisture conditions allow., usually restricted to dry *vleis* Mechanical weeding is carried out to incorporate chemical fertilisers. Much of the maize crop is intercropped so all weeding operations are carried out using the hand hoe. All too often soils become water logged early in the season especially on the wet *vleis* and weeding becomes increasingly difficult and is often not undertaken due to inadequate access into the fields.

Wheat, beans and vegetables (in protected gardens) are the main traditional *vlei* winter crops. However, the growing of wheat has declined over the years especially in communal areas, as the *vlei* are rarely fenced, and livestock use these areas for winter grazing. Wheat is now primarily grown by small-scale commercial area farmers. The seed is broadcast, with compound "D" fertiliser in April or May on to land ploughed following the maize harvest. As the crop grows into the cool dry season no weeding is needed. Wheat dries out the soils it is grown on so these can not be planted to a following maize and/or rice crop until the onset of the subsequent rainy season.

The main problems identified by farmers were:

- Difficulty in ploughing either after the *vlei* has dried out or after rain when it is too wet. *Vleis* are typically very dry in August and then become quickly waterlogged when the rain comes (these problems became worse in the 1980s).
- A general risk of dry planting.
- Non-uniformity of wetness in *vleis* makes management difficult.
- Weed problems, particularly *Cyperus* species, *Cynodon dactylon* and *Panicum repens*. Farmers have to weed all of time, especially early in season when labour is also required to plant toplands.
- Shortage of DAP.
- Waterlogging that can cause seeds to rot, and stunted crop growth.
- Nutrient deficiencies show much earlier than in toplands.
- Crops are more vulnerable to pests and diseases and early-planted crops are eaten by wildlife.
- Leaching problems.
- Crusting of soils.
- Problems with poor emergence of crop.
- Labour shortages for weeding
- Damage of winter crops by livestock.
- Problems of harvesting and storing early maize. Cobs rot and can be attacked by termites
- Shattering and loss of grain from maturing panicles of local rice landraces.

A combination of simple time line studies and mapping exercises were carried out with each community to explore how land use patterns had changed over the last 40 or so years, and how the communities perceived the future (Box 1).

Box 1: Summary of community views on *vlei* utilization

Before the 1950s: *Vleis* were being cultivated as intensively as now, but the main crops were rice and wheat with some *tsenza.* Areas cultivated per household were larger, with work undertaken by communal work parties (*nhimbe*). Where maize was grown it was on ridges with most cultivation carried out by hand. Little or no fencing was required as livestock were better controlled.

Present day: *Vleis* areas have been subdivided with a greater variety of crops grown. Topland areas less productive and the traditional dry land maize crop is now grown more intensively in *vleis*. *Vleis* now require more fertiliser and manure and more stray animals get into them. There is a perception that *vleis* are drying out.

Future: Overpopulation is expected with *vlei* cultivation being further intensified.

It is apparent that weeds are one of the major problems in the use of *vleis*, particularly when there is excess rainfall, as mechanical weed control cannot be carried out because the lands will be too wet for farmers to work on them. Predominant weed species characterising the *vleis* include a rhizomatous perennial grass *Panicum repens* (rusukira), heavy infestations of the perennial sedge *Fuirena* spp. (Gundla). These two weeds do not usually infest the same areas. Of the two identified *vlei* types, Gakata *vlei* types are characterised by a grass weed

Chivavani (*Urochloa* spp.) and Nhorobvukwa *vleis* are characterised by a grass weed Swayavelo. Weeds are therefore an important feature in the identification of *vlei* types.

<u>Household survey</u>

A household survey (Ellis-Jones and Gatsi, 2001) was undertaken in the project areas to provide quantitative information on *vlei* management practices. This was informed by, and provided additional detail to the community workshops (Mutambikwa *et al*., 2000). Four distinct resource categories of households were identified, based on participatory wealth ranking exercises (CARE, 1999), each category having different levels of assets, access to resources and income sources. This included well-resourced, average, poor and very poorly resourced households. Table 2 provides summary statistics form the survey

Table 2: Summary statistics showing the mean for each resource groups (n=163)

	RG1 (n=38)		**RG2** (n=71)		**RG3** (n=27)		**RG4** (n=27)	
% Of farmers in each resource category	23%		44%		16%		16%	
% Male HoH	74%		69%		74%		60%	
Predominant age group of HoH	Over 65		46-55		36-45		25-35	
Average household size	12.3		9.7		7.1		7.2	
% Belonging to local groups	82%		88%		77%		70%	
Average income levels (Z$ in 2000)	7364		4236		3107		1956	
Main sources of income	Dryland crops		Dryland crops		Dryland crops		Gardens	
In order of importance	Livestock		Livestock		Local wages		Local wages	
	Local wages		Remittances		Gardens		Livestock	
	Remittances		Gardens		Remittances		Pensions	
Livestock owned (head)								
Cattle	15		6		2.5		0	
Donkeys	1		0		0		0	
Goats and sheep	4		2		1		0.2	
% ***Households owning implements***								
Plough	100%		99%		93%		11%	
Cultivator	84%		32%		0%		0%	
Scotch cart	97%		85%		0%		0%	
Arable area cropped (acres)								
Homestead	2.3		1.8		1.2		1.4	
Topland	3.6		2.1		1.8		1.3	
Vlei	2.9		2.0		1.7		0.8	
Garden	0.6		0.3		0.2		0.1	
Average total crop yields (kgs)	***T***	***V***	***T***	***V***	***T***	***V***	***T***	***V***
Maize	750	300	650	220	300	240	300	140
Groundnuts	170	90	120	80	0	80	0	0
Rice		120		80		80		50
Cash expenditure on crop inputs (Z$)	3478		1991			1323		913

T=Topland, *V*=*Vlei*

Role of vleis in rural livelihoods

It was established that income from crop sales was the major income source for RG1, RG2 and RG3 households, but gardens and local wages were most important for RG4s. Production from *vleis* made an important contribution to crop production incomes as well as providing food security from a variety of different crops during the dry months.

Poorer households are more likely to be female headed, have a younger head of household; have a smaller household size with fewer people living away from home and hence less labour for agriculture operations; receive lower cash incomes; derive a greater part of their income from wages and gardens and less from dryland crops and livestock; own fewer livestock; own fewer implements; cultivate a smaller arable area; achieve lower yields; spend less on crop inputs and have less access to *vleis*.

Population pressures in all four localities indicate that the number of homesteads are increasing and therefore the area of arable land per household available (especially topland) is decreasing. Consequently, household access to the *vlei* land is becoming more important, and subdivision is occurring. For instance when someone dies, the land is sub-divided between his sons. Whilst overall productivity of the topland areas is on the decline, and areas of cultivated *vlei* is on the decline, many households are beginning to invest in *vlei* gardens. A detailed livelihood analysis was undertaken in Zimuto (Gondongwe village in Maraire) and Village 24 (Gongwe) in the resettlement area.

In Zimuto, some 50% of households cultivate *vleis*, which are regarded as more important in providing both cash and household foods, but requiring twice as much labour. Productivity for all crops in both the toplands and *vleis* was seen to be decreasing except for *vlei* gardens. In the resettlement area, there was little differentiation between topland and *vleis*, but it was significant that rice was regarded as the most important crop. In both areas other livelihood activities were important with poultry, selling fruit, beer making, and hiring out labour being important in Zimuto. In the resettlement area poultry and milk cows were important. It was established that *vlei* production made a substantial contribution to household incomes relative to other crops.

Weeding

By far the most widely used <u>weeding practice</u> is by hand with badza (over 80% in *vleis* and over 60% on toplands), followed by the ox cultivator (15%) and ox plough (7%). RG1s and RG2s use the cultivator and plough more with RG3s and RG4s being totally dependent on hand hoeing. A cultivator or plough can be only be used in maize sole crops and is commonly used in the smallscale commercial areas. Weeding is done mainly in August to September in wet *vleis* and November to December in dry *vleis* . Farmers attempt to keep the crop clean but rising water tables and waterlogging after the onset of the rain often prevents access to *vlei* fields and weeds re-establish readily under these wet conditions. Perennial sedges (particularly *Cyperus. esculentus*) and rhizomatous grasses (*Leersia hexandra* and *Panicum repens*) are particularly well adapted to *vlei* soils. Mechanical weeding by hand hoe or a cultivator allows only temporary suppression of these species at best. Most areas are weeded twice, sometimes three time sin the *vleis* and four times in the gardens. Most hand hoe weeding is undertaken by women, most DAP work with cultivator or plough by men. 10% of households hire labour and less than 5% use reciprocal labour (*nhimbe*). Weeds are usually left in the land (over 85%). Some is used for compost (10%) and some for food (5%)

<u>Hydrological survey</u>

A characterisation survey was carried out to assess the spatial and temporal variation of weeds and water tables. This involved the establishment of four matrices, each covering a *vlei* catena, in the four areas Mshagashe, Chikwanda, Gutu-Chatsworth and Zimuto. At each site, matrices were pegged out and at each intersection the depth to water table (using piezometers) was made at monthly intervals (Twomlow and Mutambikwa, 2000). Weed distribution data in each square of the matrices were also collected at the same intervals. The size of the matrices were: Mshagashe 100 x 100 m; Chikwanda 140 x 70 m; Chatsworth 110 x 110 m; Zimuto 90 x 70 m.

From baseline data collected in 2000, the water levels between these four matrices varied considerably. As an example, Figures 1 and 2 show the changes in water levels observed in two matrices, Mshagashe and Gutu-Chatsworth, over four monitoring periods in the first half of 2000. Mshagashe showed a progressive lowering of the water table from January through to June, by which time the water table was above the soil surface on only a small percentage of the total matrix area. In contrast to this, the matrix at Gutu-Chatsworth showed that although water levels were not as high in January compared to Mshagashe, measurements taken subsequently showed an increase in water level, with more areas of inundation occurring across the matrix. The difference in behaviour of the these two matrices illustrates important implications on the ability of a farmer to carry out winter cropping on the land, with conditions in the Mshagashe matrix being much more favourable than the Gutu-Chatsworth matrix

Figure 1: 3-D representation of changes in groundwater levels in the Mshagashe matrix

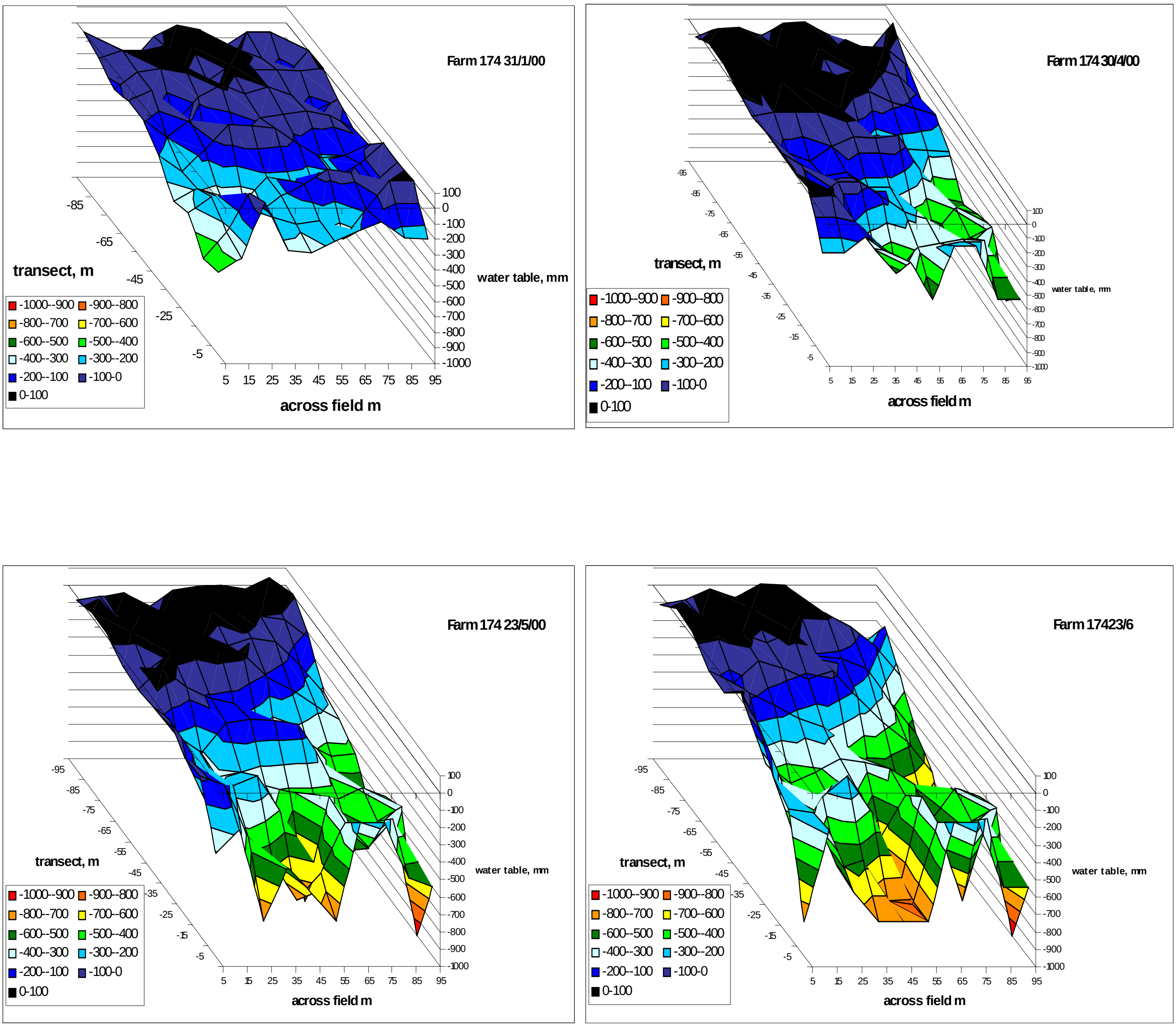
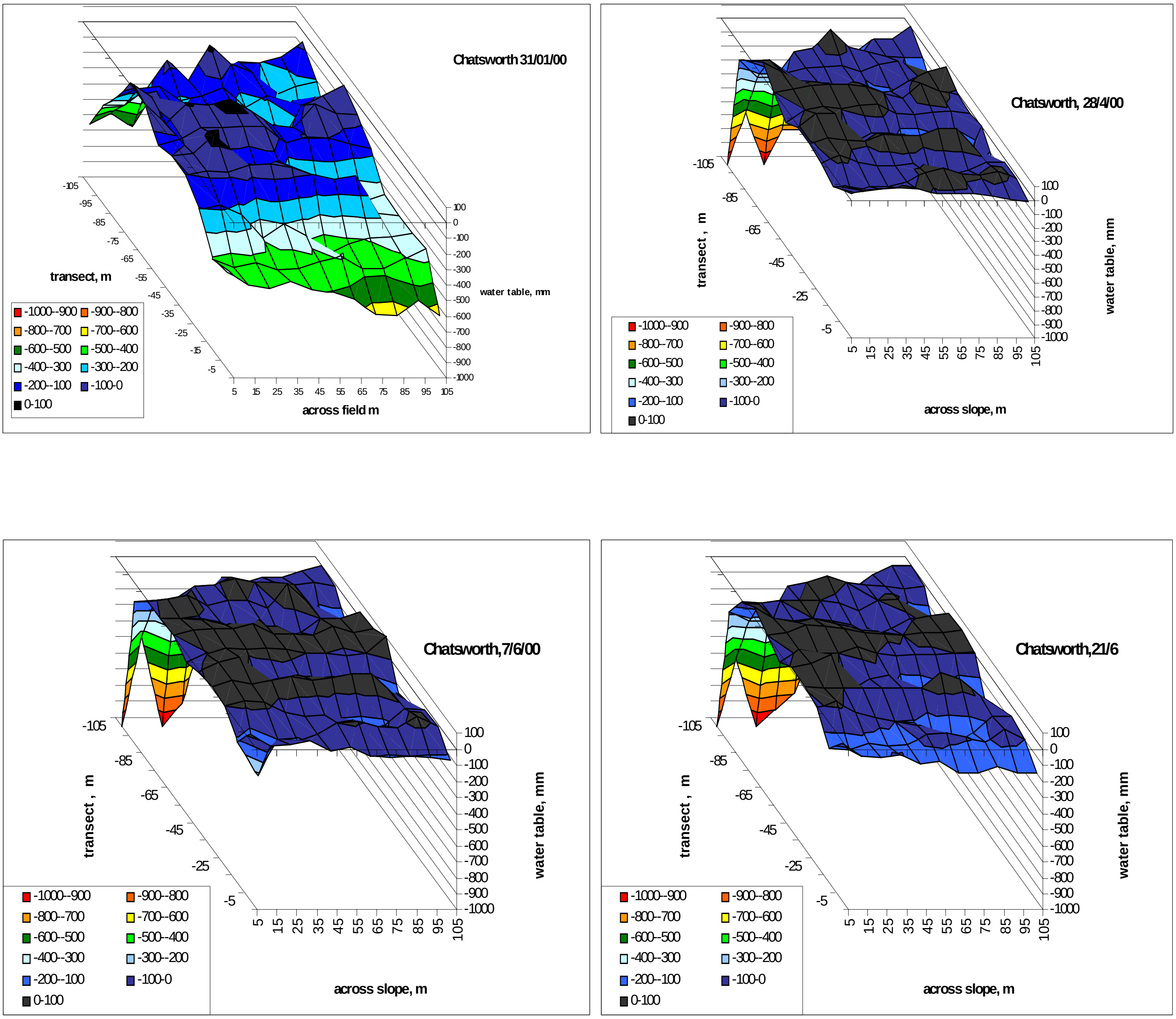


Figure 2: 3-D representation of changes in groundwater levels in the Gutu-Chatsworth matrix



Assessing strengths and weaknesses of current dissemination methods

Work undertaken by Chuma (2001) identified key dissemination objectives as being improving farmers' ability to identify and select appropriate soil, water and weed management options, supported by appropriate on-farm research with extension encouraged through effective research-extension-farmer partnerships. Feedback from farmers during workshops on their preferred methods of receiving information was achieved through pairwise ranking of alternatives (Barton, 2001). Although there was some differences between men and women preferred methods included competitions, training workshops, demonstrations, field days and exchange visits (Table 3)

Table 3: Farmers ranking of preferred methods of receiving knowledge (1=best, 9=worst)

Method	Women	Men
Competitions	**1**	**1**
Field days	**2**	**6**
Exchange visits	**3**	
Training workshops	**4**	**1**
Booklets/leaflets	5	
Radio and TV	6	
Posters	7	
Newspapers	8	
Videos/films	9	
Demonstrations		**1**

The emphasis placed on practical group learning has implications for future dissemination. Booklets, leaflets and posters common outputs of many research projects can only provide a support function to more practical methods of learning.

Review workshops

Project stakeholders convened in July 2000 (Riches, 2001) to consider the characterisation studies undertaken over the previous nine months. Options for improving soil, water and weed management, relative to household resource availability, were identified and a programme of on-farm research agreed for the next two seasons. This included a range of soil, water, weed and crop management practices, suitable for use by different resource groups involving low cost, animal drawn implements and the integration of reduced dosage herbicide use in both dry and wet *vleis*. Options included:

Soil and water management

- The comparison of the effects of a number of different tillage treatments on ground water levels through the season. Tillage methods included broad beds, furrows and pre- or post-plant ridges, all constructed across the contour at a safe grade to enhance drainage and improve access for weed control, compared to typical farmer practice of planting on the flat.
- Assessment of weeding method with and without herbicides on each tillage treatment.
- Assessment of the effects of these treatments on maize and rice yields.

Weed management in dry *vleis* (*Nhorobvukwa*)

- Maize grown as a sole crop with and without herbicide
- Maize and rice intercropped in the same row, and in alternate rows, without herbicide

Weed management in wet *vleis* (*Doro*)

- Maize grown as a sole crop with herbicide
- Rice grown as sole crop either broadcast or in rows with herbicide.
- Maize and rice inter-cropped, maize in rows with rice either broadcast (with herbicide) or planted in the same row (without herbicide).

On-farm researcher managed but farmer led experimentation of these interventions was initiated in August 2000 and continued for two crop seasons. The work focused on the existing cropping systems and household resource categories identified during the characterisation studies. Care was taken to include and work with poorer groups with least assets and access to resources.

Evaluation of innovative options for crop and weed management

Soil and water management

On-farm trials were established in each of the four areas with four farmers in each area hosting tillage trials on their *vleis.* Two offered wet *vleis*, two offered dry *vleis*, giving a total of eight wet and eight dry *vleis*. Five treatments were tested at each site (Table 4). All plots were graded at a 1:100 slope to ensure that water could be safely discharged into contour drains at a 1:250 slope.

Table 4: Tillage treatments assessed in on-farm trials on wet and dry *vleis* in Masvingo Province

T1	**Broad beds**	Two rows of maize planted on raised beds and rice planted in furrows between the beds.
T2	**Pre-plant ridges**	Maize planted on ridges constructed at planting and rice planted in the furrow.
T3	**Post-plant ridges**	Maize and rice planted on the flat and ridges made after the crops have established.
T4	**Drainage furrows**	Maize established on the flat, with furrows made after the rains start, rice planted in the furrow.
T5	**Flat** *Farmer practice*	Maize planted on the flat with rice planted either in the same row or broadcast between the maize rows.

Plots varied in size from site to site depending on the area available on each farm, but the crop rows were always a minimum of 30m in length. The maize and rice were planted on residual moisture in September 2000 before the onset of the rains. Maize variety SC513, tolerant to grey leaf spot was planted at all sites. The rice used in the trials was a local variety (*Muchecheni*). Maize was planted at a spacing of 0.9m (between row) x 0.3m (within row), while the rice was planted at a rate of 60 kg ha^{-1}. Compound D fertiliser (8%N, 14%P, 7%K) was applied to all plots at a rate of 150 kg ha^{-1} while a top-dressing of ammonium nitrate, 34%N, (AN) was applied at 100 kg ha^{-1} approximately 2 months after planting. Each plot was split in half, one half where the weeds were treated with herbicide and the other where they were controlled by hand hoeing only. On the herbicide sub-plots, bentazone (1440 g a.i. ha^{-1}) was applied 3 weeks after crop emergence (WAE) using a knapsack sprayer producing a spray volume of 300 litres ha^{-1}.

Groundwater levels were monitored using a number of observation pipes, which were inserted, into auger holes to approximately 1m depth (or to the limiting layer, eg. rock or gravel, if this was encountered first). Two pipes were placed on the upper part of the *vlei* (one on the herbicide treated plot, one on the hand hoed plot) and two were placed at the bottom end, closest to the waterway, thereby ensuring that the range in water levels across the treatments was encompassed. The groundwater levels were measured at approximately 2-3 weeks intervals. Figure 3 shows a simplified cross-section of the five treatments and the position of the monitoring pipes assuming a constant water level. It is important to note that the depth being measured at each time interval is from the soil surface to the water table (depths x on Figure 2).

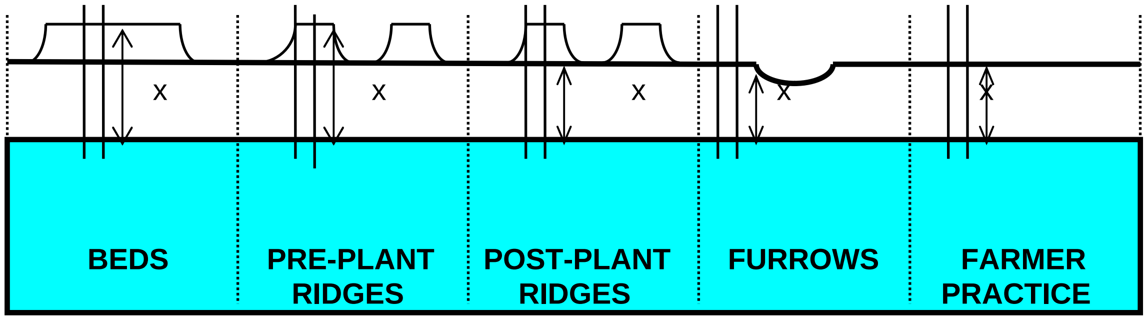


Figure 3: Cross-section of the five tillage treatments with observation pipes

Groundwater levels

Figure 4 illustrates the temporal variation in groundwater levels under the five different tillage treatments, averaged across the four areas in the 2000-01 season. The mean rainfall received during this period was 642 mm. The groundwater levels are closely related to the pattern of rainfall received, with the lowest levels associated with the depression in rainfall between 110-120 days after planting (DAP) and a significant increase in water levels on all plots as a result of rainfall received between 140 days and 180 DAP. On the wet *vleis*, broad beds had the lowest water table on five out of the seven measurements, an effect which was more pronounced during the latter half (>170 days after planting) of the season. At the fifth recording time, the water table was closest to the soil surface with the flat planting treatment, although there was little difference between that treatment and the post-plant ridges. The highest water levels on the dry *vleis* were also recorded under the flat planting treatment with a more pronounced difference compared to the other four treatments, although this was restricted to the measurements taken during the wetter part of the season. Furrows showed the highest water table during the first 125 DAP, but proved more effective in reducing groundwater levels during the wetter periods.

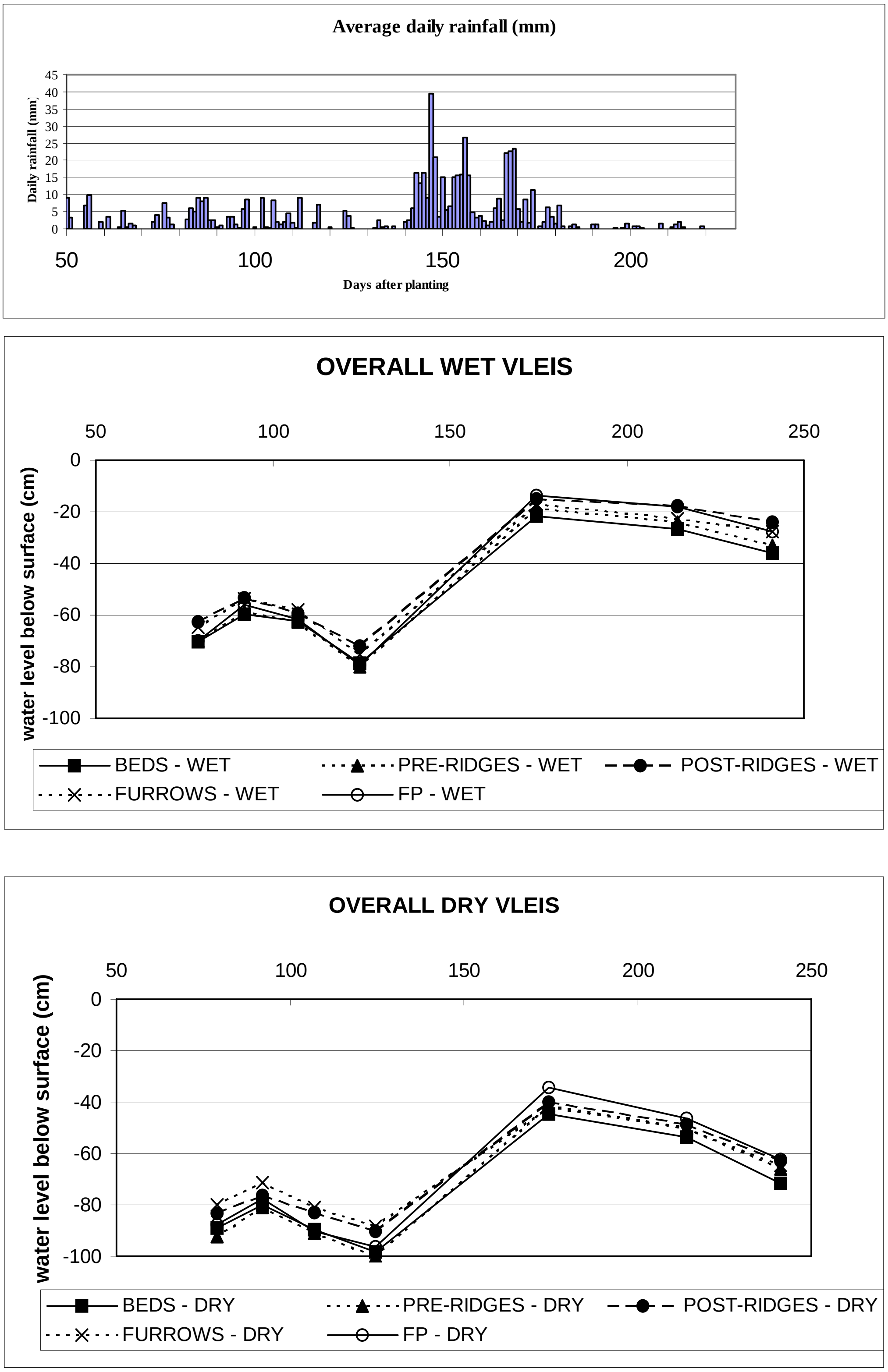


Figure 4: Temporal variation in groundwater levels on wet and dry *vleis* averaged across the sites for the five tillage treatments

The data are summarised in Tables 5a and5b. Individual ANOVAs of the water level data for each monitoring period highlighted significant effects with tillage, *vlei* type and position within the *vlei*, therefore the tables below highlight these three variables in particular.

Table 5a: Effect of tillage and *vlei* type on mean groundwater levels in the 2000-01 season

Tillage	***Vlei* type**		**Tillage mean**
	Dry	***Wet***	
Broad beds	-75.3	-50.7	*-63.0*
Pre-plant ridges	-74.5	-50.0	*-62.0*
Post-plant ridges	-69.3	-43.4	*-56.3*
Furrows	-68.3	-45.6	*-56.9*
Flat Planting	-70.7	-46.7	*-58.7*
***Vlei* type mean**	*-71.6*	*-47.3*	-

Table 5b: Effect of tillage and position in *vlei* on mean groundwater levels in the 2000-01 season

Tillage	**Position in *vleis***	
	Upper	***Lower***
Broad beds	-65.3	-60.8
Pre-plant ridges	-64.1	-60.0
Post-plant ridges	-58.3	-54.4
Furrows	-59.3	-54.5
Flat Planting	-61.3	-56.1
Position mean	***-61.7***	***-57.2***

The average depth to the water table under the broad beds was -63.0 cm, compared to -56.3 cm under the post-plant ridges, highlighting the ability of broad beds to effectively lower the water table away from the maize roots. The difference was more pronounced in the wet *vleis* where a difference of 7.3 cm was recorded between these two treatments, compared to 6.0 cm in the dry *vleis*. These averages do however mask field observations, where the water table was either at or slightly above the level of the soil surface on some of the flat planted treatments during the very wet period of the season (*c.* 150 DAP), making access to the fields for weeding and other activities very difficult or impossible. The distinction made by farmers between the wet *vleis* and the dry *vleis* is particularly important in terms of water table levels, as the means indicated that there was a 24 cm difference between the wet and the dry *vleis*. This has implications on decisions regarding cropping patterns across the farm, where areas that are frequently inundated may offer greater potential for sole rice rather than maize-rice intercropped. Similarly, the ability of the farmer to recognise the wetter or drier parts of any particular *vlei* are highlighted in Table 5b, where there was a difference of 4.5 cm in mean groundwater levels between the upper and lower positions. The relative ranking of the tillage treatments remained the same regardless of position. However, in some *vleis* included in this study, the depth to water table does not necessarily follow the lay of the land, due to interactions with the underlying geology. In practice this can mean the occurrence of wetter areas on land that is topographically higher than surrounding areas over very short distances, which can make crop management difficult.

<u>Maize germination percentages</u> before gap filling were measured on all plots. <u>Maize and rice yields</u> were measured by sampling sub-plots encompassing the middle crop rows at the upper and lower ends of each plot. The results were standardised to 12.5% moisture content and expressed on a kg per hectare basis. They were then statistically analysed using individual farms as replicates in ANOVA in Genstat, to test for effects of tillage (beds, ridges, furrows, flat), *vlei* type (wet vs. dry), herbicide usage and position in the *vlei* (upper vs. lower)

Mid-season evaluations were undertaken jointly in January 2001 by farmers, extension workers and researchers (Riches, 2001) to establish farmer evaluation criteria and their perceptions of the best treatment at that time. These evaluations are discussed further by Muzenda *et al*., 2002.

Economic analysis was based on a comparative analysis of treatments with normal farmer practice of planting on the flat without herbicide.

Weed management

Field trials were established in farmers fields based on a strip plot design. A single strip of each treatment, measuring from 30m x 5m to 45m x 5.6m, was established at each site depending on the size of suitable *vlei* available. Each treatment was replicated in three farmer's fields in each of the same four areas used in the soil and water management trials. Separate trials were established on two *vlei* types identified by farmers as *doro* (wet *vlei*) and *Nhorobvukwa* (marginal or dry *vlei)*. Four and five cropping pattern/weed management combinations were evaluated in dry and wet *vleis* respectively (Table 6). The options included planting of sole maize, sole rice and maize-rice inter-crops with weed control by herbicides, hand hoe or and combinations of herbicide and hoeing.

Table 6: Cropping patterns and weed control practices evaluated in wet and dry *vleis*.

Treatment	**Crop**	**Herbicide (application rate in g. a.i. ha^{-1})**
Dry *vleis*		
T1	Maize	Atrazine 1250 + Halisulphuron 33.75
T2	Maize	Nil
T3	Maize + rice (variable rate) in same row (Farmer practice)	Nil
T4	Maize + rice in rows between maize rows	Nil
Wet *vleis*		
T1	Rice broadcast (120 kg ha^{-1})	Bentazone 1440
T2	Maize + rice (variable rate) in same row (Farmer practice)	Nil
T3	Maize + rice broadcast	Bentazone 1440
T4	Rice in rows (120 kg ha^{-1})	Bentazone 1440
T5	Maize	Atrazine 1250 Halisulphuron 33.75

Rice seed rate was 60 kg ha^{-1} unless stated. Herbicides applied 3 weeks after planting. Hand hoe weeding was undertaken at 3 and 6 WAE.

Maize and rice were planted before rain in September, germinating on residual moisture. The land was ploughed and harrowed just before planting. A short season Grey Leaf Spot tolerant maize cultivar, SC 513, was planted (2 seeds per station) at all sites at 90cm x 30cm. Planting furrows were immediately closed using harrows, hoes or feet to avoid the soil around the seed drying out. Maize was thinned to one plant per station 2-3 weeks after emergence (WAE) to give a crop density of 37,000 plants ha^{-1}. A local variety of rice, *Muchecheni*, was either broadcast, or dribbled into shallow planting furrows opened by a plough or cultivator and subsequently covered with a harrow.

Fertiliser (Compound D - 8% N, 14% P, 7% K) was applied at 150 kg ha^{-1}, in planting furrows. Where rice was broadcast between maize rows, half the fertiliser was placed in the planting furrows and half broadcast in the inter-row area. For broadcast sole rice treatments, the fertiliser was broadcast uniformly. Ammonium nitrate (34.5% N) was side-dressed on maize or rice in rows. In maize-rice inter-crop and broadcast rice the fertiliser was applied at 100 kg ha^{-1} at 6 WAE. Herbicides were applied 3 WAE when most of the weeds were at the 2-3 leaf stage. Although emerged weeds were actively growing from residual moisture, surface soil conditions were dry and atmospheric conditions hot and dry. Before weed control at 3 WAE, weeds were counted by species, in three randomly placed 30 x 30cm quadrats in each plot. Weeds were also counted in the same marked quadrats at 6-7 WAE, just before the second weeding. Counted weeds were cut at ground level and oven dried (60 ^{o}C) to constant weight. At maize physiological maturity (12-13 WAE), weeds were counted in three 30 x 30cm random quadrats in each plot and biomass was determined as before. A third hoe weeding was necessary only for the sole rice treatments in wet *vleis* at 12-13 WAE.

Maize and rice were harvested from three marked quadrats, randomly placed within a sub-plot area of 4 rows wide x 8-10m long (for treatments with maize) or 3.6–4m wide x 8–10m long for rice. Maize yield was standardised to 12.5 % moisture content before analysis of variance. Weed density data was square root transformed before analysis of variance.

Improving rice varieties

In the first season 22 rice lines and varieties were obtained from WARDA (West Africa Rice Development Authority). These included *Oryza sativa* varieties which are widely grown in West Africa, two landraces of the African rice, *O. glaberrima*, and a number of recently developed *O. sativa* x *O. glaberrima* inter-specific hybrid lines. Although resulting from inter-specific crosses, these lines are stable and fertile. A "participatory variety selection" (PVS) methodology was adopted and in 2000-01 four farmers agreed to plant the test lines and to manage the plots (see Jiri *et al.,* 2002 for full details). Half the entries (11) plus the farmers own land race (‘*muchecheni*’) were planted on one field at each of Mshagashe and Zimuto. The other lines were planted at Chatsworth and Chikwanda. Because only limited seed was available, each line was planted on a single plot of three, five meter long rows at each site. Farmer groups evaluated the trial at Mshagashe and Chatsworth at approximately 160 days after seeding. Seed was retained and weighed from each plot.

In the second season, a further 16 inter-specific hybrids were obtained from WARDA and three lines were sourced within Zimbabwe, including two selected during earlier research on *vlei* cropping. Three activities were undertaken:

Replicated trial: All entries, including a local landrace, were evaluated in a wet *vlei* on land provided by the farmer at Farm 174 in Mshagashe Small Scale Commercial Farming Area. A randomised block design with three replications was used. Plots consisted of 5 rows each 5m long with an inter-row spacing of 45 cm. Rice seed was dry planted on 4th September 2001. The trial area was weeded at 27 and 69 days after sowing. In order to avoid problems from volunteer plants of local rice, a field, which had been fallow for the past 10 years, was used for these trials.. Fertiliser was applied as a basal dressing (compound D) at a rate of 15 kg N ha^{-1} followed by top dressing (ammonium nitrate) at a rate of 30 kg N ha^{-1}. A field day for local farmers was held on 28th February (177 days after sowing) by which time all entries that would eventually produce a yield had headed. Farmers ranked the rice lines in the trial according to their own evaluation criteria.

On-farm PVS trials: Eleven lines, which were selected by farmers in 2000-01, were tested on-farm. Because variable quantities of seed were available, harvested from the previous season’s trials, not all lines could be tested at all sites. Farmers identified by AREX extension workers in Chatsworth (2 farmers), Chikwanda (2), Mshagashe (1) and Zimuto (2) each received a set of at least 9 lines to compare with their own landrace. There was sufficient seed to plant one plot of six x 5 m long rows, spaced 45 cm between each line. Farmers hosting the trials were responsible for managing the plots with assistance from AREX. Farmer group evaluations of the trials were undertaken prior to harvest although this was not possible in Zimuto due to on-going political instability. Yields were measured at one site in each of Chatsworth, Chikwanda and Mshagashe.

Seed multiplication: 10 lines selected during farmer evaluation during 2000-01 were multiplied at Farm 174 Mshagashe, each on a plot of 100 m^2.

Joint evaluation of trials using both farmer and researcher criteria

Trials were monitored closely by farmers and researchers on a regular basis during both seasons. Evaluations by farmers, researchers and extension workers were undertaken during the middle of the season and following harvest after results were available and had been analysed at end of season workshops.

Mid-season evaluations

Field days were held in February 2001 (Riches, 2001) and January 2003. At all sites farmers showed considerable interest in the practices which improved drainage, most notably, planting on broad beds, pre-plant ridges, or adding drainage furrows into established maize. Of 101 farmers expressing an opinion, some 61 (60%) selected beds and 21 (20%) selected pre-plant ridges as their first choice. Farmers at Mshagashe, Chatsworth and Chikwanda were particularly interested in beds while at Zimuto the majority expressed most interest in pre-plant ridges.

In the weed management trials, in the dry *vleis*, farmers selected the maize-rice inter-crop with the rice seeded in rows between maize rows as the best plot, with sole crop maize with pre-emergence herbicide as the next best. Farmers were keen to produce a rice crop in the drier position of the *vlei*, even though it is a less favourable environment for the crop in many seasons.

In the wet *vleis*, sole crop rice had been introduced as an approach for maximising productivity and simplifying chemical weed control. As with the dry *vlei* trial, the initial reaction of farmers was that mixed crops are better as a risk reducing practice. Farmers therefore evaluated sole rice and mixed plots as two groups of practices.

- Sole crop rice planted in rows and treated with bentazone was favoured at Chatsworth and Zimuto. Some farmers maintained that it is easier to seed in rows than to broadcast, even though row planting needs more labour. Row planted rice is easier to thin and could be weeded with a cultivator. It is also easier to harvest and shattering (a common problem with the local land race, ‘Muchucheni’) will not be a problem. Bentazone was effective against sedges but did not control the annual grass *Setaria*, which was a particular problem at Zimuto. Herbicide use reduced labour input into weeding **but** has cost implications and problems with lack of knowledge on the safe and efficient use of herbicides.

- Conversely, broadcast rice was favoured at Chikwanda. Farmers commented that the population was much lower with a considerable number of gaps in the stand due to poorer emergence. This was seen as an advantage as individual rice plants could tiller and produce larger grains than where the population was higher on row planted crops. A lower seed rate and thinning would overcome this.

- Sole maize treated with herbicide was favoured at Chatsworth and Zimuto. Crop vigour on these plots was good due to early weed control, as the halisulphuron/atrazine tank mix had effectively controlled major weeds **and** labour at weeding was reduced. **However**, the same issues as mentioned for the wet *vlei* concerning cost and a lack of knowledge were raised again by farmers.

- Farmers also favoured broadcast rice in row planted maize system when bentazone is applied for early weed control. As previously mentioned, the mixed crop is seen as more favourable to ensure a harvest under a range of conditions. Labour use for weeding early in the season is reduced as bentazone suppresses *Cyperus esculentus*. **However**, later weeding can only be done by hoe. Some farmers also consider that competition between rice and maize is more likely when the rice is broadcast **but** this is not a generally held view.

Mid-season evaluation of the second year's crops was smaller and lower key, as large gatherings were not encouraged by the authorities as the timing coincided with the run up to the Presidential elections. However, farmers expressed similar views and were particularly keen on the bed and ridge systems, in view of the heavy rains experienced at the start of the season. After the mid-season evaluation field day held in Mukaro, farmers saw and discussed the various treatments for water and weed management in *vleis*. They saw it as an opportunity to compete with the researcher-led trials. Some of the farmers were keen to try out a selection of the treatments included in the experiment on their own farms, with assistance from the extension worker (Table 7).

Table 7: Treatments undertaken by farmers:

Treatment	**Farmers trying out technology**
Broad beds	A. Matizanadzo*, T. Mukaro, R. Machingambi, S. Tsanyawo
Broad ridges	A. Machingambi, T. Mukaro, S. Tsanyawo, A. Matizanadzo*, A. Ruzive
Rice planted on the flat in rows 45 cm apart	T. Mukaro, A. Ruzive, S. Tsanyawo, A. Matizanadzo*
Rice planted in the furrow	A. Matizanadzo*, A. Ruzive, S. Tsanyawo, T. Mukaro
Rice broadcast	A. Matizanadzo*, A. Ruzive T. Mukaro, S. Tsanyawo

An important point to note here is that the broad beds and ridge treatments were not those being tested on the researcher-led trials but were farmer modifications of these treatments. **Ridges** were broader than those used in the trials and were constructed by three runs of the plough - maize seed was dribbled on the second run and covered with the third furrow slice. It was noted that this treatment produced 100% germination. The **broad beds** were constructed by six runs of plough (compared to four under the trials) – maize seed was dribbled on the third and fourth furrow slice and covered with the fifth and sixth runs. Again, it was noted that this procedure resulted in 100% germination, as well as reducing the labour requirements, since planting stations did not have to be made with the hoe.

At the end of the season, the farmers made the following observations:

- They intend to practice some of the treatments on bigger portions of land;
- They would like to use more fertilizers;
- They are very interested in making compost in place of fertilizers;
- Many farmers want to put in infiltration pits on their farms;
- Some farmers want to experiment with higher density rice planting.

End of season evaluations

Annual evaluation and planning workshops (Twomlow *et al*., 1999; Riches, 2000, Barton, 2001 and Barton and Ellis-Jones., 2002) were held to ensure stakeholders' interest and views were fully considered on project results and planning for future activities. The results form these are discussed under Project Outputs (Innovative options for crop and weed management).

Promotion and dissemination of findings

Research findings were promoted through the mid season field days, end of season annual project workshops (whose proceedings were widely distributed), presentations at international conferences (Mutambikwa *et al*., 2002; Muzenda *et al*., 2002) and appropriate publications. Best Practice Guidelines on soil, water and weed management and knapsack use were prepared in draft for discussion at the 2003 Workshop and subsequently modified before wider distribution to extension workers through project R8191. Develop collaborating institutions' capacity to participate with rural communities, particularly women, in the identification and solution of systems constraints.

OUTPUTS

The research results and products achieved by the project. Were all the anticipated outputs achieved and if not what were the reasons? Research results should be presented as tables graphs or sketches rather than lengthy writing and provided in as quantitative a form as far as is possible.

Understanding the impact of weeds and the opportunities for improved weed management

Vleis have multiple uses including year round cropping, with winter wheat and vegetables during winter (dry) months and maize, rice, groundnuts and beans during the summer (wet) months. Most important is the ability to plant field crops, some 4 months before the rains, by utilising residual moisture, with rice and maize inter-crops being the preferred option. In many years, especially when rainfall is above average, weeds become an impossible burden, waterlogging occurs and whole fields are abandoned. Because legislation prohibits *vlei* cultivation, little previous research has been undertaken on alleviating these constraints and no guidance has been given to farmers on appropriate farming practices. Major constraints to improving productivity were confirmed as being weed, water and soil management.

A nine-month period of characterisation and learning from farmers, led to two seasons of on-farm experimentation of partner (researcher-farmer-extension) selected options. These included maize-rice cropping systems (either sole crops or inter crops) combined with different weeding practices, and soil tillage systems designed to alleviate waterlogging problems, such as broad beds, pre- and post-plant ridges and drainage furrow systems constructed with existing equipment and resources, combined with the use of low cost safe herbicides or hand weeding techniques. Improved OPV rice varieties provided by WARDA in West Africa were also evaluated through on-farm trials. Full details of these opportunities are described in the section "Review workshops", and "Evaluation of innovative options for crop and weed management".

Innovative options for crop and weed management identified

Soil and water management

Table 8 summarises the main sources of variation in maize and rice yields identified by ANOVA, showing the overall yields for each *vlei* type, tillage treatment, weeding method (herbicide or hand hoeing) and position in the *vlei*. Significant treatment effects were observed with both maize and rice yields. Maize yield with the broad bed system averaged just less than 3500 kg ha^{-1}, while drainage furrows showed the second highest yield of 3077 kg ha^{-1}. The lowest yields were observed on the farmer practice treatment at 2206 kg ha^{-1}. This pattern was observed regardless of herbicide usage. Yields from the herbicide treated plots were lower than those not treated with herbicide. This effect was not statistically significant with maize, but it was with rice yields. Bentazone, the herbicide used in the trials, provided good suppression of *Cyperus esculentus* at all sites but did not control some other abundant species including *Leersia hexdandra, Setaria pumilla* and *Richardia scabra*. These were removed by hoe weeding, possibly accounting for the higher yields with this method of weed control. The position in the *vlei* also significantly affected the maize yields, with higher yields measured on the upper part of the *vlei*. The lower part of the *vlei* is the area that suffers most from inundation, particularly where water is not effectively draining out of the *vlei* into the waterway. As the results suggest, this can adversely affect final maize yield.

Area, *vlei* type and position did not significantly affect rice yields. However, tillage treatment showed interesting differences. Contrasting with the maize yields, the highest rice yields were obtained on the farmer practice flat planting system, reaching an average of 671 kg ha^{-1}. Beds gave the second highest yields almost 100 kg ha^{-1} lower than flat planting. Zero yields on the post-plant ridges and furrows were due to a combination of reasons. In respect of the post-plant ridges, the timing of the construction of the ridges was such that the disturbed soil from the plough when thrown up next to the maize plants smothered the young rice alongside, preventing it from growing any further and thus giving no yield. However, the construction of the ridges could not have been left till later because this would have resulted in severe maize damage by cattle. This problem could possibly be overcome by using the plough without the mouldboard to create the ridges, where less soil would be disturbed in construction. Alternatively, the amount of soil disturbed could be minimised by reducing the plough depth to ensure that the rice plants are not completely covered by ridge formation. The zero yields on the furrows can be attributed to late planting, since the rice could not be sown until after the furrows had been constructed. Since the beds were not constructed until late November, it was not possible to sow rice.

Figure 5 shows the average maize germination percentages recorded in the first year. The results clearly illustrate the much lower germination on the pre-plant ridges (40%) and, to a lesser extent, beds (48%) compared to the three flat-planted treatments, which all produced around 70% success rate. These results corroborate field observations where on many farms there was much more gap filling required on the pre-plant ridges especially. The results highlight the risks associated with pre-plant ridging and the likely increase in labour required to gap fill.

Table 8: Main sources of variation in maize and rice yields (kg ha^{-1}) in on-farm tillage trials on *vleis* in Masvingo Province.

Source of variation		Maize yield	Rice yield
	Wet vlei	2919	324
	Dry vlei	2628	385
SED		156	58
	Significance	NS	NS
	df	2	2
	Beds	3441	578
	Pre-plant ridges	2417	522
	Post-plant ridges	2725	0
	Furrows	3077	0
	Flat	2206	671
SED		192	98
	Significance	***	***
	df	32	32
	Herbicide	2691	329
	Hand hoe	2856	380
SED		99	18
	Significance	NS	**
	df	40	40
	Upper vlei	2924	359
	Lower vlei	2622	350
SED		134	28
	Significance	*	NS
	df	80	40

SED Standard error of differences
NS not significant
* P<0.05, ** P<0.01, *** P<0.001

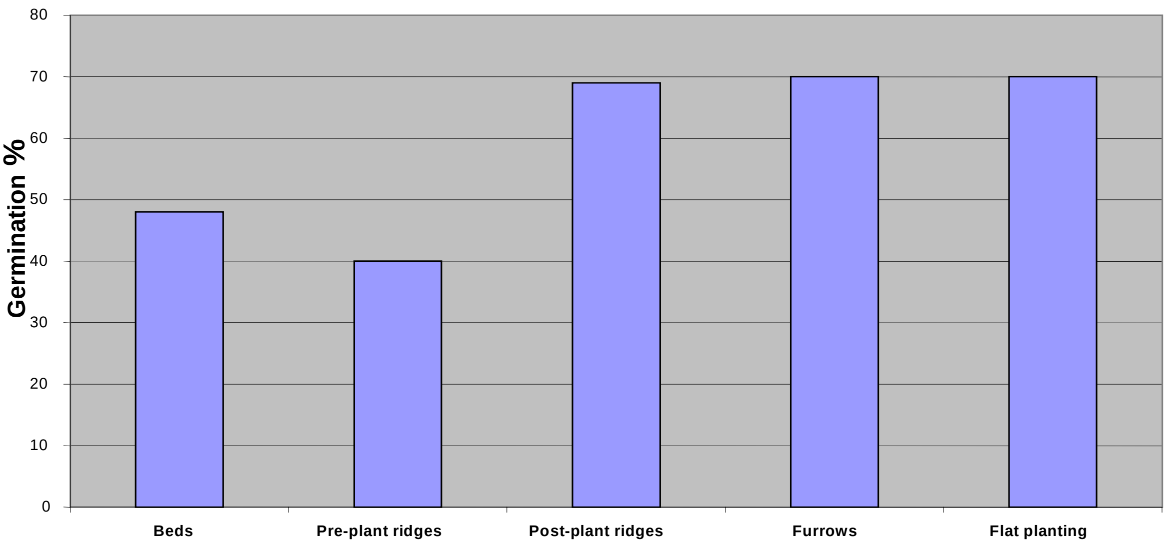


Figure 5: Germination percentages as affected by treatments

Looking at the maize germination data for the wet and dry *vleis* separately (Figure 6), the same general pattern is observed, but there is an interesting interaction between *vlei* type and treatment.

On the beds and pre-plant ridges, there was higher germination on the wet *vlei* compared to the dry *vlei*, whereas with the three flat-planted treatments the opposite was true, with higher germination on the dry *vlei*. This highlights (i) the attendant risk of waterlogging and ensuing germination problems early in the season on maize planted on the flat, particularly in wet *vleis* and (ii) the risk of germination failure due to dryness on pre-plant ridges or beds, especially on the dry *vleis*. In the experiment, all plots were gap filled to the required planting density of 37,037 plants ha-1, but there is obviously a labour implication associated with this activity.

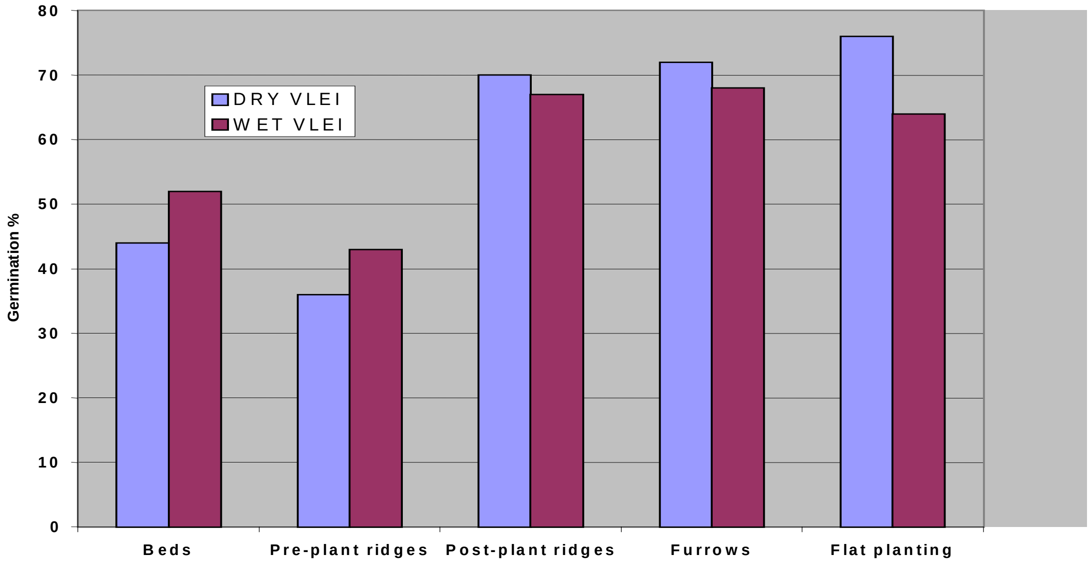


Figure 6: Germination percentages as affected by *vlei* type and treatment

Economic analysis

Key variables in determining highest productivity are crop yields adjusted for significance (Figure 7), market prices, and the cost of labour for tillage and weeding operations and applying herbicide against savings in labour for each system. Since there were significant differences between soil tillage treatments, but none between weeding methods, average yields from each tillage treatments with or without herbicides, and average farm-gate prices in August 2002 were used to determine the gross value of the crops produced (Figure 8). Herbicide and labour costs for weeding and tillage and other operations that differed for each cropping system were determined using August 2001 market prices (or opportunity cost for household supplied inputs. A partial budget analysis used to determine the most profitable treatment (Table 9). Marginal analysis allowed the net benefit between treatments to be compared showing an increase or decrease over farmer practice and returns pr labour hour to be determined (Table 9, Figure 10a and 10b).

Sensitivity analysis on these variables indicates that the prices of labour and herbicide are key. When the price of labour is low (less than Z$200 per day), traditional farmer practice on the flat and the broad bed system without herbicide are the most productive. As labour price increases, due to unavailability or opportunity elsewhere, flat systems with herbicide become more productive. At a labour price of Z$300 per day, bed systems with herbicides become marginally more productive and at $500 per day all herbicide treatments are more productive, even at the comparatively high costs of herbicide. Labour availability remains a key concern and many farmers continue to lose their entire crop due to weeds. This is not reflected in trial results, but makes the use of herbicides particularly attractive.

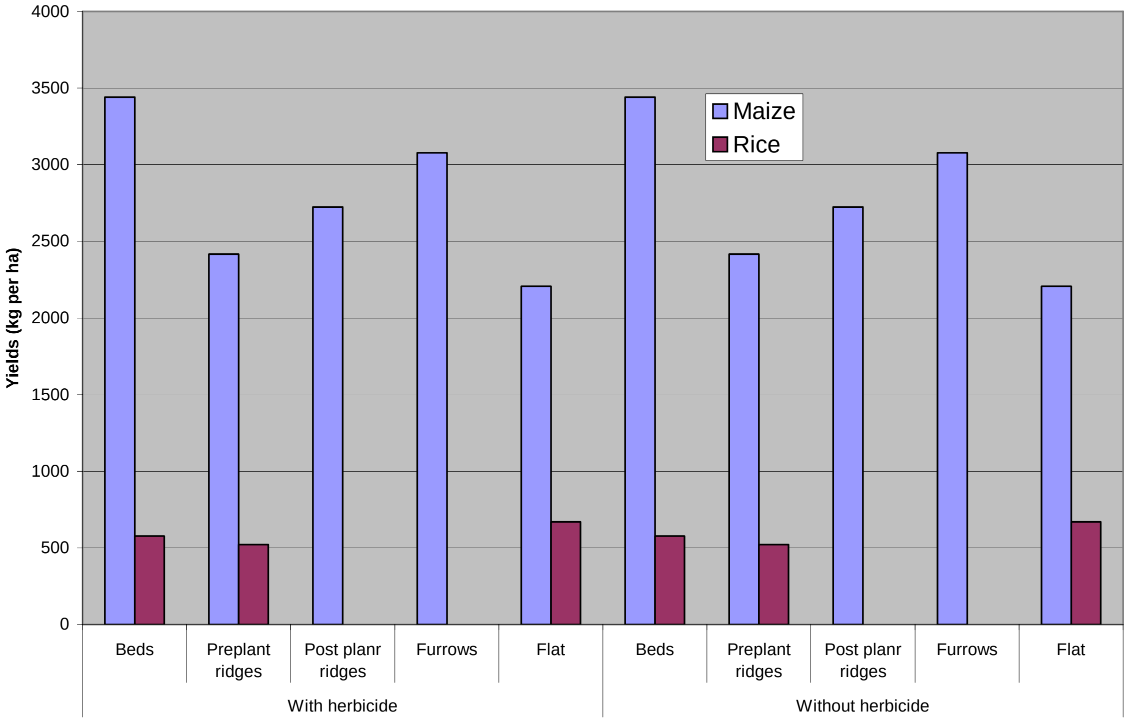


Figure 7: Average maize and rice yields (kg ha^{-1}) for each treatment

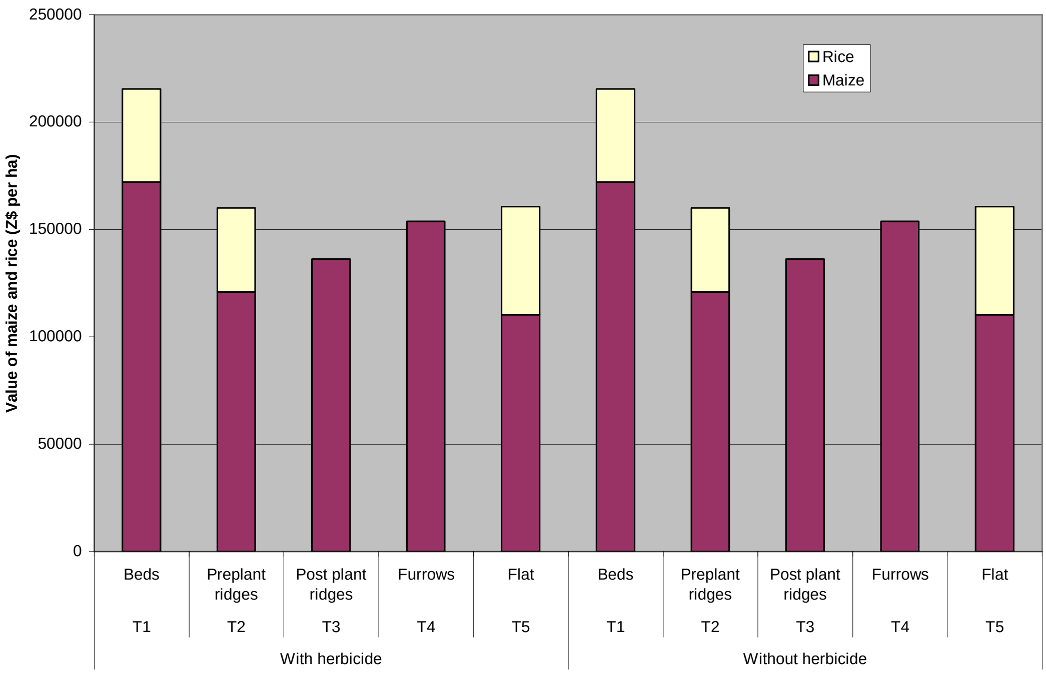


Figure 8: Gross benefits from each treatment (Z$ per ha)

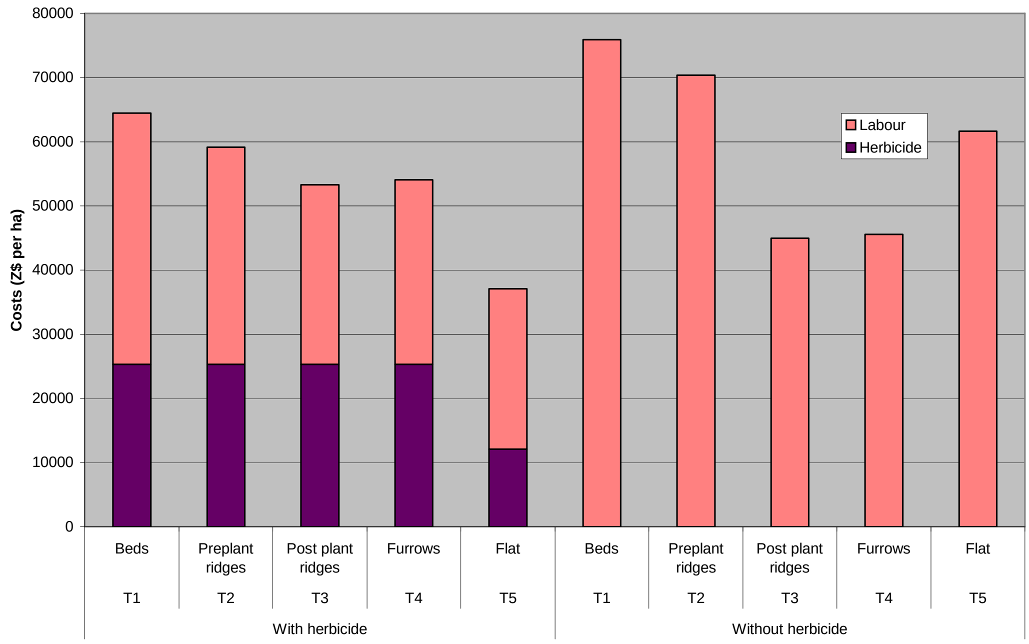


Figure 9: Labour and herbicide costs of each treatment (Z$ per ha)

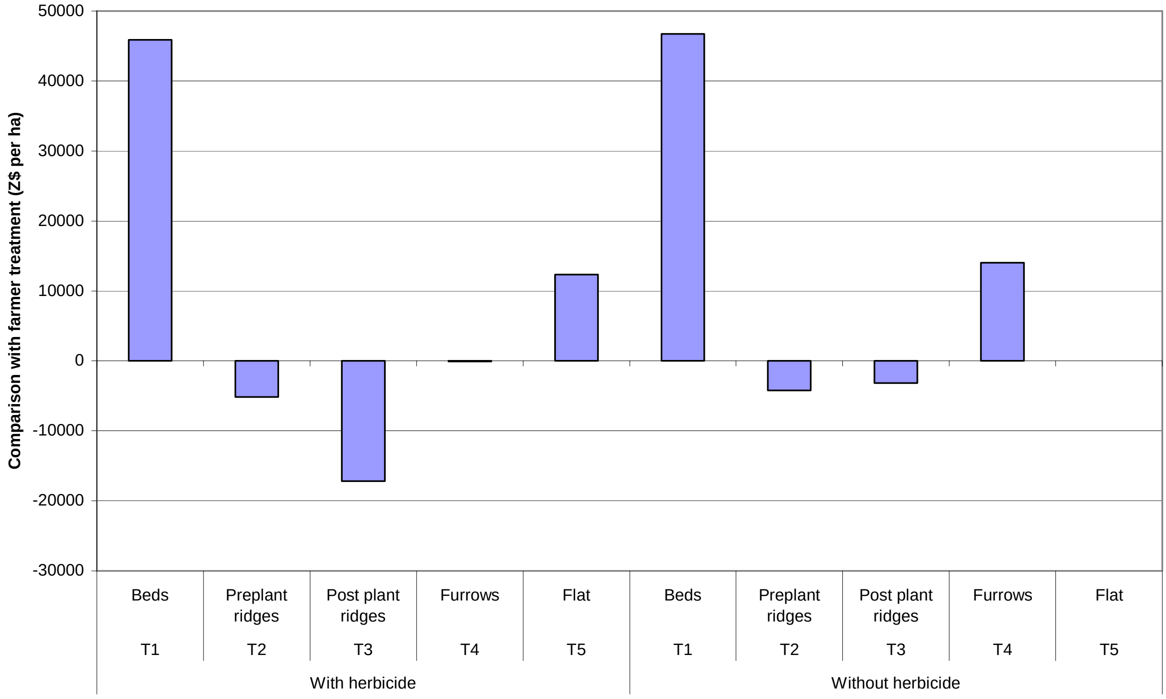


Figure 10a: Comparison with farmer treatment (T5 flat without herbicide) at a labour price of Z$ 200 per day

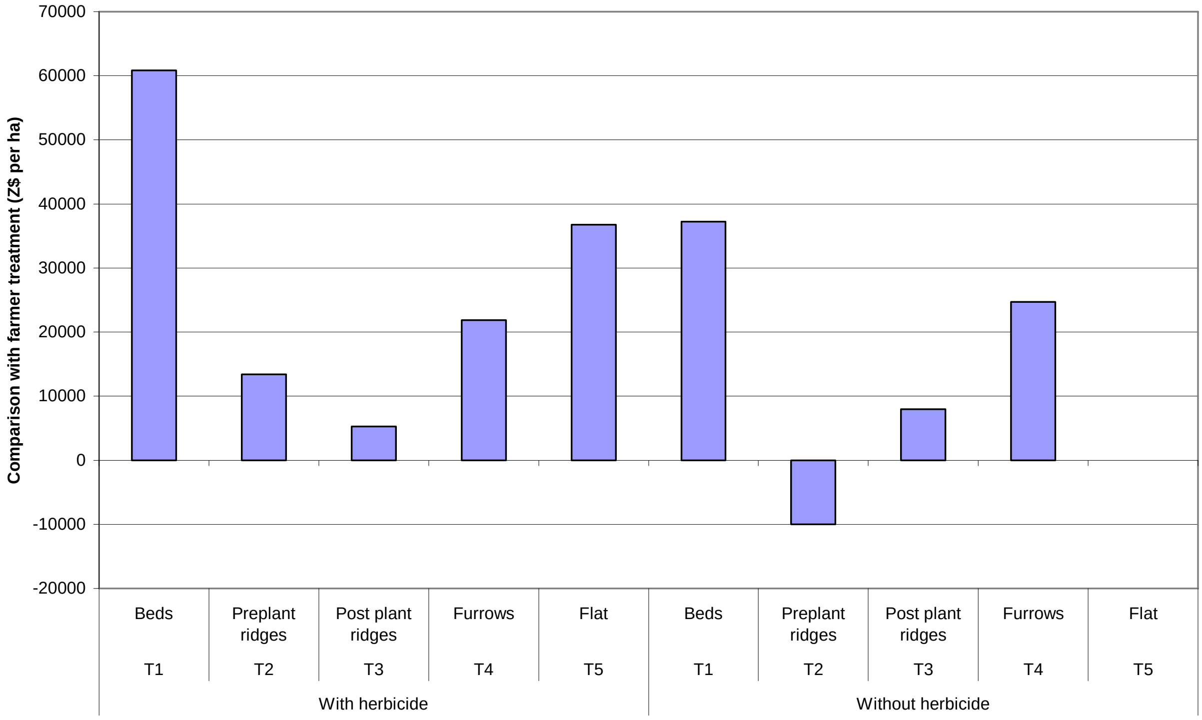


Figure 10b: Comparison with farmer treatment (T5 flat without herbicide) at a labour price Z$ 400 per day

Table 9: Partial budget analysis (Z$ per hour)

Treatment			Gross benefit			Additional cost			Margin			Returns to labour
			Maize	*Rice*	*Total*	*Herbicide*	*Labour*	*Total*	*Benefits less costs*	*Increase over flat*	*% increase over flat*	*Z$ per hour*
With Herbicide	T1	Beds	172075	34680	206755	25295	39185	64480	142275	53372	60%	264
	T2	Preplant ridges	120825	31350	152175	25295	33861	59156	93019	4116	5%	225
	T3	Post plant ridges	136250	0	136250	25295	27999	53294	82956	-5946	-7%	243
	T4	Furrows	153850	0	153850	25295	28771	54066	99784	10882	12%	267
	T5	Flat	110300	40260	150560	12110	24988	37098	113462	24560	28%	301
Without herbicide	T1	Beds	172075	34680	206755	0	75881	75881	130874	41971	47%	136
	T2	Preplant ridges	120825	31350	152175	0	70377	70377	81798	-7105	-8%	108
	T3	Post plant ridges	136250	0	136250	0	44963	44963	91287	2384	3%	152
	T4	Furrows	153850	0	153850	0	45599	45599	108251	19348	22%	169
	T5	Flat[1]	110300	40260	150560	0	61657	61657	88903	0	0%	122

[1] Farmer method

Key assumptions

Maize price: Z$ 50 per kg, Rice price: Z$ 60 per kg, Labour price: Z$ 300 per day, Herbicide costs include cost of herbicide and knapsack sprayer (spread over 5 years, 5 ha each year).

Best options in terms of net benefits are beds, furrows and flat systems, the choice being largely dependent on the availability of labour and draught animals. If these are available the bed system is appropriate. The beds are able to control the water level to minimise any adverse effects on maize yield due to waterlogging, whilst still allowing a rice crop between the beds to be harvested. However, without the resources required for making the beds, the flat system remains the best option. Worst option was post-plant ridges, although the drawback to this treatment, especially in terms of rice production, is largely a result of rice being smothered at time of ridge construction. Furrows were also problematic in terms of rice production, due to their time of construction. The rice could not be sown until after the furrows had been made, which did not occur until late November, by which time it was too late to plant rice.

A concern remains the increase in labour and DAP required for making the beds and creating a tilth for planting, although this does occur outside of peak labour times. Farmers have indicated enthusiasm for trying broad beds and, despite less than favourable results, also ridge systems, following end of season evaluations. However, those with insufficient DAP are likely to want to continue with flat planting systems. For such households it is more appropriate to plant sole crop rice on the regularly inundated portions of wet *vleis*, where maize is commonly affected by water-logging, as discussed by Muzenda *et al.,* 2002.

Weed management

Results from the testing of various weed management options on two *vlei* types (wet and dry) using maize and rice during the 2000/2001 and 2001/02 seasons are summarised by Muzenda *et al.* (2002). The rainfall distribution over the two seasons was very different, the first season favouring maize and the second rice (Figure 11). The total weed abundance on wet *vlei* was greater than on dry *vleis*. *Cyperus esculentus* was the most dominant weed on both wet and dry *vleis*. *Cynodon dactylon* was most abundant on the dry *vlei.* Other species including *Richardia scabra, Panicum repens, Eleusine indica, Leersia hexandra, Setaria pumila, Hibiscus meeusei* and *Urochloa panicoides* were observed in greater numbers on wet *vleis*.

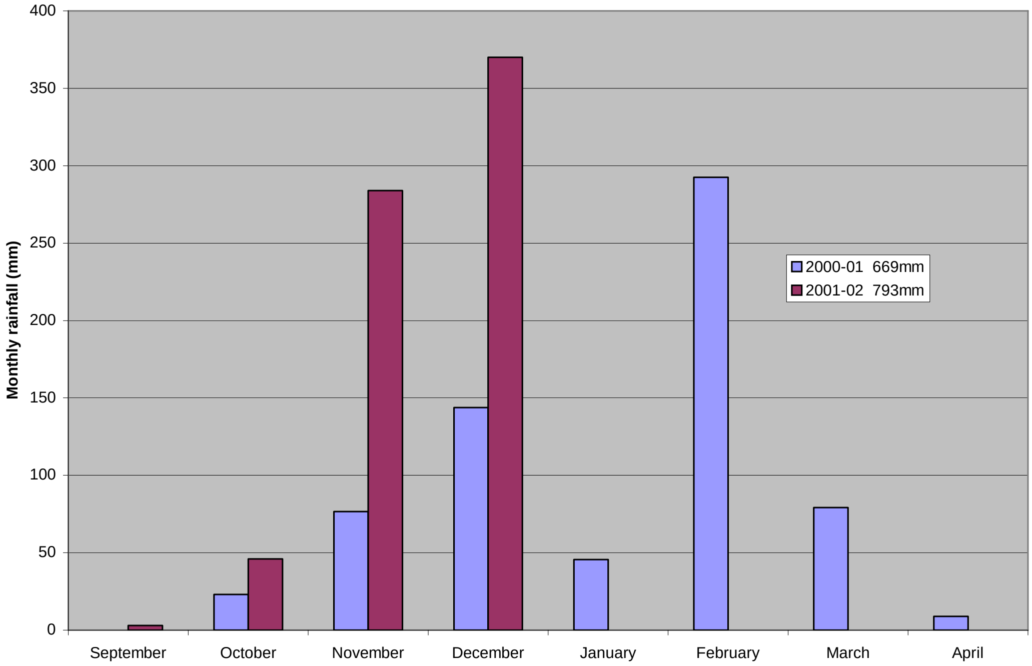


Figure 11: Rainfall (2000-01 and 2001-02 seasons)

Table 10. Mean weed density (number m^{-2}) at 6-7 weeks after crop emergence (3 weeks after weed control treatment) in wet *vleis* across 12 field sites in Masvingo Province.

Treatment	2000-01	2001-02
Broadcast rice with Bentazone	608 (22.85)	55.7 (6.64)
Maize-rice in row, hand weeded	781 (25.91)	65.3 (7.29)
Maize-rice broadcast, with Bentazone	641 (23.72)	68.5(7.02)
Rice in rows with Bentazone	504 (20.24)	58.4 (7.02)
Maize with Atrazine and halisulphuron	305 (15.58)	42.6 (5.81)
Significance	***	*
SED (d.f.)	2.02 (148)	0.464

NB. Figures in brackets show the square root transformed data.
*** Significant at P< 0.001; * Significant at P< 0.05; NS = not significant

Table 11. Mean weed density (number m^{-2} 6-7 and 12-13 weeks after crop emergence (WAE) in dry *vleis* across 12 field sites in Masvingo Province

Treatment	2000-01	2001-02
Maize with atrazine and halisulphuron	346 (16.60)	346 (16.60)
Maize with hand weeding	816 (27.49)	816 (27.49)
Maize-rice in row with hand weeding	697 (25.71)	697 (25.71)
Maize-rice alternate rows + hand weed	705 (25.60)	705 (25.60)
Significance	***	***
SED (d.f.)	1.371 (94)	1.4

Figures in brackets show the square root transformed data.
*** Significant at P< 0.001; NS = not significant

The atrazine/halisulphuron treatment in maize was the most effective in controlling weed emergence, growth in both wet and dry *vleis*. (Tables 10 and 11) This treatment was chosen at field days as the best from a weed control and crop vigour perspective by farmers (Riches, 2001) during mid season evaluations. Halisulphuron proved particularly effective against *C. esculentus.* Bentazone treatments were not as effective, as bentazone is a contact herbicide and only causes a temporary setback to the perennial sedges in both *vleis* types. Halisulphuron is selective to both maize and rice and since it proved more effective against the predominant sedge population in *vleis* than bentazone, it is recommended that halisuphuron be used in the sole rice, maize rice mixed crops and sole maize herbicide treatments. Halisuphuron in both maize and rice (inter-cropped and sole crops) looks the best-bet option. Although it was only used in sole maize in 2000/01 it was subsequently learnt that it is selective to both crops. It proved to be more effective for sedge control than bentazone. This will alleviate labour constraints experienced by farmers in the early part of the season when labour is required both to weed early-planted *vlei* crops and prepare and plant topland areas. An alternative approach for the control of *C. esculentus*, which has the added advantage of controlling problematic perennial grasses including *P. repens* and *L. hexandra* would be to use the translocated herbicide glyphosate. This was tested at four sites in wet *vleis* during 2001-02 as a directed post-emergence treatment. The herbicide was applied with a shield to weeds between rows of sole crop maize. Good weed control was achieved but subsequent waterlogging at the test sites had an adverse effect on the crop precluding harvest of meaningful yields or an economic analysis. The use of directed applications of glyphosate will be particularly knowledge intensive but does provide a possible option for some farmers.

Table 12. Mean maize and rice yields (Kg ha^{-1}) on dry and wet *vleis*; 2000-2002. All data based on 12 sites except for maize in 2001-02, which is based on 9 sites.

		2000-01		**2001-02**	
	Treatments	**Maize**	**Rice**	**Maize**	**Rice**
Dry *vleis*	Maize + Atrazine/Halisulphuron	3699		1451	
	Maize - Hand weed	3328		2330	
	Maize-rice (same row) - Hand weed	2617	577	1573	861
	Maize-rice (alternate rows) - Hand weed	2453	552	2040	939
Significance		***	NS	***	NS
S.E.D.		158	52	193	89
Wet *vleis*	Rice broadcast + Bentazone		1148		1201
	Maize-rice (same row) - Hand weed	3244	816	1119	912
	Maize-rice broadcast + Bentazone	2439	875	1278	1102
	Rice in rows + Bentazone		1058		1351
	Maize + Atrazine/Halisulphuron	4035		1123	
Significance		***	*	NS	*
S E D		253	107	259	129

*** Significant at P< 0.001; * Significant at P<0.05; NS = not significant

Maize yields were higher in the wet *vleis* in 2000/2001 season (Table 12) because of the prolonged mid-season drought experienced during January. The wet *vleis* did not suffer from waterlogging until relatively late in the season when maize crops were maturing, therefore the adverse effects of waterlogging were not apparent. Rice yields followed the same trend. Maize yields were also higher in the sole crops than in the maize-rice inter-crops in both *vleis* types. Rice yields were higher in the sole rice crops seeded at 120 kg ha^{-1} than in the maize rice mixed crops where the rice was seeded at 60 kg ha^{-1}. Sole crop yields of both maize and rice probably produced higher yields because of the absence of competition from the accompanying crop. It is also likely that the higher rice seed rate in sole rice crops contributed to higher yields. During 2001/2002, there was no significant difference in crop yields due to weeding treatments. Although the effect of weeding on weed density was significant 3 weeks after weed control treatments had been carried out, drought after the end of December appears to have negated any treatment effect on yield.

Key variables in determining the highest returns are crop yields, market prices, and the cost of applying herbicide versus savings in labour for each cropping system and weeding option. Average yields from each of the treatments were adjusted according to significance and the gross value of the crops determined using average farm-gate prices at August 2002 (Figure 12a and 12b). Labour and herbicide costs for each weed management treatment for each cropping system have been determined using August 2001 market (or opportunity costs) (Figure 14). A partial budget analysis has been used to compare treatments for both seasons at 2001-02 prices with differences in net benefit between treatments being compared by showing an increase or decrease over farmer practice (Table 13a and 13b). In year 1, in both *vlei* types greatest productivity was achieved growing sole maize crops with herbicides and as the price of labour increases, rice as a sole crop with herbicide. However the importance of inter-cropping for food security must be stressed.

Sensitivity analysis indicates that the price (and hence the availability of labour) is key. When labour is readily available (or not valued) traditional farmer practices are the most productive. However, as the labour price increases, due to unavailability or opportunity elsewhere, the new systems become increasingly attractive. This will however depend on the resources available to farmers and their production objectives.

In the first season with low early rainfall and most concentrated at the end, the growing of maize as a sole crop in both dry and wet vleis using atrazine and halisulphuron gave the highest production, the highest productivity and the highest returns to labour. In the wet vleis maize-rice planted in the same row gave the highest production and overall productivity. The highest returns to labour came from sole maize with atrazine and halisulphuron.

In the second season with high early rainfall and none in the last three months, maize and rice in alternate rows gives the highest production and productivity in the dry vleis,. In the wet vleis, maize-rice broadcast with bentazone and maize-rice in the same row gave the highest production, maize-rice in the same row gave the highest productivity with maize-rice broadcast with bentazone giving the highest returns to labour.

It should be noted that the trials do not reflect the scarcity of labour and the fact that in many seasons the entire crop is lost due to weeds. The opportunity cost of not controlling weeds can therefore be the loss of the total crop as well as the costs incurred in producing it. The inability to control weeds by hand, declining labour availability due to HIV/Aids, food shortages due to the current drought and the drudgery involved in weeding in wet conditions means that the use of herbicides is going to be increasingly justified. However the deteriorating economic circumstances in Zimbabwe are dramatically increasing the costs of imported commodities and making them increasingly unavailable. Under such circumstances it is essential that the search for low cost herbicides continue.

There is need for herbicide technology training to be carried out for extension personnel and farmers in Masvingo Province. Although farmers indicated a strong desire to use the successful herbicide combination of atrazine-halisulphuron to reduce weeding at the beginning of the season, they had little knowledge of herbicide technology. The same also applies to extension workers.

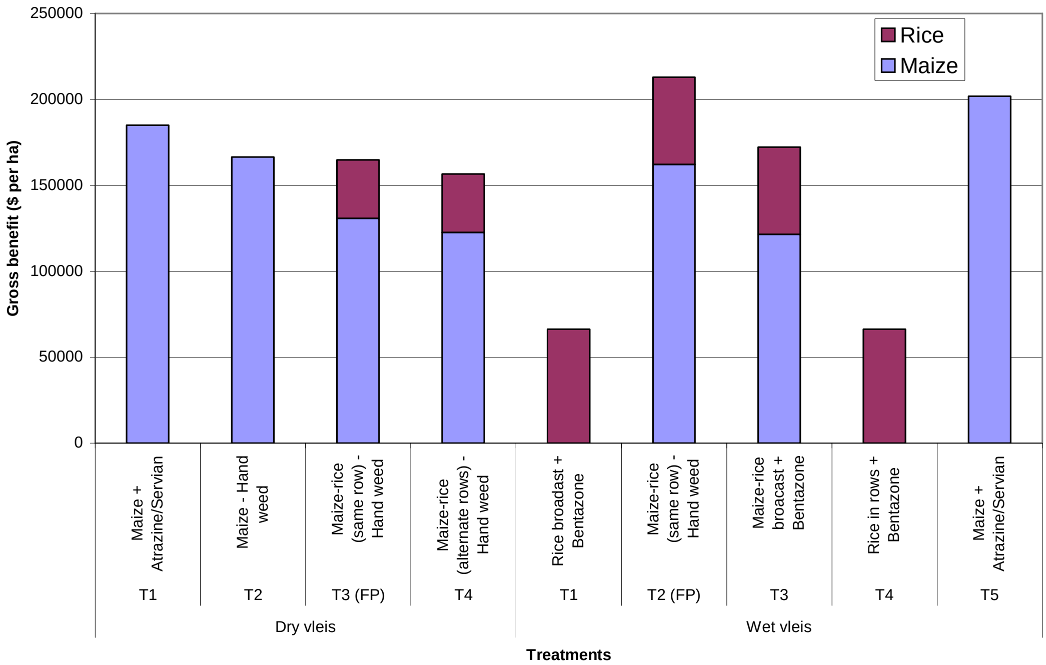


Figure 12a: Value of maize and rice yields 2000-2001 (Z$ per ha)

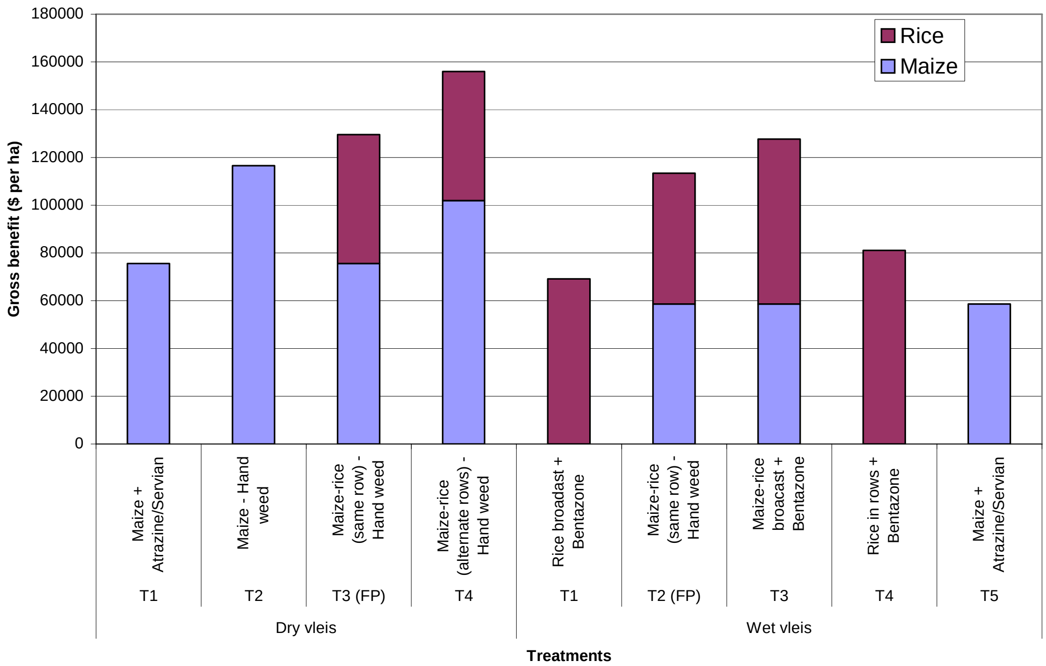


Figure 12b: Value of maize and rice yields 2001-2002 (Z$ per ha)

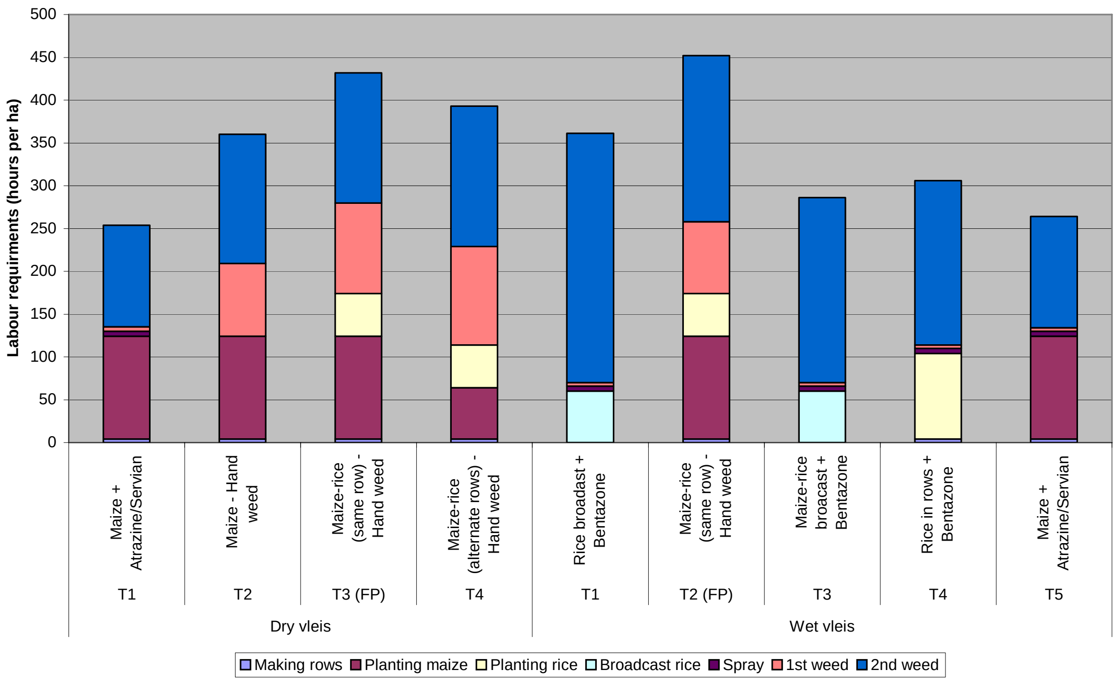


Figure 13: Labour requirement for each treatment (hours per ha)

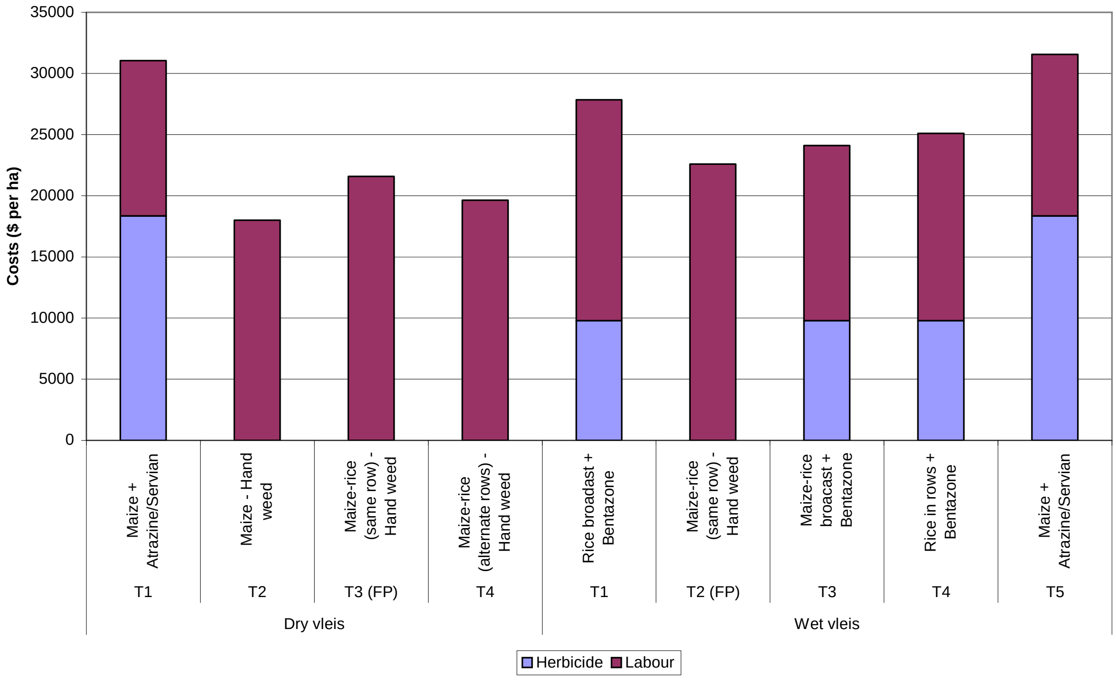


Figure 14: Labour and herbicide costs (Z$ per ha)

Table 13a: Partial budget analysis indicating increase in productivity. 2000-01

		Treatment	Gross crop value	Increased Costs: Herbicide	Increased Costs: Labour	Increased Costs: Total	Margins: Benefit less cost	Margins: Increase over FP	Margins: % Increase over FP	Returns to labour (Z$ per hour)
Dry *vleis*	T1	Maize + Atrazine/Halisulphuron	184950	18360	12700	31060	153890	10740	8%	728
	T2	Maize – Hand weed	166400	0	18000	18000	148400	5250	4%	462
	T3 (FP) [1]	Maize-rice (same row) - Hand weed	164750	0	21600	21600	143150	0	0%	381
	T4	Maize-rice (alternate rows) - Hand weed	156550	0	19650	19650	136900	-6250	-4%	396
Wet *vleis*	T1	Rice broadcast + Bentazone	66180	10172	18050	28222	37958	-152402	-80%	183
	T2 (FP) [1]	Maize-rice (same row) - Hand weed	212960	0	22600	22600	190360	0	0%	471
	T3	Maize-rice broadcast + Bentazone	172210	10172	14300	24472	147738	-42622	-22%	602
	T4	Rice in rows + Bentazone	66180	10172	15300	25472	40708	-149652	-79%	216
	T5	Maize + Atrazine/Halisulphuron	201750	18360	13200	31560	170190	-20170	-11%	764

[1] Farmer practice (FP).
Key assumptions: Maize price: Z$ 50 kg^{-1}, Rice price: Z$ 60 kg^{-1}, Labour price: US$ 300 day^{-1}; Herbicide costs include cost of herbicide and knapsack sprayer (spread over 5 years, used over 5 ha each year).

Table 13b: Partial budget analysis indicating increase in productivity, 2001-02

		Treatment	Benefits: Gross crop value	Costs: Herbicide	Costs: Labour	Costs: Total	Margins: Benefits less costs	Margins: Increase over FP	Margins: % Increase over FP	Returns to labour Z$ per hour
Dry *vleis*	T1	Maize + Atrazine/Halisulphuron	75600	18360	12700	31060	44540	-63460	-59%	298
	T2	Maize – Hand weed	116500	0	18000	18000	98500	-9500	-9%	324
	T3 (FP)[1]	Maize-rice (same row) - Hand weed	129600	0	21600	21600	108000	0	0%	300
	T4	Maize-rice (alternate rows) - Hand weed	156000	0	19650	19650	136350	28350	26%	397
Wet *vleis*	T1	Rice broadcast + Bentazone	69060	9800	18050	27850	41210	-26830	-25%	191
	T2 (FP)[1]	Maize-rice (same row) - Hand weed	90640	0	22600	22600	68040	0	0%	201
	T3	Maize-rice broadcast + Bentazone	90640	9800	14300	24100	66540	-1500	-1%	317
	T4	Rice in rows + Bentazone	69060	9800	15300	25100	43960	-24080	-22%	226
	T5	Maize + Atrazine/Halisulphuron	42100	18360	13200	31560	10540	-57500	-53%	159

[1] Farmer practice (FP).
Key assumptions: Maize price: Z$ 50 kg^{-1}, Rice price: Z$ 60 kg^{-1}, Labour price: US$ 300 day^{-1}; Herbicide costs include cost of herbicide and knapsack sprayer (spread over 5 years, used over 5 ha each year)

Summary

- In the first season, which was very dry in the first half and wet in the second half, gross output in both the wet and dry *vleis* was highest from maize-rice inter-cropped plots that were weeded by hand. However, these treatments required large amounts of labour and partial budget analysis showed net benefits to be higher on sole maize crops using herbicides.
- In the second season, which was very wet in the first half, with virtually no rain in the second half, maize yields were low and maize-rice inter-crops gave the highest outputs. In the dry *vleis*, maize and rice planted in alternate rows allowed easier hand weeding and gave the greatest return. In the wet *vleis*, maize with broadcast rice, and weed control with the herbicide bentazone resulted in the greatest productivity.
- For sole maize, a tank mix of atrazine and halisulphuron provided effective control of the dominant annual weeds and effective suppression of *C. esculentus*
- In both seasons farmers particularly liked the herbicide treatments, but remained concerned about increasing cost and their lack of knowledge in their application. Drudgery, inability to control weeds by hand in *vleis* and HIV/Aids contribute to the inability of farmers to control weeds using labour.
- Unfortunately imported inputs such as herbicides are becoming increasingly unavailable and expensive due to the deteriorating economic circumstances in Zimbabwe.
- There is currently little knowledge on the use of herbicides in the farming community. Training of extension workers and farmers will be needed to ensure that chemical weed control can be used safely and effectively in the future when the economic situation become more favourable.

The crop and weed management practice adopted is likely to depend on household objectives (Table 14) and resources available (Table 15).

Table 14: Crop and weed management practice variation according to alternative farmer objectives

Objective	***2000-01***		***2001-02***	
	Dry *vlei*	**Wet *vlei***	**Dry *vlei***	**Wet *vlei***
Highest yields	*Maize**	*Maize-rice same row or Maize**	*Maize-rice alternate rows*	*Maize-rice broadcast** Or maize-rice same rows*
Lowest labour	*Maize**	*Maize**	*Maize**	*Maize**
Lowest cash investment	*Maize*	*Maize-rice alternate rows*	*Maize*	*Maize-rice alternate rows*
Lowest weeding cost (labour and herbicide)	*Maize*	*Maize-rice same row*	*Maize*	*Maize-rice, same row*
Highest productivity	*Maize**	*Maize-rice same row*	*Maize rice same row*	*Maize-rice, same row*
Highest returns to labour	*Maize**	*Maize**	*Maize-rice alternate rows*	*Maize-rice broadcast***
Lowest risk	*Maize**	*Maize-rice same row*	*Maize-rice*	*Maize-rice broadcast***

*=Atrazine/halisulphuron, **=Bentazone

RG1s and RG2s, who have greatest access to DAP, have therefore the largest number of options from which to choose. RG2s and RG3s with limited DAP are likely to select different strategies, although reciprocal barter arrangements may give them some access to DAP. RG4s have even fewer options but need to consider using a low cost herbicide or reducing the area they cultivate.

Table 15: Soil, weed and crop management options for different resource groups

	Resource category			
	RG1	**RG2**	**RG2/3**	**RG4**
Resource availability				
Labour	Unlimited	Limited	Unlimited	Limited
DAP	Unlimited	Unlimited	Limited	Limited
Implements				
Hand hoe	X	X		X
Ox plough	X	X		
Ox cultivator	X	X		
Soil management options				
Flat	X	X	X	X
Flat then furrows	X	X	(X)	
Pre plant ridges	X	X		
Post plant ridges	X	(X)		
Beds	X	(X)		
Weed management options				
Hoe only	X		X	X
Plough minus dish	X	X	(X)	
Plough plus dish	X	X		
Cultivator	X	X		
Herbicide	X	X	X	X
Reduce area cultivated	X	X	X	X
Crop management options				
Maize only	X	X	X	X
Rice only (wet *vleis*)	X	X	X	X
Maize and rice broadcast	X		X	
Maize and rice within same or alternate rows	X	X	X	X

X= Main options available, (X)= Possible option depending on actual resource availability

Clearly the range of options is large, hence the extreme importance of encouraging farmers to test those options they think will meet their objectives within the resources available to them. It will be important that every assistance is given to farmers as they try out these new options, that they be given the opportunity to learn how and when to apply the different options including herbicides. This will need to include the use and maintenance of knapsack sprayers.

Rice variety improvements

Farmers would prefer to grow cultivars that tiller vigorously, are high yielding, drought tolerant, tall in stature (so people do not have to bend while harvesting) and which are resistant to shattering and to bird damage. They also expressed a preference for white grained rice lines, as these are easier to process than the local *muchecheni* type, which has a brown pericarp. White rice is also thought to have greater commercial potential and is of particular interest to the farmers with larger holdings at Mshagashe. Growing conditions in the *vleis*, as demonstrated by the two seasons during which this study was conducted, can be very variable. To be productive under these conditions rice lines therefore need to be highly adapted. Periodic drought is common. Rice lines, which can survive these droughts to tiller and flower when *vleis* become inundated later in the season, will be at an advantage. The local long duration *muchecheni* landrace is a vigorous type of rice which appears well adapted to the *vlei* cropping system and produced high yields in the trials, despite shattering. It is expected that grain loss would be worse when the rice is inter-cropped in maize due to the disturbance caused during the maize harvest.

A number of the introduced lines tested during this study have potential for replacing *muchecheni* as they are high yielding and posses the traits preferred by farmers (Jiri *et al*., 2002). These include both white and brown rice, the latter having a niche for household consumption and local sales. At field days farmers selected a range of lines for future production with longer duration types being favoured in the communal areas while small-scale commercial farmers liked early maturing lines. It is therefore important to multiply and distribute a number of cultivars for farmers to choose from. Indeed, individual farmers would be well advised to grow more than one line to reduce the risk of poor production due to a particular set of weather conditions. An effort was made to multiply seed of the lines most favoured by farmers in the first season. Some of these also performed well in the second season when additional lines with potential were selected. A smaller group of lines will now be tested again in a replicated trial and seed will be made available for interested farmers to multiply and produce commercially as an activity of CPP project R8191 in collaboration with AREX. These will include:

White rice	**Brown rice**
WAB 450-1-B-P-163-4-1	WAB-450-1-B-P65-4-1
WAB-450-1-B-P-320-HB	WAB-450-B-P-157-2-1
WAB-450-11-1-P26-2-HB	WAB-881-10-37-18-2-P3-HB
WAB-450-11-1-1-P31-HB	Mhara 2
WAB-880-1-38-20-26-P1-HB	
WAB-880-1-38-18-2-P2-HB	
WAB-880-1-38-20-27-P1-HB	
WAB-878-6-27-17-2-P1-HB	
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Promotion and dissemination of findings

Research findings promoted

Research findings were promoted through the mid season field days, end of season annual project workshops (whose proceedings were widely distributed), presentations at international conferences (Mutambikwa *et al*., 2002; *Muzenda et al*., 2002) and appropriate publications. Best Practice Guidelines on soil, water and weed management and knapsack use were prepared in draft for discussion at the 2003 Workshop and subsequently modified before wider distribution to extension workers through project R8191.

Developing collaborating institution's capacity

Collaborating institutions have worked with rural communities in identifying problem priorities, existing coping mechanisms, seeking possible solutions and ensuring that community institutions and organisations have participated in planning, and implementation and evaluation process. The preparation of joint reports and publications was given priority in ensuring capacity building of local organisations

Dissemination of Best Practice Guidelines

Best practice guidelines (BPGs) for crop soil and water management, and weed management in *vleis* were developed and are now being used by stakeholders in extension of the project findings elsewhere within Zimbabwe through project R8191. BPGs comprise a number of booklets and leaflets targeted at extension workers were produced by the project

- Best Practice Guidelines for the sustained cultivation of *vleis*: Crop Management Options.

- Best Practice Guidelines for the sustained cultivation of *vleis*: Weed Management Options.
- Best Practice Guidelines. How to use knapsack sprayers to apply herbicides.
- How to control weeds in *vleis* using herbicides (Leaflet)

CONTRIBUTION OF OUTPUTS TO DEVELOPMENTAL IMPACT

Include how the outputs will contribute towards DFID's developmental goals. The identified promotion pathways to target institutions and beneficiaries. What follow up action/research is necessary to promote the findings of the work to achieve their development benefit? This should include a list of publications, plans for further dissemination, as appropriate. For projects aimed at developing a device, material or process specify:

The ultimate beneficiaries are small-scale farmers and their families who will have access to a greater range of soil, crop and weed management options for maintaining or improving their crop productivity, whilst taking greater care of their wetland natural resources. This will lead to a strengthening of the rural economy with consequent advantages to local artisans and traders. By approaching crop production constraints systematically, the impacts of different soil, water and weed management practices on crop establishment and yields have been evaluated. The opportunity to use these practices should reduce the labour demand for weeding and hence the burden on women and children. There remains considerable inter-household variability in access to both draught animal power and labour. These are key determinants of the ability to weed on time - as much as 35% of the community, the poorest households, do not have access to adequate levels of these resources, neither do they have sufficient cash to hire labour or purchase herbicides (Ellis-Jones *et al*., 2001). It is therefore recognised that some of the technologies developed by this project will not have general application to all rural households. For all farmers to benefit equally may require institutional change which is beyond the scope of this project. However, no negative impact on any particular group is foreseen. The displacement of labour through herbicide use is not anticipated as any reduction in labour for weeding in *vleis* will relieve "bottlenecks" and provide more labour for timely planting of upland crops or non-farm enterprises. Those households, which have labour shortages as a result of HIV/Aids, are likely to be major beneficiaries.

The project identified three options for reducing the impact of weeds in the crop production cycle, through 1) improving soil and water management and improving crop stands better able to compete with weeds, 2) using herbicides and 3) through improved inter-cropping techniques, with higher yielding rice varieties. Option 3 remains the lowest cost and most likely to be adopted by even the poorest farmers. Option 1 requires an increase in labour and draft animal power at land preparation time, options confined to those with access to both these resources. Option2, although best suited to those with least labour, requires herbicides to be available, cash investment and training in the use of herbicide technology. It is therefore likely to be used initially by those who can access and afford the appropriate chemical. It should be noted that wetlands produced the only crop yields in Masvingo during the last season, emphasising their importance for food security during periods of drought.

Intermediate users (development organisations, extension workers and researchers) have benefited from the knowledge generated, both from the participatory process as well as the development of alternative soil, water, weed and crop production practices. This has increased awareness of the constraints faced by farmers and the process is already being used to promote wider farmer testing of technology options, facilitated by extension and development organisations.

HOW THE OUTPUTS WILL BE MADE AVAILABLE TO INTENDED USERS?

Research outputs from this project, as well as other CPP funded projects undertaken in Zimbabwe over the period 1996-2002, are being promoted as part of a new dissemination project, R8191, communicating the knowledge gained to stakeholders, including extension workers and farmers. This is an enabling project led by the University of Zimbabwe, that involves a number of NGOs, on-going development projects and commercial companies in developing a process for demonstration and further testing of a range of crop establishment and weed management technologies, targeted at poor farmers in the small scale sector. It incorporates a process for scaling-up aiming to improve the capabilities of participating organisations through improved research-extension-farmer-private sector linkages. This aims to improve access by farmers to information about technologies that can lead to increased crop yields, sustainable crop production, environmental conservation, increased income generation and improved livelihood options.

It is now accepted by most agricultural development agencies, that farmers need to be provided with a basket of technology options for testing on their own fields rather than prescriptive recommendations as was the case in the past. The latter approach did not result in farmers adopting some of the technologies as the socio-economic situation and knowledge base of the farmer tended to be ignored. AREX have pioneered this Participatory Extension Approach (PEA) in Masvingo, with some NGOs including CARE also using PEA in their activities. Crop establishment and weeding options tested on-farm by R6655 were being used beyond the original trial plots by some collaborating farmers when the project ended and there has been limited exposure of the work within some communities involved in the CARE "Small Dams and Resources Management" Project. However, the lack of associated information in the local language (Shona) and availability of ripper tines has constrained scaling up of the promotion of these ideas[1]. A supplier is now available in Masvingo with the capability to manufacture the ripper, but work is needed to place this in the market so that it is accessible to farmers. CARE runs an “agent programme” in rural communities, which will be assessed as a mechanism for supply of rippers and other inputs (knapsacks and herbicides) to farmers. The CARE Masvingo programme has expressed interest in taking forward the promotion of maize and *vlei* production technologies to continue work started with varieties, some testing of dryland farming practices and seed priming. The Masvingo Province AREX management team have also indicated the need for this project to assist with their extension efforts in promoting wider testing of sustainable maize production practices and to scale up promotion of new rice cultivars. In some areas this process is already well underway. AREX Information and Training Branch in Harare have agreed to contribute to the development of written training materials. The project is fully supported by University of Zimbabwe, which will coordinate activities and is already working with various developmental agencies in the smallholder-farming sector.

The project will involve staff with a range of relevant skills from a number of institutions, which have recent proven track records working on projects supported by DFID funds.

The University of Zimbabwe (UZ) has wide experience of undertaking adaptive research and community-based developmental projects within the rural areas of Zimbabwe. They also run short-term courses related to technologies for the smallholder-farming sector. This includes an on-going programme on farmer participatory on-farm trials of weeding practices for wetlands in Masvingo Province. Staff who contribute to this, include weed scientists Prof O Chivinge (Dean, faculty of Agriculture), AB Mashingaidze (Crop Science Department) and soil scientist and NR Specialist, Edward Chuma (Soil Science Department). UZ has appointed a co-ordinator for the Masvingo component of the project who will be responsible

[1] . During the development stage of the technologies, project R6655, and CARE facilitated the purchase of a limited number of rippers by interested farmers.

to a project steering committee, comprised of representatives of stakeholders, chaired by Professor Chivinge.

CARE-Zimbabwe has a network of field officers in Masvingo and Midlands Provinces providing the interface with rural communities. This includes facilitating farmer testing of new technologies. CARE is also responsible for training “Agents” as rural traders supplying local communities with their needs including agricultural inputs. These will play a key role in distributing not only inputs but also training and promotional material.

A number of other NGOs, including Africa 2000, Christian CARE, ITDG are expected to play key facilitating roles with farmers.

AREX in Masvingo Province has embraced the use of Participatory Extension Approaches (PEA) and has staff available in their information and training branch with expertise in the preparation and publication of information leaflets and booklets and setting up of demonstration sites and farmer field days.

COTTCO, a private company operating in both Masvingo and Muzarabani, is active in promoting cotton through a strong extension programme, providing individual and group loans to cotton producers. They also provide training on various aspects of cotton production and marketing and have already agreed to provide loan finance for the purchase of herbicides in the Zambezi valley.

AGRICURA and MONSANTO are major suppliers of crop chemicals in Zimbabwe and are expected to participate in the project in the development and printing of information for delivery to farmers through the supply chain.

SRI (Jim Ellis-Jones, leader R7473 and R7474) and NRI (Charlie Riches, leader R5742, R7189 and R6655), will provide back-stopping on tillage, crop management and socio-economics aspects of information to be produced by the project. Nicola Harford, a communication specialist based in Harare who has recently assessed agricultural information sources in Masvingo for CARE, will provide support on ensuring appropriate communication strategies are used.

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PUBLICATIONS AND REPORTS

Publications

[List only those published and in press i.e. accepted for publication. Please highlight in bold or with an asterisk outputs which have not been previously reported]

MUTAMBIKWA, A., BARTON, A. P., ELLIS-JONES, J., MASHINGAIDZE, A. B., RICHES, C. and CHIVINGE, O. ,2002. Soil and water management options for seasonal wetlands (*vleis*) in semi-arid areas of Masvingo Province, Zimbabwe. Paper presented at the 7th Eastern and Southern Africa Regional Maize Conference, Nairobi, Kenya, 11-15 February 2002.

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Project Reports

[List of reports and dates. Please highlight in bold or with an asterisk outputs which have not been previously reported]

BARTON A. (Ed.) (2001) Masvingo Weeds Project 2000-01. *Proceedings of the Masvingo Vlei Weed Management Workshop. Alvord Training Centre, Makoholi, Masvingo, Zimbabwe 12-13 July 2001. SRI IDG/01/19.*

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Extension material

Best Practice Guidelines for the sustained cultivation of *vleis*: Crop Management Options. (2002)

Best Practice Guidelines for the sustained cultivation of *vleis*: Weed Management Options. (2002)

Best Practice Guidelines. How to use knapsack sprayers to apply herbicides. (2002)

How to control weeds in *vleis* using herbicides, 2002 (Leaflet)

Theses

MUZENDA S., 2002. Weed management options for seasonal wetlands (*vleis*) in semi-arid areas of Masvingo Province, Zimbabwe. MPhil thesis in preparation

Other

All datasets collected during the project are available electronically and have been made available with the FTR.

Biometricians Signature

The projects named biometrician must sign off the Final Technical Report before it is submitted to CPP. This can either be done by the projects named biometrician signing in the space provided below, or by a letter or email from the named biometrician accompanying the Final Technical Report submitted to CPP. (Please note that NR International reserves the right to retain the final quarter's payment pending NR International's receipt and approval of the Final Technical Report, duly signed by the project's biometrician)

I confirm that the biometric issues have been adequately addressed in the Final Technical Report:

Signature:

Name (typed): Rodger White

Position: Biometrician

Date: January 2003

R7473 Project Logical framework

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumptions
Goal			
Impact of weeds in crop production cycle minimized			
Purpose			
Low cost, labour efficient weed management systems which conserve moisture in savannah cropping system developed and promoted.			
Outputs			
1 Understanding of the impact of weeds in seasonally inundated semi-arid wetlands in Zimbabwe and of the opportunities for and constraints to improved weed management. 2 . Evaluation of innovative options for crop and weed management identified using a combination of traditional and scientific knowledge. 3 . Promotion and development of findings.	Characterisation of traditional crop, weed and land husbandry practices and adoption constraints compiled by Dec 00 for initial project area and other areas identified. Appropriate crop and land husbandry solutions identified by Sept 00. Improved practices established and adopted/adapted by March 03 Findings promoted through field days, workshops, and popular and refereed publications.	Project reports Reports of collaborating institutions Publications in popular and scientific publications Information generated used in the design of extension materials.	Stakeholders' involvement from the initial design of the project, through implementation will facilitate achievement of this Output.

Activities	Inputs	Means of Verification	Important Assumptions
1.1 Planning meeting including identification of participating farmers 1.2 Characterisation of farming systems from a biophysical and socioeconomic view identifying issues and constraints, with a specific focus on weed management. PRA of farmers' perceptions of weed management and crop production techniques in seasonally inundated wetlands, institutional constraints and the farmers decision making process. Assessment of spatial variation of biophysical properties of *vleis* and influence on weeds and crop production. 1.3 Assess strengths and weaknesses of current dissemination methods with reference to farmer typologies ***1.4*** Review workshop with all project Stakeholders to identify possible points for interventions relative to resource status (economic and biophysical) of households.	£226,492	1.1 Proceedings of planning meeting available Dec 99. 1.2 Surveys and diagnostic evaluations completed by Aug 00. Literature survey, survey and discussions with stakeholders and Aug 00 (see 1.4) workshop compiled into a report Dec 2000. 1.3 SWOT analysis completed by July 00. 1.4 Workshop in Aug 00 and findings included Proceedings April 01	-Climatic conditions favourable - Farmers are willing to participate in diagnostic surveys and evaluations - Suitable in-country stakeholders from extension, research, NGOs and commercial organisations are identified and willing to collaborate - Stakeholders have the resource to publish and promote guidelines - In-country collaborators willing to acknowledge guidelines produced and incorporate findings into future research initiatives.
2.1 Farmers led experimentation of proven interventions and testing of novel ideas for each cropping system and each farmer resource category with special reference to the marginalised groups. 2.2 Joint evaluation of trials using both farmer and researcher criteria.		2.1 On farm evaluation programme agreed by Sept 00 and implemented. 2.2 Evaluation criteria agreed, implemented and completed by July/Aug 02.	
3.1 Research findings promoted through field days, end of project workshop and appropriate publications. 3.2 Develop collaborating institution's capacity to participate with rural communities, particularly women, in the identification and solution of systems constraints. 3.3 Dissemination of best practice guidelines for use in study areas and extension to other programmes in the region.		3.1 A final project workshop held by Aug 02. Two published articles 3.2 Capacity of collaborating institutions to carry out participatory research strengthened by Dec 02. 3.3 Guidelines' dissemination initiated by Sept 02 in study areas.	