PN-ABS-707

AGRICULTURAL TECHNOLOGY IMPROVEMENT PROJECT

(ATIP)

PROGRESS REPORT

1988-89 DOUBLE PLOUGHING SYSTEMS TRIAL (RESEARCHER MANAGED/FARMER IMPLEMENTED)

NUMBER: ATIP PR F90-3

BY

G. HEINRICH
F. WORMAN
S. MASIKARA

DEPARTMENT OF AGRIC. RESEARCH
MINISTRY OF AGRICULTURE
BOTSWANA

MID-AMERICA INTERNATIONAL
AGRICULTURAL CONSORTIUM
(MIAC)

SEPTEMBER 1990

PRINTED: September 10, 1990

ADDRESSES:

P/BAG 0033
GABORONE

P.O. BOX 10
MAHALAPYE

P.O. BOX 10275
TATITOWN (FRANCISTOWN

PREFACE

ATIP Progress Reports are prepared and circulated to make ATIP research findings easily available to GOB personnel and researchers interested in Botswana farming systems. A major objective of the Progress Report series is to make research findings available in a timely manner. These reports are not subject to professional review outside the Francistown team. Therefore, data and findings presented in the Progress Report series may be subject to further revision and should not be cited without permission of the authors. Findings in this report do not necessarily reflect the official views of ATIP, DAR or MIAC.

This Progress Report presents information on the Researcher Managed, Farmer Implemented (RMFI) Double Ploughing Systems Trial carried out at six locations in the Tutume Agricultural District, during the 1988-89 cropping season. The report covers the agronomic and labour data collected.

ACKNOWLEDGEMENTS

The research officers responsible for the Double Ploughing Systems Trial wish to acknowledge the invaluable assistance provided in this trial by the participating farmers and the following ATIP staff:

(a). B. Bagai (Senior Tech. Assistant, DAFS, Matobo)
(b). C. Sibanda (Senior Tech. Assistant, DAFS, Mathangwane)
(c). D. Moabi (Tech. Assistant, DAFS, Marapong)
(d). P. Batnshani (Enumerator, DAR, Marapong)
(e). H. Alacanani (Field Assistant, DAR, Marapong)
(f). M. Monyadzwe (Enumerator, DAR, Mathangwane)
(g). B. Motswaise (Enumerator, DAR, Mathangwane)
(h). M. Nkhuteleng (Enumerator, DAR, Matobo)
(i). P. Samuel (Field Assistant, DAR, Matobo)
(j). K. Talibona (Enumerator, DAR, Matobo)

1988-1989 DOUBLE PLOUGHING SYSTEMS TRIAL

ABSTRACT

The 1988-89 Double Ploughing Systems Trial was the second year of a trial designed to assess the feasibility of three different double ploughing systems implemented on large-scale plots. The three systems were for farmers who owned their own draught power (largely cattle), for farmers who shared animal draught and for farmers without access to animal draught. Each system was to be implemented at two locations with two replications. Again this year there were implementation and environmental problems which reduced the value of the trials.

Neither of the oxen/oxen double ploughing system trials was fully implemented. For the plots implemented, the double ploughed plots produced a 70 percent yield advantage and a modest economic advantage over the traditional system (P28.00 per hectare). In the tractor/oxen system, DP resulted in a higher yield, but yields from both systems were relatively low, so the economic advantage of double ploughing was limited. Double ploughing did show a marked increase in per hectare yields. However, some plots were planted late because of an unfavourable rainfall pattern, and failed to mature. When all plots (including ones that failed to mature) were included in a partial budget analysis, the tractor/oxen DP system showed a net loss of P16.00 per hectare. However, when only plots that yielded were included, DP showed an increased profit of P42.00 per hectare.

In the tractor/tractor system the traditional system produced very low yields, while the double plough system produced yields of 400 to 500 kilograms per hectare on plots that yielded. Because of the poor yield, the traditional system showed a loss, i.e., the cost of the single tractor hire was not covered. On the other hand, a partial budget analysis showed that, in that particular year, the tractor/tractor DP system resulted in an increased profit of P37.00 per hectare when all plots were included, and a P115.00 per hectare profit increase when only plots that reached maturity were included. In this case there would be a considerable advantage to switching from the traditional system to a double plough system.

In regards to systems feasibility, from a technical point of view there was evidence to suggest that all three systems could be implemented in the field.

An examination of the traction ploughing times gathered from large plots, relative to the more common small plots, showed no significant difference overall between the time required to plough the different plot sizes. The data lead to the hypothesis that there was more variation in ploughing time due to draught team capabilities, soil-type, soil moisture, etc., than to variation in plot size. This was true unless the small plot had a shape (long and narrow) which was particularly difficult, and time consuming, to plough.

OBJECTIVES

The objectives of this RMFI work were:

(a). To test three different double ploughing (DP) systems on a large-scale, and to assess their feasibility and profitability in practice.

(b). To collect labour and input data on operational scale plots, to clarify the relationship between small plot labour data and actual requirements from large-scale plots.

JUSTIFICATION

Plot level studies in the Tutume Agricultural District indicated that DP could profitably boost per hectare grain yields as long as the opportunity cost of the first ploughing was minimized (ATIP PR F87-5). Also, an economic analysis indicated a benefit in switching from two hectares single ploughed (SP2) to one hectare DP on farm units with a weeding labour constraint and/or with limited ploughing opportunities (ATIP MP 87-6).

Theoretically, several practical systems can be envisioned which could minimize the cost of the first ploughing and to allow farmers with different resource constraints to implement DP. However, these have never been tested on a large-scale to verify the theory. In order to round out the work on DP, to date, it was proposed that these systems be given a full-scale test.

APPROACH

The three systems tested applied to farmers in different traction categories described below.

1. For Farmers Who Owned Draught Power (Largely Cattle)

   With the first rains, when the animals were ready to plough, the farmer was to plough/plant an area of 25 metres by 50 metres. When the soil dried slightly below a reasonable moisture level for planting, an area of 25 metres by 50 metres was to be ploughed in preparation for DP on the next rain.

   On the next rain, the repared plot was to be planted, together with an adjacent 5 metre by 50 metre strip, to act as a traditional check (TC). As the soil moisture dropped below the optimum for planting, another 25 metres by 50 metres strip was to be prepared. This system was to be continued on subsequent rains into January, with the farmer planting on good moisture and preparing more land as the soil dried. Each DP plot was to have an adjacent check plot 5 metres wide.

   It was hoped that this trial would allow a determination of the feasibility of using drying soil moisture periods for land preparation, and to provide some estimate of the potential benefits on a whole farm level.

2. For Farmers Who Shared Animal Draught

   This assumed a government subsidy on tractor tillage, and that tractors were available. In this case, a tractor was hired to plough the land, either before the rains or during the early rains, before animals were in condition for ploughing. The tractor ploughed a quarter hectare strip, 25 metres by 100 metres. With the first planting rain that animals were available, the farmer planted

half of this area (25 metres by 50 metres), plus an adjacent unploughed area of 25 metres by 50 metres. All of this land — 0.25 hectare total — was to be either row planted or broadcast planted in the traditional manner at the farmer's discretion. On the second rain, the process was repeated using the second half of the prepared land.

As long as there is a subsidy on tractor ploughing, this system allows farmers with limited access to cattle draught to double plough without increasing their direct costs. The double ploughing should allow them to increase their production and profit from a limited ploughed area.

3. For Farmers Without Access to Animal Draught

This option also assumed a government subsidy on tractor plowing. Before the rains, or on the first rain, a tractor was hired to plough an area of 50 metres by 200 metres. With the next rain, half of the area was to be re-ploughed by tractor (50 meters by 100 meters), along with an adjacent unploughed area of equal size. Both areas — adjacent prepared and unprepared plots — were planted on the same day with the same planting method. This procedure was repeated on the second half of the ploughed area, plus on an equal adjacent area, with the next rain. As well as allowing an assessment of the double ploughing system on a large-scale, the system shed some light on the relative merit of DP with tractors.

Each of these three systems was implemented by two farmers in different villages. All labour and input data were collected to allow budgets to be constructed, and to provide comparative data on labour requirements for large and small plots.

RESULTS

1. For Farmers Who Owned Draught Power

The two farmers involved in this study had problems this year that affected their draught management systems. At location 1, a lack of labour to help in the field resulted first in a late start in bringing the animals to the village. Then, in order to get labour, the farmer entered into a draught-sharing arrangement — draught power in return for labour. This meant that she could only use her animals to plough her own land during alternate planting opportunities.

At location 2, the couple delayed in getting started. Then the husband died in a traffic accident early in the new year. This tragedy naturally caused a hiatus in planting activities in late January.

Thus neither of the farmers were able to use their draught animals as they might have chosen for the whole of the season, and so did not really fit into the category of farmers to whom this system should apply. However, as they had been involved in the study the previous year, and the problems they encountered were not entirely predictable, no switch was made to other locations.

Adding to the draught difficulties, there were no planting opportunities in November (i.e., no rainfall events of 10 mm or above) at these two locations (see Appendix A1). Preliminary ploughing and plough/planting was initiated in December for both locations, but the first planting of the DP plots did not occur until early January. This was unfortunate, as it restricted the number of plots that could be planted subsequently. In the latter part of January and the early part of February, rains were very poor. March and the first three weeks of April were also very dry. This drought period delayed maturity in millet and sorghum (both locations), particularly in crops planted in February. April was also unseasonably cool, which delayed maturity even further. As a result of these environmental factors, crops planted in February generally gave very low yields.

None the less, the trials did help to address the two primary objectives, i.e., the feasibility and profitability of the system.

Daily rainfall for each location is given in Appendix A1. The dates of all operations for each plot at each location are given in Table 1. Plant densities and grain yields are given in Table 2. Millet (v. Serere 6A) was broadcast planted in the first five plots at both locations at 2 kilograms per hectare. However, due to the lateness of the season, a short season sorghum (v.65D) was planted (at 4 kilograms per hectare) in plot six and onwards at location 1. The farmer at location 1 used four oxen for traction while four donkeys were used at location 2.

Regarding the feasibility of using good soil moisture for planting and using the drying soil moisture period for preparing more land, plots 1 through 5 (at both locations) were relevant.

There was a rainfall of 19 mm and 17 mm at locations 1 and 2, respectively, on day 106. Plot 1 was plough/planted on day 110 and 111, respectively, at locations 1 and 2. There was no emergence in either plot, indicating that the farmers waited too long to take advantage of the good soil moisture. The plots were later re-ploughed/planted and thus were changed to DP plots. Plot 2, the first DP plot, was prepared on the same or the following day at both locations.

The important points here are that:

(a). There were four to five days after the rain, at both locations, when ploughing could be done with either cattle or donkeys.
(b). The opportunity cost of ploughing on at least the last two of those days was zero.

At location 1, the first DP plot, and the adjacent TC plot were plough/planted on day 134, three days after a rainfall of 80 mm (unusually high). The next DP plot was prepared (ploughed) on day 139, eight days after the rain. Similarly at location 2, the first DP plot and adjacent TC plot were plough/planted on day 134, three days after a rainfall of 28 mm (plus 10 mm the previous day). The next DP plot was prepared (ploughed) on day 139, eight days after the rain. Thus ploughing with animal traction was feasible for at least eight days after relatively heavy rains.

In summary, then, ploughing with animal draught power was feasible for at least five days following a rainfall of 15 to 20 mm, with an opportunity cost near zero for planting on the last two of those days. Following

heavier rains (38-80 mm), ploughing was possible at least eight days later. Thus the data support the hypothesis that following rains of 15 mm or more, it should be possible for farmers, who control their own animal draught power, to use the first few days for plough/planting and still have time to prepare land for DP on drying soil moisture.

TABLE 1: DATES OF ALL FIELD OPERATIONS, OXEN/OXEN SYSTEM, DOUBLE PLOUGHING SYSTEMS TRIAL, FRANCISTOWN AREA, 1988-89

LOCATION	PLOTS	OPERATION	DATE DP [a]	DATE TC [a]
1	1	PLOUGH/PLANT	111	-
1	1	RE-PLOUGH/RE-PLANT	143	-
1	1	WEED	187	-
1	1	FIRST HARVEST	259	-
1	2	PLOUGH	111	-
1	2+3	PLOUGH/PLANT	134	134
1	2+3	WEEDING	187	189
1	2+3	FIRST HARVEST	237	260
1	4	PLOUGH	139	-
1	4+5	PLOUGH/PLANT	155	155
1	4+5	WEED	190	194
1	4+5	FIRST HARVEST	265	285
1	6	PLOUGH	155	-
1	6+7	PLOUGH/PLANT	169	169
1	6+7	WEED	194	201
1	6+7	FIRST HARVEST	285	285
1	8+9	PLOUGH/PLANT	169	169
1	8+9	WEED	201/2	202/3
1	8+9	FIRST HARVEST	286	286
2	1	PLOUGH/PLANTING	110	-
2	1	RE-PLOUGH/RE-PLANT	NA	-
2	1	WEED	182	-
2	1	FIRST HARVEST	251	-
2	2	PLOUGH	111	-
2	2+3	PLOUGH/PLANT	134	134
2	2+3	WEED	167	176
2	2+3	FIRST HARVEST	225	225
2	4+5	PLOUGH	139	-
2	4+5	PLOUGH/PLANT	146	146
2	4+5	WEED	176	182
2	4+5	FIRST HARVEST	237	258

a. Date = days from September 1, 1988.

Information on average labour times for each farmer is presented in Table 3 (complete data set in Appendix A2). In the 1987-88 Double Ploughing Systems Trials, the oxen/oxen systems were compared on the basis of five hectare systems (PR F89-1). This analysis was not made on a total five hectare system basis because neither of the farmers was able to plant the total trial. Hence, the analysis was based on four hectares for one

TABLE 2: PLANT STAND DENSITIES AND GRAIN YIELDS, OXEN/OXEN SYSTEM, DOUBLE PLOUGHING SYSTEMS TRIAL, FRANCISTOWN AREA, 1988-89

LOC	TREATMENT	PLOT	STAND DENSITY (PLANTS/HA x 1000)	GRAIN YIELD (KG/HA)
1	TC	1[a]	0.0	0
1	DP	1[a]	11.9	558
1	DP	2	6.3	372
1	TC	3	1.0	160
1	DP	4	15.3	128
1	TC	5	14.8	140
1	DP	6	20.9	71
1	TC	7	33.0	64
1	TC	8	26.8	35
1	TC	9	35.3	20
2	TC	1[a]	0.0	0
2	DP	1[a]	42.5	248
2	DP	2	17.3	472
2	TC	3	8.8	400
2	DP	4	9.1	128
2	TC	5	4.8	100

a. were planned as TC treatments but were later changed to DP due to zero emergence on first plough/plant operation.

TABLE 3: AVERAGE LABOUR TIME, PERSON-HOURS PER HECTARE, OXEN/OXEN SYSTEM, DOUBLE PLOUGHING SYSTEMS TRIAL, FRANCISTOWN AREA, 1988-89 [a]

LOC	YIELD KG	FIRST PLOUGH	PLOUGH/ PLANT	WEED TIME	HARVEST TIME	THRESH TIME	TOTAL TIME
		HOURS PER HECTARE					
		DOUBLE PLOUGHING SYSTEM					
1	5 HA TOTAL 1126	205.2	265.1	217.3	88.0	91.6	865.4
1	AVG PER HA 225	51.3	53.0	43.5	17.2	18.3	173.1
2	4 HA TOTAL 848	236.5	314.2	85.8	69.5	71.0	776.5
2	AVG PER HA 212	78.8	78.5	21.4	17.4	17.7	194.2
DP AVERAGE PER HA	219	65.1	65.8	32.5	17.3	18.0	183.6
		TRADITIONAL SYSTEM					
1	4 HA TOTAL 364		296.4	227.2	28.0	35.2	586.8
1	AVG PER HA 91		74.1	56.8	7.0	8.8	146.7
2	3 HA TOTAL 500		265.6	109.6	29.4	59.2	484.0
2	AVG PER HA 167		95.2	36.5	9.8	19.7	161.3
TC AVERAGE PER HA	129		84.7	46.7	8.4	14.3	154.0

a. Totals and averages may not be exact due to rounding.

farmer, and three for the other.[1] The average total time per hectare for DP was only 14 percent more than the average total time for the traditional system. This relatively small difference was due in part to the 44 percent saving in weeding time for the DP system.

The DP system yield per hectare was 70 percent greater than the TC system. This yield advantage resulted in an average net return from the DP system of P39.00 more per hectare than the traditional system (Table 4, complete data set in Appendix A3). This translated to a 16 thebe per hour of labour (net) advantage for the DP system.

TABLE 4: AVERAGE RETURNS PER HECTARE AND RETURNS TO LABOUR, OIEN/OIEN SYSTEM, DOUBLE PLOUGHING SYSTEMS TRIAL, FRANCISTOWN AREA, 1988-89

LOC	YIELD KG/HA	TOTAL LABOUR HOURS	GTVP PULA [a]	COSTS PULA [b]	NTVP PULA [c]	RETURNS TO LABOUR GROSS PER HR	RETURNS TO LABOUR NET PER HR
			---- PER ONE HECTARE ----				
			DOUBLE PLOUGHING SYSTEM				
1	5 HA TOTAL 1126	865.4	506.38	23.50	483.38	0.59	0.56
1	AVG PER HA 225	173.1	101.38	4.70	96.68	0.59	0.56
2	4 HA TOTAL 848	776.8	381.60	18.50	363.10	0.49	0.47
2	AVG PER HA 212	194.2	95.40	4.63	90.78	0.49	0.47
DP AVERAGE PER HA	219	184.6	98.39	4.66	93.73	0.54	0.51
			TRADITIONAL SYSTEM				
1	4 HA TOTAL 364	586.8	163.50	14.00	149.80	0.28	0.26
1	AVG PER HA 91	146.7	40.95	3.50	37.45	0.28	0.26
2	3 HA TOTAL 500	484.0	225.00	10.50	214.50	0.46	0.44
2	AVG PER HA 167	161.3	75.00	3.50	71.50	0.47	0.44
TC AVERAGE PER HA	129	154.0	57.38	3.50	54.48	0.38	0.35

a. GTVP = Gross Total value Product (yield x price) where price = P.45/kg.
b. COSTS = Estimated seed cost (4kg/ha x P.50/kg = P2) plus equipment cost estimated at P1.50/ha. For DP there were 2 equipment charges.
c. NTVP = net Total value Product (GTVP - COSTS).

A partial budget analysis indicated that there was a modest advantage (P28.00 per hectare) in shifting from the traditional practice to double ploughing in the oxen/oxen system (Table 5).

[1]. The system being tested was five hectares consisting of one single ploughed plot and four double ploughed plots. Due to implementation problems this years' systems turned out to be one single ploughed plot plus four double ploughed plots for one farmer, and one single ploughed plus three double ploughed for the other. For the first farmer the traditional check involved four plots, while there were three plots for the second farmer.

TABLE 5: PARTIAL BUDGET ANALYSIS OF SHIFT FROM TRADITIONAL SYSTEM TO OIEN/OIEN DOUBLE PLOUGHING SYSTEM, NET CHANGE IN PULAS PER HECTARE, DOUBLE PLOUGHING SYSTEMS TRIAL, FRANCISTOWN AREA, 1988-89

	CHANGES IN COSTS AND BENEFITS IN PULA OIEN/OIEN DOUBLE PLOUGHING
INCREASES:	
REDUCED COST	
TRADITIONAL LABOUR [a]	58.52
ADDED BENEFITS	
GTVP NEW SYSTEM [b]	58.55
DECREASES:	
ADDED COST	
NEW SYSTEM LABOUR [a]	69.77
ADDITIONAL EQUIPMENT COST	1.06
REDUCED BENEFITS	
GTVP TRADITIONAL [b]	58.05
NET CHANGE	28.19

a. Labour valued at Labour Based Drought Relief wage = P0.13/hr.
b. GTVP = Yield x Price, with grain valued at P0.45/kg.

2. For Farmers Who Shared Draught Power

The dates of all field operations for these two trials are given in Table 6. Daily rainfall data are given by location in Appendix B1. At both locations, the initial land preparation on the DP plot was undertaken somewhat later than optimal. The first plantings were done in early January, and subsequent poor rainfall in January and early February delayed plantings of the second replications into the second half of February. Late planting coupled with an early on-set of cold weather severely limited yields in those replications. At location 1, this second replication produced no grain at all. At location 2, this replication produced a limited quantity of grain. However, maturity was delayed past the point where cattle were allowed into the lands areas unattended, and the plants in the second replication were heavily grazed. Thus, only grain yield from the first replications (at both locations) produced meaningful data.

At both locations, the system of tractor ploughing followed by animal ploughing on DP plots appeared both practical, and in this year, beneficial at least for grain yield (see Table 7). In the first replication at both locations, planting was followed by a long drought period. During this period it appeared that the extra soil moisture stored in the DP plot before planting made all the difference to both stand establishment and eventual grain yield. This was similar to results from the tractor/tractor DP systems trials for plots planted during this period.

TABLE 6: DATES OF FIELD OPERATIONS, BY LOCATION, REPLICATION AND TREATMENT, TRACTOR/OXEN DOUBLE PLOUGHING SYSTEM, DOUBLE PLOUGHING SYSTEMS TRIAL, FRANCISTOWN AREA, 1988-89

LOCATION	REPLICATION	OPERATION	DATE DP [a]	DATE TC [a]
1	1	PLOUGH	105	-
1	1	PLOUGH/PLANT	128	128
1	1	WEED	186	186
1	1	HARVEST	265	265
1	2	PLOUGH/PLANT	169	169
1	2	WEED	-	-
2	1	PLOUGH	110	-
2	1	PLOUGH/PLANT	127	127
2	1	WEED	173	174
2	1	HARVEST	232	-
2	2	PLOUGH/PLANT	170	181 [b]
2	2	WEEDING	212	222

a. Days from September 1, 1988.
b. Traditional Check treatment was not planted on the same day as the treatment. See text for explanation.

TABLE 7: PLANT STAND DENSITIES AND GRAIN YIELDS, TRACTOR/OXEN SYSTEM, DOUBLE PLOUGHING SYSTEMS TRIAL, FRANCISTOWN AREA, 1988-89

LOC	TREATMENT	REPLICATION	STAND DENSITY (PLANTS/HA x 1000)	GRAIN YIELD (KG/HA)
1	DP	1	12.9	209
1	TC	1	1.0	20
1	DP	2	11.0	0
1	TC	2	14.8	0
2	DP	1	12.0	400
2	TC	1	0.0	0
2	DP	2	19.0	0 [a]
2	TC	2	2.4	55

a. Grazed by cattle

Additionally, an incident occurred during the planting of replication 2 at location 2 that had implications for the limited planting opportunities faced by animal draught power users. After the rain on day 165, the farmer wanted to plant the second replication. However, she was delayed until day 170 because she could not find her animals. On day 170, the DP plot still had sufficient moisture for plough/planting (there was a 7 mm rain on day 169), but the TC plot was too hard to till. Hence the TC plot had to be planted some days later (day 181) after the next heavy rain. This experience highlighted a phenomenon that has been observed previously, i.e., that preliminary preparation of the land often has the effect of extending the time when planting can be done effectively on subsequent rains, and can sometimes enable farmers to plant effectively on smaller rainfall events. Taking advantage of this effect might be significant for farmers who share animal draught power and often gain

access to the animals during non-optimal planting times, from other farmers. One scenario might be for such farmers to tractor/plough an area early in the season, on drying soil moisture. Then they might be able to capitalize on the extended planting period to employ the animals of other farmers after the optimal single ploughing period had passed on other farms.

Average labour times for the DP and TC systems are presented in Table 8 (complete data can be found in Appendix B2). If all plots were included, the average total time for DP was 109 percent greater than that of the TC because of ploughing, harvesting and threshing labour. However, if only harvested plots were compared, the average total labour time for DP was 73 percent greater.

If only plots producing a yield were included, the DP system yielded a net return of almost P70.00 per hectare more than the traditional system (Table 9, complete data in Appendix B3). If all plots were included, the DP system provided a net return of approximately P10.00 per hectare more than the traditional system. Net returns to labour were only three thebe per hour more for the DP system if all plots were included, but were 35 thebe per hour more if only harvested plots were included.

A partial budget analysis (Table 10) indicated that, if all plots were included, there was a net loss of almost P16.00 incurred in switching from the traditional system to the double ploughing system. However, if only harvested plots were included there was a P42.00 advantage to shifting from the traditional system to the DP system. This demonstrates the risk involved in using more costly technologies when there is a great deal of uncertainty in the cropping outcome, and is an important argument for timely operations.

TABLE 8: AVERAGE LABOUR TIME, PERSON-HOURS PER HECTARE, TRACTOR/OXEN SYSTEM, DOUBLE PLOUGHING SYSTEMS TRIAL, FRANCISTOWN AREA, 1988-89 [a]

SYSTEM	YIELD KG/HA	FIRST PLOUGH	PLOUGH/ PLANT	WEED TIME	HARVEST TIME	THRESH TIME	TOTAL TIME
	HOURS PER HECTARE						
ALL PLOTS							
DP AVERAGE	152	4.3	25.5	43.5	13.9	29.4	121.5
TC AVERAGE	19		24.5	32.4	0.3	1.1	58.3
HARVESTED PLOTS							
DP AVERAGE (2) [b]	305	4.3	26.2	44.3	27.7	58.8	161.2
TC AVERAGE (2)	38		25.7	64.5	0.6	2.2	93.0

a. Totals and averages may not be exact due to rounding.
b. Number of plots harvested.

TABLE 9: AVERAGE RETURNS PER HECTARE AND RETURNS TO LABOUR, TRACTOR/OXEN SYSTEM, DOUBLE PLOUGHING SYSTEMS TRIAL, FRANCISTOWN AREA, 1988-89

SYSTEM	YIELD KG/HA	TOTAL LABOUR HOURS	GTVP PULA [a]	COSTS PULA [b]	NTVP PULA [c]	RETURNS TO LABOUR GROSS PER HR	RETURNS TO LABOUR NET PER HR
			------ PER ONE HECTARE ------				
			ALL PLOTS				
DP AVERAGE	152	124.1	68.51	53.50	15.01	0.54	0.12
TC AVERAGE	19	58.3	8.55	3.50	5.05	0.15	0.09
			HARVESTED PLOTS				
DP AVERAGE (2) [d]	304	165.5	137.02	53.50	83.50	0.83	0.50
TC AVERAGE (2)	38	93.0	18.10	3.50	13.60	0.19	0.15

a. GTVP = Gross Total value Product (yield x price) where price = P.45/kg.
b. COSTS = Tractor rental P50/ha, estimated seed cost (4kg/ha x P.50/kg = P2), and animal traction equipment cost estimated at P1.50/ha.
c. NTVP = Net Total Value Product (GTVP - COSTS).
d. Number of plots harvested.

TABLE 10: PARTIAL BUDGET ANALYSIS OF SHIFT FROM TRADITIONAL SYSTEM TO TRACTOR/OXEN DOUBLE PLOUGHING SYSTEM, NET CHANGE IN PULAS PER HECTARE, DOUBLE PLOUGHING SYSTEMS TRIAL, FRANCISTOWN AREA, 1988-89

	CHANGES IN COSTS AND BENEFITS IN PULA TRACTOR/OXEN DOUBLE PLOUGHING ALL PLOT	HARVESTED PLOTS
INCREASES:		
REDUCED COST		
TRADITIONAL LABOUR [a]	22.15	35.34
ADDED BENEFITS		
GTVP NEW SYSTEM [b]	68.40	136.80
DECREASES:		
ADDED COST		
NEW SYSTEM LABOUR [a]	47.52	62.85
ADDITIONAL EQUIPMENT COST	50.00	50.00
REDUCED BENEFITS		
GTVP TRADITIONAL [b]	8.55	17.10
NET CHANGE	-15.92	42.15

a. Labour valued at Labour Based Drought Relief wage = P0.38/hr.
b. GTVP = Yield x Price, with grain valued at P0.45/kg.

3. For Farmers Without Access to Animal Draught

Location 1: Dates of all field operations are given by treatment and plot in Table 11. All ploughing was by tractor, using a three furrow disk plough. In the first replication, sorghum seed (v. Segaolane) was broadcast at 4 kilograms per hectare and ploughed down. Rainfall data by day are presented in Appendix C1. After planting the first replications, there were only two showers, of less than 10 mm each, during the following six weeks. Emergence and seedling establishment were good on the double ploughed plot, but poor on the traditional check plot.

Due to the six week drought in January-February, the second replication was dry-planted on February 14 (Day 167). This was due to the lateness of the season. Because of the late planting date, a short season sorghum (v. 65D) was substituted for Segaolane. Seed was again broadcast (4 kilograms per hectare) and ploughed down. The crops planted in January survived to produce some yield. The crops planted in mid-February did survive, but were overtaken by cold weather in April. The cold weather slowed down the growth process to the extent that the crops never produced grain. Thus only the first replication produced a yield. Plant stands and grain yields are given in Table 12.

Location 2: At this location, the preliminary ploughing was done on 15th December, 1988 (day 106). All ploughing was by tractor and moldboard plough. The first double ploughed plot and the traditional check plot were planted on 5th January, 1989 (day 127). Maize (v. Kalahari Early Pearl) was planted by hand in the furrow behind the plough. It was planted in rows, one metre between rows, and every third row was left empty (skip row planting). Seeding rate was approximately 25 kilograms per hectare. Seedling emergence was reasonable on the DP plot, but poor on the TC plot. The seedlings were later thinned to three or four plants per metre, within rows, on the DP plot.

TABLE 11: DATES OF FIELD OPERATIONS, BY LOCATION, REPLICATION AND TREATMENT, TRACTOR/TRACTOR DOUBLE PLOUGHING SYSTEM, DOUBLE PLOUGHING SYSTEMS TRIAL, FRANCISTOWN AREA, 1988-89

LOCATION	REPLICATION	OPERATION	DATE DP [a]	DATE TC [a]
1	1	Plough	105	-
1	1	Plough/plant	129	129
1	1	weed	171	171
1	1	Harvest	250	258
1	2	Plough	105	-
1	2	Plough/plant	167	167
1	2	weed	N [b]	N [b]
1	2	Harvest	N	N
2	1	Plough	106	-
2	1	Plough/plant	127	127
2	1	weed	150	N [b]
2	1	Harvest	257	N [b]
2	2	Plough	106	-
2	2	Plough/plant	177	177
2	2	weed	N [b]	N [b]
2	2	Harvest	N [b]	N [b]

a. Days from September 1, 1988. b. N = no activity.

TABLE 12: PLANT STAND DENSITIES AND GRAIN YIELDS, TRACTOR/TRACTOR SYSTEM, DOUBLE PLOUGHING SYSTEMS TRIAL, FRANCISTOWN AREA, 1988-89

LOC	CROP	TREATMENT	REPLICATION	STAND DENSITY (PLANTS/HA x 1000)	GRAIN YIELD (KG/HA)
1	SORGHUM	DP	1	30.0	563
1	SORGHUM	TC	1	2.3	46
1	SORGHUM	DP	2	12.8	0
1	SORGHUM	TC	2	5.1	0
2	MAIZE	DP	1	6.7	422
2	MAIZE	TC	1	3.3	0
2	NOT PLANTED	DP	2	-	-
2	NOT PLANTED	TC	2	-	-

There were no further planting opportunities until late February. Planting of the second DP and TC plots was attempted on 24th February, 1989 (day 177). However, the soil was too wet and the tractor became mired in the mud. By the time conditions were acceptable for planting it was March, and too late to plant. Hence only one planting date was applied at this location. The dates of all field operations performed for this planting date are given in Table 11.

Rainfall data for this location are given in Appendix C1. For the first six weeks after planting, rainfall was very poor, with only one shower of 10 mm or above. Plants in the TC plot withered and died. Plants in the DP plot showed signs of stress, but largely survived.

There was 150 mm of rainfall in late February, and this was sufficient to carry the crop through to harvest. Total post-planting rainfall was 237 mm, with 150 mm falling in late February, and 56 mm in late April.

Plant stands, measured on 26th January, 1989 (day 148), were 6,667 and 3,250 for the DP and TC treatments, respectively. Grain yields were 422 and 0 kilograms per hectare for the DP and TC treatments respectively. The DP treatment allowed the maize seedlings to survive a six week post-planting drought and produced a yield on subsequent rainfall.

At Both Locations: The long drought period following early January rains prevented the timely planting of the second replications. Regarding the results of the first replications, it was clear that the preliminary tillage was beneficial for both stand establishment and the survival of seedlings through the long post-planting dry period. The effects of DP on seedling establishment and survival throughout the drought were probably due to the existence of a greater amount of stored soil moisture at planting in DP plots. (Greater soil moisture at planting is the expected result of preliminary ploughing and improved moisture infiltration on that area, between the first and second ploughings).

The average total labour time used on the tractor/tractor double ploughing system was more than seven times as great as the total time invested in a tractor operated traditional system (Table 13). This was true whether all plots or only harvested plots were included. A complete set of labour data is included in Appendix C2. The major differences in time were attributable to more weeding time invested in the DP system, and the

harvesting and threshing time involved in processing the greater yield from the DP system. This is expected because farmers are reluctant to invest any labour in plots that have such an obviously low yield potential as the TC plots had.

TABLE 13: AVERAGE LABOUR TIME, PERSON-HOURS PER HECTARE, TRACTOR/TRACTOR SYSTEM, DOUBLE PLOUGHING SYSTEMS TRIAL, FRANCISTOWN AREA, 1988-89 [a]

SYSTEM	YIELD KG/HA	FIRST PLOUGH	PLOUGH/ PLANT	WEED TIME	HARVEST TIME	THRESH TIME	TOTAL TIME
	HOURS PER HECTARE						
ALL PLOTS							
DP AVERAGE	246	5.0	4.1	20.5	12.6	13.6	55.7
TC AVERAGE	11		4.9	0.0	1.1	0.7	6.6
HARVESTED PLOTS							
DP AVERAGE (2) [b]	492	4.0	6.9	40.9	25.2	27.3	105.2
TC AVERAGE (1)	46		4.5	0.0	4.6	2.7	11.8

a. Totals and averages may not be exact due to rounding.
b. Number of plots included.

For all plots, the net return per hectare for the double ploughing system was almost P9.00 per hectare, while the net return for the traditional system was minus P47.00 per hectare (Table 14, see Appendix C3 for complete data). If only harvested plots were considered, the net return per hectare for the DP system was almost P120.00 per hectare, while it was a minus P31.00 per hectare for the traditional system. In this particular year only the DP system paid for the costs of using a tractor, with the traditional system showing a loss approaching the tractor rental involved in the scheme.

TABLE 14: AVERAGE RETURNS PER HECTARE AND RETURNS TO LABOUR, TRACTOR/TRACTOR SYSTEM, DOUBLE PLOUGHING SYSTEMS TRIAL, FRANCISTOWN AREA, 1988-89

SYSTEM	YIELD KG/HA	TOTAL LABOUR HOURS	GTVP PULA [a]	COSTS PULA [b]	NTVP PULA [c]	RETURNS TO LABOUR GROSS PER HR	RETURNS TO LABOUR NET PER HR
	PER ONE HECTARE						
ALL PLOTS							
DP AVERAGE	246	55.7	110.79	102.00	8.79	1.99	0.16
TC AVERAGE	11	6.6	5.13	52.00	-46.87	0.78	-7.10
HARVESTED PLOTS							
DP AVERAGE (2) [d]	492	105.2	221.58	102.00	119.58	2.10	1.14
TC AVERAGE (1)	46	11.8	20.52	52.00	-31.48	1.74	-2.67

a. GTVP = Gross Total value Product (yield x price) where price = P.45/kg.
b. COSTS = Tractor rental P50/ha and estimated seed cost (4kg/ha x P.50/kg = P2).
c. NTVP = Net Total value Product (GTVP - COSTS). d. Number of plots harvested.

- A partial budget analysis indicated that a shift to double ploughing from the traditional system would create a net gain of P37.00 per hectare if all plots were considered (Table 15). However, if only harvested plots were considered, there was a net gain of P115.00 per hectare realized from shifting to a double ploughing system. Thus, in this year, shifting to double ploughing using tractor would have been advantageous to the farmer.

4. Comparative Labour Times

One of the objectives of this trial was to clarify the relationship between labour times collected in conjunction with small plots trials and labour times required for larger plot implementations. While labour data have been collected on numerous researcher managed trials, most have been for small plots, 10 meters by 40 meters or less. During the last two years data were collected on larger plot sizes in the Double Ploughing Systems Trials. Due to the small number of observations on each trial it was difficult to make meaningful statistical comparisons. However, by combining data across trials and years it was possible to identify eight studies involving small trial plots, i.e., 10 meters by 20 meters and 10 meters by 40 meters. Two of the trials, the DP Systems Trials, involved larger plot sizes, i.e., 25 meters by 50 meters and 50 meters by 100 meters. These studies provided labour data on 249 plots, 177 small plots and 72 large plots.

TABLE 15: PARTIAL BUDGET ANALYSIS OF SHIFT FROM TRADITIONAL SYSTEM TO TRACTOR/TRACTOR DOUBLE PLOUGHING SYSTEM, NET CHANGE IN PULAS PER HECTARE, DOUBLE PLOUGHING SYSTEMS TRIAL, FRANCISTOWN AREA, 1988-89

	CHANGES IN COSTS AND BENEFITS IN PULA	
	TRACTOR/TRACTOR DOUBLE PLOUGHING	
	ALL PLOTS	HARVESTED PLOTS
INCREASES:		
REDUCED COST		
TRADITIONAL LABOUR[a]	2.50	4.48
ADDED BENEFITS		
GTVP NEW SYSTEM[b]	110.70	221.40
DECREASES:		
ADDED COST		
NEW SYSTEM LABOUR[a]	21.17	39.98
ADDITIONAL EQUIPMENT COST	50.00	50.00
REDUCED BENEFITS		
GTVP TRADITIONAL[b]	4.95	20.70
NET CHANGE	37.08	115.20

a. Labour valued at Labour Based Drought Relief Wage = P0.38/hr.
b. GTVP = Yield x Price, with grain valued at P0.45/kg.

Data were collected on all phases of the crop production cycle. Generally the harvest and threshing labour was directly related to the yield, while the weeding labour was related to highly variable weed burden. Broadcast

planting took a small fraction of the total time (generally less than one hour per hectare) and no large plot data were collected on row planting.[2] Thus the major labour input which was likely to vary with plot size was ploughing labour. A set of ploughing times was developed from the trials data. It was decided to use traction time rather than labour time because of the variability between trials with tractor traction involving one person, and animal traction involving two or three people. Table 16 provides a summary of the characteristics of the data set developed from the eight sets of trials data (see Appendix D for the complete data set). Animal traction times were variable, i.e., relatively high standard deviations, which could be attributed to type and number of animals being used, condition and training of the animals, soil-type and moisture conditions, etc.

T-tests were run on the mean traction times by traction-type. The means are reported in Table 17. No significant differences were found between small and large plot mean traction times for the combined sets of data.

There was one exception to the finding of no significant differences between large and small plot traction times. When the mean traction time for large and small plots were compared for the Double Ploughing Systems Trials (1987-88 and 1988-89) data, there was a significant difference ($P<.01$) between large and small plot ploughing times for both donkey and cattle traction. It was hypothesized that this difference was due to the long narrow shape (5 meters by 50 meters) of the traditional check plots, which was difficult to plough in an efficient manner because of the turning distances and the tendency to leave "islands" in a long thin plot. These "islands" had to be ploughed individually which was time consuming.

A further comparison with two other sets of data on traction ploughing times was made. The overall traction times for small and large plot data, by traction-type, from the researcher managed studies were compared with the mean traction times from the labour coefficients study (PR G90-2), and from the ploughing labour study (PR F90-10). The results are reported in Table 18. The combined small and large plot traction times were significantly ($P<.01$) less than the corresponding times in the other studies except for the tractor traction time in the coefficients study which was significantly ($P<.01$) greater.

Within traction categories, the difference in average ploughing times between researcher managed trials and the ploughing labour study may, in part, result from the fact that down-time for machines and animals was included in total ploughing times in the ploughing labour study. Down-time was not recorded in the total ploughing time for the researcher managed trials. The average plot size for animal traction plots in the ploughing labour study was 650 to 700 square meters -- slightly larger than the normal research plot of 400 square meters, but smaller than the largest researcher managed plots (1250 square meters).

Data in the coefficients study included some of the researcher managed trials (through the 1988-89 season) and the ploughing labour study, plus data from Manalapye. This may account for the results of the coefficients study falling between the other two studies for animal traction.

2. Labor coefficients for numerous cropping activities can be found in ATIP PR G90-2.

TABLE 16: CHARACTERISTICS OF TRACTION PLOUGHING TIME DATA, RESEARCHER MANAGED TRIALS, FRANCISTOWN AREA, 1986-89

VARIABLE	CODE	FREQUENCY	PERCENT
PUBLICATION [a]			
PR F86-3	1	39	12.0
PR F86-4	2	18	7.2
PR F87-5	3	36	14.5
PR F87-7	4	38	15.3
PR F87-8 [b]	5	28	11.2
PR F88-6 [c]	6	14	5.6
PR F89-1	7	44	17.7
PR F90-3	8	41	16.5
PLOT SIZE			
10 x 40	1	108	43.4
10 x 20	2	18	7.2
15 x 20	3	38	15.3
5 x 50	4	13	5.2
25 x 50	5	53	21.3
50 x 100	6	19	7.6
FIRST OR SECOND PLOUGHING			
FIRST PLOUGHING	1	184	73.9
SECOND PLOUGHING	2	65	26.1
TRACTION-TYPE			
DONKEY	1	51	20.5
CATTLE	2	146	58.6
TRACTOR	3	52	20.9
LARGE-SCALE OR SMALL-SCALE PLOT SIZE [d]			
SMALL	1	177	71.1
LARGE	2	72	28.9
TOTAL OBSERVATIONS		249	

a. See Reference se for complete citation.
b. Excludes band pl ;ing and deep-ripping treatments.
c. Excludes contour ing ploughing treatment.
d. Small-scale includes PLOT SIZE 1-4, large-scale includes PLOT SIZE 5 & 6.

TABLE 17: MEAN PLOUGHING TIMES BY TRACTION-TYPE FOR SMALL AND LARGE PLOTS, RESEARCHER MANAGED TRIALS, FRANCISTOWN AREA, 1986-89

VARIABLE	VALUE LABEL	MEAN [a]	STD DEV	CASES
FOR ENTIRE POPULATION		14.2731	8.1837	249
DONKEYS	1	21.7059	7.6722	51
SMALL PLOT	1.00	21.6875	9.0141	32
LARGE PLOT	2.00	21.7368	5.6749	19
CATTLE	2	15.3630	5.7750	146
SMALL PLOT	1.00	15.5882	5.9680	119
LARGE PLOT	2.00	14.3704	4.8050	27
TRACTOR	3	3.9231	1.4531	52
SMALL PLOT	1.00	4.2308	1.5312	26
LARGE PLOT	2.00	3.6154	1.4164	26

a. Using a t-test, there were no significant differences between small and large plot mean ploughing times within traction-types.

TABLE 18: MEAN PLOUGHING TIMES BY TRACTION-TYPE FOR THREE PLOUGHING TIME STUDIES, FRANCISTOWN AREA, 1986-89

VARIABLE	MEAN [a]	STD DEV	CASES
DONKEYS			
RESEARCHER MANAGED TRIALS	21.71*	7.87	51
COEFFICIENTS STUDY (PR G90-2)	27.54*	3.99	9 [b]
PLOUGHING LABOUR STUDY (PR F90-10)	31.7*	18.5	21
CATTLE			
RESEARCHER MANAGED TRIALS	15.36*	5.77	146
COEFFICIENTS STUDY (PR G90-2)	16.45*	1.34	19 [b]
PLOUGHING LABOUR STUDY (PR F90-10)	21.0*	10.5	62
TRACTOR			
RESEARCHER MANAGED TRIALS	3.92*	1.49	52
COEFFICIENTS STUDY (PR G90-2)	3.24*	0.27	14 [b]
PLOUGHING LABOUR STUDY (PR F90-10)	4.2*	1.2	8

a. All means within a traction-type were significantly different (P<0.1) based on a t-test comparison of the researcher managed trials data with the (population) means from the other two studies. The ploughing labour data were also significantly different (P<0.1) from the mean of the coefficients study data. The estimated variance from the studies was used in the t-test.
b. Number of studies included, each was average of numerous observations.

REFERENCES

MP 87-6. F. Worman. "Economic ANalysis of the ATIP Double Ploughing Trials, 1983-87". ATIP, September 1987.

PR F86-3. G. Heinrich, F. Worman, S. Masikara, and R. Gray. "1986 Draught Management and Early Ploughing Trial". (Revised). ATIP, August 1987.

PR F86-4. G. Heinrich, F. Worman and S. Masikara. "1986 Hand Planter Trial". ATIP, December 1986.

PR F87-5. G. Heinrich, F. Worman, S. Masikara, and R. Gray. "1987 Double Ploughing Trial". ATIP, September 1987.

PR F87-7. S. Masikara and B. Mabongo. "1987 Cropping Systems Trials". ATIP, September 1987.

PR F87-8. G. Heinrich, F. Worman and S. Masikara. "1986-87 Tillage Systems Trial". ATIP, October 1987.

PR F88-6. G. Heinrich, F. Worman and S. Masikara. "1987-88 Water Harvesting Trial". ATIP, December 1988.

PR F89-1. G. Heinrich, F. Worman and S. Masikara. "1987-88 Double Ploughing Systems Trial". ATIP. January 1989.

PR F90-3. G. Heinrich, F. Worman and S. Masikara. "1988-89 Double Ploughing Systems Trial". ATIP. This report.

PR F90-10. F. Worman and S. Bock. "Final Report, Ploughing Labour Study". ATIP. July 1990.

PR G90-2. D. Norman, F. Worman and A. Caplan. "Suggested Standard: Volume and Labour Coefficients". ATIP. June 1989.

APPENDIX A

TABLE A1: DAILY RAINFALL AMOUNTS, BY LOCATION, OXEN/OXEN SYSTEM, DOUBLE PLOUGHING SYSTEMS TRIALS, FRANCISTOWN AREA, 1988-89

		LOCATION	
		1	2
	DATE[a]	--- RAINFALL AMOUNT IN MM ---	
OCTOBER	42	0	9
	44	24	23
	51	14	13
	59	8	13
NOVEMBER	63	1	0
	67	5	6
	69	2	5
	91	9	9
	92	4	4
DECEMBER	94	11	15
	95	1	0
	98	5	6
	102	12	8
	104	5	2
	106	19	17
	114	10	0
	120	4	3
JANUARY	125	38	30
	126	4	12
	127	3	2
	130	11	10
	131	80	28
	140	7	26
	145	3	4
	146	0	6
	149	3	3
	150	2	3
	153	7	10
FEBRUARY	165	20	20
	169	2	1
	171	17	2
	172	32	26
	173	7	23
	174	2	4
	177	11	17
	178	8	10
MARCH	196	3	3
	197	6	0
	207	10	9
APRIL	234	32	32
	236	2	0
	238	7	6
TOTAL		451	419

a. Date = days from September 1, 1988.

TABLE A2: LABOUR TIME, PERSON-HOURS PER HECTARE, OXEN/OXEN SYSTEM, DOUBLE PLOUGHING SYSTEMS TRIAL, FRANCISTOWN AREA, 1988-89[a]

LOC	PLOT	YIELD KG/HA	FIRST PLOUGH	PLOUGH/ PLANT	WEED TIME	HARVEST TIME	THRESH TIME	TOTAL TIME
			HOURS PER HECTARE					
			DOUBLE PLOUGHING SYSTEM					
1	1[b]	0		82.8	0.0	0.0	0.0	82.8
1	1[b]	556	82.8	45.6[c]	47.4	38.4	39.6	253.8
1	2	372	42.6	41.0	72.6	19.0	25.8	201.0
1	4	128	43.0	48.7	63.7	18.0	18.4	191.8
1	6	70	36.8	47.0	33.6	10.6	7.8	135.9
1	5 HA TOTAL	1126	205.2	265.1	217.3	86.0	91.6	865.4
1	AVG PER HA	225	51.3	53.0	43.5	17.2	18.3	173.1
2	1[b]	0		103.2	0.0	0.0	0.0	103.2
2	1[b]	248	103.2	70.3[c]	23.4	26.1	19.8	242.8
2	2	472	60.8	76.3	37.1	29.6	36.5	240.3
2	4	128	72.5	64.3	25.3	13.8	14.6	190.5
2	4 HA TOTAL	848	236.5	314.2	85.8	69.5	71.0	776.5
2	AVG PER HA	212	78.8	78.5	21.4	17.4	17.7	194.2
DP AVERAGE PER HA		219	65.1	65.8	32.5	17.3	18.0	183.6
			TRADITIONAL SYSTEM					
1	1	0		82.8	0.0	0.0	0.0	82.8
1	3	160		76.8	60.4	5.6	17.2	160.0
1	5	140		50.4	60.4	12.0	9.2	132.0
1	7	64		86.4	106.4	10.4	8.8	212.0
1	4 HA TOTAL	364		296.4	227.2	28.0	35.2	586.8
1	AVG PER HA	91		74.1	56.8	7.0	8.8	146.7
2	1	0		103.2	0.0	0.0	0.0	103.2
2	3	400		115.2	69.6	24.8	52.0	261.6
2	5	100		67.2	40.0	4.8	7.2	119.2
2	3 HA TOTAL	500		285.6	109.6	29.6	59.2	484.0
2	AVG PER HA	167		95.2	36.5	9.9	19.7	161.3
TC AVERAGE PER HA		129		84.7	46.7	8.4	14.3	154.0

a. Totals and averages may not be exact due to rounding.
b. Was planned as TC treatments but was later changed to DP due to zero emergence on first plough/plant operation.
c. Re-plough/planting was not timed, so an average of the other second plough/planting times for the farmer was used as an estimate.

TABLE A3: RETURNS PER HECTARE AND RETURNS TO LABOUR, OXEN/OXEN SYSTEM, DOUBLE PLOUGHING SYSTEMS TRIAL, FRANCISTOWN AREA, 1988-89

LOC	PLOT	YIELD KG/HA	TOTAL LABOUR HOURS	GTVP PULA[a]	COSTS PULA[b]	NTVP PULA[c]	RETURNS TO LABOUR GROSS PER HR	RETURNS TO LABOUR NET PER HR
			--- PER ONE HECTARE ---					
			DOUBLE PLOUGHING SYSTEM					
1	1[d]	0	82.8	0.00	3.50	-3.50	0.00	-0.04
1	1[d]	556	253.8	250.20	5.00	245.20	0.99	0.97
1	2	372	201.0	167.40	5.00	162.40	0.83	0.81
1	4	128	191.8	57.60	5.00	52.60	0.30	0.27
1	6	70	135.9	31.68	5.00	26.68	0.23	0.20
1	5 HA TOTAL	1126	865.4	506.88	23.50	483.38	0.59	0.56
1	AVG PER HA	225	173.1	101.38	4.70	96.68	0.59	0.56
2	1[d]	0	103.2	0.00	3.50	-3.50	0.00	-0.03
2	1[d]	248	242.8	111.60	5.00	106.60	0.46	0.44
2	2	472	240.3	212.40	5.00	207.40	0.88	0.86
2	4	128	190.5	57.60	5.00	52.60	0.30	0.28
2	4 HA TOTAL	848	776.6	381.60	18.50	363.10	0.49	0.47
2	AVG PER HA	212	194.2	95.40	4.63	90.78	0.49	0.47
DP AVERAGE PER HA		219	183.6	98.39	4.66	93.73	0.54	0.51
			TRADITIONAL SYSTEM					
1	1	0	82.8	0.00	3.50	-3.50	0.00	-0.04
1	3	160	160.0	72.00	3.50	68.50	0.45	0.43
1	5	140	132.0	63.00	3.50	59.50	0.48	0.45
1	7	64	212.0	28.80	3.50	25.30	0.14	0.12
1	4 HA TOTAL	364	586.8	163.80	14.00	149.80	[illegible].28	0.26
1	AVG PER HA	91	146.7	40.95	3.50	37.45	[illegible].26	0.26
2	1	0	103.2	0.00	3.50	-3.50	0.00	-0.03
2	3	400	261.6	180.00	3.50	176.50	0.69	0.67
2	5	100	119.2	45.00	3.50	41.50	0.38	0.35
2	3 HA TOTAL	500	484.0	225.00	10.50	214.50	0.46	0.44
2	AVG PER HA	167	161.3	75.00	3.50	71.50	0.47	0.44
TC AVERAGE PER HA		129	154.0	57.98	3.50	54.48	0.38	0.35

a. GTVP = Gross Total Value Product (yield x price) where price = P.45/kg.
b. COSTS = Estimated seed cost (4kg/ha x P.50/kg = P2) plus equipment cost estimated at P1.50/ha. For DP there were 2 equipment charges and 1 seed = P5/ha.
c. NTVP = Net Total Value Product (GTVP - COSTS).
d. Was planned as TC treatments but was later changed to DP due to zero emergence on first plough/plant operation.

APPENDIX B

TABLE B1: DAILY RAINFALL AMOUNTS, BY LOCATION, TRACTOR/OXEN SYSTEM, DOUBLE PLOUGHING SYSTEMS TRIALS, FRANCISTOWN AREA, 1988-89

	DATE[a]	LOCATION 1	LOCATION 2
		RAINFALL AMOUNT IN MM	
OCTOBER	42	2	0
	44	0	46
	50	9	24
	51	16	0
	52	14	2
	57	0	11
	58	12	5
NOVEMBER	63	0	8
	68	0	5
DECEMBER	95	0	11
	96	0	11
	98	10	18
	99	4	0
	101	0	30
	102	6	0
	104	0	14
	105	9	0
	106	1	0
	116	0	13
	117	30	0
JANUARY	125	24	22
	127	3	0
	145	7	0
	149	11	8
FEBRUARY	160	0	2
	165	18	11
	169	0	7
	171	0	6
	172	20	4
	173	36	16
	174	10	10
	176	71	52
	177	70	52
	178	5	10
MARCH	197	1	0
APRIL	234	30	39
	238	21	30
TOTAL		440	467

a. Days from Sept 1, 1988

TABLE B2: LABOUR TIME, PERSON-HOURS PER SYSTEM, TRACTOR/OXEN SYSTEM, DOUBLE PLOUGHING SYSTEMS TRIAL, FRANCISTOWN AREA, 1988-89[a]

LOC	REP	YIELD KG/HA	FIRST PLOUGH	PLOUGH/ PLANT	WEED TIME	HARVEST TIME	THRESH TIME	TOTAL TIME
			HOURS PER HECTARE					
			DOUBLE PLOUGHING SYSTEM					
1	1	209	4.5	28.0	44.2	16.2	20.2	113.1
1	2	0	4.5	27.9	0.0	0.0	0.0	32.4
2	1	400	4.0	24.3	44.5	39.2	97.3	209.3
2	2	0	4.0	21.7	106.8	0.0	0.0	132.6
DP AVERAGE PER HA		152	4.3	25.5	48.9	13.9	29.4	121.8
			TRADITIONAL SYSTEM					
1	1	20		24.9	58.0	1.2	4.4	88.5
1	2	0		14.1	0.0	0.0	0.0	14.1
2	1	56		26.6	71.7	0.0	0.0	98.3
2	2	0		32.4	0.0	0.0	0.0	32.4
TC AVERAGE PER HA		19		24.5	32.4	0.3	1.1	58.3

a. Totals and averages may not be exact due to rounding.

TABLE B3: RETURNS PER HECTARE AND RETURNS TO LABOUR, TRACTOR/OXEN SYSTEM, DOUBLE PLOUGHING SYSTEMS TRIAL, FRANCISTOWN AREA, 1988-89

LOC	REP	YIELD KG/HA	TOTAL LABOUR HOURS	GTVP PULA[a]	COSTS PULA[b]	NTVP PULA[c]	RETURNS TO LABOUR GROSS PER HR	RETURNS TO LABOUR NET PER HR
				PER ONE HECTARE				
			DOUBLE PLOUGHING SYSTEM					
1	1	209	113.1	94.05	53.50	40.55	0.83	0.36
1	2	0	32.4	0.00	53.50	-53.50	0.00	-1.65
2	1	400	209.3	180.00	53.50	126.50	0.86	0.60
2	2	0	132.6	0.00	53.50	-53.50	0.00	-0.40
AVERAGE		152	121.9	68.51	53.50	15.01	0.56	0.12
			TRADITIONAL SYSTEM					
1	1	20	88.5	9.00	3.50	5.50	0.10	0.06
1	2	0	14.1	0.00	3.50	-3.50	0.00	-0.25
2	1	56	98.3	25.20	3.50	21.70	0.26	0.22
2	2	0	32.4	0.00	3.50	-3.50	0.00	-0.11
AVERAGE		19	58.3	8.55	3.50	5.05	0.15	0.09

a. GTVP = Gross Total Value Product (yield x price) where price = P.45/kg.
b. COSTS = Tractor rental P50/ha, estimated seed cost (4kg/ha x P.50/kg = P2), and animal traction equipment cost estimated at P1.50/ha.
c. NTVP = Net Total Value Product (GTVP - COSTS).

APPENDIX C

TABLE C1: DAILY RAINFALL AMOUNTS, BY LOCATION, TRACTOR/TRACTOR SYSTEM, DOUBLE PLOUGHING SYSTEMS TRIALS, FRANCISTOWN AREA, 1988-89

		LOCATION	
		1	2
	DATE[a]	-- RAINFALL AMOUNT IN MM --	
OCTOBER	42	3	0
	44	0	32
	50	14	22
	51	14	0
	52	9	4
	57	0	11
	58	38	4
	59	0	0
NOVEMBER	63	22	0
	68	0	10
DECEMBER	95	0	11
	96	0	19
	98	14	12
	99	6	0
	101	0	20
	104	0	10
	105	1	0
	106	11	26
	116	0	11
	117	20	0
JANUARY	125	26	21
	127	8	0
	145	8	0
	149	2	10
FEBRUARY	160	0	2
	165	0	9
	169	0	5
	171	0	5
	172	14	12
	173	30	14
	174	10	12
	176	80	50
	177	60	52
	178	0	10
MARCH	197	1	0
APRIL	234	30	34
	238	20	22
TOTAL		441	450

a. Data = days from September 1, 1988.

TABLE C2: LABOUR TIME, PERSON-HOURS PER HECTARE, TRACTOR/TRACTOR SYSTEM, DOUBLE PLOUGHING SYSTEMS TRIAL, FRANCISTOWN AREA, 1988-89[a]

LOC	REP	YIELD KG/HA	FIRST PLOUGH	PLOUGH/ PLANT	WEED TIME	HARVEST TIME	THRESH TIME	TOTAL TIME
			HOURS PER HECTARE					
			DOUBLE PLOUGHING SYSTEM					
1	1	563	6.6	4.5	0.0	33.6	24.8	69.4
1	2	0	6.6	2.4	0.0	0.0	0.0	9.0
2	1	422	3.3	9.3	81.9	16.8	29.8	141.1
2	2	0	3.3	0.0	0.0	0.0	0.0	3.3
DP AVERAGE PER HA		246	5.0	4.1	20.5	12.6	13.6	55.8
			TRADITIONAL SYSTEM					
1	1	46		4.5	0.0	4.6	2.7	11.8
1	2	0		2.9	0.0	0.0	0.0	2.8
2	1	0		11.0	0.0	0.0	0.0	11.0
2	2	0		0.7	0.0	0.0	0.0	0.7
TC AVERAGE PER HA		11		4.9	0.0	1.1	0.7	6.6

a. Totals and averages may not be exact due to rounding.

TABLE C3: RETURNS PER HECTARE AND RETURNS TO LABOUR, TRACTOR/TRACTOR SYSTEM, DOUBLE PLOUGHING SYSTEMS TRIAL, FRANCISTOWN AREA, 1988-89

LOC	REP	YIELD KG/HA	TOTAL LABOUR HOURS	GTVP PULA[a]	COSTS PULA[b]	NTVP PULA[c]	RETURNS TO LABOUR GROSS PER HR	RETURNS TO LABOUR NET PER HR
				--- PER HECTARE ---				
			DOUBLE PLOUGHING SYSTEM					
1	1	563	69.4	253.26	102.00	151.26	3.65	2.18
1	2	0	9.0	0.00	102.00	-102.00	0.00	-11.31
2	1	422	141.1	189.90	102.00	87.90	1.35	0.62
2	2	0	3.3	0.00	102.00	-102.00	0.00	-30.54
DP AVERAGE PER HA		246	55.7	110.79	102.00	8.79	1.99	0.16
			TRADITIONAL SYSTEM					
1	1	46	11.8	20.52	52.00	-31.48	1.73	-2.66
1	2	0	2.8	0.00	52.00	-52.00	0.00	-18.44
2	1	0	11.0	0.00	52.00	-52.00	0.00	-4.73
2	2	0	0.7	0.00	52.00	-52.00	0.00	-77.84
TC AVERAGE PER HA		11	6.6	5.13	52.00	-46.87	0.78	-7.10

a. GTVP = Gross Total Value Product (yield x price) where price = P.45/kg.
b. COSTS = Tractor rental P50/ha and estimated seed cost (4kg/ha x P.50/kg = P2).
c. NTVP = Net Total Value Product (GTVP - COSTS).

APPENDIX D - DATA ON PLOUGHING TIMES [a]

PUB	PLOTSIZE	PLOUNUMB	TRACTION	PLOUTIME	LS	PUB	PLOTSIZE	PLOUNUMB	TRACTION	PLOUTIME	LS
1	1	1	2	16	1	3	1	1	2	20	1
1	1	1	2	15	1	3	1	2	2	15	1
1	1	1	2	16	1	3	1	1	2	14	1
1	1	1	2	15	1	3	1	1	2	22	1
1	1	1	1	14	1	3	1	2	2	17	1
1	1	1	1	16	1	3	1	1	2	17	1
1	1	1	2	14	1	3	1	1	2	[illegible]	1
1	1	1	2	16	1	3	1	1	2	13	1
1	1	1	2	13	1	3	1	2	2	8	1
1	1	1	2	12	1	3	1	1	2	9	1
1	1	1	2	18	1	3	1	1	2	13	1
1	1	2	2	16	1	3	1	2	2	10	1
1	1	1	2	18	1	3	1	1	2	7	1
1	1	2	2	17	1	3	1	1	1	13	1
1	1	1	2	20	1	3	1	1	1	12	1
1	1	2	2	17	1	3	1	2	1	20	1
1	1	2	1	21	1	3	1	1	1	12	1
1	1	2	2	14	1	3	1	1	1	14	1
1	1	1	1	15	1	3	1	2	1	10	1
1	1	2	1	14	1	3	1	1	1	12	1
1	1	1	1	15	1	3	1	1	2	19	1
1	1	2	1	12	1	3	1	1	2	14	1
1	1	1	2	12	1	3	1	2	2	12	1
1	1	2	2	13	1	3	1	1	2	15	1
1	1	1	2	15	1	3	1	1	2	18	1
1	1	2	2	15	1	3	1	2	2	13	1
1	1	1	2	13	1	3	1	1	2	15	1
1	1	2	2	16	1	3	1	1	2	18	1
1	1	1	2	12	1	3	1	1	2	18	1
1	1	[illegible]	2	9	1	3	1	2	2	13	1
2	2	1	2	14	1	3	1	1	2	18	1
2	2	1	2	15	1	3	1	1	2	14	1
2	2	1	2	13	1	3	1	1	2	13	1
2	2	1	2	13	1	3	1	2	2	12	1
2	2	1	2	14	1	3	1	1	2	17	1
2	2	1	2	19	1	4	3	1	3	2	1
2	2	1	2	15	1	4	3	1	3	3	1
2	2	1	2	15	1	4	3	1	2	15	1
2	2	1	2	15	1	4	3	1	2	15	1
2	2	1	2	13	1	4	3	1	2	10	1
2	2	1	2	15	1	4	3	1	2	10	1
2	2	1	2	14	1	4	3	1	2	29	1
2	2	1	2	14	1	4	3	1	2	10	1
2	2	1	2	14	1	4	3	1	2	11	1
2	2	1	2	12	1	4	3	1	2	17	1
2	2	1	2	15	1	4	3	1	3	3	1
2	2	1	2	19	1	4	3	1	3	2	1
2	2	1	2	16	1	4	3	1	2	10	1
3	1	1	2	13	1	4	3	1	2	14	1

a. See footnotes at end of appendix for codes.

APPENDIX D - DATA ON PLOUGHING TIMES [a] (CONTINUED)

PUB	PLOTSIZE	PLOUNUMB	TRACTION	PLOUTIME	LS	PUB	PLOTSIZE	PLOUNUMB	TRACTION	PLOUTIME	LS
4	3	1	2	11	1	5	1	1	3	2	1
4	3	1	2	13	1	5	1	2	3	5	1
4	3	1	2	14	1	5	1	1	3	5	1
4	3	1	2	21	1	5	1	2	3	5	1
4	3	1	2	14	1	6	1	2	2	7	1
4	3	1	2	11	1	6	1	2	2	15	1
4	3	1	3	3	1	6	1	1	3	2	1
4	3	1	3	3	1	6	1	2	2	6	1
4	3	1	2	8	1	6	1	1	3	3	1
4	3	1	2	9	1	6	1	2	2	14	1
4	3	1	2	13	1	6	1	1	3	3	1
4	3	1	2	10	1	6	1	2	2	11	1
4	3	1	2	21	1	6	1	1	3	3	1
4	3	1	2	29	1	6	1	2	2	10	1
4	3	1	2	15	1	6	1	1	2	14	1
4	3	1	2	14	1	6	1	1	2	8	1
4	3	1	2	30	1	6	1	1	2	14	1
4	3	1	2	28	1	6	1	1	2	13	1
4	3	1	2	10	1	7	5	1	2	21	2
4	3	1	2	11	1	7	5	1	2	18	2
4	3	1	2	18	1	7	5	2	2	16	2
4	3	1	2	27	1	7	5	1	2	20	2
4	3	1	2	43	1	7	5	2	2	16	2
4	3	1	2	16	1	7	5	1	2	22	2
5	1	1	1	35	1	7	5	2	2	29	2
5	1	1	1	23	1	7	5	1	2	16	2
5	1	1	1	17	1	7	5	2	2	12	2
5	1	1	1	28	1	7	5	1	1	25	2
5	1	1	3	7	[illegible]	7	5	1	1	[illegible]	2
5	1	2	1	20	1	7	5	2	1	[illegible]	2
5	1	1	3	5	1	7	5	1	1	[illegible]	2
5	1	2	1	22	1	7	5	2	1	20	2
5	1	1	3	5	1	7	5	1	1	24	2
5	1	2	1	17	1	7	5	2	1	20	2
5	1	1	3	5	1	7	5	1	1	18	2
5	1	2	1	35	1	7	5	2	1	22	2
5	1	1	3	6	1	7	4	1	2	35	1
5	1	1	3	5	1	7	4	1	2	19	1
5	1	1	3	5	1	7	4	1	2	35	1
5	1	1	3	5	1	7	4	1	2	29	1
5	1	1	3	7	1	7	4	1	1	40	1
5	1	2	1	19	1	7	4	1	1	32	1
5	1	1	3	5	1	7	4	1	1	35	1
5	1	2	1	25	1	7	4	1	1	33	1
5	1	1	3	6	1	7	5	1	3	2	2
5	1	2	1	21	1	7	5	2	1	14	2
5	1	1	3	5	1	7	5	1	3	2	2
5	1	2	1	20	1	7	5	2	1	15	2

a. See footnotes at end of appendix for codes.

APPENDIX D - DATA ON PLOUGHING TIMES [a] (CONTINUED)

PUB	PLOTSIZE	PLOUGHING	TRACTION	PLOUTIME	LS	PUB	PLOTSIZE	PLOUGHING	TRACTION	PLOUTIME	LS
7	5	1	3	2	2	8	6	2	3	2	2
7	5	2	2	8	2	8	6	1	3	3	2
7	5	1	1	14	2	8	6	2	3	5	2
7	5	1	1	12	2	8	6	1	3	3	2
7	5	1	2	10	2	8	6	1	3	4	2
7	6	1	3	2	2	8	6	1	3	3	2
7	6	2	3	3	2	8	6	1	3	5	2
7	6	1	3	3	2						
7	6	2	3	4	2						
7	6	1	3	2	2						
7	6	2	3	3	2						
7	6	1	3	3	2						
7	6	1	3	4	2						
7	6	1	3	3	2						
8	5	1	2	16	2						
8	5	2	2	9	2						
8	5	1	2	11	2						
8	5	2	2	10	2						
8	5	1	2	14	2						
8	5	2	2	16	2						
8	5	1	2	12	2						
8	5	2	2	16	2						
8	5	1	1	34	2						
8	5	2	1	23	2						
8	5	1	1	20	2						
8	5	2	1	25	2						
8	5	1	1		2						
8	5	2	1		2						
8	4	1	2	[illegible]	1						
8	4	1	2	17	1						
8	4	1	2	29	1						
8	4	1	1	38	1						
8	4	1	1	34	1						
8	5	1	3	4	2						
8	5	2	2	11	2						
8	5	1	3	5	2						
8	5	2	2	14	2						
8	5	1	3	4	2						
8	5	2	2	12	2						
8	5	1	3	4	2						
8	5	2	2	11	2						
8	5	1	2	12	2						
8	5	1	2	7	2						
8	5	1	2	16	2						
8	5	1	2	13	2						
8	6	1	3	7	2						
8	6	2	3	5	2						
8	6	1	3	7	2						

a. See footnotes next page for codes.

CODES FOR APPENDIX D:

PUB	Publication code: 1 = PR F86-3; 2 = PR F86-4; 3 = PR F87-5; 4 = PR F87-7; 5 = PR F87-8 (cmit band ploughing and deep-ripping); 6 = PR F88-6 (cmit contour band ploughing); 7 = PR F89-1; 8 = PR F90-3.
PLOT SIZE (metres)	1 = 10 X 40; 2 = 10 X 20; 3 = 15 X 20; 4 = 5 X 50; 5 = 25 X 50; 6 = 50 X 100.
PLOUGHING	1 = First ploughing; 2 = Second ploughing.
TRACTION	1 = Donkey; 2 = Cattle; 3 = Tractor.
PLOUTIME	Ploughing time in hours per hectare.
LS	1 = Small plot (PLOT SIZE 1 to 4); 2 = Large plot (PLOT SIZE 5 or 6).