Draught Power Performance and Production Management

Final Technical Report (R7352)

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LIVESTOCK PRODUCTION PROGRAMME

Draught Power Performance and Production Management

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FINAL TECHNICAL REPORT

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front cover captions

upper Planting in ripper lines (clayey soil at Hatcliffe)
middle Renovated plough in action (Mrs Magura, Mushandike, December 1999)
lower Renovated plough (Mrs Matimbe, Gari, December 1999)

Contents

Executive Summary

The purpose of the project was to evaluate ways of increasing the contribution of livestock in semi-arid cropping systems typical of smallholders in southern Africa by increasing the efficiency of draught animal power (DAP) utilisation. Results from previous projects had suggested that valuable draught animal (and therefore human) energy is being wasted because of poor use of implements and farmer reluctance to adopt productivity raising techniques, based on the use of DAP, in favour of their traditional practices.

These issues were investigated by conducting on-farm and on-station research trials. The on-farm activities were focused on farmers' attitudes to ploughs and ploughing and included split plot trials to compare the performance of ploughs in typical condition ("as found") and ploughs that had been renovated (on site by members of the project team) by fitting new parts as necessary. The renovated ploughs were also adjusted to operate at the correct depth and width of work to prepare the plots for maize and cotton crops. The on-station trials investigated i) the establishment of crops (maize) in rip lines – a conservation tillage practice which would ease the DAP demand over the bottleneck land preparation period – and ii) the use of animal-powered weeding methods to both enhance yield and reduce labour demand and drudgery.

The on-farm activities provided much information on the farmers' difficulties in using animal-drawn equipment and the general state of this equipment. The participating households were selected on the basis of their wealth (mainly physical capital as related to draught animals) to give a range and differences in capability and attitude were observed across the range. The on-farm trials provided an estimate of the cost of keeping ploughs in reasonable condition and demonstrated that, in most smallholder circumstances, the outlay would be recovered through improved yield. The advantages of plough renovation were reported by the farmers to clearly outweigh the disadvantages. The improved yield was the outcome of correct plough setting as well as renovation. To facilitate this aspect of plough use, the project team, together with the major stakeholders in the promotion of DAP, have produced Best Practice Guidelines (BPG) on plough use. The stakeholders, particularly the extension agencies, are disseminating these (in English, Shona, Ndebele, as appropriate) to farmers and other interested parties.

The on-station activities demonstrated that the individual design features of the six ripper tines tested had little effect on the edaphic and agronomic outcomes. In contrast to this, the effect of pre-ploughing the land was highly significant and led to greatly increased yields on both sandy and clayey soil, approximately 900 kg/ha and 700 kg/ha respectively. However, this would seem to be an economically attractive option only for households that had ready access to DAP for winter ploughing. Because of the cost of animal hire, there would be little gain for the poorest households. The investigation of weeding methods revealed that weeding with cultivators was generally less economically attractive than weeding with ploughs, largely because of the cost of the cultivator. The analysis identified a significant interaction between tine design and soil type. On sandy soil (typical for most smallholders), reversible tines should be replaced by duck foot tines, whereas on clayey soil the reversible tines would be preferred.
The findings from the on-farm trials have demonstrated the value of proper plough maintenance and setting in achieving an improved return from the use of DAP for land preparation. Farmers' participation in the trials has also made a major contribution to the drafting of the BPGs and their presentation in a format that will be of real use to other

farmers. Proper maintenance and setting of ploughs is a good investment as the return is higher than the expenditure and the animals are used more effectively. Reducing the wastage of DAP will improve the overall performance of the crop/livestock system.

The findings of the on-station trials have resolved several issues which had not, hitherto, been fully scientifically evaluated. The physical, agronomic and economic performance of various designs of animal-drawn ripper and cultivator (weeder) have been analysed and the implications for farmers, in different wealth categories, determined. Soundly-based recommendations on the more effective use of DAP and associated equipment can now be formulated and disseminated.

Background

Shortages of draught animal power (DAP) have been reported by smallholder farmers in sub-Saharan Africa to be a constraint on their agricultural production and productivity for many years (e.g. see Munzinger, 1982; O'Neill *et al*, 1999a). In Zimbabwe, this was exacerbated by the drought of 1991-92 when many farmers lost all their animals (e.g. see Koza *et al*, 2000a). Although some recovery has taken place, only the more wealthy smallholder farming families have access to adequate DAP for their needs (Muvirimi, 1997[1]) and there is some doubt whether they use this resource efficiently and effectively. This implies that better management of farm power (i.e draught animals, human labour and farming equipment) would help alleviate this shortage by, in effect, reducing the draught demand per hectare. It is an alternative to increasing the animal population, which, in itself, could amplify other problems such as feed shortages and over-grazing. Reducing draught power demand in Zimbabwe, rather than increasing its supply had already been suggested by Barrett *et al*, 1992[2], and Ellis-Jones, 1997[1]. Increasing the effective supply of DAP by improved animal management was also the aim of a project undertaken in South Africa (Pearson *et al*, 1999[3]).

The better management of farm power provided the basis for on-farm trials undertaken in Masvingo Province in this project. Six communities participated and the families carrying out the research were selected according to wealth rating. The wealth rating was done by the communities themselves and used a classification system developed for an earlier DAP project (Muvirimi, 1997). This involved placing the families into one of four resource groups (RGs) depending mainly on their physical capital, particularly as it related to DAP.

Most smallholder farmers are facing a steady and, in many cases, an insidious degradation in the quality of their soils. There is an increasingly urgent need to restore soil fertility in a sustainable way, whilst promoting crop production to ensure food security. The long tradition in Zimbabwe of mouldboard ploughing has been associated with soil degradation and loss of crop productivity (Vogel, 1994) but, it is estimated, less than 1% of smallholder farmers practise conservation tillage techniques (Nyagumbo, 1998). However, this proportion is not likely to increase significantly until the benefits can be clearly demonstrated to the farmers and have been evaluated by them. There is a growing interest in the concept of "conservation tillage" in sub-Saharan Africa[4] but without thorough research to give a full understanding of the advantages, the disadvantages and the likely livelihood impacts on the target farmers and their families, it would be inappropriate to promote such concepts in rural communities. Kaumbutho *et al* (1999) identified and listed a total of eight constraints on the smallholder adoption of conservation tillage practices. At least two of these - shortcomings in technology / equipment and multi-disciplinary research in soil management techniques - were addressed in this project through carefully planned on-station field trials.

[1] R5926
[2] R5185
[3] R6609
[4] e.g. see www.fao.org/act-network/home.htm (African Conservation Tillage network website)

Project Purpose

"*Develop and promote strategies for the allocation and management of on-farm and locally available resources in order to optimise livestock production and improve their contribution to the crop / livestock farming system"*

The purpose, in the specific context of this project, was to enable farmers to increase the overall productivity of their farming practices through interventions aimed at (i) more effective use of their farm power resource (which includes human labour as well as draught animals) and (ii) improved soil fertility.

Many subsistence farmers in Zimbabwe, and elsewhere in southern Africa, are unsure of how to use or maintain their ploughs and cultivators so there is considerable scope for achieving better results from animal-drawn implements and, thereby, ameliorating the shortage of DAP by improving the condition of these implements. Small surveys in previous DAP projects (e.g. "Improving the Productivity of Draught Animals in sub-Saharan Africa", R5926) had already revealed that ploughs were in generally poor condition, usually with key parts removed, thus preventing depth and width to be properly set (Chatizwa and Ellis-Jones, 1997). The project was set up in order to find ways of addressing this problem and, by examining it in greater detail, to quantify the potential benefits of making more effective use of DAP. The shortage of DAP for crop production, especially for land preparation, and the loss of yield attributable to delays, particularly amongst the poorer farmers in sub-Saharan Africa, has been acknowledged for many years. The research, carried out in six smallholder communities in Masvingo Province, involved richer and poorer farming families investigating the many factors associated with plough maintenance and renovation.

Implement use is a matter of concern not only for current practices and the waste of scarce draught power but also in the application of new methods. Typically these emerge from the general dissemination of the benefits of "conservation tillage" and are based on the results of recent research for conserving soil and moisture, often through fertility enhancement (e.g. by mulching and use of green manures) and weed control. The acceptability and adoption of any new methods in the smallholder community will be heavily dependent on the use of existing implements and how well they may be adapted (mainly by farmers but also by rural artisans) to the practices required by the new methods. Two well recognised conservation techniques, but rarely practised by smallholders - rip-line planting and the use of a green manure - were investigated through crop establishment and management trials on-station. The implications for smallholder uptake were assessed but time (being restricted to two years) and project resources did not permit evaluation through on-farm trials.

Research activities

Making better use of available DAP

The research may be divided into seven inter-relating components, as shown below.

1 Focus group discussions with farmers in pre-selected areas, during which representative farmers from each of four resource groups (RGs) were nominated to participate in the research activities.

2. Assessment of the condition of farmers' ploughs for their subsequent renovation during the field trials.

3. Field trials in six separate communities (areas) involving 15 participating farmers. A test plot was identified at each farmer's site and split into two equal sub-plots, (plot A and plot B) each measuring nominally 100m long x 8 m wide.

4. Soil moisture and bulk density readings were taken before ploughing. Animals' body masses were estimated (using girth and length dimensions). The ploughs were weighed before and after renovation.

5. At each site the farmer ploughed plot A using his/her normal practice and settings. The plough was then renovated by replacement of the necessary components replaced (see 2 above and fig 1), noting all relevant details. The farmer then ploughed plot B using the renovated plough with recommended settings and adjustments. Performance data were monitored to enable comparison of the two plots. Quality of work was assessed visually and farmers' assessments recorded.

Fig 1: Parts for plough renovation

6. Plant populations were estimated at emergence. Soil moisture, bulk density and shear strength were taken twice on monthly intervals after the date of ploughing to assess any changes in soil physical characteristics. Crop yields were determined at the end of the season.

7. Further series of group meetings and informal surveys (in addition to 2 above) were held to ascertain farmers' views on topics such as where farmers acquire their knowledge on the use of equipment, equipment maintenance and farmers' attitudes towards extension workers etc.

The sequence of activities required to undertake these components was first carried out for the 1999-2000 spring ploughing season and then repeated for winter ploughing in 2000 and again for spring ploughing in 2000-2001. Both maize and cotton, the two main smallholder crops in the selected areas, were grown in the split plot trials.

Towards the end of the project, a series of ploughing demonstrations was carried out to involve more farmers, as word had got round of the benefits that the participating farmers had experienced through their research activities.

To ensure the fullest stakeholder representation and contribution and to bestow ownership (at least part ownership) of the project and, especially, its outputs on the key stakeholders (i.e. the farmers and their local communities), three Workshops were held over the two-year duration of the project. In the first Workshop (September 1999 – see O'Neill, 1999), the project activities for both on-farm and on-station research were planned, taking the log-frame as the starting point, by all the stakeholders present. At this time the project sites were still to be identified so farmers' interests were represented by AGRITEX, CARE, OCCZIM and ZFU rather than by farmers' themselves.

At the second (see O'Neill, 2000) and final Workshops (Proceedings in preparation), most of the attendees were farmers from the participating communities and the Workshop language was Shona.

The results from the on-farm trials provided much valuable information:-

- The typical condition of farmers' ploughs
- How farmers use (abuse) their ploughs
- Typical costs of plough renovation
- Benefits, or otherwise, of plough renovation (see below)
- Attitudes regarding plough use and maintenance
- Constraints on plough use and maintenance
- Problems experienced by Extension Workers regarding plough use
- Differences between resource groups with respect to the above characteristics

The benefits of plough renovation encompassed many variables, both qualitative and quantitative. The qualitative benefits, as perceived by the farmers are summarised in Table 1. These were discussed at the final round of focus group meetings and so represent the accumulated experience over the course of the whole project (see Koza *et al*, 2001a).

Table 1: Farmers' opinions on the benefits of mouldboard plough renovation

Tillage	**Crop**
Better and more uniform inversion / weed burial	Better establishment and stand
Deeper and wider furrows	Less wilting during drought spells
Increased moisture retention	Stronger and healthier plants
Less weed growth	Faster growth
Easier plough handling and control	Bigger cobs and better yield

In contrast to these benefits, one disadvantage became apparent with the farmers practising third furrow planting (TFP). This practice involves dropping the seed in the plough furrow, which is then covered by a subsequent pass of the plough. With the renovated ploughs (plot B), the deeper furrow inhibited germination somewhat, which resulted in poorer emergence and farmers feeling obliged to fill gaps by re-planting.

A potentially significant disadvantage was the higher draught force requirement of the renovated ploughs. However, in practice this was not a concern as it was evident (as previous findings had shown) that these higher draught forces were still within the animals' pulling capability. Another inevitable disadvantage would be the increasing cost of buying spare parts. Although farmers were aware of the high cost of spares, only one farmer commented on this.

Best Practice Guidelines (BPG)

From previous work it was anticipated that farmers would have poorly maintained ploughs and would not be fully conversant with how to adjust and use them. The project therefore incorporated, as a major output, the production of appropriate documents aimed at alleviating this problem. The stakeholders at the Project Initiation Workshop (O'Neill, 1999 – *op cit*) determined that different sectors would require BPGs in different formats. It was thus agreed that, ideally, five sets of guidelines should be prepared, targeting – (i) farmers, (ii) extension workers, (iii) artisans, (iv) dealers and retailers and (v) manufacturers. Some of the on-farm work, especially during the focus group meetings, was devoted to eliciting information on preferences for the design and production of the BPGs. Three small reports have been written summarising the views on BPGs expressed by farmers (Koza *et al*, 2001b), extension workers (Koza *et al*, 2002a) and manufacturers (Koza *et al*, 2002b).

Conservation tillage techniques

The Zimbabwe experience has indicated that the major problems associated with conservation, or reduced, tillage are crop establishment and weed control (Shumba *et al*, 1992; Vogel, 1994). Recent work in Zimbabwe has aimed to develop low-input tillage / weeding systems that are based on fairly direct adaptations of smallholder farmer practices. These include the use mouldboard ploughs, ripper tines and, to a lesser extent, five-tine cultivators (Riches *et al*, 1997; Twomlow *et al*, 1999; Twomlow and Dhilawayo, 2000), but **not** the use of herbicides.

The proposed research comprised three inter-relating components – performance evaluations of (i) ripper tines, (ii) ox-drawn cultivators (weeders) and (iii) the effects of a green manure (sun hemp) on tillage requirements. The research trials were carried out at two on-station locations - Hatcliffe and Domboshawa - to provide two soil types, clay loam and sandy loam respectively. These three components turned out to be rather too ambitious for a two-year project with the meteorological conditions encountered and the resources available. The two implement trials yielded adequate data and useful results but green manure trial was beset with exceptionally adverse and uncharacteristic weather and, under the circumstances, inadequate management supervision. The latter may well have been related to the crop management demands being both unfamiliar and time-consuming. The decision was made to focus on the crop planting and weeding trials so as not to jeopardise their success.

Details of the experimental designs are given in the project Working Document 1 (O'Neill *et al*, 1999b) and are summarised below for the planting and weeding trials.

1) Planting / crop establishment

Purpose: To assess the performance of a range of rippers available in Zimbabwe for crop establishment in terms of draught power requirements, depth of work, field efficiency, crop quality and yield.

Trial design: Split plot design with primary land preparation as the main plot factor; ripper designs as sub-plot factors with at least three replications. Each sub-plot size 10m wide x 20m long.

Methods:
a) Land preparation
  – no-till or pre-ploughed (by winter- or spring- ploughing).
b) Soil type
  - sandy loam (Domboshawa) and red clay loam (Hatcliffe).
c) Preparation of planting lines.
  - eight methods of opening planting lines including "third furrow planting" (TFP - a popular smallholder practice) as a control.
  - see Table 2.
d) Crop
  - maize

Table 2: Preparation of planting lines

Method of opening planting line	Abbreviation
BSP Ripper	BSPR
Zimplow Ripper	ZR
Magoye Ripper	MR
Palabana sub-soiler	PS
Contil Knife Ripper	CKR
Contil Tool Bar	CTB
BSP light-weight plough	BSPP
BSP standard plough for TFP	TFP

The ripper tine designs are shown in fig 2.

2) Weeding

Purpose: To assess the performance of a range of cultivators available in Zimbabwe, in particular the effect of tine design, in terms of draught power requirements, depth of work, field efficiency, weeding efficiency and yield.

Trial design: Fully randomised plot design with three replications for simple one-way analysis of variance. Plot size for weeding treatments 10m wide x 25m long; block size for replications 40m wide x 25m long.

Methods:
a) Weeding treatments
  - 11 types of weeding treatment, including use of hand hoe as control
  - see Table 3
b) Soil type
  - sandy loam (Domboshawa) and red clay loam (Hatcliffe)

c) Crop
   - maize
d) Land preparation
   – pre-ploughed (by winter- or spring- ploughing)

Table 3: Methods of weeding

Weeding implement (treatment)	Tine configuration	Abbreviation	Notes
BS221 Cultivator	2 reversible tines, 2 hilling blades, 1 duck foot tine	BS2212R2H1D	
BS221 Cultivator	2 hilling blades, 3 duck foot tines	BS2213D2H	
BS41 Cultivator	5 reversible tines	BS415R	Standard set-up
BS41 Cultivator	4 reversible tines, 1 duck foot tine	BS414R1D	
BS41 Cultivator	5 duck foot tines	BS415D	
Zimplow light-weight cultivator	2 reversible tines, 1 duck foot tine	ZLW2R1D	Light-weight model has only 3 tine attachments
Zimplow light-weight cultivator	3 duck foot tines	ZLW3D	as above
Contil Tool Bar	with duck foot sweep tine attachment	CTB	Light-weight unconventional design primarily for donkeys
Standard VS8 Plough without mouldboard	plough share	SHARE	A fairly common practice amongst smallholders
Standard VS8 Plough	share and mouldboard	MB	For post-emergent ridge weeding
Hand hoe	-	HH	The basic practice included as a control

Examples of the reversible and duck foot tine designs are shown in fig 3.

Fig 2: Designs of ripper tine evaluated

Fig 3: Reversible (left) and duck foot (right) tines

Outputs

Three outputs, as stated below, were defined in the project documentation.

1. Best Practice Guidelines in implement use (setting, maintenance and harnessing), based on current knowledge, will be developed by appropriate stakeholders.
2. The appropriateness of current DAP use in maize and cotton systems will be defined in terms of management of existing resource utilisation (particularly animals, implements and labour) on yields and profitability. The potential for resource utilisation in innovative crop production measures (e.g. green manures, use of dung, crop residues) will be quantified.
3. The findings of the research will be promoted and disseminated by stakeholders.

Output 1 – Best Practice Guidelines

Contributions from on-farm activities

Surveys and qualitative information

Most of the collaboration with farmers and extension workers was aimed at collecting the information needed for the Best Practice Guidelines (BPGs) and deciding how this information should be presented. Firstly, it was necessary to gain an overview of the typical condition of farmers' implements, with the focus on ploughs and some interest in cultivators. For logistical reasons the on-farm work was restricted to two Districts in Masvingo Province (i.e. Chivi and Masvingo) but the local stakeholders requested that farming families from different backgrounds (communal, irrigation, resettlement and small-scale commercial) were included. The project embraced this and families from these backgrounds were selected. To facilitate comparison with similar on-farm research in the Province and to ensure wide representation, families were selected across a range of four wealth classifications (resource groups – RGs – see Annex 1), by agreement at community meetings.

In a survey of 100 households carried out in October 2001 (Koza *et al*, 2001c), the best resourced were generally small-scale commercial and the poorest were predominantly communal (see Table 4).

Table 4: Breakdown of background and resource group in a survey of 100 households

Background	RG1	RG2	RG3	RG4	Total
Communal	3	5	14	5	27
Irrigation	1	14	7	2	24
Resettlement	9	9	6	0	24
Small-scale commercial	20	4	1	0	25
Total	33	32	28	7	100

The condition of ploughs, according to RG is shown in fig 4. Overall, 32% of households described their ploughs in good condition, 37% in average, 28% in poor and 2% in very poor condition. Similar information for cultivators is shown in fig 5. In this case, 39% of households indicated that they owned a cultivator including 82% of RG1s, 15% of RG2s, 2% of RG3s and no RG4s. Most cultivators were described as being in average to poor condition.

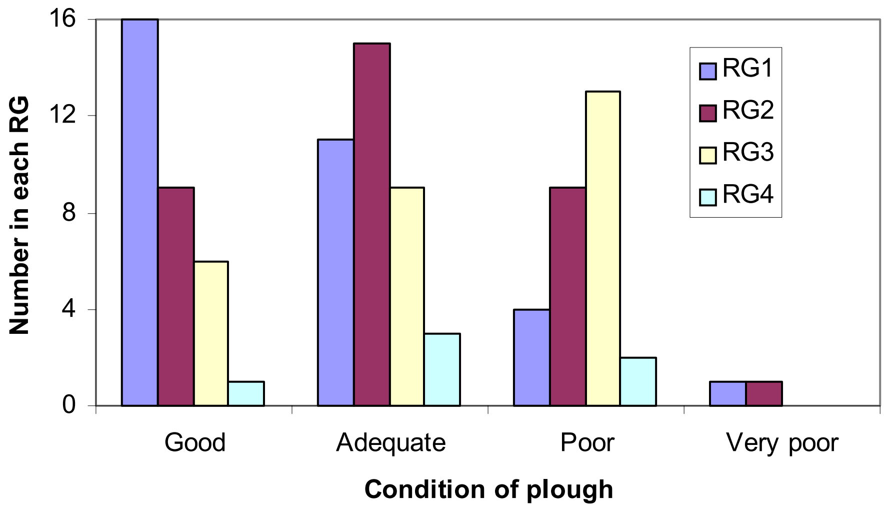

Fig 4: Plough condition in sample households according to RG

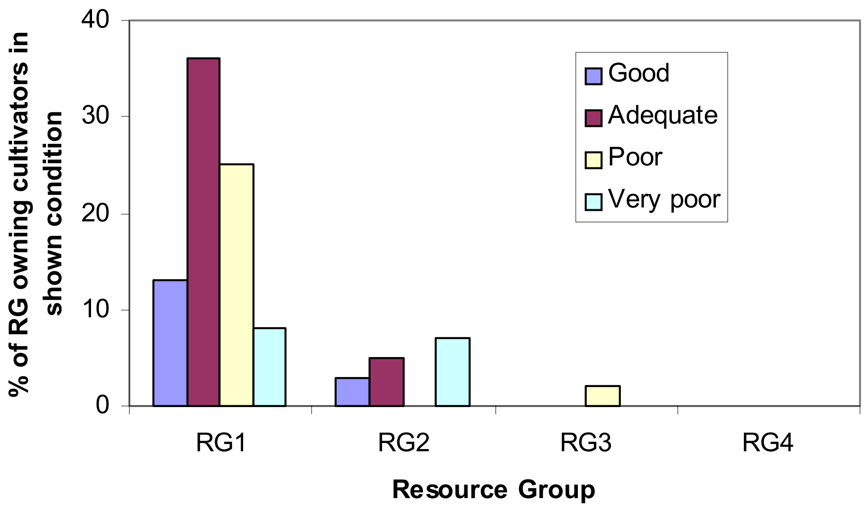

Fig 5: Ownership of cultivators in each RG (%) and distribution of cultivator condition

Ploughs were found to be, on average 17 years old and cultivators 15 years old. In both cases, newer implements tended to be owned by the better resourced households.

Table 5 shows the condition that plough parts were found to be in across all RGs. Almost half the farmers had removed had removed the components needed for setting and adjusting their ploughs. This seems to be partly due to ignorance (Koza and Magumise, 2002) but does help explain why so many farmers complain that their ploughs are heavy and difficult to control.

Table 5: Condition of plough parts in households surveyed (n=100)

Part	Good	Adequate	Poor	Removed
Share	24	39	35	2
Mouldboard	18	41	41	0
Hake regulator	21	23	6	49
Wheel	23	43	26	8
Axle	21	43	29	7
Wheel arms	29	39	27	4
Landside	22	29	48	1
Frog	32	49	16	3
Regulator and holder	18	28	5	48
U clamp assembly	20	48	13	19
Left Handle	37	51	12	1
Right handle	36	54	8	1
Hitch assembly	23	26	3	48
Stay beams	39	43	5	12
King bolt	40	44	14	2
Plough beam	56	43	1	0
Plough spanner	49	15	1	34

Table 5 could be regarded as a technician's or an engineer's view of the situation; to gain the farmers' perspective, it is helpful to consider which parts are actually replaced and with what frequency. The findings of the survey in this respect are given in Table 6.

Table 6: Frequency of replacing plough parts (% households)

Part	More than three times pa	Once or twice pa	Once every two years	Once every three years	Rarely
Share	39	55	4	2	0
Mouldboard	1	6	18	12	63
Hake regulator	-	1	1	3	94
Wheel	16	54	6	13	12
Axle	14	54	5	12	16
Wheel arms	1	14	27	12	46
Landside	8	47	15	7	22
Frog	1	2	2	7	87
Regulator and holder	-	7	3	1	89
U clamp assembly	-	9	7	8	77
Left handle	-	2	1	-	97
Right handle	-	1	1	1	97
Hitch assembly	-	-	-	3	97
Stay beams	-	1	-	3	95
King bolt	5	12	4	5	73
Plough beam	-	2	-	-	98

The items that the farmers most frequently replace are the share, landside and wheel assembly. Mouldboards, which are not often in good condition (Table 5) are not often replaced and the typical condition of landsides suggest that they should be replaced more often. The generally poor condition of the wheel assembly is probably attributable to the wheel being used as a depth control. From Table 5, the items that seem to remain the most serviceable are the non soil-engaging parts and those not involved in setting and adjustment. These parts are rarely replaced. Information of this nature gives a clear indication of priority topics for the BPGs.

On-farm trials

To demonstrate the benefits of proper plough setting and maintenance, a major initiative of the project was to conduct farmer-led trials in which they could make their own comparisons between recommended ploughing practice and their own *modus operandi*. This was effected by setting up split plot cropping trials, in which (i) the farmer prepared the first half of the plot (plot A) for the crop (maize or cotton) using the plough as he would normally have done and then (ii) prepared the second half of the plot (plot B) after members of the project team had renovated his plough, by replacing the most badly worn parts and adjusting it to work at an appropriate depth and width. All other aspects of growing the crop on the two halves were exactly the same. The results showed clear differences attributable to the changed state of the plough.

For spring ploughing in the 1999-2000 and 2000-2001 seasons, differences in plough performance are shown in Tables 7 and 8.

Table 7: Plough performance before and after renovation, spring 1999-2000 (n=15)

		Depth (mm)	Width (mm)	Draught (N)	Work rate (ha/hr)	Field efficiency (%)
Farmer-set	Mean	109	273	922	0.093	75
	Range	80-133	216-310	748-1269	0.07-0.14	
Renovated	Mean	141	287	1106	0.097	82
	range	99-176	228-353	815-1281	0.06-0.13	

Table 8: Plough performance before and after renovation, spring 2000-2001 (n=18)

		Depth (mm)	Width (mm)	Draught* (N)	Work rate (ha/hr)	Field efficiency (%)
Farmer-set	mean	91	271	1095	0.096	86
	range	62-120	221-353	734-1566	0.07-0.15	68-97
Renovated	mean	134	287	1295	0.091	80
	range	107-169	215-348	1043-1880	0.05-0.14	65-95

* n=5

For winter ploughing preceding the 2000-2001 season, differences in plough performance are shown in Table 9.

Table 9: Plough performance before and after renovation, winter 2000 (n=7)

		Depth (mm)	Width (mm)	Draught (N)	Work rate (ha/hr)	Field efficiency (%)
Farmer-set	mean	90	262	978	0.095	83
	range	75-107	228-291	778-1248	0.067-0.132	
Renovated	mean	110	254	1010	0.08	82
	range	93-133	231-293	876-1158	0.063-0.097	

In all these cases, the biggest difference is in the depth of work and this is accompanied by an increase in draught force, as might be expected. With the other performance variables barely changing, this is a very positive result, as it means the soil is being worked more deeply without any loss of performance in other respects. Some concern that the animals (usually four oxen) might not be able to meet the increased draught requirement was not realised in practice. In fact, with the plough being easier to control, the farmers felt that their animals may be less stressed working with the renovated ploughs, despite the 20% or so increase in draught.

Plough renovation was also associated with changes in crop performance. Some agronomic variables are given in Table 10.

Table 10: Agronomic results from plough renovation

Year	Crop		Plant populations (10^3/ha)			Yields (t/ha)		
			Plot A	Plot B	% increase	Plot A	Plot B	% increase
1999-	maize	mean	30.4	31.3	3.0	1.1	0.99	-10
2000	(n=11)	range	19-42	21-44		0.32-2.17	0.4-1.8	
2000-	maize	mean	33.4	31.1	-6.9	1.83	2.27	24
2001	(n=14)	range	19-47	14-49		0.14-5.4	0.66-7.1	
1999-	cotton	mean	26.9	27	0.003	0.66	0.60	-9
2000	(n=4)	range	15-32	15-34		0.44-0.89	0.28-0.92	
2000-	cotton	mean	30.6	29.4	-0.04	1.03	1.15	12
2001	(n=4)	range	27-35	23-37		0.34-1.6	0.39-1.7	

The 1999-2000 maize crop was beset with problems ranging from Cyclone Eline, as the crops were reaching maturity, to straying cattle. In the maize crops where a valid comparison was possible, an average yield increase of 0.12 t/ha (14%) was recorded (Koza *et al*, 2000b). The season 2000-2001 had less extreme meteorological events but there was, nevertheless, a long dry spell at a crucial stage of crop growth in January 2001. The mean values shown tend to conceal the wide variability between individual farmers, which is indicated by the range values given underneath the means.

It can be seen from Table 10 that, despite the increases in yields in the second season, there is no difference in plant populations. The very weak trend seems to be fewer plants on Plot B than on plot A. This endorses the farmers' views that use of the renovated plough may inhibit germination and emergence, but leads to stronger, healthier plants (see Table 1).

To realise the benefits of the yield increases, which would be valued at 3300Z$ per hectare of maize grown[5], some resources have to be directed at plough maintenance and renovation. The general condition of ploughs and plough parts have already been considered in fig 4 and Table 5, and Table 11 below lists the plough parts replaced whilst carrying out the 1999-2000 and 2000-2001 spring-ploughing trials. Four types of part were to need replacement at more than half the households. These were share (83%), landside (82%), wheel assembly (70%) and U-piece with set screw (60%). It would seem that even although farmers are aware of the need to replace the main soil-engaging parts, they do not do so frequently enough. The difference between a worn and a new share is illustrated in fig 6.

[5] yield increase for plot B of 0.44 t/ha at 7500Z$ /t (May 2001 price)

Table 11: Plough parts replaced in spring-ploughing trials, 1999-2000 and 2000-2001

Part	1999-2000		2000-2001		Mean %
	Number replaced	% of farmers	Number replaced	% of farmers	
C2 Cup head bolt	0	0	9	50	25
Draw-bar assembly	9	56	8	44	50
Frog	1	6	6	33	20
King bolt	8	50	8	44	47
Landside	13	81	15	83	82
Mouldboard	1	6	2	11	9
Mouldboard bolts	3	19	1	6	13
Regulator hake	6	38	10	56	47
Share	14	88	14	78	83
Stay bolt	0	0	2	11	6
U-clamp	7	44	8	44	44
U-piece & set screw	11	69	9	50	60
Wheel assembly	8	50	16	89	70

Fig 6: New and worn plough shares
(profile of worn share depicted on new share)

Table 12 summarises the costs of the renovations, according to household resource grouping and age of plough, for the 2000-2001 spring ploughing trials. The costs are expressed not only as Z$, but also as the equivalent value in tonnes of maize and the percent of the cost of a new plough (all at November 2000 prices – i.e 1US$ = 55 Z$, official rate[6]).

[6] a "parallel market" rate started to emerge around June 2000. This, together with fierce inflation, makes it difficult to make direct cost comparisons.

Table 12: Costs of plough renovation during spring-ploughing trials, 2000-2001

Cases		n	Mean			Range	
			Z$	% plough	t maize	Low Z$	High Z$
All	Overall	18	1155	40%	0.21	220	2640
Sex of HoH	Male	12	1265	41%	0.23	330	2640
	Female	6	1100	37%	0.2	220	2035
Category	RG1	7	825	27%	0.15	220	1540
	RG2	6	1265	43%	0.23	825	2035
	RG3	5	1650	55%	0.3	495	2035
	RG4	0					
Age of plough (yrs)	< 6	2	550	19%	0.1	220	880
	6 - 10	0					
	11 - 20	6	1155	39%	0.21	715	2035
	> 20	10	1375	45%	0.25	330	2035

Ploughs in communal areas were found to be in poorer condition than those in the other areas but, surprisingly, ploughs in female-headed households tended to be in slightly better repair than those in male-headed households. However, not surprisingly, the cost of doing the necessary repairs increased as both the household resource base decreased and the age of the plough increased. The average age of the ploughs involved in the 2000-2001 spring ploughing trials was 23.9 years.

Cost:benefit considerations

The average cost of renovating a plough is less than the average return on improved yield for any area exceeding 0.8 hectare[7]. Even the poorest farmers cultivate typically 1.7 ha (e.g. see Ellis-Jones, 2000), so the basic economics provides a convincing case. However, plough renovation was not the only factor in achieving the yield increase, the renovated plough was also set and operated correctly. The project team enabled the participating farmers to do this – the main justification for producing the BPGs is to enable the many other farmers, who have not been able to participate but are willing to maintain and use their ploughs properly, to achieve the same results and, hence, benefits. The experiences of working so closely with the participating communities, running the field trials and eliciting views on the format of the BPGs, has contributed greatly to the design of the BPGs and consequently to their value to farmers.

For farmers undertaking an annual (or seasonal) maintenance schedule, the costs would be considerably less than those shown in Table 12. Experience of plough renovation has enabled recommended schedules for maintenance and parts replacement to be compiled. When ploughs are maintained and correctly set for operation, only the soil-contacting parts will need replacing (see also Table 11). The schedule for these is given in Table 13, but in relation to area cultivated rather than elapsed time. The costs of these parts at November 2000 are also shown.

[7] Average yield increase is 0.44 t/ha (Table 10), at 3300Z$/t gives 1452 Z$/ha. Average repair cost is 1155ZS (Table 12), so need to cultivate 1155/1452 = 0.8 ha to break even.

Table 13: Plough part replacement schedule and costs

Part	Replace after	Cost (Z$)
Share	5 ha	153
Wheel and axle set (not arms)	25 ha	233
Landside	40 ha	268
Mouldboard	125 ha	842

The information given in Table 13 indicates that the cash cost of fully maintaining a plough is about 53 Z$ or approximately 1US$ per hectare. Knowledge of this schedule also serves as a guide on which, and how many, spares farmers should hold in stock. Daily and seasonal maintenance schedules, which demand time rather than cash, are shown in Table 14.

Table 14: Seasonal and daily maintenance procedures

Seasonal	**Daily**
Check plough parts and wheel for wear	Remove / scrape off soil in the field
Obtain replacement parts if necessary	Tighten all nuts and bolts
Strip the plough	Wash and apply some oil if the plough will not be used for a few days
Clean parts and paint if necessary	Store under cover
Replace worn out nuts and bolts	
Re-assemble the plough and oil it if it was not painted	
Store the plough in a safe, dry place	

Other benefits

The main benefits of plough renovation from the farmers' perspective have already been listed in Table 1. Some of these, such as furrow shape and better yield, are readily quantifiable and have been considered in the preceding paragraphs. The last benefit listed under tillage was "easier plough handling and control". This is primarily a subjective feeling of the farmer / operator but is also easily observed by onlookers. Although not planned as a project activity, an opportunity was made to monitor the physiological (cardiovascular) stress when ploughing the split plots. The farmer who was ploughing wore a POLAR SPORT TESTER™ chest band which enabled his resting, working and recovery heart rate characteristics to be recorded. The results revealed a lower working heart rate (109 to 103 beat/min) and a shorter recovery time (541s to 231s) for plot B, cultivated after renovation and correct setting of the plough, despite an increase in depth worked from 98 to 160 mm (Koza and Magumise, 2002). This implies that the work was easier and the farmer commented (which was clearly evident) that he did not have to fight the plough to cut the furrow. These findings should be validated by monitoring a larger, representative sample of farmers.

Harnessing

The type of guidance on harnessing that the farmers sought was elicited during the various survey activities and related mainly to the use of donkeys. Bertha Mudamburi, who manages the AGRITEX training facility at Hatcliffe (IAE) is an expert on harnessing and assisted with some of the survey during the winter of 2000. Many farmers who use a yoke on donkeys understand the need for a breast-band type harness but, because of the low status of donkeys, are not motivated to change (Mudamburi, 2000). Furthermore, the few farmers who are motivated by the concept of donkey welfare can not access the advice and guidance they need because their usual advisors (AGRITEX) are unable to supply it (Mudamburi, 2000). The BPGs address this problem in both the Farmer and Extension Worker versions. The issues concerning harnessing are inextricably linked with those of hitching, which, in turn, is the major problem that has to be dealt with in plough setting.

Contributions from on-station activities

The ripper tine and cultivator evaluations have provided some information for the production of the BPGs but it is a relatively small contribution compared to the on-farm activities.

Carefully controlled experiments on two types of implement were carried out at two locations, Hatcliffe (Institute of Agricultural Engineering – IAE) and Domboshawa Technical Centre (DTC). The characteristics of their soils and the rainfalls for 2000-2001 are summarised in Table 15. The soil at Domboshawa is more representative than that at Hatcliffe of the soils in most smallholder farming areas in Zimbabwe.

Table 15: Soil and rainfall characteristics at the two on-station locations

Soil type	Domboshawa deep, coarse-grained granitic sand	Hatcliffe deep red clay loam
Composition (%):		
clay	5	>60
silt	13	<60
sand	82	
Rainfall (mm):		
Oct 2000	1	56
Nov 2000	57	64
Dec 2000	272	271
Jan 2001	91	71
Feb 2001	301	332
Mar 2001	309	320
Total	1031	1114
1994-1998 annual mean	879	817

Ripper tine evaluation

As very few smallholder farmers use ripper tines and have significant problems using their ploughs, the content of the "Animal-drawn Ploughs" BPG booklet is devoted almost exclusively to plough use. However, the findings of the ripper trials relate to land preparation, using the standard plough as the control, and so have provided some insight into plough use.

The trials showed some differences between the performance of the implements but the major difference related to whether the land had been pre-ploughed, i.e. winter-plough or no-till (see Table 16).

Table 16: Draught performance characteristics for on-station ripper trials

Implement	Draught (kN)		Depth of work (mm)		Work rate (h ha^{-1})	
	No-till	Plough	No-till	Plough	No-till	Plough
BSPP	1.78	0.51	119	158	4.2	4.8
BSPR	1.02	0.30	115	138	4.3	4.4
CKR	1.90	0.53	132	187	4.4	4.5
CTB	0.24	0.25	52	82	4.6	4.6
MR	2.13	0.54	145	182	4.7	4.5
PS	0.96	0.43	96	154	4.4	4.7
ZR	0.96	0.36	110	145	4.3	4.5
TFP	1.22	0.85	-	-	13.7	14.16
Tillage SED	0.009 (1 df)		0.295 (1 df)		0.047 (1 df)	
Implement SED	0.019 (7 df)		0.552 (6 df)		0.094 (7 df)	
T by I SED	0.026 (7 df)		0.780 (6 df)		0.134(7 df)	

Table 16 summarises the key draught performance characteristics of each implement, or method of planting. The draught force requirements on the no-till plots were significantly (*P<0.001)* higher than on the pre-ploughed plots and also displayed a greater variability. The highest draught forces were measured for the MR on no-till plots. Winter ploughing also had a significant (*P<0.018)* effect on the depth of implement/tine penetration, despite the lower draught forces, typically increasing penetration depth by more than 40 mm, when compared to the no-till plots. The work rates for preparing and planting in the rip lines were significantly (*P<0.001*) faster than for the traditional TFP, typically 3 times faster per ha. (The time taken for winter ploughing, on which the benefits of reduced tillage systems seem to be dependent, has not been included in this analysis, as this operation occurs before the cropping season starts). The benefits of winter ploughing for reducing draught demand are illustrated very convincingly in fig 7.

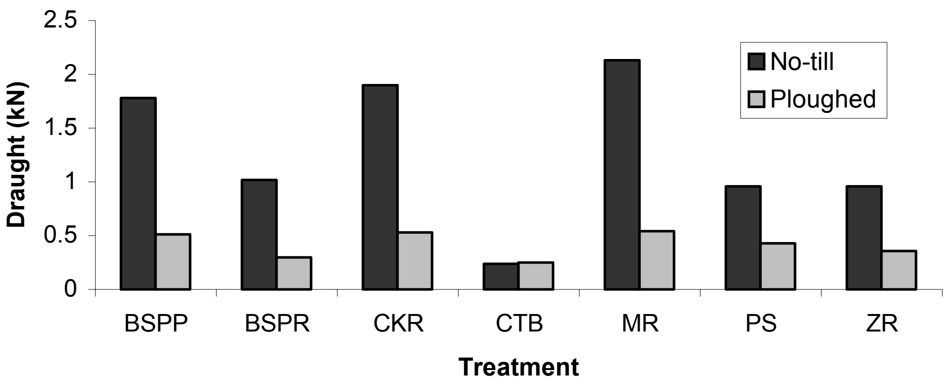

Fig 7: Draught requirements for rippers on no-till and winter-ploughed plots

However, as with most systems of production, there are pros and cons, which individuals have to balance, thereby choosing their own particular combination of positive and negative characteristics. The major disadvantages of production based on the no-till approach are the subsequently greater need for weed control and reduced crop yields. In these trials, the no-till plots had significantly (*P<0.023)* higher weed densities than the winter-ploughed plots. It is clear that tine tillage systems alone do not give adequate weed control and need to be combined with other crop husbandry practices to control weeds. Typically such practices include the use of herbicides, post emergent ridging to smother the weeds or, as in these trials, winter ploughing.

In these trials, winter ploughing had a highly significant effect on crop yields, giving large increases irrespective of tine design. Fig 8 shows that the average yield increase at Domboshawa (where the soil type is more representative of smallholders') was over 900 kg/ha (P<0.001) Yield increases were also recorded at Hatcliffe after winter ploughing, the average increase being just under 700 kg/ha (P<0.005).

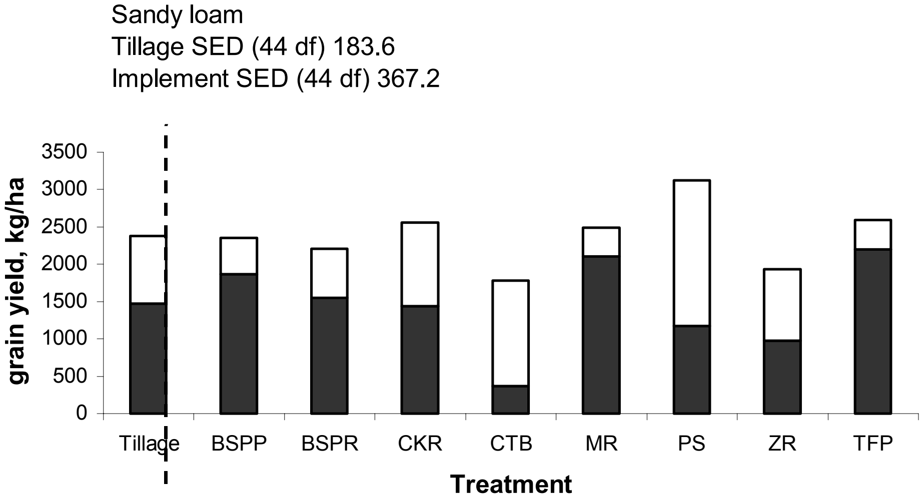

Figure 8: Yields according to use of rippers (Domboshawa, 2000/2001 season)

■ yields for no-till plots; □ incremental yield increase due to winter ploughing

At Domboshawa there was no significant interaction between tillage and implements (fig 8), but the incremental yield increases due to winter ploughing resulted in significant yield increases (P=0.01) for the CKR, CTB and PS rippers, doubling or even trebling yield responses, compared to no-till plots. The fact that winter-ploughing did not significantly increase the yield from third furrow planting (TFP) – the yield increased from to 2197 to 2592 kg/ha – is of relevance to the BPGs as TFP is a typical farmers practice. Despite the lack of statistical significance, winter ploughing effected a yield increase of 18%, and individual farmers have commented, when discussing field work, that any increase helps irrespective of whether it is statistically significant.

Cultivator evaluation

The results of the cultivator trials have made a negligible contribution to the production of the BPGs.

Output 2 – Utilisation of DAP

As is evident from the on-farm research, the current use of DAP, and hence the labour that supports it, does not fulfil its potential and could be made more efficient by better maintenance and operation of animal-drawn implements, particularly ploughs for land preparation. The economic benefits of keeping ploughs in good condition and using them properly have been summarised, in terms of increased yield, in Table 10 above. There was very wide variability between individual farmers and not every farmer recorded an increased yield in plot B over plot A, but these were usually due to interference from external or uncontrollable factors.

The widely practised technique of third furrow planting (TFP) has advantages and disadvantages, as shown in Table 17.

Table 17: Some advantages and disadvantages of third furrow planting

Advantages		Disadvantages	
Factor	**Reason**	**Factor**	**Reason**
Reduces costs (cash and opportunity) May reduce delay in planting (if rains late) and so yield not threatened	Combines land preparation and planting tasks	Weeding more difficult as crops not in straight rows Weeding takes longer or costs more	Planting lines not marked out Weeding more difficult
Good germination	Shallow planting	More plant damage if using DAP weeder	Crops not in straight rows
Good emergence		Weak plants less able to withstand wind and mini-drought	Shallow planting

Clearly, there is no win-win situation, so each farmer chooses his or her preference according to household resources. If farmers have opted for TFP, they should consider ripping for crop establishment (see fig 8), especially if they are able to winter plough. As some of the better-resourced farmers are beginning to favour this approach, it could be inferred that it is a lack of resources, especially DAP, that acts as a deterrent to the other farmers.

Rippers

The costs and benefits of plough maintenance and renovation have already been considered (Table 12 *et seq*), as have the key agronomic data from the ripper trials (fig 8). The economic implications of ripper use are now considered. The purchase costs of the implements are shown in Table 18. As nearly every household owns a plough, only the cost of the ripper attachment has been given (except for CTB, which is a complete implement). No costs are shown, therefore, against the use of a plough or TFP (the control).

Table 18: Purchase costs of rippers

Ripper (/ Treatment)	Abbreviation	Cost (Z$) (at Jan 2002)
BSP Ripper	BSPR	1324
Zimplow Ripper	ZR	1324
Magoye Ripper	MR	2000
Palabana sub-soiler	PS	2000
Contil Knife Ripper	CKR	2500
Contil Tool Bar	CTB	5000
BSP light-weight plough	BSPP	0*
BSP standard plough for TFP	TFP	0*

* for households already owning ploughs

The increase net returns, based on a partial budget including the most important variables, for using a ripper compared to TFP are shown in fig 9. The data for winter-ploughed (WP) and no-till plots are kept separate. The variables incorporated into the partial budget analysis included yields, prices and inputs costs (for three weedings and ploughing in the WP case), according to the treatment. Family supplied inputs have been included at their opportunity costs. The costs of the implements have been depreciated over five years.

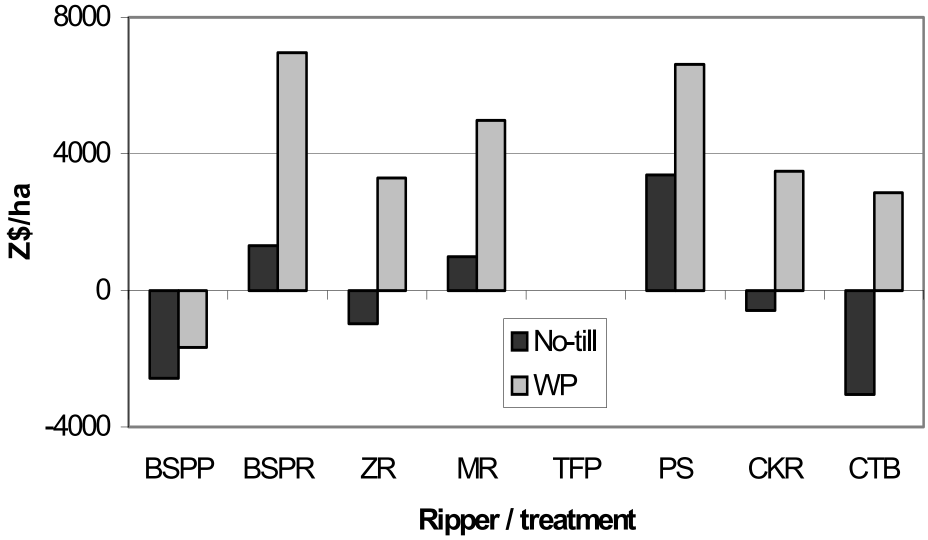

Fig 9: Increase in net returns comparing rippers to third furrow planting

As might have been expected from fig 8, there are major differences in returns between the no-till and winter-ploughed plots. A gross margin analysis comparing the means for the no-till and WP treatments is given in Table 19.

Table 19: Gross margin analysis for no-till and WP (Z$/ha unless stated)

	NT	WP		Difference	% change
Yield (kg per ha)	501	626	125	25%	Higher
Gross Income	7517	9396	1879	25%	Higher
Purchased Input costs	4541	4666	125	3%	Higher
Labour costs	6784	7225	441	7%	Higher
DAP costs	2050	4805	2754	134%	Higher
Implement costs	745	745	0	0%	-
Total costs	14120	17441	3321	24%	Higher
Gross margin including labour and DAP costs	-5858	-7300	-1442	25%	Lower
Gross margin excluding labour and DAP costs	2976	4729	1754	59%	Higher
Returns per labour hour	-11	-13	-2	18%	Lower

Key assumptions
Price of maize: Z$ 15 per kg (Z$ 15000 per tonne)
Purchased input costs differences are attributed to the additional packing material required
Price of labour: Z$ 100 per day
Price of DAP: Z$ 800 per day
Net return takes into account the annual cost of implements

The largest cost increase is in the DAP costs for WP options. However these are usually household supplied and, although they have been valued at the opportunity cost of hiring DAP, most households do not place a value on their use. If these costs are excluded from the gross margin analysis the returns are 59% higher for the WP options than the NT options, whereas if they are included WP options achieve a 25% lower gross margin but both negative. This would help explain that when winter ploughing is observed, it is more likely to be at the better-resourced households, where it carries no cash cost.

Cultivators

The different weeding methods (i.e. treatments, with hand weeding as the control) used in the on-station trials at Domboshawa and Hatcliffe have been analysed by the partial budget approach. The purchase costs of the implements are shown in Table 20 and, for the analysis, are depreciated over 10 years. This may be a little conservative, as one of the on-farm surveys found the average of a cultivator to be 15 years.

Table 20: Purchase costs of cultivators

Cultivator (weeding treatment)	Abbreviation	Cost (Z$) (at Jan 2002)
BS221 Cultivator	BS2212R2H1D	18600
BS221 Cultivator	BS2213D2H	18600
BS41 Cultivator	BS415R	17600
BS41 Cultivator	BS414R1D	17600
BS41 Cultivator	BS415D	17600
Zimplow light-weight cultivator	ZLW2R1D	10700
Zimplow light-weight cultivator	ZLW3D	10700
Contil Tool Bar	CTB	5000
Standard VS8 Plough without mouldboard	SHARE	0*
Standard VS8 Plough	MB	0*
Hand hoe	HH	250

* for households already owning ploughs

Although there are small differences in the cost of different tines, these are minor and can be negotiated at the time of purchase of the cultivator and the selected tines will be fitted for an all inclusive price.

The results from Domboshawa on the sandy soil and from Hatcliffe on the red clay soil have been analysed separately, but the former are more representative of smallholder farming conditions. The increase net returns, based on a partial budget including the most important variables, comparing cultivators to hand hoeing (HH) are shown in fig 10. The variables incorporated into the partial budget analysis were yields, prices and inputs costs (including harvesting), according to the treatment. Family supplied inputs have been included at their opportunity costs.

Fig 10 indicates that, on the sandy soils, the only DAP weeding methods that give a better return than hand hoeing are using the plough (in either form) and the light weight cultivator fitted with three duck foot tines. To make the use of cultivators more economic than the plough, from the labour saving point of view, the cost of labour would have to increase from Z$100 to Z$1250 per day. The cost of DAP does not have any effect on the results.

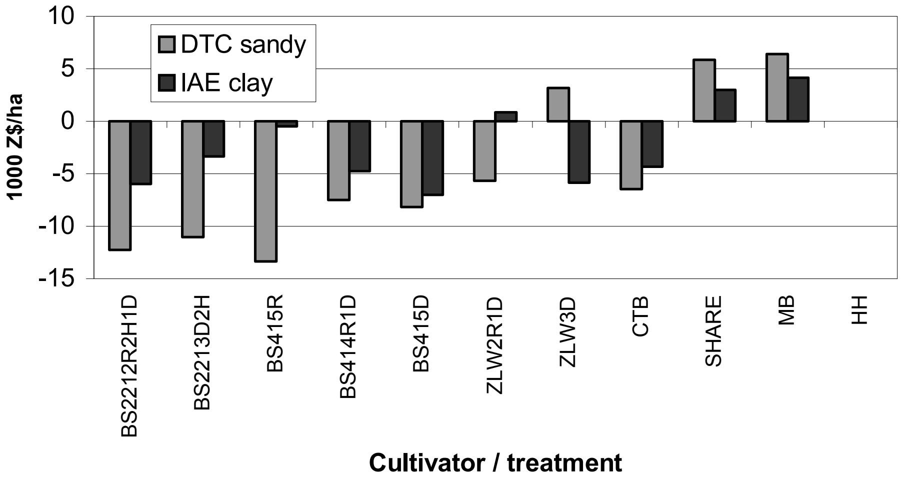

Fig 10: Increase in net returns comparing the use of cultivators to hand hoeing

In the heavier soils at Hatcliffe, again there were only three methods that gave a better return than hand hoeing. Again, both forms of plough and the light weight cultivator performed better, but, in this case, reversible tines replaced two of the duck foot tines.

Considering returns from the use of cultivators only, fig 10 suggests that duck foot tines are better suited to the sandy soils and reversible tines are better suited to the clay soils. From the agronomic point of view, the highest yields were obtained from plough-based weeding (Mbanje *et al* 2001), which is a major reason why these methods show good results in fig 10. The only cultivator to show a positive economic return was the light-weight Zimplow model. However, the return was positive only for a specific design of tine in each soil type. The interaction between tine design and soil type was highly significant with duck foot tines giving a better return (than reversible) in the sandy soil and reversible tines giving a better return (than duck foot) in the clayey soil (both $P<0.001$). The same pattern of results was obtained for the BS41 cultivator, but in these trials all the economic returns were negative.

Innovative crop production methods

Innovative practices, both the concept and implications, have been discussed by the stakeholders throughout the project. The project Workshops have included presentation and discussion sessions, leading to a paper from the final Workshop defining the situation for smallholders in Zimbabwe (Workshop Proceedings in preparation). Some key points from this paper are reproduced below.

- An innovative practice is ‘any practice that is a departure from a household’s current practice’. What might be an innovation to one household might be a current practice for another. It may be determined by an individual household’s physical and social capital.

- The innovations that the farmers associate with this project are:
  - paired plots to assess the impact of a change in practice,
  - winter ploughing (promoted, with little success, for the last 30 - 40 years).

- Because of limited household labour and the current risk management strategy of planting as large an area as possible, most crops are only weeded once, typically 4 to 6 weeks after emergence. Compared to a crop that has been weeded twice at 2-3 weeks and 6 weeks after emergence, a single weeding schedule can deprive the household of up to 40% of its yield.

- Recent work by ICRISAT and their collaborators within the Zimbabwean NARS has suggested that an extra weeding is better than applying two bags of nitrogen fertiliser.

Output 3 - Dissemination

The project, its existence and findings, have been widely disseminated by the stakeholders, particularly core members of the project team. Farmers networks have ensured that few smallholders in Masvingo Province are unaware of the project. This has caused a few problems in that farmers who have not been selected to participate have expressed concern that "we have our favourites and ignore the others". The problem is that we had fairly limited funds to do a research project, not a national development project.

AGRITEX and University of Zimbabwe staff on the project team have discussed the project with colleagues and made informal presentations at meetings within their organisations. Bertha Mudamburi disseminated information about the project at the Agricultural University, Wageningen (Netherlands). The fieldwork for her MSc thesis was supported (in part) by the project.

CARE staff, particularly those closely with the project, have also assisted with dissemination. CARE Zimbabwe sponsored two members of the project team to run a Workshop in October 2001 to train Field Officers in plough use. Five Field Officers were trained over two days of theoretical and practical tuition and demonstration (Koza and Magumise, 2001).

The project has also been able to fund ploughing demonstrations in the participating communities in order to make the findings more accessible to the families that were not directly involved. At three locations, a total of 92 people attended the demonstrations (29 men, 33 women, 21 boys, 9 girls) in the first week of December 2001 (Koza and Magumise, 2002).

The project has been represented and aspects of the work presented at the following events.

1. **Animal Traction in Mozambique** Workshop organised by VETAID, Chimoio Institute of Agriculture, Chimoio, Mozambique, 12-14 June 2000. Paper presented "Animal Traction in Zimbabwe" by Koza and Mbanje. Published on ATNESA website[8]
2. **AGENG 2000** International agricultural engineering conference organised by the European Society of Agricultural Engineers (EurAgEng), the Institution of Agricultural Engineers, the Royal Agricultural Society of England (RASE) and Silsoe Research Institute, University of Warwick, 3-7 July 2000. Two papers (Koza *et al*; 2000b; Mbanje *et al, 2000*) and one poster (O'Neill) presented.
3. **Animal Traction, Health and Technology, the Role of Draught and Pack Animals in the 21st Century.** Scientific meeting organised by World Association for Transport Animal Welfare, Royal Veterinary College, London, 28 October 2000. One paper presented "The contribution of draught animal power to sustainable livelihoods in sub-Saharan Africa: an example from Zimbabwe" by Ellis-Jones and O'Neill

[8] www.atnesa.org

4. **I World Congress on Conservation Agriculture.** Workshop organised by FAO and the European Conservation Agriculture Federation (ECAF), Madrid, 1-6 October 2001. Two papers (Sims and O'Neill, 2001; Mbanje, Twomlow and O'Neill, 2001) and two posters (associated with the papers) presented
5. **Weeds 2001.** International Conference organised by the British Crop Protection Council (BCPC), 12-15 November 2001, Brighton, UK. One paper (oral) presented (Mbanje, Twomlow and O'Neill,2001)
6. **Weed Management Using Draught Animals in the Teso Farming System.** Stakeholder Workshop organised by NARO / SAARI, Soroti, Uganda, 7-8 February 2002

A refereed paper "Sustainable dryland smallholder farming in sub-Saharan Africa" by Twomlow, S J, Riches, C, O'Neill, D H, Brookes, P and Ellis-Jones, J, based on the preparatory work for the project has been published in Annals of Arid Zone, 2000 (**38**(2), 95-135).

Articles have been published in various Newsletters such as "Draught Animal News", "Mirimbe" (Newsletter of ZFU), and the Livestock Production Newsletter. The project is also publicised on Silsoe Research Institute's promotional literature and website[9].

Most significantly, with the imminent publication of the BPGs, the local members of the project team, especially AGRITEX staff, will be distributing this major project output to all senior AGRITEX staff and all mechanisation advisers. The BPGs will also be sent to relevant NGOs and other extension organisations. Follow-up will be made as funds and opportunities permit.

A joint Workshop for all three DAP projects in the Livestock Production Programme was proposed by the project leaders but, to date, no funding has been forthcoming.

Future opportunities to disseminate the findings of the project will be taken when resources permit. It is hoped that a paper will be presented at the ATNESA Workshop, "Modernising Agriculture through Improved Animal Traction and Rural Transport Services" at Jinja, Uganda in May 2002.

Contribution of outputs

The Programme Purpose is: "*Performance of livestock (including draught animals) in semi-arid crop/livestock and livestock production systems enhanced*".

The underlying principle of the project was to enable livestock to make a more effective contribution within the crop/livestock system. This has been achieved by targeting certain system components and processes rather than by focusing on the livestock in isolation. The **application** of DAP to soil, water and crop management has provided the basic theme for the project and has sustained three interlinking areas of activity: i) traditional use of the mouldboard plough, ii) the use of rippers to prepare land for planting and iii) the use of animal-drawn implements for weed control.
The first area of activity is the most pressing from the Zimbabwean smallholders' perspective. Previous findings and limited reviews had indicated that farmers, typically, did

[9] www.sri.bbsrc.ac.uk

not maintain their ploughs nor set them correctly. This resulted in farmers struggling to do relatively poor quality work and, most relevant to this project, resulted in the inefficient use, and hence wastage, of their scarce draught energy resource. The scarcity of DAP is related to farmers' wealth: the best resourced farmers (RG1 category) are not seriously constrained by a lack of draught energy but enabling poorer farmers to get a better return on their cash outlay, or investment, in hiring draught animals directly addresses poverty issues. The results show that ploughing with properly maintained and set ploughs does not require more time (so hire charges should not be affected, if time rather than area is the payment criterion) and remains within the capability of the animals.

The on-farm research undertaken by the participating farmers has demonstrated how the available draught energy may be used more effectively in terms of crop production (see yield responses) and that the expenditure on plough renovation is easily recovered from yield gains. There are also financial incentives for proper maintaining and setting ploughs. For example, wearing parts such as the wheel and axle assembly are likely to last longer thus reducing replacement costs. Other advantages, which are not so easily defined in economic terms, are less stressful and physically demanding working conditions (a relatively greater benefit for women than men) and better control of the animal(s) and implement.

The participating farmers (and their neighbours) have become convinced of the value and benefits of correct plough use, but these will accessible to the community at large only if the necessary actions are taken by farmers on as wide a scale as possible. These necessary actions are being promoted through a set of Best Practice Guidelines (BPG) which have been compiled by the project team and other stakeholders. These BPGs explain, with many illustrations, both the benefits and how to maintain and adjust the most popular designs of plough in considerable detail. The BPGs are in the final stages of development and are being translated into Shona and Ndebele.

The second and third areas of project activity involved conducting carefully designed field trials on station to evaluate the relative performance of innovative practices. The practices in this case – preparing planting lines with a ripper tine (rather than a plough) and weeding with animal-drawn cultivators – are recognised procedures but are not established in the culture of Zimbabwean smallholders and, hence, would be described as innovative by the stakeholders. Ripping is an approach recognised within "Conservation Agriculture" and offers a potential solution to the shortage of DAP, particularly amongst the poorer households, whilst the use of animal-drawn cultivators (weeders) offers a potential solution to the shortage of labour (usually female, and associated with high levels of drudgery) for weeding. From the farmers' point of view, these two constraints would be closely associated as planting in rip lines has been associated with an increased weeding burden.

In the second area of activity, the project investigated the performance of six designs of ripper tine with respect to a range of soil and agronomic parameters. The experiment was set up to clarify two separate issues – a) the effect of winter ploughing before ripping and b) the effect of tine design – both primarily on crop yield, using the traditional practice of third furrow planting (TFP) as the control. The results showed that winter ploughing increased yield, and that the effect was more pronounced on sandy soil than on clayey soil. There were, however, no significant differences between the designs of ripper tine. Thus, for the typical smallholder cultivating sandy soil, the design of the implement (including the lightweight plough) and the geometry of its tine used to open the planting lines has little bearing on the subsequent outcomes. Although all farmers may be able to achieve a reasonable yield from ripping, only the better resourced households, with their own draught animals, are likely to benefit economically from rip-line planting. Clarification of such issues is a major advance in the identification of land preparation and cropping options for households of different resource bases.

In the third area of activity, the project investigated the performance of four types of cultivator with different configurations of tines and a standard plough (with and without mouldboard) against hand hoeing as the control. The lightweight version gave the best cultivator results but these were only marginally better than hand hoeing and not as good as either form of the plough. This is largely attributable to the cost of the cultivators but the farmers did comment that the lightweight cultivator was more stable and easier to use. The results indicated that the choice of tine should depend on the soil type, with the reversible tine being favoured for the heavier soil and the duck foot tine for sandy soil. Thus the recommendation for a smallholder farmer would be a lightweight cultivator fitted with three duck foot tines. Very few working cultivators are found in the smallholder community and this design and configuration has not been found at all. Many smallholders have abandoned their cultivators which, typically, are fitted with five reversible tines, and these findings help explain why. Farmers also commented that cultivators were not robust enough – the mechanisms failed and the tines broke.

The findings from the on-farm trials have demonstrated the value of proper plough maintenance and setting in achieving an improved return from the use of DAP for land preparation. Farmers' participation in the trials has also made a major contribution to the drafting of the BPGs and presentation in a format that will be of real use to other farmers. Reducing the wastage of DAP will improve the overall performance of the crop/livestock system.

The findings of the on-station trials have resolved several issues which had not, hitherto, been fully scientifically evaluated. The physical, agronomic and economic performance of various designs of animal-drawn ripper and cultivator (weeder) have been analysed and the implications for farmers, in different wealth categories, determined. Soundly-based recommendations on the use of DAP and associated equipment can now be formulated and disseminated.

In addition to the production and publication of the BPGs, the project team has held three Stakeholder Workshops. The first was in September 1999, when the practical details of project implementation were discussed and agreed. The second was in September 2000 and served to review the progress to date and confirm the needs for the following year of the project (then expected to run for three years). To encourage farmer involvement, most of the presentations and discussions were conducted in Shona (the Proceedings were published in English). The third and final Stakeholder Workshop was held in September 2001. Again it was conducted in Shona and there was very strong farmer representation (14 of the 39 attendees).

The findings of both the on-farm and on-station research have also been widely disseminated at scientific meetings and conferences in sub-Saharan Africa (Ghana, Mozambique, Uganda, Zimbabwe) and in Europe (International Conferences in UK – AgEng2000, Brighton Crop Protection Conference, 2001 – and in Spain – I World Congress on Conservation Agriculture).

The project is also earning a good reputation in Masvingo Province. A senior member of the project team (Engineer Tiri Koza) has already been commissioned by CARE Zimbabwe to provide training to Field Officers on the effective use of draught animals and implements. The training was successfully delivered by two members of the project team in October 2001 (Koza and Magumise, 2001). Further opportunities of this nature and for farmer field-days are likely to arise but will also be keenly sought by local members of the project team.

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Annex 1

Resource categories of households in Masvingo Province

Indicator	Well resourced (RG1)	Average (RG2)	Poor (RG3)	Very Poor (RG4)
Livestock	More than 5 cattle and donkeys	At least 2 cattle and donkeys	Possibly a single animal owned	No livestock
Implements	Has full range of implements, often more than one	Plough and possibly one other implement	Hand tools only	No implements Old hoes
Crop Inputs used	Purchases seed Has adequate manure Uses fertiliser regularly	Purchases seed, some manure, occasional fertiliser use	None, some manure	None
Yields achieved (food security)	Sufficient for family Sells surplus most years	Sufficient for household in good years Shortfall in poor seasons	Insufficient for household security	Very low if any
Homestead	Asbestos or tin roof house plus huts Granary Brick toilet	Asbestos or tin roof house plus huts Granary Blair toilet	2-3 huts No toilets No granaries	1-2 huts No toilets No granaries
Education	Complete secondary ("O" levels) Nice schools	Secondary (Form 2-4) May complete "O" levels	Primary May attend secondary	Primary only
Sources of income	Many remittances Formal employment (pensions, professions	Occasional remittances Small pension IGAs Some formal employment	Hiring out labour Some IGAs	Hiring out labour for food, seed or cash

Note: RG=Resource Group, IGA=Income generating activity

Source: CARE, 1999. Masvingo livelihoods survey.