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PROGRESS REPORT

1985 DRAUGHT MANAGEMENT AND EARLY PLOUGHING TRIAL
(RESEARCHER MANAGED/FARMER IMPLEMENTED)

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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) Draught Management and Early Ploughing Trials carried out in the villages of Matobo and Mathangwane, Tutume Agricultural District, during the 1985-86 cropping season. The report covers the agronomic and labour data collected and provides an analysis of returns and a partial budget analysis. The report also discusses the feasibility of feeding animals for early ploughing and reports results of forage collection on one farm.

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1986 DRAUGHT MANAGEMENT AND EARLY PLOUGHING TRIAL (RM.FI)

ABSTRACT

Three farmers using cattle draught and one using donkey draught power participated in the Draught Management and Early Ploughing Trial conducted by the ATIP Francistown staff during the 1985-86 cropping season. In this researcher managed, farmer implemented trial, supplemental feed was provided for the animals so they were in condition to start ploughing with the first rains. 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 loss in yield from ploughing and not planting) and the other planted the same day as the double ploughed plot. Labour data were collected on all operations and costs of feeding were recorded.

The results indicated that the double ploughing system doubled yield on a per hectare basis, and produced the same yield as two hectares single ploughed. The advantage of the double ploughing system was that it reduced total labour by 18 percent for the same grain yield. Returns to labour and to traction time were also greater for the double ploughing system. While supplemental feeding of animals was feasible, it is not likely to be done given the socio-economic situation in Tutume District. The increased yield from double ploughing was not dependent on early ploughing, so supplemental feeding would not be necessary to attain yield per hectare benefits from double ploughing. The trial also indicated that forage harvesting would be worthwhile if there was a direct or indirect market for the forage.

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.

OBJECTIVES

(a). To determine procedures necessary to have draught animals in proper condition for ploughing immediately after the first planting rain.

(b). To determine the feasibility, cost, input requirements, potential benefits and economic returns associated with having draught animals ready to plough at the first opportunity.

(c). To further refine and test the double ploughing system and assess the economic benefits thereof.

(d). To examine whether ploughing with the first rains is necessary in order to realize benefits from double ploughing.

JUSTIFICATION

Botswana agricultural researchers have established the positive effects of early ploughing, without planting, on moisture conservation and grain yield. However, farmers who do not have access to a tractor usually cannot do early

ploughing because of the poor condition of their draught animals. The most limiting factor is usually the lack of adequate forage (feed) both at the cattle post and at the lands during the weeks immediately preceding the early rains. Feed available in the form of crop residue and hay are a fair source of energy (carbohydrates) but are a poor source of protein. Lack of protein decreases appetite, thus leading to inadequate energy intake (McDowell).

Research conducted by ATIP/Francistown in 1984-85, suggested that there was considerable potential to increase per hectare crop yields through adding a single early ploughing to the traditional system (ATIP Annual Report Number 3). However, providing supplemental feed to draught animals in the dry season was costly, and required further economic analysis. Also, it was felt necessary to test the system again to verify the 1984-85 agronomic results, to further refine the system, and to conduct a more detailed economic analysis of the double ploughing option. (Specifically this involved including more check plots to examine opportunity costs of double ploughing, and effects on total labour.)

APPROACH

The study was conducted with five farmers. Four used cattle for draught power and one used donkeys. The supplemental feeding programme included forage (wild grasses from the Pandamatenga area cut and dried as hay) and a mineral-mix made up of 50 percent salt and 50 percent dicalcium phosphate. The hay was purchased from the Livestock Advisory Centre, Francistown for P1.50 per bale (20 kg/bale). In addition, oxen farmers were supplied with Rumevite (urea-mineral) blocks. Forage feeding began the first week of September and continued through November. The numbers of animals fed varied from 12 to 21 cattle, since farmers were unable to separate the draught animals from the rest of the herd.

Supplemental feeding was done to ensure that animals were in condition to perform an "early ploughing" operation at the onset of the rainy season. All participating farmers performed this operation.

In the field, plot layout consisted of two blocks of five plots each. Plots were 10m by 40m. In the first block the ploughing and planting schedules were as follows:

Rain 1 Plough/plant plot 1, plough (only) plots 2 and 4
Rain 2 Plough/plant plots 2 and 3
Rain 3 Plough/plant plots 4 and 5

The result was that plot 1 was planted in the traditional way on the date when early ploughing was done in plots 2 and 4. Plot 3 was planted in the traditional way on the same day that plot 2 was planted thus plots 1 and 3 were traditional checks for plot 2. In the same way, plots 1 and 5 served as traditional checks for plot 4.

The second block of 5 plots was ploughed and planted in the same manner as block 1. The only difference was that the first ploughing on the second block started on the 4th planting rain. This was to test whether the first ploughing of the double ploughing system had to be performed early in the season to provide a reasonable benefit to crop growth, or whether the same benefits could be achieved when the first ploughing was done late in the season. This question is very relevant, because if a late start makes no difference, then dry season feeding of draught animals becomes much less important.

Data collected on the field trials included stand density measurements (twenty 4 square metre quadrat samples per plot) and grain yield measurements (plots harvested and threshed separately by the owner of the field, then weighed by ATIP staff). In addition, all field activities (such as ploughing) were timed by ATIP staff, using stop watches, and records were kept on the sex and number of people performing each operation, from first ploughing through threshing. Time values used covered the total time it took to perform an operation from start to finish on a plot.

Crops planted were millet (v. Serere 6A) in Mathangwane and Marapong villages, and sorghum (v. Segaolane) in Matobo village. Analysis of results was performed by comparing various groups of plots (across locations) to answer specific questions. In general, the differences between paired plots were tested to determine whether the mean difference was the same or different from zero. (As per Steel and Torrie, p. 102.) This allowed somewhat more precision than a general t-test when comparing meaningfully paired observations.

AGRONOMIC RESULTS

Rainfall data for the growing season are given by farm and month in Table 1.

TABLE 1 RAINFALL AMOUNTS FOR FARMS PARTICIPATING IN THE DRAUGHT MANAGEMENT AND EARLY PLOUGHING TRIALS, FRANCISTOWN AREA, 1985-86

		RAINFALL (MM) BY MONTH								
FARMER	VILLAGE	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	TOTAL
1	Mathangwane	19	15	13	22	29	80	128	0	306
2	Mathangwane	30	50	24	28	39	60	145	0	376
3	Matobo	46	0	124	41	35	78	84	0	408
4	Matobo	37	0	80	37	35	47	78	0	314
5	Marapong	28	0	44	43	42	30	126	0	314

Ploughing and planting dates with resultant stand density and grain yields are given in Table 2.

No data from Marapong has been used in analysing trial results because of the two participants there, one dropped out early in the year, and the second abandoned her field before harvest. Normally an abandoned field should be included as zero yield, however the trial plots were surviving. Irregular rains and drought caused the majority of the farmer's plots to fail and eventually the trial plots were the only plots surviving in the field. These were not large enough to warrant the full time attention of a person to protect them so the farmer quit going to the field. Bird damage was severe, and later, someone turned cattle in on the field to graze, destroying the remainder of the crop. The trial would not have produced a zero yield had there been any other crops standing in the field. It is therefore treated as lost, rather than a no-yield plot.

The remaining data was examined to answer specific questions which are discussed below.

The first question was whether there were differences in stand densities achieved on single ploughed versus double ploughed plots. To test this,

mean stand densities were compared between plots in each block, across locations. For the first, second, third, fourth, and fifth plots averaged across the five blocks included in the analysis, mean stand densities were 31.7, 42.2, 30.6, 31.7, and 29 thousand plants per hectare, respectively. This is quite uniform. There were no significant differences among them.

TABLE 2 PLOUGHING AND PLANTING DATES, STAND DENSITY AND GRAIN YIELD DATA. DRAUGHT MANAGEMENT AND EARLY PLOUGHING TRIALS, FRANCISTOWN AREA, 1985-86

FARMER	BLOCK NBR.	PLOT NBR.	PLOUGH DATE/a	PLANTING DATE/a	STAND DENSITY (x 1000 PL/HA)	GRAIN YIELD (KG/HA)
1	1	1	67	67	1.6	20
	1	2	67	122	73.3	239
	1	3	122	122	41.6	150
	1	4	68	129	11.9	214
	1	5	129	129	2.5	43
2	1	1	65	65	6.5	3
	1	2	65	73	5.9	24
	1	3	73	73	3.0	10
	1	4	67	114	12.9	145
	1	5	114	114	25.3	93
3	1	1	96	96	51.5	149
	1	2	96	96	62.9	213
	1	3	106	109	48.9	88
	1	4	96	122	46.8	483
	1	5	122	122	31.5	356
4	1	1	67	67	12.6	374
	1	2	68	95	44.0	439
	1	3	95	95	51.0	266
	1	4	68	109	49.9	130
	1	5	109	109	48.4	263
	2	6	121	121	86.5	536
	2	7	121	129	24.9	875
	2	8	120	129	7.9	184
	2	9	121	156	37.0	711
	2	10	156	156	37.5	205

a. Dates given in days from September 1, 1985 = day 1.

The next question was whether double ploughed plots produced higher grain yields than single ploughed plots. This was compared in two ways. First, the yield of double ploughed plots (plots 2 and 4 block 1's or 7 and 9 block 2's) were contrasted with grain yields from the adjacent single ploughed plot that was planted on the same day. The differences between the two were examined to determine whether they were equal to zero or not. (Using the standard deviation of a mean difference.) The mean yield of the double ploughed plots was 347.3 kg/ha. The mean yield of the respective check plots (those planted on the same day) was 165.8 kg/ha. The average increase in per hectare grain yield due to the additional ploughing was 181.5 kg/ha, or an increase of 109 percent. This was significant at the five percent level.

The second approach taken was to examine whether there were any differences

between the yield of one hectare double ploughed, and the yield of two hectares single ploughed. This was done by comparing the yield of the two related check plots (i.e. the yield of each double ploughed plot versus the sum of the check planted when the double ploughed plot was first ploughed plus the check planted at the time of the second ploughing (planting)). Mean yields of the double ploughed plots were 347.3 kg/ha. Mean yields of the sum of the two respective check plots for each double ploughed plot was 342.2 kg/ha. In these trials, two hectares single ploughed yielded almost exactly the same as one hectare of double ploughed land. Thus these data indicate that the yield from one hectare double ploughed was equivalent to the yield from two hectares farmed in the traditional manner.

While overall there was practically no difference in yields from the DP and SP2 plots, there was a difference between yields from plots planted to millet and those planted to sorghum. Since millet was planted in Mathangwane and sorghum in Matobo, this difference may have been due to location as much as to crop. In the millet plots the DP yielded 155.5 kg/ha, while the SP2 plots yielded 85.5 kg/ha, a difference of 70 kg/ha or a 82 percent increase for the DP system. The plots planted to sorghum showed a different picture, with the DP plots yielding 475 kg/ha and the SP2 plots yielding 513 kg/ha. This represents a 8 percent advantage for the SP2 system.

OTHER AGRONOMIC QUESTIONS

In addition to the questions of stand count and increased yield, there were three other primary agronomic questions which were addressed with these experiments. First was the question of whether the opportunity cost of the initial ploughing in the DP system (as measured by yield forgone by only ploughing the first time without planting) could be reduced by ploughing at non-optimal planting times (i.e. when the soil was too dry to be good for planting). To address this question, yields of check plots planted at the time of first ploughing were compared with yields from check plots planted immediately after subsequent rains (i.e., when the DP plots were planted). There was some difficulty in this comparison because the DP plots were not always planted at the precisely optimum soil moisture. However, the comparison showed no significant differences. In this set of trials, the opportunity cost of the initial ploughing was not reduced. This could in part be explained by the fact that grain yields can be affected as much by the post-planting rainfall as by soil moisture conditions at planting. This question will be examined again in the next season.

The second question was whether there were any effects of allowing an interval of one rain versus an interval of two rains between the first ploughing and the second ploughing/planting operation. Again, analysis of these data indicate there was no difference.

Lastly, there was the question of whether "early" ploughing, on the first rain of the season, was necessary to obtain the benefits of double ploughing. This is an important question because it relates directly to the importance of providing supplemental feed to draught animals, to have them ready to plough on the first rain. A clear answer to this question was obtained from the data from farmer number 4. On this farm, the first ploughing/planting was done on day 67 (November 6th). The last planting in the first block of five plots was completed on day 109 (December 18th). A hot dry period during panicle development caused the differences between treatments in that block to be minimal. On the same farm, the first ploughing/planting was done in the second block of treatments on day 121 (December 30th), the last planting was done on day 156 (February 3rd). In

this last block, DP plots out yielded the sum of their two respective check plots by 355 and 170 kg/ha. Thus it is clear that benefits from double ploughing can still be obtained, even when the initial land preparation is done as late as the end of December. The implication is that the DP system could be of benefit to per hectare yields, even if the initial land preparation was performed late in the season i.e., it is not necessary to do the first ploughing on the first rain of the season to obtain an effect from double ploughing. Thus the supplemental feeding of draught animals to get them ready to plough on the first rain of the season is not necessary for obtaining yield benefits from double ploughing.

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. Labour for harvesting stover was estimated for one farmer. 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 much 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

TABLE 3 AVERAGE LABOUR TIMES, HOURS PER HECTARE. DRAUGHT MANAGEMENT AND EARLY PLOUGHING TRIALS, FRANCISTOWN AREA. 1985-86/a

	PLOT	YIELD KG/HA	PLOUGH TIME	PLANT TIME	BC SEED TIME	TOTAL PREP	WEED TIME	PROC TIME	TOTAL TIME
AVERAGE	1(6)	176	0.00	39.01	.95	39.97	43.20	33.65	116.82
AVERAGE	2(7)	358	35.54	36.48	.90	72.92	65.65	74.90	213.47
AVERAGE	3(8)	140	0.00	29.13	.80	29.93	40.90	36.85	107.68
AVERAGE	4(9)	337	32.83	36.05	.75	69.63	31.20	56.10	156.93
AVERAGE	5(10)	192	0.00	35.67	.90	36.57	23.05	38.40	98.02
AVERAGE	2 & 4	347	34.18	36.27	.83	71.27	48.43	65.50	185.20
AVERAGE	3 & 5	166	0.00	32.40	.85	33.25	31.98	37.62	102.85
OVERALL AVERAGE		241	34.18	35.27	.86	49.80	40.80	47.98	138.58

a. PLOUGH = Plough Time First Ploughing of Double Ploughing
PLANT = Plough/Plant Operation, Second Ploughing of DP Plots
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

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 were 34.2 versus 36.3. (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 ploughing the first and second time may be obtained from estimates of team time used in ploughing. As can be seen in Table 4 (summary of Appendix Table A2), there was an average of two hours per hectare less time spent on the second ploughing for the DP plots, a difference which was not significant but which was a 14 percent reduction in team ploughing time.

Person hours required for ploughing were fairly consistent across treatments. They averaged 34.2, 36.3, 39.0, 29.1, and 35.7 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 4 AVERAGE TEAM PLOUGHING HOURS/HECTARE. DRAUGHT MANAGEMENT AND EARLY PLOUGHING TRIALS, FRANCISTOWN AREA, 1985-86/a

	YIELD KG/HA	FIRST PLOUGH HOURS	PLOUGH/ PLANT HOURS	TOTAL TEAM HOURS
AV SINGLE PLO	166x	0	15a	15a
AV DOUBLE PLO	347y	16	14a	30b
AV 2 SINGLE PLO	342y	0	32b	32b

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

TABLE 5 AVERAGE LABOUR TIME, HOURS/HECTARE. DRAUGHT MANAGEMENT AND EARLY PLOUGHING TRIALS, FRANCISTOWN AREA, 1985-86/a

	YIELD KG/HA	ACTIVITY TIME PREP/b HOURS	WEED HOURS	PROC/c HOURS	TOTAL HOURS
AV SINGLE PL/HA	166x	33b	32x	38b	103b
AV DOUBLE PL/HA	347y	71a	48y	66a	185a
AV 2 SINGLE PL/2HA	342y	73a	75z	71a	219a

a.Within columns, means followed by different letters (a,b) and (x,y,z) 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.

Table 5 (summary of Appendix Table A3) provides information on the average

labour hours used in the three tillage systems; single plough one hectare (SP1), double plough one hectare (DP), and single plough two hectares (SP2). As was expected there was a significant difference between preparation labour for SP versus DP or SP2 but not between DP and SP2. Unexpectedly, there was a significant difference (5 percent level) between weeding for the SP and DP plots. This may be due to the fact that with the increased productivity of the plots, indicated by the doubling of the yield and possibly caused by water conservation and improved tilth with the DP system, there was also an increase in weed growth, requiring the auditional weeding time. However, when comparing the total ploughing and weeding labour on DP plots versus SP plots, the amount of person hours required for one hectare DP was significantly less (at the 1 percent level) than the amount required on two hectares of SP land, (means were 119 versus 148 person hours required for one hectare DP versus two hectares SP, respectively). Thus to produce the same amount of grain required about 24 percent more ploughing and weeding labour using the traditional method (SP2) as compared to the DP system. If total labour is considered, the SP2 system required 18 percent more labour than the DP system to produce the same amount of grain.

SUPPLEMENTAL FEEDING OF DRAUGHT ANIMALS

One of the hypothesis to be tested in this trial was that it is necessary to plough early in the season to obtain the benefits of double ploughing. In order for farmers using animal draught to plough early it was necessary to bring the animals to the lands for training and to have them available when the first rains came. Since this was a time with limited forage at the lands area it was necessary to provide supplemental feed to the animals. The question then was to determine if the cost of supplemental feeding was justified.

Table 6 provides information on the cost of supplemental feeding. The donkey farmer fed 63 bales of hay to five donkeys at a cost of P94.50. The donkeys were in excellent condition at ploughing time and remained in good condition until the end of the ploughing season. Oxen farmers fed an average of 168 bales of hay and nine blocks of Rumevite. The hay cost P244.50 and the cost of Rumevite was P45.00, for a total cost of P300.75 per herd, including P.75 per animal for mineral-mix. Assuming that farmers could and would separately feed only the ploughing teams, the average cost for cattle teams would be P137.31 per team and P78.60 for the donkey team. Dividing this cost over the hectares ploughed by each team resulted in a per hectare average team cost of P26.21 for cattle and P23.82 for donkeys.

The main advantage of supplemental feeding appeared to be that it could allow farmers to start ploughing or planting earlier in the season thereby enabling them to plant more area or to double plough additional areas. Did this early ploughing provide enough increase in production to pay the costs of supplemental feeding? The cost of providing supplemental feed (purchased at a subsidized rate) to 5 donkeys was P98.25. The average cost for oxen was P300.75 per herd. (This involved feeding all cattle in the herd.) Assuming an average price in the village for a 70 kg bag of sorghum grain is P30.00, then to cover the cost of the feed (transport included) donkey farmers would have to produce an extra (98.25 / 30) x 70 = 230 kg's of grain. With the capacity to start ploughing earlier, this might well have been feasible for the donkey farmer by either planting one and one-third additional hectares or by double ploughing an additional two-thirds of a hectare./3

TABLE 8 COST OF FEEDING, DRAUGHT MANAGEMENT AND EARLY PLOUGHING TRIALS, FRANCISTOWN AREA, 1985-86

FARMER	DRAUGHT	ANIMALS FED	COSTS (PULA) MIN-MIX/a	HAY/b	PROTEIN/c	TOTAL COST	HECTARES PLOUGHED	COST/ HECTARE	COST/ ANIMAL	ANIMALS/ TEAM	COST/ TEAM	COST/ TEAM/HA
1	CATTLE	12	9.00	253.50	45.00	307.50	6.1	50.41	25.63	6	153.75	25.20
2	CATTLE	21	15.75	258.50	45.00	329.25	9.5	34.66	15.68	8	125.43	13.20
3	DONKEY	5	3.75	94.50	0	98.25	3.3	29.77	19.65	4	78.90	23.82
4	CATTLE	12	9.00	211.50	45.00	265.50	3.3	80.45	22.13	6	132.75	40.23
OVERALL AVERAGE		12.5	9.38	307.00	33.75	250.13	5.55	45.07	20.77	6	122.83	25.91
CATTLE AVERAGE		15	11.25	244.50	45.00	300.75	6.3	47.74	21.14	8.7	137.31	26.21

a.Mineral-Mix = P.75/animal
b.Hay = P1.50/bale
c.Rumevite = P5.00/block

Oxen owners, on the other hand, would have needed to produce an extra (300.75 / 30) x 70 = 702 kg's of grain. Thus to recoup an expenditure of P300.75, the early feeding would have to enable a farmer to double plough at least two hectares more than he/she would otherwise have ploughed, or to single plough at least four hectares more. In either case, this would represent an increase of 60 to 65 hours of ploughing time. Assuming ploughing is done for 6 hours per day (maximum), this would require a gain of 10 or 11 days of planting. Such a gain from supplemental feeding would be possible (e.g., if there were two weeks of wet weather at the onset of the rains), but somewhat unlikely. Assuming a cattle farmer has 300 pula to invest, it would probably be much safer, and considerably less work for that farmer to purchase 10 - 70 kg bags of sorghum and store them rather than invest the money in supplemental, dry season feed for all of his/her animals in order to prepare the draught animals.

If the farmer would be willing, and able, to feed only the animals in the draught team(s) then the cost of purchasing feed for cattle would be significantly reduced. Average team costs for cattle feeding were P137.31, which translated into 321 kg's of additional grain, representing an additional DP hectare or five days of extra ploughing. Given that the farmer would be able to plough following early rains it is very likely he/she could double plough/plant an extra hectare of land. The additional labour involved in maintaining animals at the lands on supplemental feed has not been included but would need to be considered particularly if the farmer was obliged to maintain two herds, one at the lands and one at the cattle post.

If the cost for purchasing supplemental feed is divided among the total hectares actually ploughed by the participating farmers, then on a per hectare basis the farmer would need to show an increase in production attributable to the early ploughing effect of at least 55 kg/ha using donkey draught and 61 kg/ha using cattle draught to justify the early feeding of purchased hay. Although rains subsequent to the early ploughing often mask the effect of the early ploughing, this type of increase in production from early ploughing if done in conjunction with double ploughing is consistently obtainable. Thus if the farmer can either use the early ploughing to plough an additional two hectares or if the time is used to prepare land for double ploughing it is probable that the early feeding will at least pay for itself in years such as the 1985-86 cropping year.

The cutting and storing of crop residues, to use as dry season feed if grazing runs out, or for use for special animal enterprises (like milk production) also has merit, and would reduce the cash output for early feeding, thus enhancing the acceptability of the practice. However, purchasing feed in order to prepare animals for ploughing is probably uneconomical if farmers must pay the full (unsubsidized) cost of feed or if they require a "risk premium" over and above the break even point in order to be induced to invest cash in a traditionally low cash input enterprise.

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 7 summarizes data for gross total value product (GTVP), 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 1986. 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. Costs included seed and an estimate for equipment depreciation, but were primarily based on the costs of purchasing livestock feed needed for early ploughing. NTVP was 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 hectare. 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 was 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.

As is indicated in Table 7, the GTVP was significantly greater for DP and SP2 compared to SP1 but not between the two higher yielding technologies. Costs per hectare were almost the same for two single ploughed hectares or for ploughing one hectare twice because cost of traction was the major cost. While gross and net returns to labour were not significantly different among the three technologies, DP provided a gross return per hour of labour which was 24 percent greater than the return on SP1 and 39 percent greater than for labour spent on SP2. DP also provided a net return per hour of labour which was 44 percent greater than the SP1 return and 63 percent greater than the SP2 return. Returns for preparation hours of labour, which included ploughing, plough/planting, and broadcasting of seed, indicated that gross returns for DP were 37 percent greater than SP1 and SP2, while net returns for DP were 132 and 98 percent greater than SP1 and SP2, respectively. 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 number of ploughing days when the soil is moist enough to plant is one major limiting factor to increasing production in arable agriculture in Tutume District. If this was 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 8 (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 LABOUR, IN PULA, WITH SUPPLEMENTAL FEEDING, DRAUGHT MANAGEMENT AND EARLY PLOUGHING TRIALS, FRANCISTOWN AREA, 1985-88/a

LOC	PLOT	YIELD KG/HA	ACTIVITY TIME PREP/b HOURS	POST/PL HOST/PL/c HOURS	TOTAL HOURS	GTVP/d PULA	COSTS/e PULA	POST/PL LABOUR/f COSTS	NTVP/g PULA	GROSS RETURN/h LAB/HR	NET RETURN LAB/HR	GROSS RETURN PREP/HR	NET RETURN PREP/HR
AV	SINGLE PLO	168x	33a	70a	102a	71.29ax	31.24	28.45a	40.08x	0.88	0.34	1.41	0.40
AV	DOUBLE PLO	347y	71b	114b	185b	149.34y	81.27	43.29b	88.07	0.82	0.49	1.93	0.93
AV	2 SINGLE P	342y	73b	149b	220b	147.15b	82.47	55.85b	84.67y	0.59	0.30	1.41	0.47

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.COSTS = seed - P.30/kg for 4 kg, equipment estimated P1.50 and feed for animals from Table 6.

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

g.NTVP = Net Total Value Product (GTVP - COSTS).

h.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 8 AVERAGE RETURNS TO TEAM PLOUGHING HOURS, IN PULA, WITH SUPPLEMENTAL FEEDING, DRAUGHT MANAGEMENT AND EARLY PLOUGHING TRIALS, FRANCISTOWN AREA, 1985-88/a

	YIELD KG/HA	TOTAL TEAM HOURS	GTVP/b PULA	POST/PL LABOUR/c COST	COSTS/d PULA	NTVP/e	RETURNS PER TEAM HOUR/f GROSS	NET
AVERAGE SINGLE PLO	168x	15a	71.29xa	28.45x	31.24	40.08x	3.11	2.77
AVERAGE DOUBLE PLO	347y	30b	149.34y	43.29y	81.27	88.07	3.98	3.30
AVG 2 SINGLE PLO	342y	32b	147.15b	55.58;	82.47	84.67y	3.05	2.85

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.COSTS = seed - P.30/kg for 4 kg, equipment estimated P1.50 and feed for animals from Table 8.

e.NTVP = Net Total Value Product (GTVP - COSTS).

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.

The returns to team hours spent in double ploughing were greater than returns from either of the single ploughing technologies, but not significantly so. Gross returns per team hour for DP were 27 percent greater than SP1 and 30 percent greater than SP2, while the net returns for DP were 20 and 17 percent greater than SP1 and SP2 technologies,

respectively.

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.

(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.

These two issues are addressed in a partial budgeting framework with results presented in Tables 9 and 10. 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, seed costs, and costs of providing supplemental feed to draught animals. 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 slightly over P16 per hectare in both cases.

TABLE 9 PARTIAL BUDGET: DOUBLE PLOUGHING INSTEAD OF SINGLE PLOUGHING ON A SINGLE HECTARE, DRAUGHT MANAGEMENT AND EARLY PLOUGHING TRIALS, FRANCISTOWN AREA, 1985-86

PART A: BASIC BUDGET ANALYSIS

REDUCED COST		
Total labour hours SP (102.85 hrs @ 38 t/hr)/a	39.08	
ADDED BENEFIT		
Double plough yield (347.3 kgs @ 43 t/kg)/b	149.34	
SUB-TOTAL		188.42
ADDED COST		
Total labour hours DP (185.2 hrs @ 38 t/hr)/c	70.38	
Depreciations/d	1.50	
Animal feed attributable to second ploughing/e	28.53	
REDUCED BENEFIT		
Single plough yield (165.8 kg)/f	71.29	
SUB-TOTAL		171.70
NET GAIN		16.72

PART B: SENSITIVITY ANALYSIS

	NET GAIN
YIELDS, RESOURCE USE AND VALUATION	
Top three yield differences/g	135.05
Bottom three yield differences/h	-70.92
Labour valued at 53 t/hr./i	4.27
Grain valued at 26 t/kg./j	-14.12
Traction costed at 50 p/ha; no ploughing labour/k	11.20
Traction costed at 25 p/ha; no ploughing labour/l	36.20
Without supplemental feed for animals/m	45.25

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 P1.50 per hectare ploughed.
e. Average additional cost for feeding animals, from Table A2, minus equipment depreciation of P1.50.
f. Average yield for SP trial plots valued at P.43/kg, the prevailing rate in Matobo for the 1985-86 harvest season.
g. Based on average yields for three trials with largest positive difference in yields between DP and SP.
h. Based on average yields for three trials with largest negative difference in yields between DP and SP.
i. The urban minimum wage rate.
j. The BAMB guaranteed price (P 18.17 per 70 kg) for producers of number 2 mixed sorghum in 1985-86.
k. ARAP tractor hire rate.
l. Slightly above the Mahalapye donkey hire rate.
m. Without supplemental feeding of animals.

TABLE 10 PARTIAL BUDGET: DOUBLE PLOUGHING INSTEAD OF SINGLE PLOUGHING TWO HECTARE, DRAUGHT MANAGEMENT AND EARLY PLOUGHING TRIALS, FRANCISTOWN AREA, 1985-86

PART A: BASIC BUDGET ANALYSIS

REDUCED COST		
Total labour hours 2SP (219.67 hrs @ 38 t/hr)/a	83.47	
Seed saving (4 kg @ 30 t/kg)	1.20	
ADDED BENEFIT		
Double plough yield (347.3 kgs @ 43 t/kg)/b	149.34	
SUB-TOTAL		234.01
ADDED COST		
Total labour hours DP (185.2 hrs @ 38 t/hr)/c	70.38	
REDUCED BENEFIT		
Two single plough hectares yield (342.2 kg)/d	71.29	
SUB-TOTAL		217.52
NET GAIN		16.49

PART B: SENSITIVITY ANALYSIS

	NET GAIN
YIELDS, RESOURCE USE AND VALUATION	
Top three yield differences/e	111.19
Bottom three yield differences/f	-90.62
Labour valued at 53 t/hr./g	21.66
Grain valued at 26 t/kg./h	15.62
Traction costed at 50 p/ha; no ploughing labour/i	15.75

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 18.17 per 70 kg) for producers of number 2 mixed sorghum in 1985-86.
i. ARAP tractor hire rate.

In comparing DP with SP1, the increased labour cost in the DP system (involving increases in ploughing, weeding and processing labour) are more than 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 large net loss for shifting systems. An increase in the labour wage rate to the urban wage rate decreases the net gain for DP over SP1, while valuing the grain at the BAMB producer guaranteed price produces a negative value for the shift. If traction is hired rather

than provided by the farmer, there is only a slight decrease in net gain if the ARAP price of P50 per hectare is used, while the net gain is more than doubled if the traction is valued at P25 per hectare. The changes are related to not only the difference in labour requirements for the second ploughing of the DP system but also to the cost of supplemental feeding included in the team cost for the second ploughing. If the cost of supplemental feeding is not included, then the net gain for the DP system is almost three times that of the basic budget.

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 similar to those observed in the DP - SP1 comparison. Valuing labour at the urban wage rate slightly increases the net gain, and valuing grain at the BAMB rate slightly reduces the net gain as does hiring traction at P50/ha. As with the returns analysis the partial budgeting analysis indicates that for all farmers, given the conditions faced in 1985-86, the shift to double ploughing from either single ploughing one hectare or single ploughing two hectares is worth considering. There is a risk that the shift would be detrimental if the SP1 or SP2 systems yield well compared to the DP system, which could happen depending on rainfall timing and soil environments, or in the case of SP1 if the price received for the grain is low. However, on average, the shift appears to be beneficial.

FORAGE HARVESTING

One farmer, number 3, harvested and stored crop residue from the experimental plots for use in feeding animals at the beginning of the 1986-87 cropping season. Labour time to harvest a hectare of forage was approximately 25 hours and the amount of forage harvested, kilograms of dry matter by plot on a per hectare basis, was: 839 kg; 1498 kg; 1344 kg; 2473 kg; and 1652 kg on plots 1-5 respectively. Thus there was an average of 1278 kg of dry matter per hectare on the three single ploughed plots and 1985 kg on the two double ploughed plots.

Table 11 provides information for calculating returns to labour for the entire crop, including forage, for farmer 3. The price for forage used was the price of the government subsidized drought relief hay used to feed the livestock prior to ploughing./4 At this price the forage was worth almost as much as, or more than, the grain harvested. However, since no market for forage existed in the Tutume area, it was difficult to say if the price of forage used was realistic. With the prices used, the gross returns to total labour were almost the same for the SP and DP technologies, and were 26 and 28 percent greater, respectively, than the SP2 returns. For net returns to total labour the SP system was highest, with DP returning 3 percent less and SP2 returning 30 percent less./5 If gross returns to time spent harvesting the forage were calculated using the value of the forage only, then it appears the forage was well worth harvesting as it yielded a return from P4.49 to P7.01 per hour of harvest time. The SP2 system yielded the highest amount of forage and returned 18 percent more than the DP system and 56 percent more than the SP system for hours spent in the harvesting.

TABLE 11 RETURNS FROM FORAGE PRODUCTION, FARMER 3, IN FULA, WITH SUPPLEMENTAL FEEDING, DRAUGHT MANAGEMENT AND EARLY PLOUGHING TRIALS, FRANCISTOWN AREA, 1985-86

PLOT	GRAIN YIELD KG/HA	FORAGE YIELD KG/HA	CROP TIME HOURS	FORAGE TIME HOURS	TOTAL TIME HOURS	CROP GTVP/a FULA	FORAGE GTVP/b FULA	TOTAL GTVP FULA	COSTS/c FULA	NTVP/d FULA	GROSS RETURN/LABOUR PER HR	NET RETURN/LABOUR PER HR	GROSS/e RETURN PER HR
3	88	1344	112.75	25	137.75	37.34	100.80	138.84	28.52	112.12	1.01	0.81	4.03
5	358	1652	89.12	25	114.12	153.08	123.90	276.98	28.52	250.46	2.43	2.19	4.98
AV SP	222	1498	100.93	25	125.93	95.48	112.35	207.80	28.52	181.29	1.72	1.50	4.49
2	213	1498	209.69	25	234.69	91.58	112.35	203.94	51.84	152.10	0.87	0.65	4.49
4	483	2473	124.82	25	149.82	207.69	185.48	393.17	51.84	341.33	2.82	2.28	7.42
AV DP	348	1988	167.25	25	192.25	149.64	148.91	298.55	51.84	246.71	1.75	1.48	5.98
163	237	2183	224.48	25	249.48	101.91	163.73	265.64	53.04	212.60	1.02	0.82	8.55
165	505	2492	210.83	25	235.83	217.15	188.83	403.98	53.04	350.94	1.71	1.49	7.47
AV SP2	371	2337	222.65	25	247.65	159.53	175.28	334.81	53.04	281.77	1.37	1.15	7.01

a. CROP GTVP = Gross Total Value Product [yield x price] for crops where price = P.43/kg for sorghum.
b. FORAGE GTVP = Gross Total Value Product [yield x price] for forage where price = P.075/kg for forage, based on price of subsidized hay, 20kg bale at P1.50.
c. COSTS - Seed - P.30/kg for 4 kg, equipment estimated P1.50 and feed for animals from Table 8.
d. NTVP = Net Total Value Product [GTVP - COSTS]
e. GROSS RETURN PER FORAGE HOUR = FORAGE GTVP/FORAGE TIME

CONCLUSIONS

From these data, it appeared that double ploughing one hectare required the same amount of labour as ploughing two hectares once only, and that it did not significantly reduce the amount of weeding per hectare (with the possible exception of areas infested with cynodon dactylon). However, if preparation and weeding hours were combined, then the double ploughed hectare required 24 percent less weeding and preparation labour than the two single ploughed hectares combined. 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. Thus 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 18 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 plots. For the same amount of grain, the gross return to labour was 39 percent higher for the double ploughing system over the two hectares single ploughed. The net return was 63 percent greater for the double ploughing. 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 38 percent more gross returns, and 17 percent more net returns than two hectares single ploughed. A partial budget analysis suggests that, on average, a shift from systems using single ploughing of one or two hectares to a system of double ploughing results in a net gain for the farmer.

Providing supplemental feed to animals so they were in shape for early ploughing was costly, due in part to the feeding of the farmer's whole herd.

If only traction teams were fed then the practice would at least break even, however since farmers tend to look at arable production in terms of minimizing investment, and if they have any alternative use for the funds or would require a risk premium to invest in feeding, then the practice of early feeding would probably not pay for itself. Harvesting forage, on the other hand, appeared to be quite worthwhile if there was some sort of off-farm market or if the forage could be used on-farm in an economically productive way. If, for example, forage was used instead of drought relief hay (which costs P.075/kg), then hours spent in cutting and stacking stover would be worth between P4.49 and P7.01 depending on the production system used.

Using only the double ploughing system, (with a fixed amount of ploughing time in a season) would mean that farmers could only plant half the area that they could with the traditional system. Farmers are unlikely to accept that trade off as they would probably perceive the reduction in planted area as an increase in their risk of crop loss (whether this is true is another question). Therefore, unless it can be demonstrated that the initial land preparation can be done in non-planting periods, farmers are not likely to adopt the system until they perceive that they are "land constrained". Options for land preparation at non-optimal planting times include the use of tractors to do the initial ploughing during dry periods, or using cattle to plough when the soil is still soft, but too dry for planting.

Even though double ploughing increased returns to labour and to team time, it will not increase whole farm production unless it is possible to increase the rate of ploughing, which might be done by using a tractor for the first ploughing of a double ploughing system or by using a two furrow plough, or by creating new opportunities for ploughing time. This might be done by getting animals into the fields earlier, through supplemental feeding, or by ploughing the first time on a double ploughing system when it is too dry to plant.

The double ploughing system would be very beneficial for farmers with sufficient draught power but limited land, such as is the case of many farmers in the North East District. Where land is the limiting factor, the intensification of production (by doubling production per unit of land) is likely to be quite attractive.

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. This discussion is based on breaking even and does not include any estimate of the additional "risk premium" which a farmer would need before he/she would invest in the purchase of feed. Perrin, et al., suggest that this additional return required by farmers before they invest is at least 20 percent and may be 50 percent or more. In the case of Botswana where farmers tend towards minimum investments in arable cropping it could be on the higher side, in which case the likelihood of farmers feeding is greatly reduced. A second complicating factor was that the inputs had been subsidized by the Government of Botswana and if farmers had to pay the true cost of the feed it would probably be significantly higher, thus necessitating a higher return from the early ploughing.

4. Farrington and Mayer used the cost of purchasing sorghum fodder as their cost for feed in their Winter Stall Feeding Trial. This cost, P.11/kg, was higher than the cost of purchasing subsidized drought relief hay, P0.75/kg. Using the former price raised the gross and net returns from including forage in the analysis and increased the gross returns to labour for forage harvest to P6.59 to P10.28 per hour of forage harvest time. However, without an established market for forage in Tutume District the best value for this study was probably the value of the subsidized drought relief hay as that was an established price.

5. These percentages were 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 were calculated, then gross returns to SP were 6 and 22 percent greater than for DP and SP2, respectively. SP plots showed a 12.5 and 26 percent greater net return than the DP and SP2 plots, respectively. Thus the difference in returns was partly due to averaging and, because there were so few plots involved, the averages may not have reflect the true relationships among yields, costs and hours of labour which were included in the gross and net returns to labour calculations.

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APPENDIX A

TABLE A1 LABOUR TIMES, HOURS PER HECTARE, DRAUGHT MANAGEMENT AND EARLY PLOUGHING TRIALS, FRANCISTOWN AREA, 1985-86/a

LOCATION	PLOT	YIELD KG/HA	PLOUGH TIME	PLANT TIME	BC SEED TIME	TOTAL PREP	WEED TIME	PROC TIME	TOTAL TIME
1	1	20	0.00	37.38	1.25	38.63	0.00	8.75	47.38
1	2	239	35.24	32.23	1.00	68.46	4.50	155.75	228.71
1	3	150	0.00	32.66	.75	33.41	4.50	94.00	131.91
1	4	214	36.52	34.81	.75	72.08	0.00	70.25	142.33
1	5	43	0.00	30.51	1.00	31.51	0.00	28.25	59.76
2	1	3	0.00	64.46	1.75	66.21	35.25	2.50	103.96
2	2	24	61.23	51.56	1.75	114.55	24.75	11.50	150.80
2	3	10	0.00	32.23	1.75	33.98	0.00	5.50	39.48
2	4	145	42.97	57.58	1.25	101.80	0.00	42.00	143.80
2	5	93	0.00	30.08	1.75	31.83	0.00	30.25	62.08
3	1	149	0.00	26.21	.50	26.71	68.25	26.75	121.71
3	2	213	30.08	40.61	.50	71.19	100.00	38.50	209.69
3	3	88	0.00	27.50	.25	27.75	63.50	21.50	112.75
3	4	483	30.51	24.06	.50	55.07	10.00	59.75	124.82
3	5	356	0.00	31.37	.50	31.87	9.00	48.25	89.12
4	1	274	0.00	37.81	.50	38.31	62.50	56.00	156.81
4	2	439	24.92	25.35	.75	51.02	154.00	55.00	260.02
4	3	266	0.00	27.50	.50	28.00	90.50	34.75	153.25
4	4	130	29.22	45.76	.75	75.73	105.00	23.75	204.48
4	5	263	0.00	62.74	.75	63.49	75.75	28.75	167.99
4	6	336	0.00	29.22	.75	29.97	50.00	74.25	154.22
4	7	875	26.21	32.66	.50	59.37	45.00	113.75	218.12
4	8	184	0.00	25.78	.75	26.53	46.00	28.50	1.03
4	9	711	24.92	18.05	.50	43.47	41.00	84.75	169.22
4	10	205	0.00	23.63	.50	24.13	30.50	56.50	111.13
AVERAGE	1(6)	176	0.00	39.01	.95	39.97	43.20	33.65	116.82
AVERAGE	2(7)	358	35.54	36.48	.90	72.92	65.65	74.90	213.47
AVERAGE	3(8)	140	0.00	29.13	.80	29.93	40.90	36.85	107.68
AVERAGE	4(9)	337	32.83	36.05	.75	69.63	31.20	56.10	156.93
AVERAGE	5(10)	192	0.00	35.67	.90	36.57	23.05	38.40	98.02
AVERAGE	2 & 4	347	34.18	36.27	.83	71.27	48.43	65.50	185.20
AVERAGE	3 & 5	166	0.00	32.40	.85	33.25	31.98	37.62	102.85
OVERALL AVERAGE		241	34.18	35.27	.86	49.80	40.80	47.98	138.58

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, WITH SUPPLEMENTAL FEEDING, DRAUGHT MANAGEMENT AND EARLY PLOUGHING TRIALS, FRANCISTOWN AREA, 1985-86

LOCATION	PLOT	YIELD KG/HA	FIRST PLOUGH HOURS	PLOUGH/ PLANT HOURS	TOTAL TEAM HOURS	POST/PL GTVP/a PULA	POST/PL LABOUR/b COST	POST/PL COSTS/c PULA	POST/PL NTVP/d PULA	GROSS RETURNS PER HR	NET TRACT PER HR
SINGLE PLOUGH PLOTS											
1	3	150	0.00	18.33	19.33	64.50	37.43	27.90	36.60	1.68	2.24
1	5	43	0.00	15.25	15.25	18.49	10.74	27.90	-9.41	0.51	-0.62
2	3	10	0.00	16.11	16.11	4.30	2.09	15.90	-11.80	0.14	-0.72
2	5	93	0.00	15.04	15.04	39.99	11.50	15.90	24.09	1.69	1.60
3	3	88	0.00	13.75	13.75	37.84	32.30	26.52	11.32	0.40	0.82
3	5	356	0.00	15.88	15.88	153.08	21.78	26.52	126.58	8.37	8.07
4	3	266	0.00	13.75	13.75	114.38	47.60	42.93	71.45	4.88	5.20
4	5	263	0.00	15.68	15.68	113.09	39.71	42.93	70.16	4.88	4.47
4	8	184	0.00	12.89	12.89	79.12	28.31	42.93	38.19	3.94	2.81
4	10	205	0.00	11.82	11.82	88.15	33.06	42.93	45.22	4.66	3.83
AVERAGE SINGLE PLO		166	0.00	14.63	14.63	71.29	26.45	31.24	40.06	3.11	2.77
DOUBLE PLOUGHED PLOTS/e											
1	2	239	17.62	18.11	33.73	102.77	60.90	54.90	48.17	1.34	1.43
1	4	214	18.26	17.40	35.67	92.02	28.70	54.90	37.42	1.80	1.05
2	2	24	20.41	17.19	37.60	10.32	13.78	30.60	-20.28	-0.09	-0.54
2	4	145	21.49	14.39	35.88	62.35	15.96	30.60	31.75	1.29	0.88
3	2	213	15.04	13.54	29.58	91.59	52.63	51.84	39.75	1.36	1.39
3	4	483	15.25	12.03	27.29	207.69	28.51	51.84	155.85	8.64	5.71
4	2	439	12.46	12.68	25.14	188.77	79.42	84.96	104.11	4.35	4.14
4	4	130	14.61	15.25	29.86	55.90	48.93	84.96	-28.78	0.23	-0.98
4	7	875	13.11	16.33	29.43	376.25	60.33	84.96	291.59	10.73	9.91
4	9	711	12.46	9.02	21.49	305.73	47.79	84.66	221.07	12.01	10.29
AVERAGE DOUBLE PLO		347	16.07	14.39	30.47	149.34	43.29	61.27	88.07	3.96	3.33
TWO SINGLE PLOUGHED PLOTS COMBINED											
1	1 & 3	170	0.00	35.02	35.02	73.10	40.00	55.8	17.30	0.95	0.49
1	1 & 5	83	0.00	33.95	33.95	27.09	14.06	55.8	-28.71	0.38	-0.85
2	1 & 3	13	0.00	37.60	37.60	5.59	18.44	31.8	-26.21	-0.29	-0.70
2	1 & 5	98	0.00	36.52	36.52	41.28	25.64	31.8	9.42	0.42	0.26
3	1 & 3	237	0.00	26.86	26.86	101.91	68.40	53.04	48.87	1.25	1.82
3	1 & 5	505	0.00	29.79	29.79	217.15	57.96	53.04	164.11	5.53	5.70
4	1 & 3	640	0.00	32.66	32.66	275.20	92.83	85.96	189.34	5.59	5.80
4	1 & 5	637	0.00	34.59	34.59	273.91	84.74	85.86	188.05	5.47	5.44
4	6 & 8	520	0.00	27.50	27.50	223.60	75.53	85.96	137.74	5.38	5.01
4	8 & 10	541	0.00	26.43	26.43	232.63	80.29	85.86	146.77	5.77	5.55
AVG 2 SINGLE PLO		342	0.00	31.99	31.99	147.15	55.58	62.47	84.67	3.05	2.85

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. COSTS = seed - P.30/kg for 4 kg, equipment estimated P1.50 and feed for animals from Table 8.
d. NTVP = Net Total Value Product (GTVP - COSTS).
e. Costs for double ploughed plots include costs for two ploughings by team i.e. cost for two hectares of team time.

TABLE A3 LABOUR TIME, HOURS/HECTARE, AND RETURNS, WITH SUPPLEMENTAL FEEDING, DROUGHT MANAGEMENT AND EARLY PLOUGHING TRIALS, FRANCISTOWN AREA, 1985-86

LOC	PLOT	YIELD KG/HA	ACTIVITY TIME PREP/a HOURS	POST/PL/b HOURS	TOTAL HOURS	GTVP/c P/LA	COSTS/d P/LA	POST/PL LABOUR/e COSTS	NTVP/f P/LA	GROSS RETURN LAB/HR	NET RETURN LAB/HR	GROSS RETURN PREP/HR	NET RETURN PREP/HR
					SINGLE PLOUGHED PLOTS								
1	3	150	33.41	98.50	131.91	54.50	27.30	37.43	38.80	0.49	0.29	0.84	-0.02
1	5	43	34.51	29.25	59.79	18.49	27.30	12.74	-9.41	0.31	-0.16	0.25	-0.64
2	3	10	33.98	5.50	39.48	1.00	15.37	2.05	-11.90	0.11	-0.29	0.07	-0.40
2	5	93	34.92	30.25	62.38	39.39	15.30	11.50	24.09	0.64	0.39	0.90	0.40
3	3	98	27.75	85.00	112.75	37.64	26.52	32.30	11.32	0.34	0.10	0.28	-0.75
3	5	356	34.97	57.25	92.12	153.08	26.52	21.75	126.56	1.72	1.42	4.12	3.29
4	3	298	28.00	125.25	153.25	114.38	42.30	47.60	71.45	0.75	0.47	2.29	0.86
4	5	293	80.48	104.50	187.98	113.29	42.30	39.71	70.16	0.57	0.42	1.16	0.48
4	8	184	26.53	74.50	101.03	79.12	42.30	28.01	36.19	0.78	0.36	1.92	0.30
4	10	205	34.13	97.00	111.13	88.15	42.30	33.08	45.22	0.79	0.41	2.28	0.50
AV SINGLE PLO		188	30.25	69.80	102.85	71.29	31.34	26.45	40.06	0.68	0.34	1.41	0.40
					DOUBLE PLOUGHED PLOTS/g								
1	2	229	58.46	160.25	229.71	122.77	54.80	80.00	24.17	0.45	0.24	0.81	-0.19
1	4	214	72.38	70.25	142.63	93.32	54.80	28.70	37.42	0.65	0.26	0.91	0.15
2	2	24	114.56	36.25	150.80	10.32	30.80	13.78	-79.26	0.07	-0.13	-0.03	-0.30
2	4	145	101.80	42.00	143.80	62.35	30.80	15.38	31.75	0.43	0.22	0.48	0.16
3	2	213	71.19	138.50	209.69	91.59	51.84	52.83	39.75	0.44	0.19	0.56	-0.19
3	4	420	56.07	69.75	124.82	227.69	51.34	26.51	155.85	1.85	1.25	3.09	2.35
4	2	438	51.02	209.00	260.02	188.77	54.88	79.42	104.11	0.73	0.40	2.14	0.48
4	4	130	75.73	129.75	204.48	55.90	54.88	48.30	-29.78	0.27	-0.14	0.09	-1.02
4	7	875	59.37	158.75	218.12	376.25	54.36	80.03	221.59	1.72	1.34	5.32	3.90
4	9	711	43.47	125.75	169.22	305.73	54.88	47.79	221.07	1.81	1.31	5.83	3.99
AV DOUBLE PLO		347	71.27	113.33	185.20	149.34	51.27	43.25	98.07	0.42	0.48	1.33	0.53
					TWO SINGLE PLOUGHED PLOTS COMBINED								
1	153	110	72.34	107.25	179.29	73.10	55.80	40.70	17.30	0.41	0.10	0.45	-0.33
1	155	53	70.14	37.50	107.14	27.09	55.80	14.26	-42.71	0.25	-0.37	0.19	-0.81
2	1.3	13	100.19	43.25	143.43	5.23	51.70	15.44	-61.91	0.03	-0.19	-0.11	-0.43
2	155	96	98.03	88.00	186.03	44.09	51.70	25.61	6.48	0.25	0.03	0.45	-0.17
3	153	337	54.46	180.00	234.46	154.81	53.04	68.10	33.67	0.43	0.01	0.93	-0.36
3	155	505	58.58	152.25	210.83	217.15	53.04	57.76	164.11	1.03	0.78	2.72	1.81
4	153	840	98.31	243.75	342.06	385.00	85.06	70.00	299.94	0.88	0.87	2.75	1.45
4	155	937	101.80	323.00	424.80	429.31	85.06	84.74	343.25	0.81	0.59	1.78	1.01
4	5&8	525	56.52	198.75	255.25	223.73	85.06	71.50	137.74	0.88	0.54	2.92	1.10
4	5&10	541	54.10	211.25	265.35	232.43	85.06	80.79	146.77	0.88	0.55	2.92	1.23
AV 2 SINGLE P		342	70.22	146.45	216.67	147.15	62.47	52.15	84.67	0.68	0.30	1.41	0.47

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.42/kg.

d.COSTS = seed - P.30/kg for 4 kg, equipment estimated P4.50 and feed for animals from Table 6.

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

f.NTVP = Net Total Value Product (GTVP - COSTS)

g.Costs for double ploughed plots include costs for two ploughings by team i.e. cost for two hectares of team time.