PN-AAY-718
ISN 53339

AGRICULTURAL TECHNOLOGY IMPROVEMENT PROJECT

(ATIP)

PROGRESS REPORT

1987 DOUBLE PLOUGHING TRIAL
(RESEARCHER MANAGED/FARMER IMPLEMENTED)

NUMBER: ATIP PR F87-5

BY

G. HEINRICH
F. WORKAN
S. MASIKARA
R. GRAY

DEPARTMENT OF AGRIC. RESEARCH
MINISTRY OF AGRICULTURE
BOTSWANA

MID-AMERICA INTERNATIONAL
AGRICULTURAL CONSORTIUM
(MIAC)

SEPTEMBER 1987

PRINTED: 2/10/87

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.

This Progress Report presents information on the Researcher Managed, Farmer Implemented (RM,FI) Double Ploughing Trials carried out in the villages of Matobo, Marapong, and Mathangwane, Tutume Agricultural District, during the 1986-87 cropping season. The report covers the agronomic and labour data collected, and provides analysis of returns to labour and a partial budget analysis.

ACKNOWLEDGEMENTS

The research officers responsible for the Double Ploughing Trials 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, Matobo)
c. J. Basthodi (Enumerator, DAR, Marapong)
d. P. Batshani (Enumerator, DAR, Marapong)
e. M. Monyaduwe (Enumerator, DAR, Mathangwane)
f. K. Mumasuwe (Field Assistant, DAR, Mathangwane)
g. M. Nkhutelang (Enumerator, DAR, Matobo)
h. P. Samuel (Field Assistant, DAR, Matobo)
i. M. Tembo (Enumerator, DAR, Matobo)

1987 DOUBLE PLOUGHING TRIAL (RM,FI)

ABSTRACT

Four farmers using cattle draught and one using donkey draught power participated in the Double Ploughing Trial conducted by the ATIP Francistown staff during the 1986-87 cropping season. In this researcher managed, farmer implemented trial. Plots were laid out so that comparisons could be made between: a) a double ploughing system, b) a single ploughing system planted on the same day as the double plough trial, and c) a system involving two plots, one planted the day the double ploughed plot was first ploughed (to give an idea of the opportunity cost of ploughing and not planting) and the other planted the same day as the double ploughed plot. Labour data were collected on all operations.

The results indicated that the double ploughing system more than doubled yield on a per hectare basis, and produced the same yield as two hectares single ploughed. The advantage of the double ploughing system over planting two single ploughed hectarer was that it reduced total labour by 43 percent for the same grain yield. Returns to labour and to traction time were also greater for the double ploughing system. Partial budget analysis showed an advantage to shifting from single ploughing two hectares to double ploughing one hectare.

Double ploughing would be useful where land is constrained since it increased yield per area of land. The system also provided increased returns to labour and to traction when compared to the traditional system.

INTRODUCTION

This trial was basically the same as the "Draught Animal Management and Early Ploughing Trial" performed in 1985-86. The term "early ploughing" changed to "double ploughing" since it appeared that the observed per hectare yield increases were due to the fact that plots were ploughed twice, rather than their being ploughed "early".

Regarding dry season feeding of draught animals, farmers who participated in the 1985-86 trials were encouraged to harvest crop residues for fodder and feed these to their draught animals just prior to the start of the 1986-87 rainy season. A significant proportion did harvest some residues and feed them to their animals. However, this side of the management (dry season feeding) was largely left to the farmers discretion and did not form a major component of the study in 1986-87.

OBJECTIVES

The objectives of this RMFI work were to determine whether:

(a). Ploughing one hectare twice is more profitable than ploughing two hectares once,
(b). Whether there is any advantage in allowing an interval of two rains between first and second ploughing versus allowing a single rain, and
(c). Whether it is necessary to start ploughing on the first rains to realize the yield advantage of double ploughing.

JUSTIFICATION

These trials were initiated in 1985-86 to resolve some specific questions regarding the profitability of double ploughing (DP) and to help adapt DP into a practical system for farmer usage. A second year of data was required to verify results over seasons.

APPROACH

The agronomy work continued to examine ideas for improving the productivity of the DP system. These improvements were based on observations of experiments in 1984-85. The changes are discussed below.

The same five farmers participated in this years trial as participated in 1985-86. The trials were conducted on light and medium textured soils. This allowed more specificity in determining where DP could be effective.

Two blocks of five plots were marked out on the fields of participating farmers. The plots were 10m by 4um, making each block 50m by 40m in size. The ploughing and planting sequence for the first block was as follows:

<u>Rain 1</u> Plant plot 1 (traditional check 1)
Plough plot 2
Plough plot 4

<u>Rain 2</u> Plant plot 2 (double ploughed plot)
Plant plot 3 (traditional check 2)

<u>Rain 3</u> Plant plot 4 (double ploughed plot)
Plant plot 5 (traditional check 3)

Note:
Plough = single ploughing without planting
Planting = broadcast seed/plough under

The sequence was the same for the second block, but started on Rain 4.

All ploughing was supposed to be done on soil that was dryer than optimal for planting. All planting for the DP plots was to be done on good moisture, within two to three days after a planting rain. The question of fertiliser effects was left out because there was a need to keep the trials as simple as possible.

To estimate plot grain yields, the farmers harvested and threshed whole plot yields under researcher supervision. The grain was sun dried and weighed by ATIP staff.

The economic focus for these trials was to collect sufficient specific labour use, input cost, and harvested output information on the individual trials to allow the analysis of returns to labour and the formulation of budgets used in comparing potential interventions. The partial budgets were used in comparing DP with the traditional systems options in order to determine which were economically superior.

Fodder yield data was collected on all plots at four locations, using a sampling procedure. Eight samples (2 m x 2 m) were collected from each plot.

AGRONOMIC RESULTS

Rainfall amounts for the 5 locations are given by month in Table 1.

TABLE 1 RAINFALL AMOUNTS BY MONTH FOR ALL LOCATIONS, DOUBLE PLOUGHING TRIALS, FRANCISTOWN AREA, 1986-87/a

	---------- PRECIPITATION (MM) ----------								
	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	TOTAL
Location 1	10	73	71	61	47	27	10	0	299
Location 2	10	60	44	100	40	28	5	0	287
Location 3	15	51	71	81	112	22	15	0	367
Location 4	22	36	72	45	109	18	9	0	307
Location 5	11	99	66	26	56	60	3	0	321

a.Location number corresponds to farmer numbers used in ATIP progress report PR F86-3.

All ploughing and planting was done using the farmers own animal draught power, equipment and labour. Dates of ploughing and planting, stand densities and grain yields are given by plot in Table 2.

To address the question of whether one (DP) hectare would out yield two single ploughed hectares, the grain yield of each DP plot was compared with the sum of the yields of its two respective check plots. (ie, Plot 1 + Plot 3 vs Plot 2, Plot 1 + Plot 5 vs Plot 4, Plot 6 + Plot 8 vs Plot 7). The overall means of the DP plots versus the sum of the two check plots was 100 kg/ha vs 108 kg/ha respectively (plots 1, 2 and 3 at location 5 are ignored here because of having the remains of a large ant hill in plot 2). Using a paired t-test for comparisons, there was no statistical difference between the yield of one hectare DP and two hectares single ploughed (with or without plots 1,2 and 3 in location 5). This is the same result as observed in the 1985-86 trials, though yields were much lower in 1986-87 due to poor rainfall. (ATIP PR P86-3).

Again ignoring location 5, the grain yields of one hectare DP versus 1 ha single ploughed, were 109 kg/ha versus 54 kg/ha respectively. This represents a per hectare yield increase of 101 percent, again consistent with the data from 1985-86.

No significant differences were observed for stand counts on DP versus single ploughed plots planted on the same days respectively.

Regards the question of whether there is a difference between allowing a gap of two rains versus one rain between first and second ploughings of the DP system, this was examined by comparing the yield of plot 2's versus the yield of plot 4's. These gave average yields of 115.6 and 106.25 kg/ha respectively when location 5 is ignored. When location 5 is included, average yields are 165 versus 85 kg/ha respectively. In 1985-86, no differences in grain yields were observed from allowing an interval of one versus two rains. The data would suggest that the effects observed at location five are an artifact of this season's rainfall pattern (which favoured earlier planting) and does not represent a real difference due to the number of rains occurring between the first and second ploughings. The principal conclusion is that post-planting rainfall is likely to have a

lt per effect on crop yield results than is caused by leaving an interval of one versus two rains between the first and second ploughings. (The latter is likely to be small if it exists at all). While this set of trials can give some insight on this question, in retrospect it is perhaps not the best design for producing a definitive answer. Such a design would require that the preparation ploughing was implemented such that both plots could be planted on the same day, and only the initial ploughing dates be varied.

TABLE 2 PLOUGHING AND PLANTING DATES, STAND DENSITY AND GRAIN AND STOVER YIELD DATA, DOUBLE PLOUGHING TRIALS, FRANCISTOWN AREA, 1986-7

LOCATION	BLOCK NBR	PLOT NBR	PLOUGH DATE/a	PLANT DATE/a	STAND DENSITY (x1000 PLNTS/HA)	GRAIN YIELD (KG/HA)	STOVER YIELD KG DM/HA
1	1	1	73	73	56.1	6.25	897
(Sorghum)	1	2	73	94	30.5	80.00	897
V.Segaolane	1	3	94	94	23.1	87.50	777
	1	4	73	101	21.1	227.50	957
	1	5	101	101	13.5	75.00	538
2	1	1	66	66	27.	0	239
	1	2	66	93	82.9	0	239
(Sorghum)	1	3	93	93	68.6	0	239
V.Segaolane	1	4	66	100	26.9	22.50	897
	1	5	100	100	28.3	7.50	418
3	1	1	93	93	91.3	85.00	837
	1	2	93	99	9.6	182.50	478
(Sorghum)	1	3	99	99	14.1	157.50	299
V.Segaolane	1	4	93	122	23.1	50.00	478
	1	5	122	122	10.3	0.00	0
4	1	1	94	94	59.8	0	
	1	2	94	12*	37.0	200.00	
(Sorghum)	1	3	121	121	55.0	125.00	
V.Segaolane	1	4	94	143	22.3	125.00	
	1	5	143	143	11.4	97.50	
	2	6	122	122	33.6	105.00	
	2	7	122	143	32.1	200.00	
	2	8	143	143	14.1	1.00	
5/b	1	1	36	36	15.1	250.00	598
(Millet)	1	2	36	92	66.5	362.50	1375
V.Serere 6A	1	3	92	92	11.9	450.00	718
	1	4	36	137	86.4	-	
	1	5	137	137	77.0	-	

a. Dates given as days from September 1, 1986 = day 1.
b. After planting, found there had been an old ant hill in plot 2, Loc. 5, which severely affected crop growth in such of the plot.

On the question of whether "early" ploughing is required to produce a benefit from "double" ploughing, plantings in the second blocks (starting from rain 4) were to be examined. Unfortunately, only one farmer managed to plant part of the second block. In this block (location 4, Table 2), the initial ploughing

was done on December 30, 1986, and planting [plots 2 and 3] on January 21, 1987. As can be seen [Table 2] the DP produced a significant yield increase over the two respective single ploughed plots.

Similar observations were reported in both researcher managed and farmer managed trials in the proceding season [ATIP Annual Report No 4]. While the number of observations on late season land preparation and planting are few, our conclusion is that DP can produce significant benefits for per hectare grain yields even when the first ploughing is done as late as December or January. An important caveat is that for double ploughing to produce a benefit, there must be sufficient post planting rainfall to produce significant grain yield.

STOVER YIELDS

Using paired t-tests to compare data across the four locations where forage yields were measured, it was found that:

[a].DP plots produced more stover than their companion check plots planted on the same day [780 vs 427 kg dry matter/ha for DP and SP respectively, 95% level of probability].

[b].There was no significant difference in fodder yields between one hectare double ploughed plots and the sum of their respective check plot plus fodder production on plot 1 [2 ha single ploughed]. DP fodder yields averaged 780 kg DM/ha versus 1078 kg DM/ha for 2 ha single ploughed.

LABOUR CONSIDERATIONS

Labour data was collected by stop watch on all field operations. Bird scaring labour was not collected because bird scaring tends to take place in conjunction with other activities and is thus difficult to allocate to a particular plot accurately. Because of the relatively small plots, 10 by 40 metres, the data was not considered representative for estimating absolute values of times required to perform the field operations on a full hectare or larger operation. However, the data was considered adequate for making comparisons of relative times required for field operations among the technologies being examined and the traditional system. Thus this discussion of labour hours is for comparative purposes and should be considered as only an approximation of the absolute times involved in the different field operations under each technology. The small plots utilized in these trials required a higher percentage of turning time compared to row plough time than would be true in a normal field situation. Therefore, the ploughing times have been adjusted to compensate for the greater amount of turning time./1

As has been previously discussed, plot 2 location 5 was discovered to contain an old ant hill which made this an unrepresentative comparison. The following discussion is based on a data set with the data from plot 2, location 5, removed. The comparative data for plot 2, i.e. plot 3 and the combination of plots 1 and 3, were also removed to preserve the balance in the data set. The complete labour data set, plus the summary tables for returns and the partial budget tables for the entire data set are presented in Appendix B.

When the labour hours were examined by plot across locations, the average number of person hours required to complete the first ploughing versus the second ploughing on double ploughed plots was 31 versus 27. [Table 3,

summary of Appendix Table A1] This was not a significant difference. Because labour for ploughing involved a varying number of people working with the animals, a better estimate of time spent on the first and second ploughing may be obtained from estimates of draught team time used in ploughing. As can be seen in Table 4 [summary of Appendix Table A2], there was an average of three hours per hectare less time spent on the second ploughing for the DP plots, a difference which was not significant but which was a 25 percent reduction in team ploughing time.

TABLE 3 AVERAGE LABOUR TIMES, PERSON HOURS PER HECTARE, DOUBLE PLOUGHING TRIALS, FRANCISTOWN AREA, 1986-87/a

	PLOT	YIELD KG/HA	PLOUGH TIME	PLANT TIME	BC SEED TIME	TOTAL PREP	WEED TIME	PROC TIME	TOTAL TIME
AVERAGE	1[6]	74	0.00	29.36	0.73	30.15	66.25	7.67	104.07
AVERAGE	2[7]	132	30.30	27.42	0.80	59.11	55.20	18.15	133.46
AVERAGE	3[8]	74	0.00	27.42	0.85	28.27	36.70	11.25	76.22
AVERAGE	4	65	31.02	25.01	0.80	56.83	19.70	37.25	113.78
AVERAGE	5	34	0.00	27.33	0.85	28.18	35.55	10.30	74.03
AVERAGE	2 & 4	109	30.36	26.21	0.80	57.97	37.45	28.20	123.62
AVERAGE	3 & 5	54	0.00	27.37	0.85	28.22	38.13	10.73	75.12
OVERALL	AVERAGE	79	30.96	27.16	0.83	40.33	41.55	17.91	99.50

a.PLOUGH = Plough Time First Ploughing of Double Ploughing
PLANT = Plough/Plant Operation
BC SEED = Broadcast Seed before Planting
TOTAL PREP = Sum of PLOUGH, PLANT and BC SEED
PROC = Harvesting and Threshing Time
Number in parenthesis is plot number for the second set of plots for farmer 4.

TABLE 4 AVERAGE TEAM PLOUGHING HOURS/HECTARE, DOUBLE PLOUGHING TRIALS, FRANCISTOWN AREA, 1986-87/a

	YIELD KG/HA	FIRST PLOUGH HOURS	PLOUGH/ PLANT HOURS	TOTAL TEAM HOURS
AV SINGLE PLO	54x	0	14a	14a
AV DOUBLE PLO	109y	15	12a	27b
AV 2 SINGLE PLO	108	0	27b	27b

a.Within columns, means followed by different letters [a,b] and [x,y] differ significantly [P < .01] and [P < .05], respectively. Based on pairwise comparisons between treatments./2

Person hours required for ploughing were fairly consistent across treatments. They averaged 31.0, 26.2, 23.4, 27.4 and 27.3 person hours per hectare for the first ploughing on double ploughed plots, the second

ploughing on double ploughed plots, ploughing the first traditional plots, and ploughing the second and third check plots respectively. This indicates that the labour required to double plough one hectare is about the same as that required to single plough two hectares.

Table 5 [summary of Appendix Table A3] provides information on the average labour hours used in the three tillage options; single plough one [plot 3] hectare [SP1], double plough one [plot 2] hectare [DP], and single plough two [plots 1 & 3] hectares [SP2]. The average yields for DP and SP2 are almost equal with the difference in yields between SP1 and DP being significant, but the difference between SP1 and SP2 is not significant. As was expected there was a highly significant difference between preparation labour for SP1 versus DP or SP2, but not between DP and SP2. For weeding labour the situation was reversed with SP2 requiring significantly [P < .01] more weeding labour than either SP1 or DP. There was no significant difference between weeding labour for SP1 and DP. For processing time there was a significant difference between SP1 and SP2. Also there was a highly significant difference between SP2 and both DP and SP1 in total labour hours, and a significant difference between DP and SP1 total labour hours. Based on this years results, the amount of time required to produce approximately the same amount of grain is significantly less [P < 0.1] for the DP system compared to the SP2 system. This represents a saving in total labour of 43 percent for the double ploughed hectare. Both the yield and the total labour are significantly greater in the DP system compared to the SP1 system. In this case on a per hectare basis, an increase of 102 percent in grain yield is achieved with an increase of 35 percent in total labour.

TABLE 5 AVERAGE LABOUR TIME, HOURS/HECTARE, DOUBLE PLOUGHING TRIALS, FRANCISTOWN AREA, 1986-87/a

	YIELD KG/HA	ACTIVITY TIME PREP/b HOURS	WEED HOURS	PROC/c HOURS	TOTAL HOURS
AV SINGLE PL/HA	54x	23a	36a	11x	75xa
AV DOUBLE PL/HA	109y	56b	37a	23xy	124ya
AV 2 SINGLE PL/2HA	108	58b	103b	17y	177b

a.Within columns, means followed by different letters [a,b] and [x,y] differ significantly [P < .01] and [P < .05], respectively. Based on pairwise comparisons between treatments./2
b.PREP TIME = Preparation Time includes ploughing and planting.
c.PROC TIME = Processing Time includes harvesting and threshing.

RETURNS ANALYSIS

Where labour is the primary input to a cropping system, it is useful to look at gross and net returns to labour when comparing alternative technologies within the cropping system. Table 6 summarizes data for gross total value product [GTVP], post planting labour costs, net total value product [NTVP], and returns to labour. [Complete data in Table A3.] GTVP was calculated by taking the yield times price for sorghum in Matobo in August 1989. Although the price of millet was slightly higher than the price of sorghum [P.49/kg

vs. P.43/kg], the sorghum price was used for all valuations to avoid confusion. Also the 1986 price was used in 1987 as there was insufficient harvest in 1987 to establish a local market price. Costs were estimated for seed and equipment depreciation. NTVP is GTVP minus costs. GTVP and NTVP were then divided by the total number of hours of labour per hectare to obtain gross and net returns to labour per hour. The returns to preparation time were also calculated as it was assumed that major constraints on arable cropping were inadequate ploughing labour and/or a limited number of days suitable for plough/plant operations, both of which mean that the farmer would like to maximize his/her returns from the preparation time which is available. In calculating returns to preparation time, post planting labour, with the exception of bird scaring, was valued at P.38/hour, the Labour Based Drought Relief wage rate. This post planting labour cost was subtracted from the GTVP and NTVP before calculating returns to preparation labour. Bird scaring time was not included as it tends to occur in conjunction with other activities and thus is assumed to have a very low opportunity cost.

TABLE 6 AVERAGE RETURN TO LABOUR, IN PULA, DOUBLE PLOUGHING TRIALS, FRANCISTOWN AREA, 1986-87/a

	YIELD KG/HA	ACTIVITY TIME PREP/b HOURS	POST/PL HOURS	TOTAL HOURS	GTVP/d PULA	POST/PL LABOUR COST	NTVP/e PULA	GROSS RETURN/f LAB/HR	NET RETURN LAB/HR	GROSS RETURN PREP/HR	NET RETURN PREP/HR
AV SINGLE PLO	54x	23a	47a	75ax	23.26x	17.82a	20.56x	0.35	0.31	0.17	0.07
AV DOUBLE PLO	109y	56b	86a	124ay	46.75y	24.95a	44.06y	0.40	0.38	0.30	0.26
AV 2 SINGLE PLO	108	58b	119b	177b	46.38	45.41b	40.98	0.26	0.23	-0.04	-0.13

a.Within columns, means followed by different letters [a,b] and [x,y] differ significantly [P < .01] and [P < .05], respectively. Based on pairwise comparisons between treatments./2
b.PREP TIME = Preparation Time includes ploughing and planting.
c.POST PLANTING TIME includes weeding, harvesting and threshing.
d.GTVP = Gross Total Value Product [yield - price] where price = P.43/kg.
e.NTVP = Net Total Value Product [GTVP - COSTS] where COSTS [per hectare] = seed - P.30/kg for 4 kg, equipment estimated P1.50
f.GROSS and NET RETURNS are averages of RETURNs by plot, so are slightly different than RETURNS calculated using the averages of activity times and values.

As is indicated in Table 6, both GTVP and NTVP were significantly greater for DP compared to SP1 but not between the two single ploughing technologies. While gross and net returns to labour were not significantly different between DP and SP2, DP provided a gross return per hour of labour which was 54 percent greater than the return on SP2./3 The double ploughing system provided a higher gross return, 14 percent, per hour of labour than did the traditional [SP1] system with the rainfall conditions in 1986-87. DP also provided a net return per hour of labour which was 23 percent greater than the SP1 return and 65 percent greater than the SP2 return. Post planting labour costs per hectare were almost twice as much for two single ploughed hectares as for ploughing one hectare twice. Returns for preparation hours of labour, which included ploughing, plough/planting, and broadcasting of seed, indicated that gross returns for DP were 78 percent greater than SP1 while SP2 showed a negative return to preparation hours of labour. Net returns for DP preparation labour were 271 percent greater than SP1 and SP2 provided a negative net return. Thus an average hour of labour spent on double ploughing was worth considerably more in terms of return to labour than the same hours spent on single ploughing either one or

two hectares in this comparison trial.

It has been hypothesized that the small number of ploughing days when the soil is moist enough to plant is one major limiting factor to increasing production in arable agriculture in Tuluwe District. If this is indeed the case then examining returns per team hour provides a measure of which technology would produce the greatest return for the use of a farmer's scarce plough/planting days. Table 7 [summary of Appendix Table A2] presents information on returns per team hour. Calculations were made as discussed in the labour returns section above.

TABLE 7 AVERAGE RETURNS TO TEAM PLOUGHING HOURS, IN PULA, DOUBLE PLOUGHING TRIAL, FRANCISTOWN AREA, 1986-87/a

	YIELD KG/HA	TOTAL TEAM HOURS	POST PLANT HOURS	GTVP/b PULA	POST/PL LABOUR/c COST	NTVP/d PULA	GROSS RETURNS/e PER HR	NET TRACT PER HR
AV SINGLE PLO	54x	14a	47a	23.25x	17.22a	20.56x	0.33	0.11
AV DOUBLE PLO	109y	27b	66a	46.76	24.30a	44.06	0.63	0.52
AV 2 SINGLE PLO	108	27b	119b	46.38y	45.41b	40.38y	-0.20	-0.42

a.Within columns, means followed by different letters [a,b] and [x,y] differ significantly [P < .01] and [P < .05], respectively. Based on pairwise comparisons between treatments./2

b.GTVP = Gross Total Value Product [yield x price] where price = P.43/kg.

c.POST PLANTING LABOUR COSTS = Labour for weeding and processing valued at the Labour Based Drought Relief wage rate of P.38/hour.

d.NTVP = Net Total Value Product [GTVP - COSTS] where COSTS [per hectare] = seed - P.30/kg for 4 kg, equipment estimated P1.50.

e.GROSS and NET RETURNS to TRACTION are averages of returns by plot, so are slightly different than returns calculated using the averages of activity times and values.

The returns to team hours spent in double ploughing were greater, but not significantly so, than returns from either SP1 or SP2. Gross returns per team hour for DP were 91 percent greater than for SP1 while returns to SP2 were negative because of the high number of post planting hours, primarily weeding hours, for SP2. The net returns to team time for DP were 372 percent greater than SP1 and again net returns to team time for SP2 were negative, with a net loss of P.42 per hour.

PARTIAL BUDGET ANALYSIS

A returns analysis provides an indication of which cropping system among those tested provides the greatest return to various resources. A more specific economic comparison between two systems is provided by a partial budget analysis. A partial budget analysis is used to address two specific issues:

[a].Should a farmer double plough rather than single plough a given hectare? This is a relevant question for farmers who have a limited amount of land to plough or who are faced with a weeding labour constraint. It is also relevant to farmers with resources to plough

at times when they would not normally plant.

TABLE 9 PARTIAL BUDGET: DOUBLE PLOUGHING INSTEAD OF SINGLE PLOUGHING ON A SINGLE HECTARE, DOUBLE PLOUGHING TRIALS, FRANCISTOWN AREA, 1986-87

PART A: BASIC BUDGET ANALYSIS		
REDUCED COST		
Total labour hours SP [75.12 hrs @ 38 t/hr]/a	28.55	
ADDED BENEFIT		
Double plough yield [109 kgs @ 43 t/kg]/b	46.87	
SUB-TOTAL		75.42
ADDED COST		
Total labour hours DP [123.62 hrs @ 38 t/hr]/c	48.98	
Depreciations/d	1.50	
REDUCED BENEFIT		
Single plough yield [54 kg]/e	23.22	
SUB-TOTAL		71.70
NET GAIN		3.72

PART B: SENSITIVITY ANALYSIS	NET GAIN
YIELDS, RESOURCE USE AND VALUATION	
Top three yield differences/f	41.13
Bottom three yield differences/g	-20.79
Labour valued at 53 t/hr./h	-3.56
Grain valued at 29 t/kg./i	-3.98
Traction costed at 50 p/ha; no ploughing labour/j	-34.98
Traction costed at 25 p/ha; no ploughing labour/k	- 9.96

a.Average labour time for SP trial plots valued at the Labour Based Drought Relief wage of P .38/hour.

b.Average yield for DP trial plots valued at P .43/kg, the prevailing rate in Matobo for the 1985-86 harvest season.

c.Average labour time for DP trial plots valued at the Labour Based Drought Relief wage of P .38/hour.

d.Depreciation of equipment estimated at P 1.50 per hectare ploughed.

e.Average yield for SP trial plots valued at P .43/kg, the prevailing rate in Matobo for the 1985-86 harvest season.

f.Based on average yields for three trials with largest positive difference in yields between DP and SP.

g.Based on average yields for three trials with largest negative difference in yields between DP and SP.

h.The urban minimum wage rate.

i.The BAMB guaranteed price [P 20.55 per 70 kg] for producers of number 2 mixed sorghum in 1986-87.

j.ARAP tractor hire rate.

k.Slightly above the Mahalapye donkey hire rate.

[b].Should a farmer double plough a single hectare rather than single plough two hectares? This question is relevant for farmers who are not land constrained and who do not have weeding labour constraints. The key trade-off for these farmers is the opportunity cost of the

first ploughing, represented by the yield which would have been obtained if the first ploughing time was spent plough/planting an additional hectare. If a farmer uses the traditional system to plant two hectares (on the day of first ploughing and on the day of plough/planting for the double plough system), then returns to the total field, to labour or to rainfall may be higher. In addition, planting on two dates may be less risky than planting on a single date due to the erratic rainfall patterns in this environment.

TABLE 10 PARTIAL BUDGET: DOUBLE PLOUGHING INSTEAD OF SINGLE PLOUGHING TWO HECTARE, DOUBLE PLOUGHING TRIALS, FRANCISTOWN AREA, 1986-87

PART A: BASIC BUDGET ANALYSIS		
REDUCED COST		
Total labour hours 2SP (177.40 hrs @ 38 t/hr)/a	67.41	
Seed saving (4 kg @ 30 t/kg)	1.20	
ADDED BENEFIT		
Double plough yield (109 kgs @ 43 t/kg)/b	46.87	
SUB-TOTAL		115.48
ADDED COST		
Total labour hours DP (103.52 hrs @ 38 t/hr)/c	49.98	
REDUCED BENEFIT		
Two single plough hectares yield (108 kg)/d	46.44	
SUB-TOTAL		93.42
NET GAIN		22.07
PART B: SENSITIVITY ANALYSIS		
	NET GAIN	
YIELDS, RESOURCE USE AND VALUATION		
Top three yield differences/e	68.79	
Bottom three yield differences/f	-27.60	
Labour valued at 53 t/hr./g	30.13	
Grain valued at 29 t/kg./h	21.93	
Traction costed at P 50/ha; no ploughing labour/i	22.42	

a. Average labour time for 2SP trial plots valued at the Labour Based Drought Relief wage of P .38/hour.
b. Average yield for DP trial plots valued at P .43/kg, the prevailing rate in Matobo for the 1985-86 harvest season.
c. Average labour time for DP trial plots valued at the Labour Based Drought Relief wage of P .38/hour.
d. Average yield for 2SP trial plots valued at P .43/kg, the prevailing rate in Matobo for the 1985-86 harvest season.
e. Based on average yields for three trials with largest positive difference in yields between DP and 2SP.
f. Based on average yields for three trials with largest negative difference in yields between DP and 2SP.
g. The urban minimum wage rate.
h. The BAMB guaranteed price (P 20.55 per 70 kg) for producers of number 2 mixed sorghum in 1986-87.
i. ARAP tractor hire rate.

These two issues are addressed in a partial budgeting framework with results presented in Tables 8 and 9. Each budget presents the expected changes in costs and benefits associated with the proposed shift in tillage system. The main costs and benefits considered are grain yields, labour time, and seed costs. Resources are valued at appropriate opportunity costs. In the case of labour, this is the Labour Based Drought Relief wage. For yields, the price received by farmers for their grain in Matobo is used. The second part of each table presents a sensitivity analysis of the basic budget taking into account different yields, resource use levels and resource valuations.

As with the returns analysis, few unequivocal statements can be made concerning the partial budget analysis. In considering double ploughing versus single ploughing one hectare and double ploughing versus single ploughing two hectares, the double ploughing provides net gains of almost P4 and P22 per hectare in the comparison with single ploughing one and two hectares, respectively.

In comparing DP with SP1 in this drought year, the increased labour cost in the DP system (involving increases in ploughing, weeding and processing labour) are just paid for by the increased yields. If the three yields where the difference between DP and SP1 are greatest are compared, then DP performs much better, however the three plots where the yield difference was greatest in favour of SP1 show a P21 net loss for shifting systems. An increase in the labour wage rate to the urban wage rate produced a net loss for a shift to DP from SP1, while valuing the grain at the BAMB producer guaranteed price produced a similar negative value for the shift. If traction is hired rather than provided by the farmer, there is an increase to P35 in the net loss if the ARAP price of P50 per hectare is used, while the net loss is less than P10 if the traction is valued at P25 per hectare. In this case, the value of grain produced under either system is insufficient to pay the tractor hire cost, so ploughing should not be hired.

In comparing the double ploughed and two single ploughed hectare systems, the changes in net gain for the top and bottom three differences in yields are a net gain of P67 and net loss of P28 from the shift. Valuing labour at the urban wage rate increases the net gain by a third, and valuing grain at the BAMB rate reduces the net gain slightly. When traction is hired rather than provided by the farmer, there is a slight increase in the net gain from changing systems.

CONCLUSIONS

In strictly agronomic terms, conclusions from these trials were:

(a). On average, DP did increase per hectare grain yields significantly;

(b). There did not appear to be any major differences in the DP effect, when using an interval of one versus two rains between the first and second ploughings; and

(c). There was evidence to support other data indicating that the effects of DP can be obtained even when the first ploughing is not done "early": as long as there is sufficient post planting rainfall to produce a yield.

A more complete picture of the relative benefits of DP versus SP1 or SP2 is obtained through economic analysis. From these data, it appeared that double ploughing one hectare required the same amount of labour as ploughing

two hectares once only, and that DP did significantly reduce the amount of weeding per hectare when compared to two hectares single ploughed. The data also suggested that farmers could expect approximately the same amount of grain from one double ploughed hectare as from two single ploughed hectares. The primary benefit, from the double ploughing system, as compared to two single ploughed hectares, was that it reduced the total amount of labour required to produce a given amount of grain by 43 percent.

If labour was a constraint, then labour spent on double ploughing plots yielded a higher return per hour than labour on either of the other two systems. For the same amount of grain, the net return to labour was 35 percent higher for the double ploughing system over the two hectares single ploughed. An increase in yield of 102 percent was achieved when comparing DP and a single ploughed hectare, for an increase in labour of only 35 percent. Returns to team hours also were greater for the double ploughing system. Thus, if the number of hours a team could be in the field was limited because the ground was too dry for plough/planting, then the time spent on double plough operations was returning 372 percent more net returns than time spent single ploughing one hectare, while net returns to traction for two hectares single ploughed were a negative P.42 per hour.

Utilizing a partial budget analysis shows that the average net grain from shifting to DP from SP1 is positive, but the results are sensitive to changes in wages, grain value and hired traction costs, all of which produce a net loss from the shift. The shift from single ploughing two hectares to double ploughing one hectare is a more positive shift with changes in labour value, crop value and changing to hired traction all resulting in net positive gains.

While the evidence from returns analysis and partial budgeting analysis is not overwhelming, it does indicate that, given the conditions faced in 1986-87, the shift to double ploughing from single ploughing two hectares is worth considering. The shift from single ploughing one hectare to double ploughing one hectare is less likely to be profitable. There is a risk that the shift from SP1 to DP would be detrimental if grain prices decreased or labour prices increased, or if traction hire were required. However, on average, the shift from either SP1 or SP2 to DP appears to be slightly beneficial.

ENDNOTES

1. Because of the small plots involved in the experiment, 10 by 40 metres, the amount of time spent turning animals was much higher than if the plots were 100 or 125 metres long, a more common length. Based on measured turn times and run times an adjustment of -14.06 percent was arrived at to account for the extra turning time. Hence, per hectare ploughing and planting operation times were adjusted downward by that factor.

2. Steel and Torrie suggest that "Tests of hypotheses with meaningfully paired observations are seen to reduce to testing that the mean of differences is a specified number, often zero." (p.102) Thus in most cases the hypotheses being tested was that the mean of the differences in each paired comparison among the three trials was zero. This involved three separate tests to test all possible combinations of the three trials.

Because the test used was a paired comparisons test where the mean of the differences was compared to zero (rather than testing the difference of the means of the two trials), and because the difference was being compared in each pairwise test, it was possible to obtain a significant result between a pair which had a lower absolute difference between their means than a pair with a higher absolute difference between their means but with a non-significant test result.

3. These percentages are in part due to averaging the gross and net returns to labour. If the gross and net returns for the mean hours of labour, GTVP and NTVP are calculated, then the gross and net returns to labour are calculated on the basis of these average figures, there is a difference in the percentage gain or loss for DP versus the SP1 and SP2 systems. Thus the difference in returns is partly due to averaging and, because there are so few plots involved, the averages may not reflect the true relationships among yields, costs and hours of labour which are included in the individual gross and net returns to labour calculations.

BIBLIOGRAPHY

ATIP, ATIP Annual Report Number 4, September 1986. ATIPRD 86-1.

Steel, R.G.D. and J.H. Torrie, Principles and Procedures of Statistics, second ed., McGraw Hill Book Co., NY, 1980.

Heinrich, G., F. Worman, S. Masikara, and R. Gray, 1986 Drought Management and Early Ploughing Trial, August 1987, ATIP PR F86-2 (Revised).

APPENDIX A

TABLE A1 LABOUR TIMES, HOURS PER HECTARE, DOUBLE PLOUGHING TRIALS, FRANCISTOWN AREA, 1986-87/a

LOC	PLOT	YIELD KG/HA	PLOUGH TIME	PLANT TIME	BC SEED TIME	TOTAL PREP	WEED TIME	PROC TIME	TOTAL TIME
1	1	8.25	0.00	25.35	0.75	26.10	67.50	10.00	103.60
1	2	80	39.99	30.08	0.75	70.79	12.50	56.50	139.79
1	3	87.5	0.00	28.79	0.75	29.54	17.50	40.75	87.7[illegible]
1	4	227.5	43.40	34.38	0.50	78.28	3.00	137.25	218.53
1	5	75	0.00	33.09	0.75	33.84	17.00	38.50	89.34
2	1	0	0.00	24.49	0.75	25.24	81.00	0.00	106.24
2	2	0	28.43	16.76	1.50	44.69	167.00	0.00	211.69
2	3	0	0.00	17.15	1.00	18.99	48.75	0.00	67.44
2	4	22.5	25.78	19.77	1.25	46.80	17.25	20.50	84.55
2	5	7.5	0.00	14.18	1.50	15.68	18.00	9.00	42.68
3	1	55	0.00	26.35	0.75	29.10	76.25	6.00	108.35
3	2	182.5	24.06	40.39	0.25	64.71	9.75	13.25	97.71
3	3	157.5	0.00	24.49	0.25	24.74	9.75	11.50	45.99
3	4	50	27.50	19.77	0.50	47.77	36.25	18.50	102.52
3	5	0	0.00	24.49	0.50	24.99	32.25	0.00	57.24
4	1	0	0.00	37.39	1.00	38.38	41.75	0.00	80.13
4	2	200	27.07	23.63	0.75	51.45	65.00	9.00	125.45
4	3	125	0.00	30.51	0.75	31.26	81.50	2.50	115.26
4	4	125	32.68	26.21	0.75	59.62	20.50	10.00	90.12
4	5	87.5	0.00	30.08	0.75	30.83	20.50	4.00	55.33
4	6	105	0.00	36.09	1.00	37.09	65.00	6.25	108.34
4	7	200	36.95	26.21	0.75	63.92	21.75	17.00	102.67
4	8	1	0.00	36.09	1.00	37.09	26.00	1.50	64.59
5	1	250	0.00	27.50	0.50	28.00	66.00	23.75	117.75
5	4	0	25.78	24.92	1.00	51.70	21.50	0.00	73.20
5	5	0	0.00	24.81	0.75	35.56	30.00	0.00	125.56
AVERAGE 1[8]		74.38	0.00	29.36	0.79	30.15	66.25	7.67	104.07
AVERAGE 2[7]		132.50	30.90	27.42	0.80	59.11	55.00	19.15	133.45
AVERAGE 3[8]		74.20	0.00	27.42	0.85	28.27	38.70	11.25	78.22
AVERAGE 4		35.00	31.32	25.01	0.80	56.83	19.70	37.25	113.78
AVERAGE 5		34.00	0.00	27.33	0.85	28.18	35.55	10.30	74.03
AVERAGE 2&4		158.75	30.96	26.21	0.80	57.97	37.45	28.20	123.62
AVERAGE 3&5		54.10	0.00	27.37	0.85	28.22	36.13	10.78	75.12
OVERALL AVE		79.34	30.36	27.15	0.83	40.33	41.55	17.91	99.80

a.PLOUGH = Plough Time First Ploughing of Double Ploughing
PLANT = Plough/Plant Operation
BC SEED = Broadcast Seed before Planting
TOTAL PREP = Sum of PLOUGH, PLANT and BC SEED
PROC = Harvesting and Threshing Time

TABLE A2 TEAM PLOUGHING HOURS/HECTARE AND RETURNS, DOUBLE PLOUGHING TRIAL, FRANCISTOWN AREA, 1986-87

LOCATION	PLOT	YIELD KG/HA	TOTAL TEAM HOURS	POST/PL PERSON HOURS/HA	GTVP/a PULA	POST/PL LABOUR/b COST	NTVP/c PULA	GROSS RETURNS PER HR	NET TRACT PER HR
				SINGLE PLOUGH PLOTS					
1	3	88	14.55	58.25	37.53	22.14	34.93	1.09	0.89
1	5	75	16.54	55.50	32.25	21.09	29.55	0.97	0.51
2	3	0	9.69	48.75	0.00	19.53	-2.70	-2.16	-2.47
2	5	8	7.09	27.00	3.23	10.25	0.53	-0.99	-1.37
3	3	157.5	12.25	21.25	67.73	8.08	65.03	4.87	4.65
3	5	0	12.25	32.25	0.00	12.26	-2.70	-1.00	-1.22
4	3	125.00	15.25	84.00	53.75	31.92	51.05	1.43	1.25
4	5	87.50	15.04	24.50	37.63	9.31	34.93	1.88	1.70
4	8	1	18.05	27.50	0.43	10.45	-2.27	-0.56	-0.70
5	5	0	17.40	90.00	0.00	34.20	-2.70	-1.97	-2.12
AV SINGLE PLO		54.10	13.69	46.90	23.26	17.82	20.56	0.33	0.11
				DOUBLE PLOUGH PLOTS					
1	2	80	35.02	60.00	34.40	26.22	31.70	0.23	0.16
1	4	228	38.20	140.25	97.93	53.30	95.13	1.15	1.28
2	2	0	17.19	167.00	0.00	63.46	-2.70	-3.69	-3.85
2	4	23	18.48	37.75	9.68	14.35	6.98	-0.25	-0.40
3	2	183	22.13	23.00	78.48	8.74	75.79	3.15	3.03
3	4	50	23.93	54.75	21.50	20.81	18.80	0.33	-0.08
4	2	200	25.35	74.00	86.00	28.12	83.30	2.28	2.19
4	4	125	29.43	30.50	53.75	11.59	51.05	1.43	1.34
4	7	200	31.58	38.75	86.00	14.73	83.30	2.28	2.17
5	4	0	25.35	21.50	0.00	8.17	-2.70	-0.32	-0.43
AV DOUBLE PLO		108.75	26.71	65.65	45.76	24.35	44.06	0.63	0.52
				TWO SINGLE PLOUGHED PLOTS COMBINED					
1	1 & 3	94	27.07	135.75	40.31	51.53	34.91	-0.42	-0.62
1	1 & 5	81	29.22	133.00	34.94	50.54	29.54	-0.53	-0.72
2	1 & 3	0	16.76	129.75	0.00	49.31	-5.40	-2.34	-2.26
2	1 & 5	8	15.25	108.00	3.23	41.04	-2.18	-2.48	-2.83
3	1 & 3	243	24.32	103.50	104.29	39.33	98.88	2.61	2.39
3	1 & 5	85	24.92	114.50	36.55	43.51	31.15	-0.29	-0.50
4	1 & 3	125	33.95	125.75	53.75	47.79	46.35	0.18	0.02
4	1 & 5	88	33.79	99.25	37.83	25.18	32.23	0.37	0.21
4	8 & 3	106	38.74	98.75	45.58	37.53	40.18	0.22	0.07
5	1 & 5	250	31.15	179.75	107.50	68.31	102.10	1.28	1.08
AV 2 SINGLE PLO		107.85	27.37	119.50	46.38	45.41	40.98	-0.20	-0.42

a.GTVP = Gross Total Value Product (yield x price) where price = P.43/kg.
b.POST PLANTING LABOUR COSTS = Labour for weeding and processing valued at the Labour Based Drought Relief wage rate of P.38/hour.
c.NTVP = Net Total Value Product (GTVP - COSTS) where COSTS (per hectare) = seed - P.30/kg for 4 kg, equipment estimated P1.50.

TABLE A3 LABOUR TIME, HOURS/HECTARE, IN PULA, DOUBLE PLOUGHING TRIALS, FRANCISTOWN AREA, 1986-87

LOC	PLOT	YIELD KG/HA	ACTIVITY TIME PREP/a HOURS	POST/PL/b HOURS	TOTAL HOURS	GTVP/c PULA	POST/PL LABOUR COST	NTVP/d PULA	GROSS RETURN LAB/HR	NET RETURN LAB/HR	GROSS RETURN PREP/HR	NET RETURN PREP/HR
					SINGLE PLOUGHED PLOTS							
1	3	88	29.54	58.25	87.79	37.63	22.14	34.93	0.43	0.40	0.52	0.43
1	5	75	33.84	55.50	89.34	32.25	21.09	29.55	0.36	0.33	0.33	0.25
2	3	0	18.69	48.75	67.44	0.00	19.53	-2.70	0.00	-0.04	-0.99	-1.14
2	5	8	15.68	27.00	42.68	3.23	10.25	0.53	0.08	0.01	-0.45	-0.62
3	3	157.5	24.74	21.25	45.99	67.73	8.08	65.03	1.47	1.41	2.41	2.30
3	5	0	24.99	32.25	57.24	0.00	12.25	-2.70	0.00	-0.05	-0.49	-0.60
4	3	125.00	31.25	84.00	115.25	53.75	31.92	51.05	0.47	0.44	0.70	0.61
4	5	87.50	30.83	24.50	55.33	37.63	9.31	34.93	0.68	0.63	0.92	0.83
4	8	1	37.00	27.50	64.59	0.43	10.45	-2.27	0.01	-0.04	-0.27	-0.34
5	5	0	35.58	90.00	125.58	0.00	34.20	-2.70	0.00	-0.02	-0.96	-1.04
AV SINGLE PLO		54	28.22	46.90	75.12	23.26	17.82	20.56	0.35	0.31	0.17	0.07
					DOUBLE PLOUGHED PLOTS/e							
1	2	80	70.79	60.00	130.79	34.40	26.22	31.70	0.25	0.23	0.12	0.08
1	4	228	78.29	140.25	218.53	97.93	53.30	95.13	0.45	0.44	0.57	0.53
2	2	0	44.69	167.00	211.69	0.00	63.46	-2.70	0.00	-0.01	-1.42	-1.48
2	4	23	46.80	37.75	84.55	9.68	14.35	6.98	0.11	0.08	-0.10	-0.16
3	2	183	64.71	23.00	87.71	78.48	8.74	75.79	0.89	0.86	1.08	1.04
3	4	50	47.77	54.75	102.52	21.50	20.81	18.80	0.21	0.18	0.01	-0.04
4	2	200	51.45	74.00	125.45	86.00	28.12	83.30	0.69	0.66	1.12	1.07
4	4	125	59.52	30.50	90.12	53.75	11.59	51.05	0.60	0.57	0.71	0.66
4	7	200	63.92	38.75	102.67	86.00	14.73	83.30	0.94	0.81	1.12	1.07
5	4	0	51.70	21.50	73.20	0.00	8.17	-2.70	0.00	-0.04	-0.16	-0.21
AV DOUBLE PL		109	57.97	65.65	123.62	45.76	24.35	44.06	0.40	0.38	0.30	0.26
					TWO SINGLE PLOUGHED PLOTS COMBINED							
1	1 & 3	94	55.64	135.75	191.39	40.31	51.59	34.91	0.21	0.18	-0.20	-0.30
1	1 & 5	81	59.34	133.00	192.34	34.94	50.54	29.54	0.13	0.15	-0.26	-0.35
2	1 & 3	0	43.93	129.75	173.68	0.00	49.31	-5.40	0.00	-0.03	-1.12	-1.25
2	1 & 5	8	40.92	108.00	148.92	3.23	41.04	-2.18	0.02	-0.01	-0.92	-1.06
3	1 & 3	243	50.85	103.50	154.35	104.29	39.33	98.88	0.68	0.64	1.39	1.17
3	1 & 5	85	51.10	114.50	165.60	36.55	43.51	31.15	0.22	0.19	-0.14	-0.34
4	1 & 3	125	69.64	125.75	195.39	53.75	47.79	46.35	0.28	0.25	0.09	0.01
4	1 & 5	88	69.21	99.25	168.46	37.63	25.18	32.23	0.29	0.24	0.18	0.10
4	5 & 8	106	74.19	98.75	172.94	45.58	37.53	40.18	0.26	0.23	0.11	0.04
5	1 & 5	250	63.56	179.75	243.31	107.50	68.31	102.10	0.44	0.42	0.62	0.53
AV 2 SINGLE PLO		108	57.00	119.50	177.40	46.38	45.41	40.98	0.26	0.23	0.04	-0.13

a.PREP TIME = Preparation Time includes ploughing and planting.
b.POST PLANTING TIME includes weeding, harvesting and threshing.
c.GTVP = Gross Total Value Product (yield x price) where price = P.43/kg.
d.NTVP = Net Total Value Product (GTVP - COSTS) where COSTS (per hectare) = seed - P.30/kg for 4 kg, equipment estimated P1.50
e.Costs for double ploughed plots include two equipment costs and one seed cost (P4.20/ha).

APPENDIX B

This appendix contains the entire labour data set including the location 4 plots which were not included in the main analysis because of the presence of an old ant hill in plot 2 which was considered to have invalidated that plot information and its use in comparisons with plot 3.

TABLE B1 LABOUR TIMES, HOURS PER HECTARE, DOUBLE PLOUGHING TRIALS, FRANCISTOWN AREA, 1986-87/a

LOC	PLOT	YIELD KG/HA	PLOUGH TIME	PLANT TIME	BC SEED TIME	TOTAL PREP	WEED TIME	PROC TIME	TOTAL TIME
1	1	6.25	0.00	25.35	0.75	26.10	67.50	10.00	103.60
1	2	80	39.98	30.08	0.75	70.79	12.50	56.50	139.79
1	3	87.5	0.00	28.79	0.75	29.54	17.50	40.75	87.79
1	4	227.5	43.40	34.38	0.50	78.28	3.00	137.25	218.53
1	5	75	0.00	33.09	0.75	33.84	17.00	38.50	89.34
2	1	0	0.00	24.49	0.75	25.24	31.00	0.00	106.24
2	2	0	26.43	16.78	1.50	44.69	167.00	0.00	211.69
2	3	0	0.00	17.19	1.50	18.69	48.75	0.00	67.44
2	4	22.5	25.78	19.77	1.25	46.80	17.25	20.50	84.55
2	5	7.5	0.00	14.13	1.50	15.63	18.00	9.00	42.63
3	1	85	0.00	25.35	0.75	26.10	76.25	6.00	108.35
3	2	182.5	24.06	40.39	0.25	64.71	9.75	13.25	87.71
3	3	157.5	0.00	24.49	0.25	24.74	9.75	11.50	45.99
3	4	50	27.50	19.77	0.50	47.77	36.25	18.50	102.52
3	5	0	0.00	24.49	0.50	24.99	32.25	0.00	57.24
4	1	0	0.00	37.38	1.00	38.38	41.75	0.00	80.13
4	2	200	27.07	23.63	0.75	51.45	65.00	9.00	125.45
4	3	125	0.00	30.51	0.75	31.26	81.50	2.50	115.26
4	4	125	32.66	26.21	0.75	59.62	20.50	10.00	80.12
4	5	87.5	0.00	30.08	0.75	30.83	20.50	4.00	55.33
4	6	105	0.00	36.09	1.00	37.09	65.00	6.25	108.34
4	7	200	36.95	26.21	0.75	63.92	21.75	17.00	102.67
4	8	1	0.00	36.09	1.00	37.09	26.00	1.50	64.59
5	1	250	0.00	27.50	0.50	28.00	66.00	23.75	117.75
5	2	362.5	25.79	21.06	0.50	47.34	28.50	69.25	145.09
5	3	450	0.00	24.43	0.25	24.74	15.00	54.25	93.99
5	4	3	25.79	24.82	1.00	51.70	21.50	0.00	73.20
5	5	0	0.00	34.81	0.75	35.56	30.00	0.00	125.56
AVERAGE 1(5)		74.38	0.00	29.38	0.70	30.15	68.25	7.67	104.07
AVERAGE 2(7)		170.33	30.04	26.36	0.75	57.15	50.75	27.50	135.40
AVERAGE 3(8)		136.83	0.00	25.33	0.75	27.58	33.09	13.42	73.18
AVERAGE	4	85.00	31.02	25.01	0.80	56.03	19.70	37.25	113.78
AVERAGE	5	34.00	0.00	27.33	0.85	28.18	35.55	10.30	74.03
AVERAGE 2 & 4		131.92	30.49	25.74	0.77	57.01	36.64	31.93	125.57
AVERAGE 3 & 5		90.09	0.00	27.11	0.80	27.31	34.20	14.73	76.84
OVERALL AVERAGE		79.34	30.49	27.18	0.81	40.33	41.55	17.81	99.80

a.PLOUGH = Plough Time First Ploughing of Double Ploughing
PLANT = Plough/Plant Operation
BC SEED = Broadcast Seed before Planting
TOTAL PREP = Sum of PLOUGH, PLANT and BC SEED
PROC = Harvesting and Threshing Time

TABLE B2 AVERAGE LABOUR TIME, PERSON HOURS/HECTARE, DOUBLE PLOUGHING TRIALS, FRANCISTOWN AREA, 1986-87/a

	YIELD KG/HA	ACTIVITY TIME PREP/b HOURS	WEED HOURS	PROC/c HOURS	TOTAL HOURS
AV SINGLE PL/HA	90x	28a	34a	15x	77xa
AV DOUBLE PL/HA	132	57b	37a	32	126ya
AV 2 SINGLE PL/2HA	162y	57b	101b	23y	181b

a.Within columns, means followed by different letters [a,b] and [x,y] differ signif'cantly [P < .01] and [P < .05], respectively. Based on pairwise comparisons between treatments./2
b.PREP TIME = Preparation Time includes ploughing and planting.
c.PROC TIME = Processing Time includes harvesting and threshing.

TABLE B3 AVERAGE RETURNS TO LABOUR, IN PULA, DOUBLE PLOUGHING TRIALS, FRANCISTOWN AREA, 1986-87/a

	YIELD KG/HA	ACTIVITY TIME PREP/b HOURS	POST/PL/c HOURS	TOTAL HOURS	GTVP/d PULA	POST/PL LABOUR COST	NTVP/e PULA	GROSS RETURN/f LAB/HR	NET RETURN LAB/HR	GROSS RETURN PREP/HR	NET RETURN PREP/HR
AV SINGLE PLO	90x	28a	49a	77xa	38.74x	18.50a	36.04x	0.50	0.46	0.77	0.67
AV DOUBLE PLO	132	57	69b	126ay	56.68	25.00a	53.38	0.45	0.44	0.50	0.48
AV 2 SINGLE PLO	162y	62b	120b	180b	69.50y	48.77b	64.10y	0.36	0.33	0.45	0.36

a.Within columns, means followed by different letters [a,b] and [x,y] differ significantly [P < .01] and [P < .05], respectively. Based on pairwise comparisons between treatments./2
b.PREP TIME = Preparation Time includes ploughing and planting.
c.POST PLANTING TIME includes weeding, harvesting and threshing.
d.GTVP = Gross Total Value Product [yield x price] where price = P.43/kg.
e.NTVP = Net Total Value Product [GTVP - COSTS] where COSTS [per hectare] = seed - P.30/kg for 4 kg, equipment estimated P1.50.
f.GROSS and NET RETURNS are averages of RETURNS by plot, so are slightly different than RETURNS calculated using the averages of activity times and values.

TABLE B4 AVERAGE RETURNS TO TEAM PLOUGHING HOURS, IN PULA, DOUBLE PLOUGHING TRIAL, FRANCISTOWN AREA, 1986-87/a

	YIELD KG/HA	TOTAL TEAM HOURS	POST PLANT HOURS	GTVP/b PULA	POST/PL LABOUR/c COST	NTVP/d PULA	GROSS RETURNS/e PER HR	NET TRACT PER HR
AV SINGLE PLO	90x	14a	43a	38.74x	18.59a	26.04x	1.54	1.32
AV DOUBLE PLO	132	26b	69a	56.68	26.06a	53.98	1.03	0.92
AV 2 SINGLE PLO	162y	27b	123b	69.52y	45.77b	64.12y	0.60	0.44

a.Within columns, means followed by different letters [a,b] and [x,y] differ significantly [P < .01] and [P < .05], respectively. Based on pairwise comparisons between treatments./2

b.GTVP = Gross Total Value Product [yield x price] where price = P.43/kg.

c.POST PLANTING LABOUR COSTS = Labour for weeding and processing valued at the Labour Based Drought Relief wage rate of P.38/hour.

d.NTVP = Net Total Value Product [GTVP - COSTS] where COSTS [per hectare] = seed - P.30 /kg for 4 kg, equipment estimated P1.50.

e.GROSS and NET RETURNS to TRACTION are averages of returns by plot, so are slightly different than returns calculated using the averages of activity times and values.

TABLE B5 PARTIAL BUDGET: DOUBLE PLOUGHING INSTEAD OF SINGLE PLOUGHING ON A SINGLE HECTARE, DOUBLE PLOUGHING TRIALS, FRANCISTOWN AREA, 1986-87

PART A: BASIC BUDGET ANALYSIS

REDUCED COST		
Total labour hours SP [76.3 hrs @ 38 t/hr]/a	29.18	
ADDED BENEFIT		
Double plough yield [132 kgs @ 43 t/kg]/b	56.76	
SUB-TOTAL		85.94
ADDED COST		
Total labour hours DP [125.6 hrs @ 38 t/hr]/c	47.73	
Depreciations/d	1.50	
REDUCED BENEFIT		
Single plough yield [90 kg]/e	38.70	
SUB-TOTAL		87.93
NET GAIN		-1.98

PART B: SENSITIVITY ANALYSIS

	NET GAIN
YIELDS, RESOURCE USE AND VALUATION	
Top three yield differences/f	41.02
Bottom three yield differences/g	-33.68
Labour valued at 53 t/hr./h	-9.30
Grain valued at 29 t/kg./i	-7.88
Traction costed at 50 P/ha; no ploughing labour/j	-40.93
Traction costed at 25 P/ha; no ploughing labour/k	-15.33

a.Average labour time for SP trial plots valued at the Labour Based Drought Relief wage of P.38/hour.

b.Average yield for DP trial plots valued at P.43/kg, the prevailing rate in Metobo for the 1985-86 harvest season.

c.Average labour time for DP trial plots valued at the Labour Based Drought Relief wage of P.38/hour.

d.Depreciation of equipment estimated at P1.50 per hectare ploughed.

e.Average yield for SP trial plots valued at P.43/kg, the prevailing rate in Metobo for the 1985-86 harvest season.

f.Based on average yields for three trials with largest positive difference in yields between DP and SP.

g.Based on average yields for three trials with largest negative difference in yields between DP and SP.

h.The urban minimum wage rate.

i.The BAMB guaranteed price [P20.55 per 70 kg] for producers of number 2 mixed sorghum in 1986-87.

j.ARAP tractor hire rate.

k.Slightly above the Mahalapye donkey hire rate.

TABLE 88 PARTIAL BUDGET: DOUBLE PLOUGHING INSTEAD OF SINGLE PLOUGHING TWO HECTARE, DOUBLE PLOUGHING TRIALS, FRANCISTOWN AREA, 1986-87

PART A: BASIC BUDGET ANALYSIS		
REDUCED COST		
Total labour hours 2SP [180.52 hrs @ 38 t/hr]/a	68.80	
Seed saving [4 kg @ 30 t/kg]	1.20	
ADDED BENEFIT		
Double plough yield [132 kgs @ 43 t/kg]/b	58.79	
SUB-TOTAL		128.58
ADDED COST		
Total labour hours DP [125.6 hrs @ 38 t/hr]/c	47.73	
REDUCED BENEFIT		
Two single plough hectares yield [152 kg]/d	69.66	
SUB-TOTAL		117.39
NET GAIN		9.17

PART B: SENSITIVITY ANALYSIS

	NET GAIN
YIELDS, RESOURCE USE AND VALUATION	
Top three yield differences/e	37.26
Bottom three yield differences/f	-70.72
Labour valued at 53 t/hr./g	17.41
Grain valued at 23 t/kg./h	13.37
Traction costed at 50 P/ha; no ploughing labour/i	9.02

a. Average labour time for 2SP trial plots valued at the Labour Based Drought Relief wage of P.38/hour.
b. Average yield for DP trial plots valued at P.43/kg, the prevailing rate in Matobo for the 1985-86 harvest season.
c. Average labour time for DP trial plots valued at the Labour Based Drought Relief wage of P.38/hour.
d. Average yield for 2SP trial plots valued at P.43/kg, the prevailing rate in Matobo for the 1985-86 harvest season.
e. Based on average yields for three trials with largest positive difference in yields between DP and 2SP.
f. Based on average yields for three trials with largest negative difference in yields between DP and 2SP.
g. The urban minimum wage rate.
h. The BAMB guaranteed price [P20.55 per 70 kg] for producers of number 2 mixed sorghum in 1986-87.
i. ARAP tractor hire rate.