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# An Evaluation of five tillage systems for smallholder agriculture in Zimbabwe

## Vergleichende Untersuchung von fünf Bodenbearbeitungstechniken für kleinbäuerliche Betriebssysteme in Simbabwe

By H. Vogel[1]

### 1 Introduction

Soil tillage is a key component of agricultural production systems (KRAUSE et al., 1984). In Zimbabwe's smallholder farming areas, excessive inversion tillage to shallow depth (NORTON, 1989) is a leading cause for high surface runoff and soil erosion from arable fields (ELWELL, 1989). In addition to these losses of soil and water, plant nutrients and organic matter are lost at a proportionally higher level in the eroded soil than in the original soil (STOCKING, 1986).

In recognition of this erosion problem, a collaborative conservation tillage project was established between the Department of Agricultural Technical and Extension Services (AGRITEX) and the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH. Its major task is to test selected animal-powered tillage systems with a view to promoting sustainable crop production systems.

### 2 Methods and Materials

This paper summarizes the results of four trial years (1988-89 to 1991-92). Research work was conducted on coarse-grained sandy soils at two experimental sites, i.e. Domboshawa Training Centre near Harare and Makoholi Experiment Station near Masvingo.

The tillage techniques being investigated include the traditional methods of badza holing-out (hand hoeing) and mouldboard ploughing (control) plus two ripping systems

[1] H. Vogel, Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH Conservation Tillage Project, P.O. Box BW 415, Borrowdale, Harare, Zimbabwe

(ripping into maize residues and into bare ground respectively) and no-till tied ridging. Cultivation is across the slope and to a depth of 200-250 mm. This depth has been found optimal for crop production on sandveld soils (GRANT et al., 1979). The standard method for badza holing-out is to dig moderately deep sowing holes employing the traditional hand hoe (badza).

Runoff and erosion measurement techniques are identical to those developed and used at the Institute of Agricultural Engineering (IAE) of AGRITEX (WENDELAAR & PURKIS, 1979). An exception is the tie-ridge treatment which has larger erosion field plots (VOGEL, 1992a). In order to simulate worst erosion conditions, a bare fallow treatment was included employing a tractor disc plough.

Maize is being grown throughout the erosion and additional yield trials and fertilizer application are in accordance with standard recommendations (VOGEL, 1992b). For the first two seasons, the long season hybrid SR52 was grown at Domboshawa and thereafter the short season variety R215. At Makoholi, the early maturing hybrid R201 was grown in all seasons. All research field plots have been laid out in randomized block designs with an unequal number of treatment replications. Planting is by hand to a depth of approximately 50 mm. Yields are being determined from harvest plots of 6 metres by 4 crop rows and are presented at 12,5 % (grain) and 0 % (dry matter) moisture respectively. Statistically significant treatment yield differences are reported at the 0,05 probability level.

## 3 Results

Results for the four-year trial period provide accurate, although preliminary and site-specific, information on the effect of tillage on soil protection and maize production. They also allow conclusions to be reached on specific labour constraints and on implement requirements asscociated with the selected tillage systems.

### *3.1 Rainfall patterns*

There was extremely high annual rainfall variability during the trial period (Fig. 1). During the first two seasons, rainfall was high at Domboshawa. Rainfall was poor at Makoholi in 1988-89 but above average in 1989-90. The third 1990-91 season was characterized by dry conditions at Domboshawa and drought at Makoholi. During the last 1991-92 season most of Zimbabwe, including Domboshawa and Makoholi, experienced an unprecedented drought.

### *3.2 Treatment yields and erosion*

As a result of the high annual rainfall variability, the time required for 50 % silk emergence and hence treatment yields varied significantly from season to season at both sites (Tab. 1). Due to the absence of early planting rains even in the wet years,

Tab. 1: Maize crop emergence, days to 50% silk emergence, and treatment yields at Domboshawa and Mokoli, Zimbabwe.

| | | Domboshawa | | | | Makoholi | | | |
|---|---|---|---|---|---|---|---|---|---|
| Tillage Treatment | Rainy Seasons | Crop Emergence % | 50% Silk days | Grain Yield t·ha⁻¹ | TotalDry Matter t·ha⁻¹ | Crop Emergence % | 50% Silk days | Grain Yield t·ha⁻¹ | TotalDry Matter t·ha⁻¹ |
| | 1988-89 | 67,1 | 90 | 3,82 | 9,15 | 89,9 | 85 | 2,81 | 4,56 |
| Convent. | 1989-90 | 83,7 | 84 | 2,76 | 8,26 | 85,3 | 71 | 6,49 | 10,78 |
| Tillage | 1990-91 | 56,3 | 77 | 3,06 | 4,79 | 83,5 | 100 | 1,71 | 3,51 |
| | 1991-92 | 80,8 | 75 | 1,16 | 7,17 | 72,3 | NA | Nil | 1,27 |
| | 1988-89 | 61,0 | 90 | 4,04 | 9,58 | 89,9 | 85 | 2,44 | 4,26 |
| Clean | 1989-90 | 83,7 | 91 | 1,94 | 6,35 | 85,4 | 71 | 5,89 | 9,66 |
| Ripping | 1990-91 | 62,2 | 77 | 3,83 | 5,73 | 85,6 | 100 | 1,80 | 3,28 |
| | 1991-92 | 80,7 | 75 | 0,54 | 5,51 | 75,8 | NA | Nil | 1,28 |
| | 1988-90 | 66,4 | 90 | 5,03 | 11,45 | 88,8 | 85 | 2,34 | 3,93 |
| Tied | 1989-90 | 81,0 | 84 | 4,56 | 10,33 | 77,0 | 71 | 5,41 | 9,16 |
| Ridging | 1990-91 | 50,4 | 70 | 4,56 | 7,14 | 67,8 | 100 | 0,93 | 3,75 |
| | 1991-92 | 60,1 | 75 | 0,75 | 5,97 | 74,5 | NA | Nil | 0,98 |
| | 1988-89 | 61,0 | 90 | 3,81 | 9,01 | 89,9 | 85 | 2,52 | 4,42 |
| Mulch | 1989-90 | 79,0 | 91 | 2,07 | 6,45 | 83,7 | 71 | 5,93 | 10,02 |
| Ripping | 1990-91 | 67,7 | 77 | 3,96 | 6,52 | 84,1 | 100 | 2,31 | 4,01 |
| | 1991-92 | 83,7 | 75 | 0,34 | 4,56 | 79,4 | NA | Nil | 1,26 |
| Hand | 1989-90 | 87,8 | 84 | 3,41 | 8,17 | 86,2 | 71 | 3,86 | 7,31 |
| Hoeing | 1990-91 | 70,6 | 77 | 3,74 | 5,60 | 71,1 | 100 | 0,96 | 2,80 |
| | 1991-92 | 75,5 | 75 | 0,92 | 5,41 | 85,8 | NA | Nil | 1,30 |

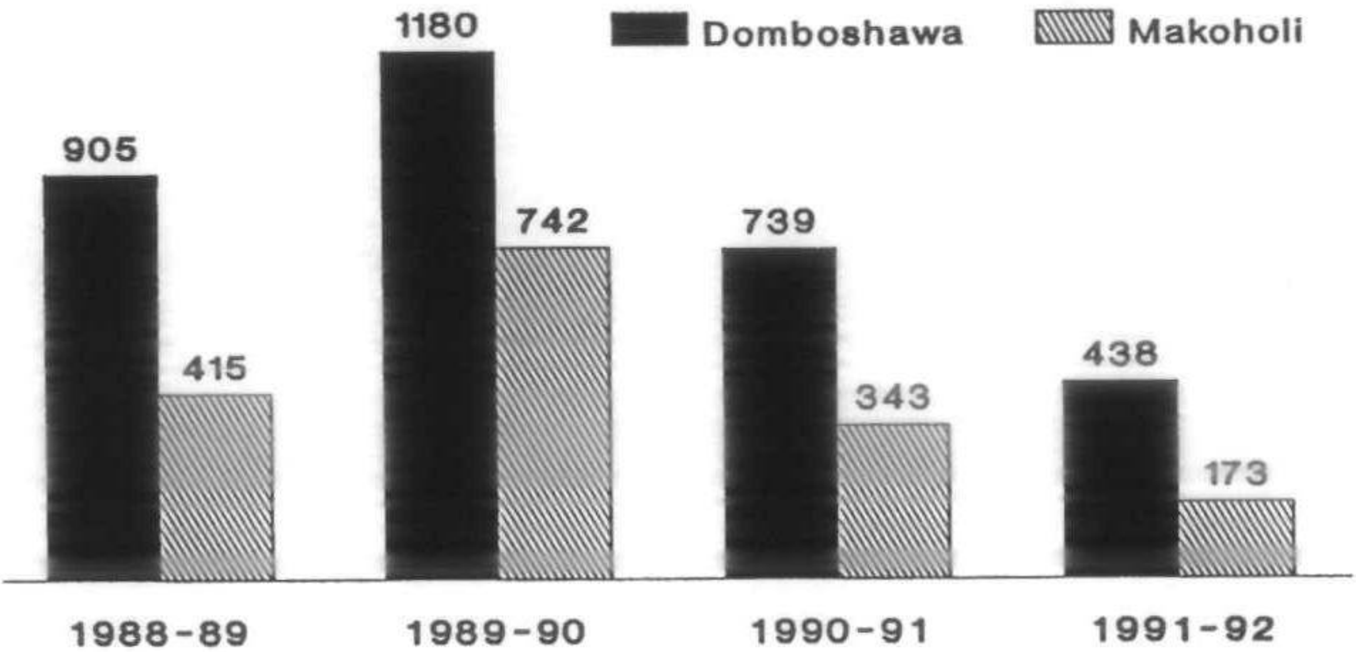


Fig. 1: Seasonal rainfall totals at Domboshawa and Makoholi, Zimbabwe

sowing was always delayed at both sites taking place during the last week of November and/or the first week of December, instead early to mid November. Hence, overall yields were necessarily below optimal levels as maize cultivars experience yield losses up to 9 % per week if planting is delayed (SHUMBA et al., 1992a). Even though, yields obtained during the four seasons were fair to good, except during the last 1991-92 season when the crop failed completely at Makoholi.

Overall, surface runoff and soil loss was relatively low for all cropped tillage systems under investigation but high for the bare fallow treatment (Tab. 2) which was kept free of weeds through regular herbicide applications.

Tab. 2: Surface runoff and soil loss at Domboshawa and Makoholi, Zimbabwe.

| | | Domboshawa | | | Makoholi | | |
|---|---|---|---|---|---|---|---|
| Tillage Treatment | Rainy Seasons | Surface Runoff | | Soil Loss | Surface Runoff | | Soil Loss |
| | | mm | % | t/ha | mm | % | t/ha |
| | 1988-89 | 62,9 | 7,0 | 1,7 | 6,9 | 1,7 | 0,7 |
| Convent. | 1989-90 | 274,3 | 23,3 | 9,5 | 92,9 | 12,5 | 1,3 |
| Tillage | 1990-91 | 15,0 | 2,0 | 1,1 | 41,5 | 12,1 | 5,7 |
| | 1991-92 | 9,4 | 2,2 | 1,0 | 1,0 | 0,6 | 0,7 |
| | 1988-89 | 64,7 | 7,2 | 2,0 | 6,2 | 1,5 | 0,5 |
| Clean | 1989-90 | 211,8 | 18,0 | 7,0 | 79,8 | 10,8 | 1,3 |
| Ripping | 1990-91 | 6,6 | 0,9 | 1,2 | 24,4 | 7,1 | 2,1 |
| | 1991-92 | 1,4 | 0,3 | 0,6 | 0,7 | 0,4 | 0,4 |
| | 1988-90 | 2,3 | 0,3 | 0,2 | 0,0 | 0,0 | 0,0 |
| Tied | 1989-90 | 116,5 | 9,9 | 2,2 | 26,1 | 3,5 | 0,1 |
| Ridging | 1990-91 | 1,4 | 0,2 | 0,3 | 0,2 | 0,1 | 0,1 |
| | 1991-92 | 0,1 | 0,02 | 0,1 | 0,1 | 0,04 | 0,1 |
| | 1988-89 | 86,2 | 9,5 | 2,0 | 5,3 | 1,3 | 0,5 |
| Mulch | 1989-90 | 109,1 | 9,3 | 2,6 | 48,6 | 6,5 | 1,0 |
| Ripping | 1990-91 | 4,8 | 0,7 | 0,6 | 1,8 | 0,5 | 0,6 |
| | 1991-92 | 1,0 | 0,2 | 0,3 | 0,5 | 0,3 | 0,3 |
| | 1988-89 | NA | NA | NA | NA | NA | NA |
| Hand | 1989-90 | 119,5 | 10,1 | 6,5 | 100,7 | 13,6 | 0,9 |
| Hoeing | 1990-91 | 9,9 | 1,4 | 1,1 | 24,7 | 7,2 | 1,8 |
| | 1991-92 | 6,6 | 1,5 | 0,6 | 2,3 | 1,3 | 0,8 |
| | 1988-89 | 110,4 | 12,2 | 2,3 | 51,2 | 12,4 | 3,6 |
| Bare | 1989-90 | 373,3 | 31,6 | 85,1 | 223,0 | 30,1 | 32,2 |
| Fallow | 1990-91 | 220,9 | 29,9 | 53,7 | 83,9 | 24,5 | 34,5 |
| | 1991-92 | 46,0 | 10,5 | 8,5 | 38,9 | 22,6 | 18,7 |

The relatively low rates of sheetwash for the cropped treatments can be attributed to the good level of management provided on station and, possibly, optimal initial soil tilth since research field plots were opened up from virgin lands (Makoholi) or from fields which had previously been fallow for more than 20 years (Domboshawa). Assuming a reduction of soil tilth resulting from continuous cultivation (KARLEN et al., 1990), losses of rain, soil and nutrients due to sheet erosion are likely to increase after several years of cultivation. Higher surface runoff and sheet erosion rates than the ones observed on-station are also likely to occur on farmers' fields since many sandveld soils in smallholder farming areas are totally depleted in fertility because of excessive tillage and poor residue management (SMITH, 1988).

### *3.3 Mouldboard ploughing*

Mouldboard ploughing yielded rather inconsistently, in particular at Domboshawa (Tab. 1). At this site, grain yields for mouldboard ploughing (and the two ripping techniques) were significantly lower than for tied ridging for the first two growing seasons because of waterlogging. In 1990-91, a drier year (Fig. 1), mouldboard ploughing again yielded significantly less grain than tied ridging but was statistically not different from the other treatments. Contrary to this, mouldboard ploughing yielded highest during the drought year of 1991-92, although not significantly higher than hand hoeing and tied ridging.

At Makoholi, mouldboard ploughing yielded most grain for the first two seasons (1988-89, 1989-90), although significantly more than tied ridging and hand hoeing only in 1989-90 (Tab. 1). During the drought season of 1990-91, grain yields for mouldboard ploughing were significantly lower than for mulch ripping, statistically not different than for clean ripping, but again significantly higher than for hand hoeing and tied ridging. In 1991-92, which experienced the worst drought on record, no grain yields were recorded for any of the treatments at Makoholi.

With regards to weeds, mouldboard ploughing was the only treatment providing relatively weed-free seedbeds at planting time but, later in the season, weed pressure was as high as for the other treatmens (VOGEL, 1992c). However, mouldboard ploughing considerably reduced overall weeding time (by approx. 30-40 %) if the last weeding was done through autumn ploughing (May).

As expected, mouldboard ploughing tended to record highest runoff and soil loss of all cropped treatments (Tab. 2). Arising from the high annual rainfall variability, surface runoff and hence sheetwash erosion for this treatment ranged from a mere 1 mm (0,7 t ha-1) in 1991-92 at Makoholi to as high as 274 mm (9,5 t ha-1) in 1989-90 at Domboshawa.

### *3.4 Clean ripping*

Statistically, yields for clean ripping were never significantly different than those for mouldboard ploughing, except in 1991-92 at Domboshawa (lower) (Tab. 1).

Even the labour requirements for hoe weeding were not much different between the two treatments (VOGEL, 1992c). However, clean ripping quickly developed a severe perennial weed problem.

With regards to surface runoff and sheet erosion, clean ripping also performed similarly to mouldboard ploughing. The observed runoff and erosion rates were generally on a par or even lower than for mouldboard ploughing (Tab. 2).

### *3.5 Tied ridging*

Tied ridging produced significantly higher grain yields than mouldboard ploughing for the first three growing seasons at Domboshawa (subhumid region) but significantly lower yields for the same years at Makoholi (semi-arid region) (Tab. 1). Only during the last 1991-92 drought year were grain yields not significantly different for the two treatments at either site.

The higher grain yields at Domboshawa had been due to the prevention of waterlogging during the first two seasons and greater rooting depth (approx. 500 mm as compared to approx. 300 mm) during the third 1990-91 season. However, during the following 1991-92 drought season, tied ridging closely approached its climatic limits on the experimental sandy soils.

At Makoholi, tied ridging always had significantly lower yields than mouldboard ploughing except for the last 1991-92 season when all treatments failed to produce a crop (Tab. 1).

From the experience gained with this treatment, it appears that poorer and/or delayed seed germination (up to 3 weeks in 1991-92 at Domboshawa) and poorer seedling establishment played the major role for the reduced yields of tied ridging under dry conditions. This resulted from highest soil temperatures and lowest soil water contents in the elevated ridges (VOGEL, 1992d). The latter is rather surprising since tied ridging is an ideal rainwater harvesting technique with little surface runoff (Tab. 2). However, the plant-available water capacity at both sites is only about 10 % by volume. In addition, aggressive weed sprawl from the wetter furrows also suppressed yields, in particular at Makoholi (VOGEL, 1992c). Delayed germination or partial germination failure for the ridge-till system on sandy soils has also been observed in other parts of Zimbabwe (STEVENS, 1989) as well as neighbouring Zambia (MEIJER, 1992).

### *3.6 Mulch ripping*

Treatment effects of mulch ripping began to show up only starting from the second 1989-90 season as no crop residues had been available for the first 1988-89 season. At both sites, yields recorded for the second season were statistically not different than for mouldboard ploughing (Tab. 1). However, in 1990-91, grain yields were higher than for mouldboard ploughing at both sites, although significantly higher only at

Makoholi where drought conditions prevailed throughout the growing season. During the severe drought year of 1991-92, even mulch ripping failed to produce a crop at Makoholi. At Domboshawa it produced the least grain. There, an unknown pathogen reduced grain yields to nil on two out of seven mulch ripped field plots.

With regards to hoe weeding, mulch ripping also required about as much weeding time as mouldboard ploughing because the surface residue cover obstructed hoeing considerably (VOGEL, 1992c). Mulch ripping did, however, drastically reduce surface runoff and sheet erosion rates as compared to mouldboard ploughing (Tab. 2). As crop residues became available after the first season, mulch ripping improved steadily from an erosion point of view and losses were thereafter nearly as low as for tied ridging.

### *3.7 Hand hoeing*

Hand hoeing or badza holing-out had been included after the first 1988-89 season in order to provide an extreme minimum tillage treatment. The choice had fallen on badza holing-out not because it was considered an innovative treatment but because it is widely practised in Zimbabwe by non-cattle owners.

At Domboshawa, mean yields for badza holing-out and mouldboard ploughing were statistically never significantly different (Tab. 1). In contrast, yields for badza holing-out were always significantly lower than for mouldboard ploughing at Makoholi except for the last 1991-92 season.

At both sites, badza holing-out gave rise to strongest weed infestations and hence highest hoe weeding requirements (VOGEL, 1992c). Runoff and soil loss were, however, lower than for mouldboard ploughing (Tab. 2), most likely because the maize stubble was left in place after harvesting and because the soil was still in good condition from 20 plus years of fallow.

## 4 Discussion

The most important criteria to ensure smallholder farmers will adopt new tillage systems are, apart from yields, labour and energy requirements (WIENEKE, 1986; TRUSCOTT, 1991). Conservation of soil and water is usually not their prime concern (SHAXSON et al., 1989; WADDINGTON, 1991). Yet, labour and energy availability are the biggest constraints faced by smallholder farmers throughout Zimbabwe (SHUMBA, 1985; 1986). Hence, new tillage systems such as tied ridging and the two ripping techniques are likely to be adopted by smallholders only if they also address these problems successfully.

### *4.1 No-till tied ridging*

Tied ridging is part of Zimbabwe's agricultural extension programme since the 1989-90 cropping season (Gotora, 1991). In order to reduce labour and draught requirements, it is being promoted as a no-till system (ELWELL and NORTON, 1988). However, in spite of labour and draught power savings in subsequent years, the high work input required for the initial installation of the system (ploughing plus ridging plus cross-tying) poses a crucial bottleneck for the adoption of the system (NYAGUMBO, 1992). Four years of on-station experience with the system have also shown that timely planting and weeding is more important for tied ridging than for the other tillage systems under investigation (VOGEL, 1992b).

Weed management, in particular, is made more difficult by the lack of efficient implements. This is being seen as a major disadvantage by smallholder farmers (GROHS, 1991). The locally available high wing ridger copes with weeds well only in the furrows and also causes crop root pruning from as early as two to three weeks after germination through laterally undercutting the ridges. Depth control is also very difficult, particularly where there are old ties and strong weed infestation. Thus, the high wing ridger requires both heavy-weight draught animals and a physically strong operator. Not surprisingly then, the mouldboard ridger has been reported to be unpopular with farmers (MASWAURE, 1992; SARUPINDA, 1992).

Another labour constraint of the ridge system involves the annual construction of cross-ties. These have to be put in by hand using a hoe or, preferably, with an ox-drawn tie-maker. Although simple and efficient tie-makers can be made at low costs from scrap metal, the extra working run partly offsets the system's time savings. This may explain why farmers often do not (re-)tie their ridges (MUCHEDZI, 1991; GOTORA, 1992).

In response to this lack of suitable implements, appropriate mechanization was initiated. First results involve the adaptation of a tractor-mounted two-disc unit disc ridger (KRAUSE and LORENZ, 1979) into a trailed-type disc ridger for animal traction (HAGMANN, 1992a). With disc ridgers the formation of ridges is achieved by the rotation of the discs rather than by the passive action of the share and mouldboards. Thus, there is less draught force required resulting in a much higher work rate, particularly if a tie-maker is integrated (Tab. 3).

Tab. 3: Work rates (h/ha) for three different sets of implements for re-ridging plus re-tying as recorded at Domboshawa, Zimbabwe.

| Mouldboard plough plus tie-maker | High wing ridger plus tie-maker | Disc ridger with integrated tie-maker |
|---|---|---|
| 14,7 | 10,2 | 6,2 |

(Power input = 2 oxen; reference area = 1500 m$^2$)

However, a disadvantage of the disc ridger is that it requires a relatively high weight in order to penetrate into the soil and thus is slightly more difficult to manoeuver at turns and within homesteads. In addition, the higher weight also entails higher costs. However, the future programme includes a project to overcome these disadvantages. Additional future efforts, aimed at mechanising weeding, involve developing more effective and efficient ridge-till cultivators (VOGEL, 1992c).

### *4.2 Clean ripping*

Clean ripping may be more attractive to communal farmers as the observed yield levels were not significantly different from mouldboard ploughing and since it requires less draught power and only a relatively cheap tine. Hence, a reduced tillage method (SHUMBA, 1984; ABELER, 1991) may suit farmers' needs best. A pre-requisite, however, would be that the anticipated problems of increased soil erosion, severe perennial weed pressure, and high instantaneous draught forces, can be addressed successfully.

With regards to soil erosion, clean ripping performed slightly better than conventional tillage. This appears to have been due to the fact that between-row ripping was practised. Rip-between-row as opposed to rip-on-row leaves previous seasons' maize stubble in the field. This reduced surface runoff and thus soil erosion (Tab. 2).

In order to cope with the perennial weed problem, cheap but efficient weeding implements need to be developed and tested (VOGEL, 1992c). Although, theoretically, herbicides may constitute an alternative (SHUMBA et al., 1992b), from a practical point of view it is hard to imagine how they could be economically viable under the present conditions in communal farming.

A crucial aspect of ripping with regards to implement wear and tear is its high instantaneous draught forces (kN). It is well established that severe shock loads of a magnitude 5-10 times higher than the normal (steady-state) draught force can occur when a moving implement such as a rigid ripper tine suddenly hits a rock or stump (STARKEY, 1989). This is because the pressure (force/unit area) exerted upon a ripper tine is much higher than that exerted upon a mouldboard and plough share. Because a rigid tine cannot readily deflect that pressure it easily bends if no stone protection device is available as has often been observed at both sites.

A series of draught trials conducted at Domboshawa (SMITH, 1988) and Makoholi (HAGMANN, 1992b) also showed that even the normal draught force requirements of the locally-used narrow tine (lift angle ≈ 30°, width = 7 cm length = 27 cm) are as high as for a standard mouldboard plough. The trials at both sites established that the average draught force at a working depth of between 150 mm (farmer practice) to 230 mm (recommended depth) and at an average forward speed of 1 m $sec^{-1}$ ranges between 1,4 to 2,2 kN for both the single rigid ripper tine and the single-furrow moulboard plough. This means that ripping with a single rigid tine does not reduce draught power (force x speed) requirements (kW). Given a 90 cm crop spacing, it is only the rate of work ( h $ha^{-1}$) and hence the net energy (work rate x draught power) requirements (kWh $ha^{-1}$) that are in favour of ripping compared to ploughing the whole field. Yet, in animal traction this may be of minor importance as single bullocks cannot pull above 0,9 kN (SLINGERLAND, 1989) and a pair of oxen cannot be expected to sustain a draught load above 1,7 kN (SMITH, 1988).

An alternative to clean ripping may be to practise winter ploughing (to eradicate late weeds) followed by shallow-tine planting (to facilitate early planting) before the onset of the rains (MEIKLE, 1975; SHUMBA et al., 1992a; 1992b). However, from a conservation point of view, any strategy promoting combined winter ploughing and spring tine planting, would have to include sound agronomic practices (mixed, relay and/or strip cropping).

### *4.3 Mulch ripping*

Mulch ripping protected the soil very effectively from erosion (Tab. 2) and also helped regulate topsoil temperatures (VOGEL, 1992d) and water contents (VOGEL, 1992b). Thus, mulch ripping produced significantly higher yields than mouldboard ploughing during the drought season of 1990-91 at Makoholi. However, because of the observed poor water holding capacity of the experimental sandy soils, the protective effect on topsoil water level was too minimal during the severe drought in 1991-92 to produce any grain yields at Makoholi. At Domboshawa, continuous mulching with maize residues may have developed a pathogen problem on some field plots where grain yields were reduced to nil and stover yields were minimal in 1991-92.

Even if these problems could be overcome, it is unlikely that this treatment fits into present communal farming systems. Crop residues for mulching are scarce in Communal Areas since they are grazed on-field after harvest or kraal-fed during the dry season. However, the system may well fit into resettlement and small-scale commercial farming areas. For this to become an option, future efforts aim at mechanising weeding (ZWEIER, 1990) and planting (CHOUDHARY, 1988; EIKEL and SIEBERTZ, 1990) under mulch ripping.

## 5 Conclusions

It is generally accepted that the granite-derived sandy soils of Zimbabwe require some sort of cultivation in order to optimize rooting depth and water use. Although several conservation and/or reduced tillage techniques are available for animal traction, there are various limitations to each of these practices. Hence, tillage techniques must be carefully chosen for each specific environment. No general recommendations can be made.

From the studies conducted at Domboshawa and Makoholi it appears that no-till tied ridging is the best conservation and production technique available for the subhumid north of Zimbabwe and mulch ripping showed great potential for the semi-arid south.

Both face, however, considerable constraints with respect to required levels of management and inputs and, therefore, may not be readily acceptable to smallholder farmers. Similarly, clean ripping to the recommended depth of 200-250 mm is faced with a perennial weed and a draught force problem. Since winter ploughing combined with shallow-tine planting in spring addresses both constraints more successfully, it may stand a better chance of farmer adoption. However, because of the associated erosion risk, tine planting cannot be recommended at present due to lack of evidence that the system is sustainable.

Against the background of the observed multitude of constraints, an approach may be required of ploughing and reduced tillage in sequence to utilize the advantages of both methods. Such a tillage rotation should include improved agronomic practices to reduce erosion losses, improve soil fertility, spread work load, and to minimize weed and pest and disease pressures.

## 6 Summary

Soil erosion, both in the form of gully erosion from grazing lands and sheet erosion from arable fields, is widespread in smallholder farming areas in Zimbabwe.

A collaborative conservation tillage project between the Department of Agricultural Technical and Extension Services (AGRITEX) and the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH is researching into the sheet erosion problem from cropped land. Launched in 1988, the prime objective of the programme is to assess the soil and water conservation merits and yield potentials of four tillage systems (tied ridging, two ripping techniques, and badza holing-out) as compared to traditional mouldboard ploughing. Research work was conducted on granite-derived sandy soils at two experimental sites, i.e. Domboshawa Training Centre (subhumid natural region) near Harare and Makoholi Experiment Station (semi-arid natural region) near Masvingo.

The results achieved over this period of four years suggest, that each of the four selected treatments has pros and cons over mouldboard ploughing.

From a conservation and production point of view, tied ridging appears to be the best tillage technique available only for smallholder farmers under high rainfall conditions. It requires, however, more timely management than mouldboard ploughing with respect to planting (only when ridges are wet) and first weeding (when weeds are still small). It also requires extra labour inputs for cross-tying the ridges and for hoe weeding if the first weeding is not achieved through re-ridging.

Mulch ripping, appears to be a sound protection and production technique for dry climatic conditions as the surface residue cover not only protects the soil from being eroded but also facilitates slightly higher topsoil water levels at the beginning of the season as compared to ploughing. However, crop residues for mulching are very scarce in smallholder farming areas.

Clean ripping requires less net draught energy than ploughing and only a cheap tine. However, steady-state draught force is as high as for ploughing and the system also does not provide for a weed-free seedbed.

Badza holing-out, already practised where draught power is not available, yields at comparable levels to ploughing in wetter areas and requires hardly any implement input. However, it raises overall labour requirements drastically.

In response to the above, research work into the testing and development of appropriate mechanization (ridgers, rippers, cultivators) and improved agronomic practices (mixed, relay and/or strip cropping) was initiated.

**Zusammenfassung**

Bodenerosion infolge nicht angepaßter Bodenbearbeitungsverfahren führt zur irreversiblen Degradation der kleinbäuerlichen Ackerflächen in Simbabwe. Vor diesem Hintergrund wurde Anfang 1988 ein deutsch-simbabwisches Kooperationsprojekt ins Leben gerufen, das in agrar-ökologisch repräsentativen Gebieten Simbabwes agrartechnisch-bodenkundliche Forschungsarbeiten durchführt. Noch im Verlaufe des Jahres 1988 wurden zwei knapp über 10 ha große Versuchsstationen im sub-humiden Norden (Doboshawa) und im semi-ariden Süden (Makoholi) Simbabwes aufgebaut. Auf beiden Stationen stehen granitische Sandböden mit minimaler Kationenaustausch- und Wasserspeicherkapazität an. Kern der Forschungsarbeiten gilt der Erprobung und Entwicklung von vier konservierenden Bodenbearbeitungstechniken (Kammerfurchen, zwei Hakenpflug- bzw. Grubbertechniken sowie reiner Hackbau) im Vergleich zum konventionellen Inversionspflügen mit dem Streichblechpflug.

Die bisher vierjährigen Versuchsreihen (1988-1989 bis 1991-1992) auf den beiden Stationen haben zu folgenden Ergebnissen geführt:

Die niedrigsten Bodenverluste verzeichnete das Kammerfurchensystem während die höchsten Erosionsraten beim Inversionspflügen mit dem Streichblechpflug auftraten. Das Anlegen von Kammerfurchen reduzierte den jährlichen Bodenabtrag in der Regel auf weniger als 0,5 t $ha^{-1}$ während bis zu 9,5 t $ha^{-1}$ an Bodenmaterial bei konventioneller Bodenbearbeitung mit dem Pflug erodiert wurden. Hakenpflügen unter Belassung einer Mulchdecke aus Maisstengeln verzeichnete einen deutlichen Rückgang der Bodenerosionsraten mit zunehmender Verfügbarkeit von Ernterückständen über die Jahre. Die beiden restlichen Bodenbearbeitungssysteme, nämlich Hakenpflügen ohne Mulchdecke und reiner Hackbau, verzeichneten Bodenabtragsraten in der Größenordnung des Pflügens.

Hinsichtlich der Maiserträge zeigte sich, daß das Kammerfurchensystem infolge der Verhinderung von Staunässe und erhöhter Durchwurzelbarkeit die wohl beste Technik für den sub-humiden Norden des Landes darstellt. Anders im semi-ariden Süden, für den die Ergebnisse der vierjährigen Versuchsreihen nahelegen, daß das Kammerfurchen-

system aufgrund der geringen Wasserspeicherkapazität der granitischen Sandböden und erhöhter Oberbodentemperatur zur Pflanzzeit in seinem jetzigen Entwicklungsstadium nicht propagiert werden sollte. Für diesen Naturraum zeichnete sich Mulchen als das potentiell beste Verfahren ab.

Im Falle sämtlicher konservierender Bodenbearbeitungssysteme ohne Pflug trat eine frühe und stark wasserzehrende Verunkrautung auf, die bei verspäteter Bekämpfung zu Auflaufproblemen oder gar völligen Kulturpflanzenausfällen führte. Die alleinige Unkrautbekämpfung mit der traditionellen Handhacke erwies sich als extrem arbeitsaufwendig. Zwischen 150 und 200 Arbeitsstunden pro Hektar wurden für zweimaliges Unkrauthacken pro Wachstumsperiode im Süden des Landes benötigt und zwischen 300 und 400 Stunden für drei Arbeitsgänge im feuchteren Norden. Der generell hohe Arbeitsaufwand zur Unkrautbekämpfung ließ die Notwendigkeit einer angepaßten Mechanisierungskampagne deutlich werden.

Insgesamt unterstreichen die Ergebnisse der vierjährigen Versuchsreihen an den beiden klimatisch unterschiedlichen Standorten, daß Lösungsansätze und Beratungsinhalte zur Verbreiterung von konservierenden Bodenbearbeitungssystemen räumlich determiniert sind. Obwohl das Kammerfurchensystem durch alternatives Anlegen beziehungsweise Weglassen der Verbunddämme theoretisch diametral entgegengesetzte Naturräume adressiert, so zeigte sich in der Praxis, daß humusarme Sandböden den positiven Effekt des Regenwassersammelns selbst bei relativ hoher Lagerungsdichte konterkarieren. Darüberhinaus zeigten die Versuche deutlich auf, daß agrartechnische Lösungsansätze um agronomische Maßnahmen (z.B. Streifen-, Zwischenfrucht- oder Staffelanbau) ergänzt werden müssen — insbesondere hinsichtlich der Unkrautproblematik — um Aussicht auf erfolgreichen Transfer in kleinbäuerliche Betriebssysteme zu haben.

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