ANNEX 4

The use and maintenance of animal-drawn equipment for smallholder crop production: costs and benefits

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Abstract
Farmers' difficulties in using and maintaining their animal-drawn implements for land preparation and weeding have been investigated. The project was carried out in Masvingo Province in Zimbabwe with more than 30 smallholder households participating in the research. The households were selected on the basis of their wealth (mainly physical capital, as related to draught animal ownership) to cover four categories.

The costs and benefits of maintaining and using equipment properly were examined through farmer trials based on the use of their ploughs, as the equipment example, for the production of maize and cotton crops. Constraints other than direct financial costs were also considered and are discussed. The methodology required that each household selected a plot for maize or cotton and divided it into two, cultivating the first half with the plough in its typical state, and then the second half after the plough had been renovated and correctly set for depth and width of work. All other conditions and activities in the growing of the crop were kept the same.

Various performance indicators were monitored with crop yield being the most important. The economic analysis demonstrated that the investment in plough maintenance would give a net economic benefit for most smallholder families.

Introduction
Complaints by smallholders that ploughs are heavy and difficult to use have been widely observed in Zimbabwe. There is also evidence that these smallholder farmers do not keep their ploughs in good condition, not paying any heed to the repair or maintenance of their ploughs (Chatizwa and Khumalo, 1996; Chatizwa and Ellis-Jones, 1997). If this is true, how serious is the problem, particularly in terms of wastage of scarce draught animal power (DAP) and the associated human effort? These issues were investigated in a research project aimed at enabling crop / livestock farmers to increase the overall productivity of their farming practices.

Methods and equipment
On-farm field trials were set up to test the hypothesis that ploughs in good condition make better use of DAP than ploughs in poor condition. All the trials were conducted by farmers, using their usual equipment, land and other resources. The role of the project team was to renovate the farmer's plough and compare the performance of the plough before and after renovation in a split-plot trial. At each site the farmer ploughed plot A using his/her normal practice and settings. After renovation by replacement of the necessary components (see fig 1), the farmer ploughed plot B with recommended settings and adjustments. All other conditions for crop establishment and growth remained the same. The trial crops were maize and cotton and the area of each plot was approximately 100 m by 8 m.


Fig 1 Parts needed for plough renovation

The participating households were selected from four representative resource groups during group discussions in their communities. The resource groups were identified according to the households' physical capital relating mainly to their access to draught animals and likely implement ownership (see Table 1).

Resource Group	Draught animals	Ploughs	Cultivators
RG1	Owns more than enough	Owns at least one	Owns one
RG2	Owns adequate	Owns one	Owns none
RG3	Owns inadequate	Owns one	Owns none
RG4	Owns none	Owns none	Owns none

Table 1 Criteria for resource group categories

The households were from communal, resettlement, irrigation and small-scale commercial areas to ensure a representative range of rural communities as well as poverty levels.

Results and discussion

The condition of the ploughs and cultivators used by the participating households, according to RG is shown in figs 2 and 3 respectively.

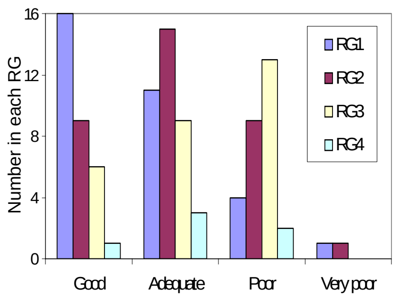

Fig 2 Plough condition for each RG

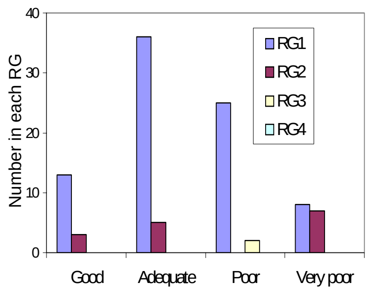

Fig 3 Cultivator condition for each RG

Fig 2 shows that only 31% of the ploughs were in good condition and that most of these were in RG1 households. Fig 3 reflects the expected distribution of cultivators and shows that very few of them were in good condition.

The frequency with which farmers replace their plough parts was also investigated and the results are given in Table 2.

Table 2 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 are not often replaced.

The performances of "as found" and renovated ploughs, in terms of the key work parameters are summarised and compared in Tables 3 and 4 for spring 1999-2000 (n=15) and spring 2000-2001 (n=18) respectively.

Table 3 Plough performance before and after renovation, spring 1999-2000

		Depth (mm)	Width (mm)	Draught (N)	Work rate (ha/hr)	Field efficiency (%)
As found	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 4 Plough performance before and after renovation, spring 2000-2001

		Depth (mm)	Width (mm)	Draught* (N)	Work rate (ha/hr)	Field efficiency (%)
As found	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

In each case the renovated implement ploughed deeper and wider and, hence the draught demand increased. However, the increased demand did not appear to cause the oxen any additional stress and seemed to remain within their capability. If this were not the case, it is likely that their work rates would have reduced but, as Table 4 shows, work rates and field efficiencies remained about the same.

The comparative performance in terms of key agronomic variables is summarised in Table 5, with plot A giving the "as found" and plot B giving the renovated results. The increases refer to plot B over plot A.

Table 5 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
1999-2000	maize (n=11)	mean	30.4	31.3	3.0	1.1	0.99	-10
		range	19-42	21-44		0.32-2.17	0.4-1.8	
2000-2001	maize (n=14)	mean	33.4	31.1	-6.9	1.83	2.27	24
		range	19-47	14-49		0.14-5.4	0.66-7.1	
1999-2000	cotton (n=4)	mean	26.9	27	0.003	0.66	0.60	-9
		range	15-32	15-34		0.44-0.89	0.28-0.92	
2000-2001	cotton (n=4)	mean	30.6	29.4	-0.04	1.03	1.15	12
		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*, 2000). 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.

The effects of plough renovation inevitably implicates many variables, both qualitative and quantitative. The qualitative **benefits** of renovation, as perceived by the farmers are summarised in Table 6. These were discussed at the final round of focus group meetings and so represent the accumulated experience over the course of the whole project (Koza *et al*, 2001).

Table 6 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 emerged with the farmers who practised 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, which resulted in poorer emergence and farmers feeling obliged to fill the gaps by doing some re-planting. However, as can be seen from Table 5, despite the increases in yields in the second season, there is no difference in plant populations. The very weak trend in 2000-2001 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 6).

The last benefit listed under tillage in Table 6 is "easier plough handling and control". This is primarily a subjective feeling of the farmer / operator but is also easily observed by onlookers. On one occasion there was an opportunity to monitor the physiological (cardiovascular) stress when ploughing the split plots. The farmer who was ploughing wore a heart rate monitor 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, and this was clearly evident, that he did not have to fight the plough to cut the furrow.

The general condition of ploughs has already been considered in fig 1. Table 7 lists the plough parts replaced whilst carrying out the 1999-2000 and 2000-2001 spring-ploughing trials. Four types of part needed replacement at more than half the households. These were wheel assembly (89%), landside (83%), share (78%), and regulator hake (56%). 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.

Table 7 Plough parts replaced in spring-ploughing trials, 2000-2001

Part	Number replaced	% of farmers
C2 Cup head bolt	9	50
Draw-bar assembly	8	44
Frog	6	33
King bolt	8	44
Landside	15	83
Mouldboard	2	11
Mouldboard bolts	1	6
Regulator hake	10	56
Share	14	78
Stay bolt	2	11
U-clamp	8	44
U-piece & set screw	9	50
Wheel assembly	16	89

Table 8 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$).

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, as might have been expected, 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.

Table 8 Costs of plough renovation during spring-ploughing trials, 2000-2001

Cases		n	Mean			Range	
						Low	High
			Z$	% plough	t maize	Z$	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%	0.20	220	2035
Category	RG1	7	825	27%	0.15	220	1540
	RG2	6	1265	43%	0.23	825	2035
	RG3	5	1650	55%	0.30	495	2035
	RG4	0					
Age of plough (yrs)	< 6	2	550	19%	0.10	220	880
	6 - 10	0					
	11 - 20	6	1155	39%	0.21	715	2035
	> 20	10	1375	45%	0.25	330	2035

Calculating the cost:benefit ratio of plough renovation to improved yield suggests that renovation would be a good investment for most farmers. The average maize yield increase in 2000-2001 was 0.44 t/ha (Table 5); at 3300Z$/t this increase is equivalent to 1452 Z$/ha. As the average repair cost was found to be 1155ZS (Table 8), the typical farmer would need to cultivate 0.8 ha (i.e. 1155/1452) to break even. Even the poorest households cultivate on average 1.7 ha (e.g. see Ellis-Jones, 2000), so the basic economics provides a convincing case.

Nevertheless, there are impediments, particularly regarding access to spare parts. The basic (and rapidly increasing) cost of the spares is, in effect, increased further by the cost of travelling to buy them, especially if they not available at the local shop(s). Local stores can not be relied upon to stock the right parts (although they may claim that the parts are correct) and farmers have expressed reluctance to buy from local blacksmiths because of poor metal quality. As a consequence, most farmers maintain or repair their implements only when work stops due to a problem. Then, valuable crop establishment time and maybe opportunities are likely to be lost.

For farmers undertaking an annual (or seasonal) maintenance schedule, the costs would be considerably less than those shown in Table 8. When ploughs are maintained and correctly set for operation, only the soil-contacting parts will need replacing (see also Table 7). The schedule for these is given in Table 9, but in relation to area cultivated rather than elapsed time. The costs of these parts in November 2000 are also shown.

Table 9 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

Conclusions and recommendations

The condition of implements varies from household to household and ranges from very poor to good, irrespective of their resource group (RG). Shares, landsides and wheel assemblies were the parts needing the most frequent replacement, at approximately four out of every five households.

Results from the spring ploughing trials show that farmers can improve productivity through plough renovation. Although higher draught forces were experienced after plough renovation, the ploughs were easier to handle and control and no excessive stress was placed on the animals. Plots prepared with the renovated ploughs had healthier plants which were better able to withstand stress and produced higher yields than the plots prepared with the ploughs in "as found" condition.

The farmers' trials have demonstrated how the available draught animal power (DAP) may be used more effectively in terms of crop production and that expenditure on plough renovation may be easily recovered from yield gains (typically of the order of 10 to 20%).

The cash cost of fully maintaining a plough is about 53 Z$ or approximately 1US$ per hectare (from Table 9). Knowledge of this schedule also serves as a guide on which, and how many, spares farmers should hold in stock. In addition to maintenance based on wear, daily and seasonal schedules, as shown in Table 10, can be recommended.

Table 10 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	

Improving the use of DAP requires training in the proper operation, repair and maintenance of implements, especially the plough being the farmers' most widely used implement, as well as an appropriate supply chain for spare parts.

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