Conservation Tillage with Animal Draught in Zambia

W.B. Hoogmoed[1], **P.A Stevens**[2], **S. Muliokela**[2]

[1]Soil Technology Group, Wageningen University, The Netherlands, Email: willem.hoogmoed@wur.nl
[2]Golden Valley Agricultural Research Trust, Chisamba, Zambia

Abstract: The Golden Valley Agricultural Research Trust (GART) investigates the possibilities for the introduction of conservation tillage to small farmers in the (semi-arid) central and southern provinces of Zambia. Major emphasis is given to the implementation of conservation tillage by using animal drawn rippers, as an alternative to conventional mouldboard ploughing. This simple technology has already proven (by on-station research and on-farm adaptive trials) to be quite successful in being able to establish a good crop stand while requiring little energy. It may provide the best opportunity to reduce the negative effects of drought, and thus improve food security and protect the agricultural base from further degradation. Crops are maize, cotton, sunflower and soybean.

Results of this work will be presented with regard to operational (time and energy consumption) and agronomical aspects (soil structure, water availability, crop establishment, yields and weeds). Various tillage systems are being assessed and compared: shallow ripping by oxen, deep (15-25 cm) ripping by oxen, ploughing using a common ox-drawn mouldboard plough, ridging after deep ripping (all by oxen), manual hoe or stick planting, manual preparation of basins.

Energy input was by far the lowest in shallow ripping, followed by deep ripping. These operations can be carried out rapidly and timely (even before the onset of the rains). The most intensive tillage treatments (mouldboard ploughing, ridging) showed higher yields and caused the lowest weed pressure. In the very dry season 2001-2002, however, crops on ripped fields had a higher survival rate than on conventionally tilled fields.

INTRODUCTION

As elsewhere in Southern Africa, Zambian farmers used to apply a centuries old conventional shifting cultivation system, in which a long fallow period is required to restore soil productivity, exhausted during a short cropping cycle. Because of population growth, severe pressure is now put on the availability of fallow land and has led to increasing deforestation. These factors forced farmers to shorten fallow periods, leading to a process of degradation, resulting in lower crop yields, and a serious deterioration of their most valuable asset: the soil.

Today, organizations and agencies involved in smallholder and commercial agriculture in Zambia agree that Conservation Farming (CF) systems, which incorporate Conservation Tillage (CT), sound conservation practices, and crop diversification, provide the best opportunity to reduce costs, increase productivity, reduce the effects of drought, improve food security and protect the agricultural base from further degradation.

Zambia has a total area of over 75 million ha, with more than 16 million ha potentially agricultural land, though only 1.5 million ha is cultivated every year. Three categories of farmers can be distinguished; small holder (between 0.5 and 5 ha, heavy reliance on family labour, form more than 90% of farmer population, 65% of food production), emergent (5 to 20 ha, 6 to 7% of farmers, 15% of food production, animal traction and some mechanisation) and commercial farmers (few %, independent, resource rich).

Conservation tillage aims at: soil protecting by crop residue mulch, reducing water losses by run off, improving efficient use of fertiliser / manure and seed, and improving management, such as timely planting and weeding. This all means reducing tillage operations to the minimum: making a planting hole or furrow where the crop is to be established leaving the rest of the land undisturbed.

Zero-tillage or direct seeding practices as applied on a large scale in the USA and in South America may constitute an adequate solution from a soil- and water conservation point of view. However, under most small holder farming conditions in South Africa, the prerequisites for a successful application of such techniques appear to be difficult to fulfil. Constraints for adoption by small-holder farmers in southern Africa's semi-arid regions are linked with:

- absence of a significant layer of mulch on the soil surface (crop residue is used as animal feed for cattle herds)
- limited or no access for resource-poor farmers to external inputs essential for the success of such zero-tillage systems (in particular intensive chemical weed control) and lack of related infra-structural support facilities.

In addition, zero tillage systems based on mulching, planting and weeding by hand have not met with success in Zambia and Zimbabwe due to excessively high labour requirements. This also holds true for other conservation techniques such as tied ridging, strip cropping, 'potholing' etc.

Thus, in the development of sustainable soil management systems sufficient consideration must be given to a number of very practical constraints faced by small-holder farmers. These are typically: labour constraints and a limited access to external inputs. New systems should be based on animal draught power; innovative use of already existing equipment or simple adaptations or attachments on the standard plough beam should be emphasised. Based on the experience collected since the early nineties in an on-station and on-farm research project in Zambia a system using a simple ripper is now promoted. This is a reduced tillage system which enables the farmer to break up shallow plough pan layers in the soil before or after the first rains and to prepare planting furrows with adequate depth in one pass. A simple planter unit can be attached to the ripper and will enable direct planting into the ripper furrows.

Currently this technology is undergoing extensive testing in on-station and on-farm tests carried out in the Conservation Tillage Research Project carried out by GART with support from IMAG, The Netherlands. In this project, a central role is given to on-farm participatory research and farmers' acceptability trials. Results of the on-farm activities are to be confirmed and quantified by research under controlled (on-station) conditions.

In this paper, some results of on-station experiments on clay (Chisamba) and loam (Magoye) soils will be presented, with regard to practical aspects (time and energy consumption), engineering aspects (design, construction and use of implements), and agronomical aspects (soil structure, water availability, crop establishment, yields and weeds). As a strong emphasis is placed on participation of farmers (male and female) in on-farm assessment of the CT system, an account of the farmers' involvement and their reactions will be given.

MATERIALS AND METHODS

The research activities take place in the areas most important for food production in Zambia, the Central and Southern Provinces. Farmers in representative areas are selected and given the ripper equipment for testing. They are monitored regularly during the cropping period their experiences are collected and analysed. On-station research is carried out on GART's locations in Chisambe (Central Province, 50km north of Lusaka), Magoye. Soils in these locations are clay and sandy loam, respectively. In this paper, some examples of the tillage experiments (started in 1999) are presented.

The main 'tillage systems trial' compares 6 tillage treatments:

RS shallow ripping by oxen with the so-called Magoye ripper for direct planting

RD deep (15-25 cm) ripping by oxen with the Palabana subsoiler
PL ploughing using a common ox-drawn mouldboard plough
RI ridging after deep ripping (all by oxen)
MP manual hoe or stick planting
MB manual preparation of basins

Figure 1. The Magoye ripper in use by women farmers in Zambia.

Figure 2. The ripper attachment.

As can be seen from Figure 2, the ripper consists of a chisel made form hardened steel that can be attached to the beam of any commonly used animal drawn plough. It is equipped with two small wings to keep the furrow open thus allowing manual (or even mechanical) sowing and creating enough soil disturbance to catch water that may be running on the soil surface during a heavy shower.

The on-station trials are laid out in a split-block design (sub-treatments no- or basic fertilisation) with 4 replications. Main plot size is 4.5 x 20 m. The trial is repeated 3 times at each site for 3 different crops, soya, cotton and maize for Chisamba and pigeon pea, cotton and maize for Magoye.
Observations and measurements include soil bulk density and moisture content, surface relief after tillage, crop parameters (emergence, plant development, yields), weed infestation and management related parameters such as time and energy needed for tillage and for weeding.

RESULTS

Some results for the 1999-2000 and 2000-2001 seasons are given for the most important crop, maize. In Magoye, speed and draft forces of the tillage operations were measured during the beginning of the growing season under conditions normal for that time of the year (Table 1).

Table 1. Working width, draught force, speed and energy input for Magoye tillage.

	Working width m	**Draught force** N	**Speed** m/s	**Energy input** kWh/ha
Shallow ripping	0.75	430	1.02	1.6
Deep ripping	0.75	1158	0.90	4.3
Ploughing	0.28	1181	0.96	11.0
Ridging	0.75	1682	0.93	6.2

The shallow ripping operation clearly requires a very low draught force compared to the other operations under the same soil conditions, with a low total energy input per ha of 1.6 kWh. It allows the operation to be carried out with one animal and is, in view of the larger working width and slightly higher speed, almost three times as quick as traditional ploughing. Draught requirements on heavier soil such as in Chisamba are higher, but the relative differences are the same.

Maize grain yields are given in Table 2, for two seasons, 1999-2000 which was a 'normal year' in terms of rainfall, and 2000-2001, a very dry year. The tillage treatments were split with a fertiliser treatment, comparing no fertiliser gift with a basal dressing of NPK at planting time.

Table 2. Maize grain yields (in 1000 kgs per ha).

	Chisamba (clay)				**Magoye (loam)**			
	No fertiliser		**With fertiliser**		**No fertiliser**		**With fertiliser**	
	2000	2001	2000	2001	2000	2001	2000	2001
5.2	1.2	7.7	4.1	3.9	0.5		5.2	2.6
5.4	0.9	7.8	4.3	4.1	0.8		5.7	3.2
6.8	1.6	7.3	5.9	4.4	2.0		5.9	3.0
5.3	1.1	7.5	4.8	4.1	1.0		5.8	2.5
5.7	1.2	7.7	5.2	3.6	1.1		5.5	2.7
6.8	1.5	8.1	3.9	3.8	0.6		5.3	2.9
Average	5.9	1.3	7.7	4.7	4.0	1.0	5.6	2.8

The most striking effect is that of the fertiliser application, with average yields increasing with more than 30% in the normal year, and tripling in the dry year. Average yields were very low in the dry year. The shallow ripping treatment showed an average to slightly-below average both in the fertilised and non-fertilised treatments, Ploughing generally gave the highest results.

The effect of the tillage treatments on weed pressure is given in Table 3, where weeding time in maize for Magoye is shown, and in Table 4, giving weed scores (obtained by independent observations of 5 people) for Chisamba.

Table 3. Weeding time in maize, Magoye (in mandays/ha)

Tillage system	1st Weeding	2nd Weeding	3rd Weeding	Total
Shallow ripping	19.5	2.3	4.3	26.1
Deep ripping	12.5	1.8	5.3	19.6
Ploughing	4.5	2.0	5.3	11.8
Ridging	6.8	2.5	3.5	12.8
Planting stick	27.5	15.0	14.8	57.3
Basin planting	16.8	14.0	15.0	45.8

Table 4. Weed scores in maize, Chisamba (in % based on visual observations).

	15 DAS*	55 DAS	70 DAS
Shallow ripping	69		22
Deep ripping	60		22
Ploughing	22		31
Ridging	15		22
Planting stick	85	40	92
Basin planting	97	40	92

* DAS = Days after sowing

The weed results confirm the expectations, that a more intensive tillage leaves the cleanest field, with the ploughing treatment requiring less than half the labour for weeding. The manual conservation tillage methods (planting stick and basin tillage), however, gave an even stronger weed infestation. Yet, the reduced tillage system with shallow ripping is favoured by many farmers that have had access to the ripper for on-farm evaluation (GART, 2002a). Their positive assessment is due to the fact that sowing can be done earlier, as tillage can be done either before the rains, or with a much higher capacity once rains have started, and thus precious time is gained. As in most cases land is not the main limiting factor, a larger area can be sown. The extra weeding time required can be spread over a longer period.

In Table 5, the results are given from an ongoing evaluation of ripper use on farms in the areas around Magoye and Chisamba. It is important to note that these farmers (both male and female) were only given the ripper for use at their farms and possibly their neighbours'; there was no other incentive (such as money or agronomic input) provided by the program.

Table 5. Proportions of area cultivated under ripping compared to ploughing.

Season	No. of farmers	Total area (ha)	Ripped (%)	ploughed + ripped (%)	Ploughed (%)
1999-2000	48	5.6	27	19	54
2000-2001	57	5.9	43	25	31
2001-2002	58	6.2	44	29	27

Source: GART 2002 Yearbook

The data show that the farmers who were given the rippers, continued to use these for the preparation of their fields. There was an increase as in the second year, levelling off in year 3. On about one third of the farm, the ripper is used after ploughing as a tool to make the planting lines. This is generally done on fields that are heavier infested with weeds, or in situations where the farmer had time to work the field twice.

Farmers are very well aware of the need for a timely (early!) planning of weeding and said to be using an animal drawn cultivator whenever possible.

DISCUSSION AND CONCLUSIONS

Grain yields were highest for the treatments with the most intensive tillage (ploughing and deep ripping). On the clay soils of Chisamba the hand planted treatments also gave higher yields, on the lighter soils in Magoye hand planting resulted in lower yields than shallow ripping. The yield increases due to fertilising show that any change in tillage system should be accompanied by fertilising. This is even more crucial in dry years.

The most intensive tillage treatments also caused the lowest weed pressure. In both locations the hand planting and reduced tillage had the highest scores and weeding times. Even though farmers may use a cultivator to weed in between the plant rows, this can only be done when there is only a small amount of residue from the previous crop. In those cases, the weeding has to be done entirely by hand (hoe) and may pose a serious problem. Developments now are under way to provide a simple weed-wipe to farmers allowing them to apply herbicides in a safe and simple way.

Even though on first sight the agronomic results *per se* may not justify the use of a ripper, the farmers are interested in its use, since they are very positive about the ease of use and the savings in time and energy. The main advantage as was agreed upon by the developers of the ripping methodology, lies in its soil and water conserving effect. Because the soil is not inverted and opened only at a wide spacing, it does not create a clean field and thus it does far less expose the field to the erosive energy of rain, compared to mouldboard ploughing. Water that cannot infiltrate quickly enough during intensive rainfall will not run off but will be trapped by the rough surface in the ripped lines. In addition, the crop and weed residues left at the surface will help to improve the organic matter content of the soil. This is very important as particularly the light soils in Zambia suffer from a low organic matter content resulting in a poor structure and low buffering capacity for nutrients.

It would be very difficult to introduce a new methodology such as ripping to the small farmer, when only difficult-to-prove arguments as soil and water conservation or slow processes as organic matter build-up are to be used. The fact that farmers may accept the methodology based on practical considerations, will hopefully help in the introduction. A large number of rippers has been made available to farmers in Zambia by using existing networks of cotton growers associations with the help of external donors (GART, 2002b).

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References

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