Conservation tillage for sustainable crop production systems: Experiences from on-station and on-farm research in Zimbabwe (1988-1997)

by

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1. Introduction

Conservation Tillage is generally defined as any tillage sequence the object of which is to minimise or reduce the loss of soil and water. Operationally it is a tillage or tillage and planting combination which leaves at least 30% or more mulch or crop residue cover on the surface (SSSA, 1987). In Zimbabwe this term has been loosely used to refer to any tillage system whose objective is to conserve or reduce soil, water and nutrient loss or which reduces draft power input requirements for crop production. It is in this context that the term is used in this paper.

The Conservation Tillage project entitled "Conservation Tillage for Sustainable Crop Production Systems" (CONTILL) was a collaborative project between the department of Agricultural, Technical and Extension Services (AGRITEX) and the Germany Agency for Technical Cooperation (GTZ). The project was initiated in response to extensive problems of soil loss and run-off which were being experienced by smallholder farmers in Zimbabwe which were considered unsustainable (Elwell and Stocking, 1988; Whitlow, 1998). The primary objective of the project was to assess the soil and water conservation and yield merits of several tillage systems with a view to the development of sustainable crop production systems suitable for smallholder farmers in different agro-ecological regions.

In 1988, two experimental sites were established on sandy soils under natural rainfall at Domboshawa Training Centre and Makoholi Experiment Station. The first site, Domboshawa (17°35' S, 31°10'E) lies about 35 km North of Harare at an altitude of 1560m above sea level (asl) in a relatively high potential region receiving 750-1000mm rainfall while the second at Makoholi Experiment Station (20°10' S, 30°45'E, 1210 m asl) lies about 40km near Masvingo in a semi-arid region receiving 450-650mm rainfall per annum.

Both sides were under rain-fed maize production. Soils on both sites were shallow granite-derived sands with clay content lower than 5 percent, bulk densities were in the order of 1.6 Mg/m3 while organic levels were low (0.2-0.5 percent).

Five tillage systems were put in place on two sites and research activities were identical and focused on the effects of hand or animal powered conservation tillage systems on surface run-off, sheet erosion and crop performance.

To ensure the technologies generated from these experimental sites would be acceptable within the farmers' socio-economic environment, adaptive on-farm trials were established in 1990. These trials were composed of 32 farmers (8 farmers per cluster) drawn from 8 communal areas with 4 of the clusters in Natural Region IIa and the other 4 in Natural Region IV. Up to 1995 a total of seven clusters each composed of 8 farmers per cluster participated in the trials with Communal Areas of Musana, Chiweshe and Chinamhora in the sub-humid north and four clusters in the South: Zaka, Chivi, Gutu and Chikwanda.

Objectives

The objectives of the trials was to test the performance and assess the acceptability of one of the conservation tillage techniques, no-till tied ridging (nttr) by communal farmers though a farmer participatory approach. A two pronged approach inter-linking both on-station and on-farm research was established.

This paper highlights some of the major results and experiences from this work since 1998. Results from the project's work have been published in various forms and a total of 15 research reports have so far been produced.

2. Methodology

Five tillage systems were investigated on-station since 1988. These are:

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1. No till tied ridging:

A system of semi-permanent ridges with cross-ties along the furrows to trap run-off. The ridges were laid across the main slope at a grade of 0.4-1%. Normally once constructed the ridges were not destroyed for a period of six seasons depending on the crop rotations practised by the farmer. Planting is done on top of the ridges. In subsequent seasons land preparation simply involves planting on top of the ridges. For good emergence, planting is recommended only when the ridges are fully moist. In drier areas planting may also be carried out in the furrows where most of the run-off water collects.

2. Mulch ripping:

A conservation tillage system involving the retention of stover on the surface and use of a ripper to open up planting lines. Crop rows alternate between seasons. Planting was carried out along the rip-lines. No ploughing took place.

3. Clean ripping:

This system was the same as mulch ripping except that no stover was retained after harvesting to mimic livestock grazing situations. An ox-drawn ripper was used to open up rip lines into which planting was done.

4. Hand hoeing:

Involved the use of hoes to open up planting holes to mimic situations where draft power is not available. Weed control was achieved by hand weeding.

These treatments were being tested relative to control, the conventional farmer practice: the annual mouldboard ploughing. Mouldboard ploughing involved ploughing to a depth of about 23 cm and planting into a clean seed-bed. These tillage plots were set in a completely randomized block design replicated 3 times.

3. Highlights of findings

3.1 Soil loss, runoff and maize yields

Soil loss measurements on-station (slope 4.5%) at Domboshawa Training Centre and at Makoholi Experiment Station gave the results presented in Figure 1. The results generally showed effectiveness of the tested conservation tillage techniques against sheet erosion, particularly no-till tied ridging and mulch ripping. On both stations a dramatic increase in soil loss levels was observed under the conventional tillage system after 4 cropping seasons probably indicating declining soil organic carbon below some threshold value below which soil erodibility abruptly increased.

Since the season 1993/4 (fifth cropping season) conventional tillage systems consistently gave the lowest maize yields at Domboshawa compared to other tillage systems (Figure 1c) but with a somewhat erratic performance at Makoholi (Figure1d). From these and other results mulch ripping and tied ridging were considered as the most sustainable tillage techniques (see Chuma and Hagman, 1995; Munyati, 1997; Vogel 1993; and Vogel et al. 1994) for detailed descriptions of some of the work on these sites.

3.2 Organic carbon

Conventional tillage since 1989 consistently showed the lowest organic carbon levels compared to the other conservation tillage systems (Figure 2). It is noteworthy here that hand-hoeing was introduced a year later than the other treatments and therefore seemed to portray the highest organic carbon levels. The general trend showed a gradual decline in organic carbon for all treatments but a rather steeper gradient with conventional tillage. This has also been matched by increases in annual soil loss and run-off from this treatment. No statistical analysis has been carried out yet to confirm how statistically significant the differences are. Similar results were observed at Makoholi (Chuma and Hagmann, 1995) where percent organic carbon levels declined by 41% for conventional tillage compared to 9% for mulch ripping after five years of cropping.

It appeared therefore that continuous cropping with conventional tillage generally led to a decline in soil organic carbon and an increase in soil erodibility leading over long periods to unsustainable levels of annual soil loss.

3.3 Weeds

A major criticism of conservation tillage systems lies in the problems associated with weed control. Heavy weed infestations were generally observed at Domboshawa on all tillage systems and on conservation tillage systems particularly clean ripping and mulch ripping where perennials such as couch grass (Cynodon dactylon) and Mexican clover (Richardia scabra) posed serious problems. Conventional tillage tended to suffer more from heavy infestations of annual weeds soon after crop emergence. An in-depth study of weeds under the different tillage systems is given by Vogel (1994a). A statistically significant treatment effect on weed biomass was observed for the seasons 1992/93 and 1993/94.

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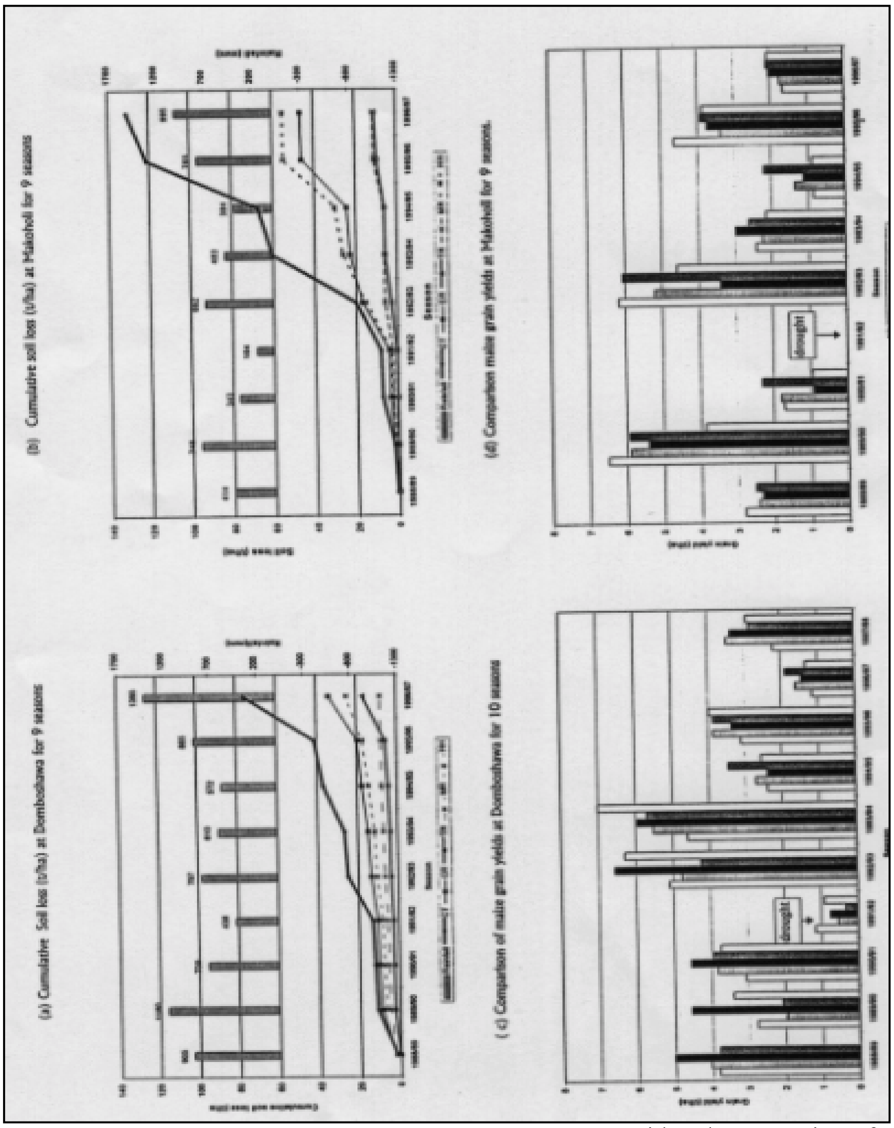

Effects of 4 conservation tillage systems on cumulative seasonal soil loss (t/ha) and maize grain yields (t/ha) at Domboshawa Contil site (sub-humic North) and Makholi Experiment Station (semi arid South).

The results of this study also showed that application of Round-up Dry (glyphosate) at the rate of 2.2 kg active ingredient per hectare resulted in an effective perennial weed suppression while hand-hoe weeding proved inefficient and highly labour intensive for conservation tillage systems (Vogel, 1994a; Vogel, 1994b). The traditional farmer's practice of inter-cropping maize with cow-peas or pumpkins also showed a significant weed suppression effect and could be a potential weed management alternative.

Post-planting weed biomass patterns at Domboshawa for the last four seasons since 1994/95 show that tied ridging in most seasons experienced the lowest weed biomass levels particularly where weeding was carried out after re-ridging with an ox-drawn ridger or plough (Figure 3). This result was also confirmed by farmers participating in the on-farm trial programme who considered suppression of weeds and hence lower weeding labour demands as being one of the major advantages of tied ridging over the conventional mouldboard ploughing systems. Field assessments also ratified this point (Nyagumbo, 1993). Furthermore the prevalence of mexican clover has declined appreciably in the last 3 seasons resulting in lower total weed biomass levels under tied ridging.

In a separate study at Makoholi Experiment Station Riches et al., 1997 found that the weeding effort which accounted for more than 60% of the labour used for maize production in semi-arid Zimbabwe, was greatly eased while grain yields and return to weeding labour significantly improved where animal drawn implements such as cultivators and ploughs were used to control weeds. The efficiency of weed control was also found to greatly improve

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where farmers used re-ridging with the plough as a weed control measure under no-till tied ridging in the sub-humid north of Zimbabwe (Nyagumbo, 1993).

Complimentary work by Shumba et al. (1992) showed that the use of the ripper tine for primary land preparation allowed for timely planting but resulted in earlier and heavier weed infestations. Thus, unless effective weed control can be achieved the benefits of timely planting accrued using the ripper tine in conservation tillage systems are lost. The relatively higher adoption of conservation tillage in the large scale commercial farming sector could therefore be attributed to the availability of suitable machinery and the use of herbicides which have tended to be unaffordable to smallholder farmers in Zimbabwe. Weed control in conservation tillage systems therefore remains a major bottleneck to smallholder farmers in Zimbabwe.

3.4 On-farm research

On-farm research on no-till tied ridging was carried out extensively from 1990. Despite its high effectiveness in reducing run-off and soil loss levels measured on-station, no-till tied ridging did not give the desired crop yield increases over the conventional tillage system. Instead maize yields from no-till tied ridging compared to conventional tillage tended to be erratic and site-specific, depending on season quality, soil types and farmer's management skills. Table 1 shows typical yields from the sub-humid north obtained from these farmer managed adaptive tirals. Across-site ANOVA (analysis of variance) on the 1992/93 yield results (Nyagumbo, 1993) showed a significant correlation between treatment and farmer input leading to the conclusion that the performance of the tied ridging system was strongly dependent on farmer circumstances like management, rainfall, soil type and other resources.

Weekly monitoring of soil profile water contents also revealed that on sands the tied ridging system did not overally increase soil profile moisture due to excessive dessication in the ridge caused by a higher exposed surface area. Measurements at Domboshawa estimated 14% over conventional tillage and low water holding capacity of sands. It is however noteworthy that these profile measurements were being taken from the ridge top. In the furrows water content tended to be higher, a situation attributed to water flow concentration in the furrows.

Formal and informal surveys during implementation of the trials revealed that farmers faced a multi-sectoral range of problems which were classified into four main categories namely financial, technical, environmental and social. All these led to the core problem of hunger and starvation (Nyagumbo, 1993). Results also indicated that farmers were seriously resource constrained in terms of draft power, land, implements and labour.

Socio-cultural factors were also observed during the studies which included attitude problems like the receiver mentality, beliefs in withcraft, suspicion and jealousy among peers, abuse of customary laws and high death rates (Nyagumbo, 1997). These constraints generally contributed to instability within the communities and thus tended to hamper development.

3.4.1 Realizations

Following statistical analysis of results of 1992/3, from subsequent seasons and from complimentary work in Masvingo (Chuma and Hagmann, 1993), conclusions were reached that there was no scope for giving blanket recommendations to farmers on no-till tied ridging. Instead there was need to offer farmers a basket of technology options from which they could select the ones most suited to their resource endowments. It was also realised from this work that tied ridging alone could not address the wide range of farmers' problems. There was a need to consider these issues from a farming systems perspective in order to comprehensively address farmers' problems. For instance, it was not much benefit to address conservation alone without the fertility component incorporated. Tied ridges could not work without the support of structures such as contour ridges, infiltration pits, *fanya juus* and other preventive structures.

Transfer Strategies

The above realisations led to new thinking and development of alternative approaches to the problems at stake. Years of on-farm research work with smallholder farmers had yielded no appreciable adoption of the technologies by farmers.

From the conclusions drawn, transfer strategies particularly the traditional top-down approach extensively used by the local extension service AGRITEX, was identified as one of the key factors hampering adoption. Cook-book recommendations and solutions were being resented by farmers with only certain aspects of recommended technologies being taken up. This realisation led to the development of various farmer participatory technology developments and extension strategies as the best approaches for technology transfer

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through farmer experimentation (Hagmann et al., 1996a; Hagmann et al., 1996b; Nyagumbo, 1997).

4.1 Way forward

A farmer participatory research and extension approach known as Kuturaya (lets try) was initiated and developed in Masvingo in Chivi district (Hagmann et al., 1996a). This approach involved the develoment of a research and extension approach which recognized farmer's views and aspirations. Farmers were taken as partners and equals in research and farmers indigenous technical knowledge was taken as the basis for innovation development.

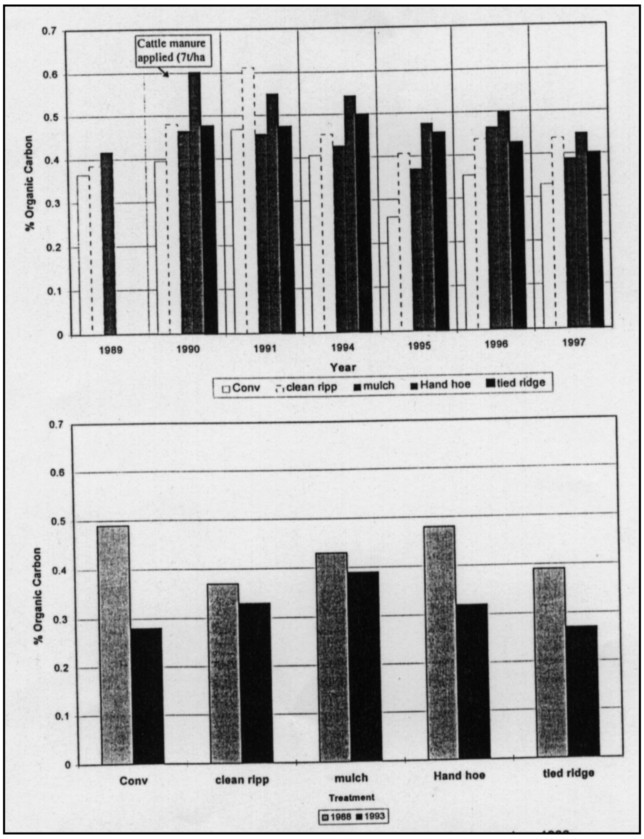

Figure 2: a) Average tillage treatment % organic carbon trends at Domboshawa since 1988 and b) Reduction in average tillage treatment % organic carbon after five years of cropping at Makholi.

Farmers were exposed to various technological options which they could experiment on and implement according to their own resource endowments and preferences. Annual evaluations were carried out together with farmers where farmers played a leading role.

Due to the success of this approach farmers embarked on various innovations which they tried to test on their own.

Currently other tillage techniques such as mulch and clean ripping and strip cropping have been introduced in Musana, Chiweshe and Chinamhora communal lands where conservation farming competitions were initiated in 1996 through a farmer participatory research and extension approach.

The use of this approach, ratified by a technical workshop in Masvingo in 1995 (Twomlow et al., 1995), has resulted in the identification and recognition of farmer innovations. For example the widespread use of infiltration pits originates from a farmer in Zvishavane (Maseko, 1995). Most local institutions including NGOs have now adopted the participatory approach as a tool for implementation in various smallholder projects.

4.2 Other initiatives

4.2.1 Reference material

Another constraint identified and recommendation made during the Masvingo (1995) workshop (Twomlow et al., 1995) was the unavailability of technical information on the promising technologies and the need to develop reference material for extensionists, technocrats and farmers. The development of these materials is now being facilitated by the integrated Rural Development Programme (IRDEP) in Masvingo as "material for technocrats and extensionists" and DFID (the United Kingdom Department for International Development as "material for farmers", together with other local and international stakeholders. Final draft copies of these materials were due to be ready by September 1998.

4.2.2 Farmer participatory development project

Farmer participatory development of sustainable soil and water management techniques in the smallholder farmer sector of Zimbabwe is a follow-up project based on It will implement the recommendations of the work done by the CONTILL project.

It is a joint effort by the Department of Agricultural Technical and Extension Services (AGRITEX) and the Department of Research and Specialist Services (DR&SS) and is to be funded by the Agricultural Services Management Programme (ASMP).

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Table 1: Typical maize yields over five seasons comparing no-till tied ridging to the farmer practice annual mouldboard ploughing obtained on four on-farm sites in Chinamhora, Musana and Chiweshe communal lands, sub-humid north , Zimbabwe.

Farmer	Season	Tied Ridging	Conventional Till
		(t/ha)	(t/ha)
Kapita	1991/92	1.02	0.41
(chinamhora)	1992/93	9.57	9.24
	1993/94	7.41	8.17
	1994/95	4.10	3.47
	1995/96	8.08	7.96
Mean (t/ha)		**6.04**	**5.85**
Basikoro N	1991/92	1.19	0.79
(Musana)	1992/93	9.15	8.26
	1993/94	7.79	8.27
	1994/95	1.34	2.00
	1995/96	5.74	6.18
Mean (t/ha)		**5.04**	**5.10**
Marewo J.	1991/92	0.98	0.33
(Chiweshe)	1992/93	5.17	5.32
	1993/94	9.90	7.80
	1994/95	2.96	4.90
	1995/96	6.52	6.08
Mean (t/ha)		**5.10**	**4.89**
Bulawayo P.	1991/92	1.11	1.06
(Chiweshe)	1992/93	5.91	7.07
	1993/94	5.84	5.55
	1994/95	4.86	3.17
	1995/96	5.73	5.55
Mean (t/ha)		**4.69**	**4.48**
Overall Mean		**5.22**	**5.08**

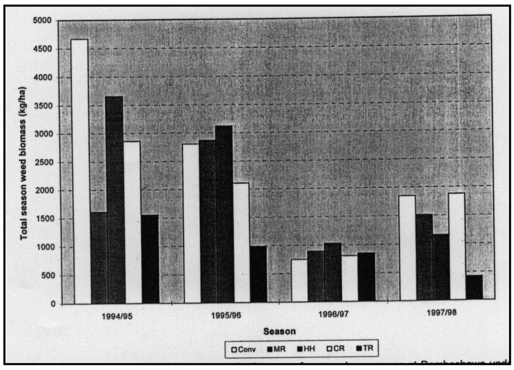

Figure 3: Postplanting dry weed biomass production over four growing seasons at Domboshawa under five tillage systems: Conv (conventional mouldboarld); MR (mulch ripping); HH (hand hoeing); CR (clean ripping and TR (tied ridging)

The project aims at focussing on conservation technologies from a catchment perspective and intends to engage in participatory experimentation with soil and water management technologies.

1. The indigenous Soil and Water Conservation Project (Phase 2) dubbed (ISWC2) co-ordinated by the Institute of Environmental Studies, University of Zimbabwe is aimed at further strengthening and developing indigenous local farmer knowledge and innovations through joint experimentation with farmers. This project comes as a result of another phase (ISWC1) in which current and indigenous soil and water conservation practices in Africa were identified and documented as reported by (Reij et al., 1996).

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5. Summary

Some of the major findings and conclusions reached from the project include:

- That no-till tied ridging and mulch ripping are the most sustainable crop production techniques of the treatments tested from a run-off and soil loss point of view. They maintained soil loss levels to below the tolerable limit of 5 tonnes per hectare per year using data from the first 6 years. When compared to conventional tillage and averaged over the first six years, the nttr system reduced soil loss by 84% (from 4.4 to 0.7 t/ha/yr.) and by 90% (from 10.1 to 1.0 t/ha/yr.) at Domboshawa and Makoholi respectively.

- Mulch ripping on the other hand reduced soil loss by 72% (from 4.4 to 1.2 t/ha/yr) and by 89.5% (from 10.1 to 1.1 t/ha/yr.) at Domboshawa and Makaholi respectively. With regard to ecological sustainability the research has confirmed that conventional mouldboard ploughing is not a sustainable tillage system.

- That the advantages of tied ridging over conventional mouldboard plouging are most pronounced under waterlogged conditions.

- Despite its outstanding water harvesting benefits through run-off reduction, tied ridging on sandy soils, does not overally increase soil water content within the rooting zone due to the low water holding capacity of sands. However no till tied ridging increases the effective rooting depth of crops though the elevated ridges which also increases the rooting volume for nutrient up-take when growing conditions are optimum. It has been confirmed that sandy soils under conventional tillage tend to develop a hard pan which limits the rooting volume.

- That there is not much scope for giving blanket recommendations as yield results from on-farm trails have tended to be site-specific depending on seasonal rainfall, soil type and management capabilities of the farmer.

- That socio-economic and socio-cultural constraints play a very important role in the adoption or rejection of innovations. These problems can sometimes override the technical constraints associated with an innovation. Experience has shown that some of these problems can be alleviated through the use of various development tools which encourage farmer participation.

- Farmers' problems are multi-sectoral. Conservation tillage technologies alone will not address farmers' problems. There is need to combine tillage strategies with other erosion control structures such as infiltration pits, *fanya juus* as well as fertility improvement measures.

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