

DOUBLE PLOWING: A LOW-EXTERNAL-INPUT TECHNOLOGY FOR
INCREASING GRAIN PRODUCTION ON HARDVELOD SOILS
IN EASTERN BOTSWANA

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Introduction: Double plowing (DP) was examined as a potential first step up the technology ladder for limited resource farmers in Tlokweng Agricultural District (TAD), Botswana. It was considered a good beginning option because it required no new external inputs (e.g., equipment, chemicals) and no new skills for implementation. This presentation summarizes the yield data collected on DP in TAD over the past five seasons.

Background: To appreciate the effects of DP it is necessary to understand the context in which this technology option was applied. Therefore, a brief overview of common soil types, rainfall regime, the traditional crop production system, and long term average grain production levels are given below:

Soils: Typical soils in TAD found along the toposequence are given below. Both USDA and FAO classification are presented. Soil classifications are given starting at the top of the toposequence (Soil no. 1) and in descending order to the bottom of the toposequence (Soil no. 5).

FAO Classification

1. Eutric Regosol
2. Chromic Luvisol
3. Ferric Luvisol
4. Gleyic Luvisol
5. Calcic Luvisol

USDA Classification

- Ustorthept
Haplustalf
Kanhaplic Haplustalf
Aqualf
Ustalf

Personal communication. 1988. P. DeWitt. FAO soils mapping unit, Ministry of Agriculture, Dept. of Agric. Field Services, PVT. Bag 003, Gaborone, Botswana.

These soils are generally infertile and lacking in structure, particularly higher on the toposequence.

Rainfall: The long term average annual rainfall for the area (1921-1980) is 473 mm¹. The "rainy season" occurs from October through April. Mean seasonal rainfall (July to July) totals for the area during the years 1981-85, 85-86, 86-87 and 87-88 were 443, 328, 312 and 741 mm respectively. (Data collected by ATIP Staff, TAD. Reported in the respective ATIP annual reports.)

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Farming Description: The research was conducted with limited resource farmers practicing small scale, dryland agriculture in TAD. Most of these farm families own some livestock (goats, sheep, cattle), do some crop cultivation in season (sorghum, millet, cowpeas, groundnuts, maize, water melon, etc.) and participate (to some extent) in off-farm employment. Thus, farm operations are quite diverse, as is necessary in a "high-risk" environment.

Regarding cropping practices, the typical approach for planting is to scatter mixed crop seeds on the untilled soil surface, and then plow the area (burying the seeds), usually using animal draft power (cattle or donkeys). The average area planted in this way is 3 to 5 hectares per farm household.

Mean cereal grain yields for TAD prior to 1980² are given below. A drought persisted in the area between 1981 and 1987.

a) Average sorghum yield (1967-79)	263 kg/ha
Maximum annual average	486 kg/ha
Minimum annual average	45 kg/ha
b) Average millet yield (1967-73, & 79)	127 kg/ha
Maximum annual average	271 kg/ha
Minimum annual average	40 kg/ha

The minimum grain requirements for a household of 7 people is in the range of 1000 to 1500 kg per year. Thus it is clear that traditional cropping practices barely meet subsistence needs in most years, and often fall below the required level. This short fall is often compensated for by cash income generated from the sale of livestock, off-farm employment, and/or government supplied food aid. It is within this context that the effects of DP must be evaluated.

Double Plowing Definition: DP means adding a single preliminary plowing to the traditional system of broadcast and plow-down. One or two rains of more than 10 mm should occur between the first plowing and the broadcast/plow-down operation.

Study Objectives: Between 1983 and 1988, series of experiments were performed to examine a number of questions concerning DP, including:

- a) Potential yield increases for DP;
- b) The best times and methods for implementing DP;
- c) The economics of using DP versus the traditional system; and
- d) The effectiveness of DP under farmer management.

In the data presented here, most of these studies were combined to examine the magnitude and dependency of the effect of DP on grain yields across environments, crops and years.

Approach: A list of the trials included in this analysis are given in Appendix A. All of the trials are described in detail in the relevant ATIP Annual Reports and Progress Reports listed in a separate handout. The data included four sets of researcher managed (RM) trials, and three years of farmer managed (FM) trials. Each of the RM trials was laid out in a randomized complete block design with two replications per location on three to six locations per year. Within the RM trials, DP and traditional check plots in the same replication were treated as paired plots for the purposes of the analysis. The FM trials involved simple paired plots (DP and traditional), with one pair per crop, per location, and included from 12 to 62 locations per year. The total number of pairs of plots

(DP and traditional) used in the analysis was 100 pairs.

Each pair of plots (whether RM or FM) was sown with the same crop on the same day. RM plots were 10m x 1m in size, FM plots were 10m x 50m. In sorghum trials, variety Segalane was sown at 4 kg/ha. For millet trials, variety Serere 6A was sown at 2 kg/ha, and for cowpea trials the majority were sown with variety Blackeye at 25 kg/ha. A few were also sown with varieties ERA, IVA and R005C1.

Whole plot grain yields were harvested and threshed by the farm holder, and weighed by research staff.

The yield data for all pairs of plots were then combined and analyzed within crops, both within and across years. N.B. Comparisons where neither plot produced any measurable grain yield (either because of drought or late planting) were excluded from the analysis. The analysis was performed on an Apple IIe micro computer, using the paired t-test in the DAISY PROFESSIONAL statistical analysis program.

Results: A print-out of the full data set is available from the authors. A summary of the data analysis is presented in Table 1.

It can be seen from Table 1 that DP provided a significant and relatively consistent increase in grain yields across years for all crops. One possible cause for the lower percentage increase in cowpea grain yields was that all of the cowpea comparisons were put in under farmer management. The cowpea crop was severely attacked by insect pests in both the 1986-87 and 87-88 seasons, and farmers were largely unable to spray. Thus yields in general were low, and yield differences may have been suppressed. Evidence that DP could have a large effect on cowpea yields is seen in the single comparison implemented in 1985-86.

Plowing has often been regarded as detrimental to soil structure, and leaving plowed areas open (without planting) might be construed as encouraging soil erosion by both wind and water. However, in TAD, conditions are such that these assumptions do not necessarily apply. First, the rainy season is usually preceded by five months of virtually zero rainfall. During this time it is common practice for cattle to graze the crop stubble to the point where the field surface is virtually bare by the time the rain begins. Second, the local soils commonly contain very minimal amounts of soil organic matter, and consequently have very little structure. Soil bulk densities of 1.7 and 1.8 are common. Hence, particularly in the beginning of the rainy season, fields are bare and the soil is compact. These conditions combine to cause considerable runoff from the fields, with the subsequent loss of potentially useful moisture. Because of the lack of structure, plowed soils may also compact quickly again, after a heavy shower. Under these conditions, the initial plowing may actually serve to reduce runoff (and erosion) and conserve moisture in the field for later plant use. The second plowing (at planting time) may serve to re-loosen the soil and assist more rapid root growth and seedling establishment. These hypotheses are currently being examined in collaboration with a soil physicist (Sarina Persaud, INTSORMIL, Dept. of Agric. Research, P.O. Bag 0033, Gaborone, Botswana.)

Double plowing is an easy technology option for limited resource farmers to adopt in that it does not require purchasing any inputs or equipment beyond that already necessary for crop production in the traditional manner. Nor does it require farmers to learn any new skills. It could be useful for reducing rainfall run-off, often reduces weed burdens and weeding labor requirements¹ and increases grain yield per hectare.

Double plowing does, however, increase the amount of plowing and plowing labor

required during the planting period. And because DP requires farmers to plow when they might be performing a plow-planting operation, there is also an opportunity cost attached. (Unless the plowing is done when planting would not normally be done, e.g. at marginal soil moisture levels.)

Table 1. A Summary of the Yield Data Analysis from the Comparisons of Double Plowing versus the Traditional System, 1983-88, ATIP, IAD, Botswana.

CROP	YEARs	YIELD (KG/HA)/b		% YIELD INCREASE	NO. OF OBSERVATIONS
		DP	TC/c		
SORGHUM	1983-85	459**	238	93	18
	85-86	489**	254	93	12
	86-87	201***	99	103	21
	87-88	694*	340	78	11
	All Years	406***	214	94	62
MILLET	1983-85	677ns	365	85	7
	85-86	390*	240	63	9
	86-87	178ns	103	10	10
	87-88	427**	253	69	18
	All Year	402***	234	72	44
COWPEAS	1983-85	No Comparisons			
	85-86	929	472	95	1
	86-87	156*	99	58	12
	87-88	181**	130	39	30
	All Years	191***	129	48	43

- 1983-85 includes only RM trials data. 1985-87 includes both RM and FM trials data, and 1987-88 includes only FM trials data.
- ns denotes no significant differences between treatments. *, **, and *** denote significant differences between treatments at the 95, 99 and 99.9 percent levels of probability, respectively.
- TC refers to the traditional system of broadcast and plow-down.

An extensive economic analysis was performed on DP data in 1987¹. This analysis found that despite the additional labor requirement and opportunity cost, adoption of DP could be advantageous for limited resource farmers who owned their own draft animals and faced either a land or weeding labor constraint. (Both constraints occur commonly within the region.)

Summary: This study was done with limited resource farmers in Tutume Agricultural District, in north eastern Botswana between 1983 and 1988. The long term average annual rainfall for the area was 473 mm, but a drought persisted in the area for most of the study period.

Double plowing (DP) refers to adding a single preliminary plowing to the traditional system of broadcasting seed on the soil surface, and plowing it under. Double plowing is a low-external-input technology because it does not require any new inputs or skills for implementation.

During the study period, DP increased per hectare grain yields of sorghum by 94 percent, of millet by 72 percent, and of cowpeas by 48 percent.

Economic analysis of the DP option showed it would be most beneficial for limited resource farmers who owned their own draft animals, and faced either a land or weeding labor constraint.

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- (3) Worran, F. 1987. Economic analysis of the ATIP double plowing trials, 1983-87. ATIP MP 87-6. Dept. of Agric. Research, Ministry of Agric., Pvt. Bag 0033, Gaborone, Botswana.

APPENDIX A

TRIALS INCLUDED IN THE DOUBLE PLOWING ANALYSIS 1983-88.

TRIAL	TYPE/a	YEAR	REFERENCE/b
1. Steps in Technology	RM	1983-84	ATIP Ann Rep 2
2. Steps in Technology	RM	1984-85	ATIP Ann Rep 3
3. Draft Management and Early Spring Plowing	RM	1984-85	ATIP Ann Rep 3
4. Draft Animal Management and Early Plowing	RM	1985-86	ATIP PR F86-3
i. Double Plowing Trial	RM	1986-87	ATIP PR F87-5
j. Tillage Systems Trial	RM	1986-87	ATIP PR F87-8
5. Double Plowing/Broadcast Planting Systems Trial	FM	1985-86	ATIP PR F86-2
6. Farmer Groups Technology Options Testing Trial	FM	1986-87	ATIP PR F87-6
7. Technology Options Test with Farmer Groups	FM	1987-88	In preparation

a. RM = Researcher managed trials
FM = Farmer managed trials

b. All ATIP reports are assigned numbers, and are available through ATIP, Dept. of Agric. Research, Ministry of Agriculture, Pvt. Bag 0033, Gaborone, Botswana.

From prior to 1986, full details of all trials were given in the Annual Reports. From 1986 onwards, details of trials were reported in Progress Reports (PR Series) and only summaries were included in the Annual Reports.

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ATIP FRANCISTOWN PUBLICATIONS ON DOUBLE PLOWING

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