Improving animal traction technology

Photo: Lotta Sylwander

Animal-powered tillage and weeding technology

Improving animal-powered tillage systems and weeding technology

by

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Abstract

Tillage is discussed in relation to soil erosion and water management. Conservation tillage, primarily aimed at improving soil structure and organic matter content, is unlikely to be a practical answer for most smallholder farmers in Africa. In order to become successful, improved tillage systems should address the problems of farmers' direct labour capacity and of soil degradation at the same time. Alternatives to plowing are reviewed. The potential of ridging is highlighted and some practical aspects discussed. Ridging should be encouraged on fairly even land in subhumid areas and on heavy soils in semi-arid areas. Ties between ridges should be recommended. Ripping has great potential on sandy soils in semi-arid areas. However, further adaptive research is still required to investigate the practical implications of both ridging and ripping and to see how they can be tuned to farmer needs and preferences. Weed control will be a major bottleneck, but the specific management problems of preventing the risk of increased erosion and run-off should also be given attention. Although weeding remains a major problem on farms, labour-saving solutions do exist and further research is not a primary requirement at present. Farmers should be given access to information about weeding using animal traction, and to appropriate implements. Different existing weeding techniques are considered. In particular, weeding methods that reduce the need for additional hand labour should be promoted. The availability and quality of most weeding implements must be improved.

Introduction

The three major factors that influence crop production are soil condition, climate (rainfall) and farmers' skills (management). Because tillage influences yield only indirectly (Vogel, 1991), it is difficult to improve yields by tilling the soil in a different ("improved") way (Palabana, 1991). This is not serious, since improved tillage serves other immediate objectives: it alters soil conditions and affects farm management requirements.

Improving tillage can mean the introduction of draft animals where only hand labour was used before. In many cases, however, it refers to finding suitable alternatives for conventional plowing, or it means diversification and intensification of tillage practices.

Improving weed control within the context of animal traction generally implies using animal-drawn weeding implements instead of a hand hoe. Reducing weed infestations plays a role in farmers' decisions almost the whole year round, starting with land preparation.

A number of topics on the above themes are dealt with in this paper. They are only a few, but the predominant, facets of the problem of improving smallholder farming under different conditions using animal traction technology. The information and views presented here are based partly on personal experience in Zambia, Zimbabwe, Niger and Indonesia, and very much on the experience of others working on the same problems. The topics covered are:

- tillage and conservation
- ridging and tie-ridging systems
- tine tillage and ripping
- comparison of weed control methods and implements.

Tillage and conservation

According to Lal (1988), widespread soil degradation is an important factor responsible for the continuing food shortage in sub-Saharan Africa. People try to escape the degradation of their fields by extending them, or by moving to nearby fields, and finally by migrating to other areas, leaving behind land unsuitable for cultivation, thus creating more pressure on the land still available, and spreading the problem (Stocking, 1988).

Soil degradation is an extremely complex problem, of which soil erosion is a major part. Soil tillage plays a vital role in the analysis of its causes and the formulation of solutions. Sheet erosion, caused by raindrop impact on bare soil, is the root of all erosion (Elwell, 1986). Tillage techniques for improved soil and water management are helpless

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against rill and gully erosion once started, but are aimed at counteracting sheet erosion, and hence at preventing the advancement of those two more visible and devastating offspring of sheet erosion.

Soil structure and organic matter

Reduced tillage, minimum tillage, zero tillage, mulch or residue farming and conservation tillage are all different techniques but with the same aim—to provide better control of soil erosion and water and nutrient run-off than the so-called conventional techniques of plowing and harrowing. This is best indicated by the word *conservation*; soil, water and nutrients must be maintained to secure agricultural production. The other terms imply that less tillage is a prerequisite for this; seedbed preparation and weed control should take place with less energy being applied to the soil. A key element is soil structure, which is believed to be generally poor after years of cultivation. Conventional mouldboard plowing is a technique imported from European temperate zones, where its damaging impact is much less profound than in tropical hot and dry climates, unless irrigation is applied (Elwell, 1989). However, by considerably reducing the soil disturbing actions of tillage operations, the soil structure would rejuvenate to pre-cultivation levels. Tillage loosens the soil, but only temporarily: ultimately it leads to more compact soils (Foth, 1984). However, restoring or maintaining a good soil structure under minimal tillage can take place only if the organic matter content of the soil increases considerably.

Conservation tillage

Vowles (1989) defines conservation tillage as any tillage practice which leaves at least a 30% crop residue cover on the soil surface after planting. The crop residues serve two main purposes: to build up organic content in the soil, and to protect the soil surface from erosion, run-off and extreme temperatures. The resulting intensive biological activity has a loosening action on the soil, and this replaces tillage.

Conservation tillage is currently receiving a lot of attention in Zimbabwe within the commercial farming community, initially probably more because of the reduced tractor running costs and time-saving in land preparation than because of reduced soil erosion and the long-term effect of improved soil structure. Oldreive (1989), a large-scale farmer in Zimbabwe who practises conservation tillage with great success, is convinced of its potential for smallholder farmers also, depending on the availability of animal draft power and hand labour. However, most African smallholder farmers live in remote areas characterised by poor soils and climatic conditions, high population pressure and poverty. One major problem is that often not enough crop residues are available to serve as soil cover and to improve soil condition; the little that are produced are required for many other purposes. Another problem is that conservation tillage is not without risk; if it is not properly managed, weeds, pests and diseases become insurmountable problems. Large-scale commercial farmers in the USA, who have been applying conservation tillage techniques successfully for decades, use herbicides and other chemicals to overcome these problems, but such a solution is generally not available to small-scale farmers in Africa: although economic analyses show the profitability of herbicides (eg, Tembo, 1989), these inputs are usually too costly.

Farmers' goals

The primary goal of improvements in agriculture is increased production—higher outputs. The conservation approach, however, focuses on economising on inputs, with the aim of helping to make production levels sustainable rather than maximal. The scarcity of all the factors involved in the production system is emphasised.

In this sense, conservation tillage techniques can help smallholder farmers who have access to animal traction to overcome some of their most urgent problems. A major goal of farmers is to increase labour productivity at maintained or increased production levels (in weight and money terms). Farmers want to increase production, but if they have to rely on hand labour for land preparation, and especially weeding, they can only cultivate a limited area. Sensible use of oxen, donkeys or cows, or even camels, with suitable implements, provides them with the potential for increasing their labour capacity. Hence they can extend their cropped area, intensify soil and crop management, achieve timely planting and fast weeding, and grow more cash crops. Although most farmers recognise the general problem of erosion and water loss in the many areas where this occurs, and acknowledge the fact that this affects their farm as well, the labour capacity problem is more urgent to them. Stocking (1988) goes further by stating that: "Soil conservation and the prevention of land degradation are never seen as ends in themselves by farmers". If improved tillage systems are to be successful in the long term, they should address both the labour capacity problem and the erosion problem at the same time.

Plowing

Plowing is, for good reasons, still the tillage practice that is most recommended. Indeed, in many areas the plow is the only implement available to farmers who use draft animals. Where other implements are available, these are generally of secondary importance.

The essential feature of plowing is that soil inversion is carried out over the whole surface. Plowing must be deep enough to achieve this—in Zimbabwe the recommended depth is 20–25 cm (Smith, 1989)—and so the operation is quite an intensive soil treatment, in terms of both time and energy.

Plowing normally takes place at the beginning of the season, at a time when draft animals are not in their best condition (they have been weakened by the dry season and often require some retraining). Farmers need to plant as early as possible, but in many years too little rain, or even drought, at the beginning of the season delays land preparation. Many farmers have to hire or borrow draft animals, and so have to wait until the owners of the animals have finished their own work. Probably, in view of the time constraint, farmers tend to plow too wide, with the result that stretches of the soil surface between the furrow lines are not worked at all, but are covered only with some soil sliding off the mouldboard. Shallow plowing, which some farmers have to resort to as a way to offset the problem of draft power shortage, restricts water infiltration and is likely to induce run-off and soil loss (Norton, 1987). The Animal Draft Power Research and Development Programme in Zambia has demonstrated that "proper" plowing—plowing with a well-set and maintained or new plow (rather than a worn one)—results in greater plowing depth and cutting width, and leads to higher crop yields and fewer weeds (Meijer, Chanda and Hoogmoed, 1990). Still, for many farmers "proper" plowing seems to be unnecessary or even inappropriate. Besides, there are better options.

Ridging and tie-ridging

Ridging results in better soil and water management than plowing. Ridging determines the slope along which water can run off. Thus ridging can effectively reduce the slope of a field, from, say, 4% (the actual slope of the field) to, say, 1% (the slope of the ridges and furrows). With correct ridging that reduces the effective slope, water cannot run down the field at a high and destructive speed. Excess water should be able to flow away through the furrows. If the ridges are laid out exactly along the contour, during heavy storms water will fill up the furrows. It will then spill over the ridges and run straight down the hill, making rills or small gullies on its way and thereby increasing the streaming water mass. This would be a more devastating situation than run-off on flatly plowed fields where water continuously and evenly spread over the surface can flow in a more gentle manner, a situation, however, that is prone to sheet erosion.

For Zimbabwe, Gotora (1991) advises that ridges be laid out on fairly even land and at a maximum slope of 1%. Ridges should not be laid out on stony fields or fields with many rock outcrops or termite heaps; and uneven land resulting from rill erosion or bad plowing should be smoothed (Elwell and Norton, 1988). Laying out ridges is a complicated task, especially on fields with steep slopes or slopes in more than one direction. Meijer (1992) warns of the danger of increased erosion under these circumstances. The risk of run-off from higher land must be taken into account when planning to ridge a field. Even if ridges are properly designed, severe erosion can result if they are not adequately maintained (Unger, 1984). During the season, ridges should be rebuilt when necessary, particularly after heavy storms, to bring washed-away soil back onto the ridges. This operation also helps to control weeds.

Cross-ties keep the water in small pools so that it can slowly infiltrate the soil and become available to the crop. They are therefore very useful in dry areas and during dry spells in more humid areas. Gotora (1991) suggests that ties be constructed only half to two-thirds as high as the ridges, so that water will flow over the ties and remain in the furrow instead of streaming over the ridges and running downhill. Under very wet conditions, or when the soil profile is saturated, ties should not be constructed, or should be broken down (Elwell and Norton, 1988) if the water itself has not already washed them away (Gotora, 1991).

Tie-ridging

In the USA, tie-ridging as a water conservation method for subhumid and semi-arid areas appears not to reduce crop yields in wet years, and probably leads to increased yields in dry years, if properly applied (Harris and Krishna, 1989). Considerable increases in cereal yields from ridging and tie-ridging have been reported from research in Burkina Faso and Mali (van der Ploeg and Reddy, 1988).

In Niger, van der Ploeg and Reddy (1988) studied the effects of ridging and tie-ridging as water conservation techniques for sorghum on clay soils, compared to flat cultivation. Usually these soils are plowed late, after the millet has already been planted on the upland sandy fields. Labour is

Table 1: Comparison of tillage systems for sorghum on clay soils in Kolo, Niger

	Grain yield (t/ha)			*Stover yield (t/ha)*		
Tillage system	*1985*	*1986*	*1987*	*1985*	*1986*	*1987*
Flat	1.0	0.5	0.4	5.3	2.1	3.4
Ridged	1.2	0.7	0.7	5.3	2.8	5.2
Tie-ridged	1.6	0.8	0.7	7.1	3.3	5.7

Source: van der Ploeg and Reddy (1988)

somewhat less of a limiting factor at that time, although weeding of the upland crops may demand attention then. Table 1 shows harvest results for Kolo, in the valley of the Niger near Niamey. Ridging increased yields considerably compared to flat cultivation (plowing): on plots where ties were made, yields were even higher. Straw production is very important in a country where biomass is a scarce product; it is used for animal feed during the long dry season, as building material or fuel, or for making mats.

Table 2 illustrates the beneficial effect of establishing the ridges before planting instead of afterwards during weeding (which is the normal farming practice); seed germinated more vigorously, and plants grew higher and bigger and produced more grain and stover. A probable reason is that the plants can develop a bigger root system, which makes the crop less vulnerable in dry spells, reduces seepage losses (van der Ploeg and Reddy, 1988), and is favourable for good soil structure and fertility. However, it was expected that farmers would have a major problem with establishing the ridges and the ties during land preparation, in view of the weakness of the draft animals at the beginning of the season, and because of the limited labour available (van der Ploeg and Reddy, 1988). This does not necessarily imply that farmers do not already know the advantages of ridging before planting: it is very likely that most farmers are just not in a position to adopt the "best" system, because of time constraints and lack of available farm power. The benefits of that "best system" are apparently not big enough to persuade farmers to take a risk.

Vogel (1991) reported rapid water percolation below root depth on coarse-grained soils in unsaturated conditions, which destroyed the water harvesting effect. On the other hand, ridging prevented crops planted on the ridges from becoming waterlogged in more humid areas: this is also important in dry areas for crops, such as millet, that are very sensitive to waterlogging and suffer after only a short time (some days). Ridging to control temporary excess of water in the field is a traditional technique known to farmers; loose (and comparatively fertile) topsoil is brought together in ridges on undisturbed strips of soil by hand hoe, thus combining better water management with relatively fast land preparation (Meijer, 1992). When the move to animal traction is made the plow and flat cultivation take over. However, later in the season (when the soil becomes saturated) many farmers use their plow, or a ridger, to earth-up the crop rows and weed at the same time. Apparently, making ridges after plowing but before planting is not always practical; it requires extra time in a period in which no time should be lost for planting. Recently-plowed soil can still cope with the rains at the beginning of the season.

From point of view of erosion control, and in order to catch more water for the crop so that it is better able to withstand dry spells, (tied) ridges should be laid out at the start of the season. Two approaches to facilitate this are being reviewed: direct ridging, as is being studied by the Animal Draft Power Research and Development Programme in Zambia; and the so-called "no-till tie-ridging" system developed by the Institute of Agricultural Engineering in Zimbabwe.

Table 2: Comparison of establishing ridges before and after planting sorghum on clay soils in Niger

	Germination (plants/m^2)	*Plant height (cm)*	*Plant weight (g)*	*Grain yield (t/ha)*
Ridging before planting	27	11	0.5	0.8
Ridging after planting	15	4	0.2	0.5

Source: van der Ploeg and Reddy (1988)

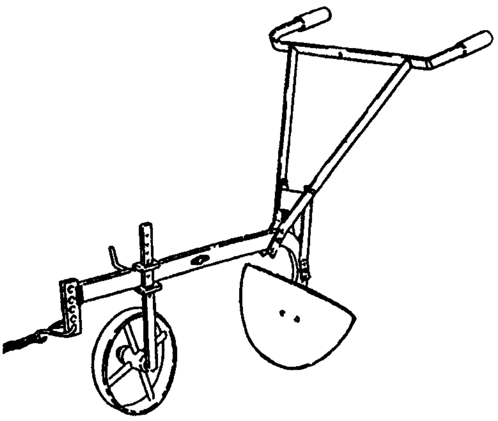


Figure 1: A simple ridge-tier

"No-till tie-ridging"

"No-till tie-ridging" aims to combine the advantages of minimum tillage and tie-ridging in one system that is practical for farmers. It is a permanent or semi-permanent system of ridges.

In the first year of construction of the ridges, good plowing is recommended to produce enough loose soil to build large ridges—about 25 cm high before consolidation (Gotora, 1991). Plowing is probably good also because it keeps weeds under control from the beginning, thus enabling a good start for the system. Ridging is done with a mouldboard plow, and great care is taken to set out the first "master" ridge at an acceptable slope. Ties are made with a hand hoe or a simple ridge-tier made out of scrap material; this consists of a mouldboard or a (half) disc of a disc harrow or plow fitted on an implement frame (Figure 1) or a wooden pole. Planting is done on top of the ridges, as early as possible, but only when the ridges are wet throughout (Elwell and Norton, 1988). Earthing-up during the season, and supplementary weeding (additional to hand weeding) on the top of the ridges, are done with the plow.

In subsequent years the ridges of the previous season are merely re-ridged for the next season (thus the system is actually "reduced till" rather than "no-till"). It is also foreseen that in "no-till tie-ridging" the land should be plowed afresh once every few years (for example, to incorporate manure or to loosen the soil). The length of the tillage cycle is not yet known, but will probably be at least four years for sandy soils and more than 10 years for clay soils. As a result the system as a whole would require less time and energy input than annual plowing (Elwell and Norton, 1988).

It is claimed that if the ties are properly put in and maintained, soil losses will decrease to less than 2 t/ha per year (from 50–100 t/ha per year under conventional tillage) and that run-off losses will drop from 30–40% of the seasonal rainfall to 10%, with minimal nutrient losses (Elwell and Norton, 1988). Vogel (1991) suggests that 5 t/ha per year is the critical level of acceptable soil erosion.

On-station results from three years of "no-till tie-ridging" in Zimbabwe, in a subhumid region (Harare) and a semi-arid region (Masvingo), are shown in Table 3. Vogel (1991) recommends tie-ridging as a most promising technique for the higher rainfall areas of Zimbabwe, because of the consistently good yields resulting from improved protection against waterlogging in combination with little soil loss. This is consistent with findings from on-farm trials in different agro-ecological zones in Zimbabwe (Stevens, 1989). The poor yields for "no-till tie-ridging" in the much drier area of Masvingo are attributed to drought in combination with inadequate management (planting when ridges are not yet moist enough, untimely first weeding) which leads to poor emergence on the still dry ridges (Vogel, 1991). Complementary to the on-station trials, adaptive on-farm trials have been established in Zimbabwean Communal Areas from 1989/90 onwards (Gotora, 1991); conclusive results from these trials are not yet available.

Table 3: Comparison of tillage systems for maize on sandy soils in Zimbabwe

	Subhumid zone			*Semi-arid zone*		
	1988/89	*1989/90*	*1990/91*	*1988/89*	*1989/90*	*1990/91*
Grain yield (t/ha)						
Conventional tillage	3.8	2.8	3.1	2.8	6.5	1.9
"No-till tie-ridging"	5.0	4.6	4.6	2.3	5.4	1.0
Sheet erosion (t/ha)						
Conventional tillage	1.7	9.5	1.1	0.7	1.3	5.7
"No-till tie-ridging"	0.2	2.2	0.3	n/a	0.1	0.1

Source: Vogel (1991)

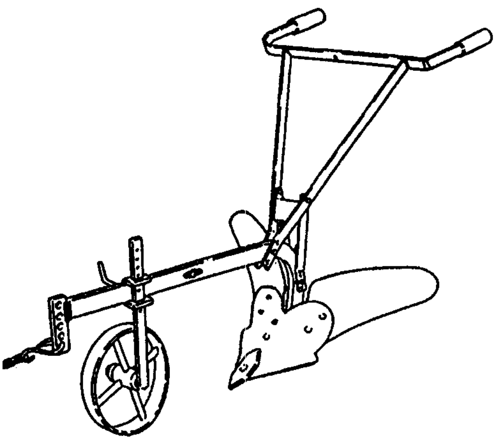


Figure 2: West African type of ridger (made by Lenco, Lusaka)

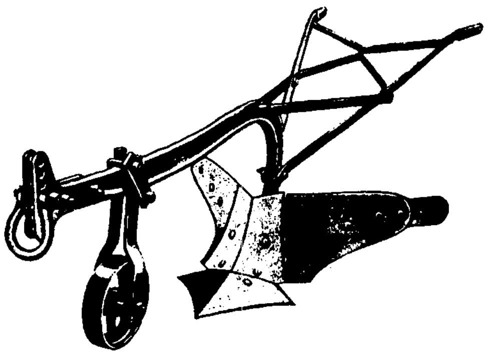


Figure 3: "Safim-type" ridger

Direct ridging

The Animal Draft Power Research and Development Programme in Magoye, Zambia, has been studying direct ridging since 1988 (Meijer, 1992). An animal-drawn ridger is used to make ridges at the beginning of the season without any prior tillage operation. Among the ridgers used was one manufactured in Lusaka by Lenco, which was based on a design that is widely used in francophone West Africa (Figure 2). Once installed, the ridges are re-ridged at the beginning of subsequent seasons. Meijer (1992) reports time savings of more than 50% as compared to plowing, and 70% when compared to ridging after plowing, while draft force requirements on moist sandy loam were found to be comparable (slightly lower) to those for plowing. However, ridges on direct-ridged plots tend to be smaller than those made on plowed plots.

Draft force requirement and ridge size vary with the type of ridger used. The most common ridgers in eastern and southern Africa are commonly known as the "Safim-type" (Figure 3). Although various manufacturers make these ridgers and they differ in various ways, they are all similar to the ridgers that used to be made by the Safim company of South Africa. In most parts of the region, Safim-type ridgers are the only ones available. They are big, heavy implements with large triangular shares, rudders and long curved wings that can turn inward and outward on hinges. Their draft force requirement is generally high and they are heavy to operate. Production of this rather complicated design is often of low quality resulting in ridgers which may be difficult to control and adjust. Unlike the ridger used in francophone West Africa, the Safim-type ridger consists of many bits and pieces. Its frog which holds the soil working parts is moulded and tends to break if it hits a stump. Because of its high draft force requirement it is considered unsuitable for direct ridging. In tests at the Institute of Agricultural Engineering in Harare Safim-type ridgers were rejected (because of their high draft force requirement) in favour of locally-made prototypes based on the West African design (Chatizwa, Nazare and Norton, 1988; Chatizwa and Norton, 1989). However, attempts to interest local manufacturers in producing these have so far been unsuccessful.

In a three year on-station trial at Magoye Regional Research Station, Zambia (Meijer, 1992), higher weed pressure and greater soil compaction in the ridges of directly-ridged plots became apparent in the third year; crop development was clearly impeded and yields (of cotton) were only two-thirds of those on plowed and ridged plots. These observations led to the rather radical assumption that annual re-ridging should not be recommended; it would instead be better to alternate each year of direct ridging with a year of plowing. The advantages of ridging as a primary tillage method would then apply only half of the time. A practical objection (from a farmer's point of view) to alternating ridging and plowing every year could be the more difficult plowing of the undulating fields that were ridged during the previous year. Consequently, farmers might consider it better to forget about ridging altogether, and to continue annual plowing.

"No-till tie-ridging" versus direct ridging

One essential difference between "no-till tie-ridging" and direct ridging occurs in the first year. The extra effort required for the initial plowing in the first year of "no-till tie-ridging" will certainly discourage farmers. Another important difference is the much greater care needed in the "no-till tie-ridging" system to lay out the ridges properly, in view of potential erosion hazards. Originally, "no-till tie-ridging" was supposed to be an extension to the "contour layout". This consists of grass waterways, storm drains and contour ridges to protect arable land from rill and gully erosion and is a very common feature in the better farming areas of Zimbabwe. The new ridging system should take care of the sheet erosion that hitherto could not be controlled (Elwell and Norton, 1988). This scrupulous concern for land protection is understandable: "no-till tie-ridging" is developed in a country with much sloping land and a grave erosion problem. Genuine soil conservationists in Zimbabwe even regard the "no-till tie-ridging" system merely as a practical compromise for smallholder farmers without enough crop residues to practise true conservation tillage (Elwell and Norton, 1988). Two other, but not crucial, differences between "no-till tie-ridging" and direct ridging are the use of a plow instead of a ridger, and the making of ties; both features could easily be interchanged between the systems without changing them basically. Making ridge-ties should be seen as an extra operation to improve any ridging system.

The obvious advantage of using a plow for (re-)ridging is that (apart from a simple ridge-tier) only one implement, the most common one, is required; it is assumed that a plow will remain indispensable on the farm, even when a ridger is available. Another practical advantage is that farmers only need a plow yoke, and not a second, longer (weeding) yoke for making and weeding ridges with a ridger; a span of oxen on a long yoke is relatively difficult to handle. However, plowing is not nearly as fast as ridging.

Re-ridging

Elwell and Norton (1988) envisage that soil structure will be improved as a result of the slight soil disturbance of re-ridging, although the results from the Magoye trial (Meijer, 1992) seem to contradict this. Re-ridging in subsequent years may not destroy (cover) weeds on the sides and tops of the ridges satisfactorily, as experienced in Magoye while using a ridger (Meijer, 1992). A plow brings more soil onto the ridge, but if it is not properly set it can easily cut away part of the ridge base. In general, more care must be taken than in annual plowing to keep weeds under control, also during the late season and even after harvest. It is very important that weeds are prevented from producing seed; occasional hand pulling of the biggest weeds should be an effective means of ensuring this. Timely ridging at the beginning of the season is vital; in particular, weeds in the future crop lines must not be so high that they cannot be fully covered with soil. Hence problems arise in seasons that start with only a few or small showers, because weeds will begin to grow while the soil is still too hard to work.

Ridge-splitting

Splitting the ridges, either every year or after a few years of re-ridging, could be an alternative to plowing in both the ridging systems discussed above; it loosens compacted ridges, it kills weeds established in the ridges, and it maintains the advantage of fast land preparation.

Ridge-splitting can be done with a plow or a ridger. Preliminary results from an on-farm ridging study on sandy soil in Kaoma (Zambia) by the Animal Draft Power Research and Development Programme indicate that, with the ridgers currently available, splitting ridges is a heavy job for the oxen and also requires considerable effort from the operator. If the ridger does not dig deep enough, it tends to flatten out the remains of the old ridges, instead of building new ridges in one pass. This problem was initially experienced with the Lenco ridger (Figure 2), but was solved by removing the wheel to reach the desired working depth. When the ridger is working at the correct depth a lot of soil has to be moved and this requires a high draft force. A Safim-type ridger works more easily during ridge-splitting as its rudder helps to keep it in the old ridge.

Ridge-splitting must be done with a plow yoke. One ox is forced to walk in a furrow in which a new half ridge has already been built during the foregoing pass.

Ridging and planting

Planting on ridged land requires different techniques to planting on flat, plowed land.

Several planting methods are available for plowed land, and the farmer can choose the one most appropriate to the crop and to the time and labour available. A very common method is planting behind the plow, whereby seeds are dropped by hand in a furrow and covered with soil by the next pass of the plow. This method is only as fast as the plowing itself, but planting can begin as soon as the land is ready for plowing. A much faster method, but one that can begin only when plowing is completed, is hand planting into a small furrow made with a plow or ripper. Seed placement is more regular and not necessarily as deep as with planting behind the plow. Broadcasting seed, followed by harrowing, can be used with small-grained crops like millet. Planting in regular lines marked out with a rope is a time-consuming process. Some farmers, particularly those with a considerable area of cash

Figure 4: Cross-section of ridges with sharp crest (left) and flat crown.

crops, use a planter. The most common planter, and probably the only available one in most countries in eastern and southern Africa, is the "Safim-type" planter, with either chain or Pitman drive.

A method similar to planting behind the plow can be used on land that is being ridged; seeds are placed on the first half of the ridge and covered with soil when the ridge is finished at the second pass. This method, although fast, is not recommended because seed placement is too deep and irregular, and seeds may fall from the ridges. A planter suitable for planting on ridges does exist, but is not available in the region (Bordet, 1988). The Institute of Agricultural Engineering in Harare is studying the use of an animal-drawn tine to open a plant line on top of the ridges.

The method generally recommended for planting on ridges is to hand plant in holes made using a hoe or a stick, and then to close the hole and cover the seed using the feet. This method is labour-intensive and therefore might mitigate against the acceptance of ridging as a land-preparation system. A variation of this method, but one which avoids the need to make holes by hand, involves changing the way in which the ridges are constructed. If, during the second pass of the ridger, the implement is kept a little further away from the first half ridge, then it will gently deposit soil against the side of the first half ridge, rather than push soil partly over it. The result will be a massive, strong ridge with a broad base and a flat crown instead of a sharp crest (see Figure 4). Hand planting can then take place immediately; seeds can be dropped in the small depression on top of the ridge and covered by the action of walking over it. Experience with this planting system for millet (on-station) and cowpeas was gained in Niger with direct ridging on sandy soil after the first shower (15–20 mm) had moistened the soil enough for planting (Stevens, 1988). Planting cowpeas on ridges using this method was found to be faster than traditional planting in hand-made holes on flat land (Table 4).

The crop is normally planted on top of the ridge, to prevent it from becoming waterlogged and to permit mechanised weeding. In the dry south of Zimbabwe, ridging for water harvesting is being studied on Vertisols in Chiredzi with different crops planted in the furrow bottom; crop growth and yields are significantly higher than for crops on flat land, but weeding is a major problem (Jones, 1990).

Tine tillage and ripping

Tined implements such as cultivators (Figures 5–9) can be used as primary tillage implements on light soils to loosen the soil with little turning or incorporation of surface residues.

In dry areas with sandy soils, on which a crust forms after showers, a shallow cultivation to break the crust enhances water infiltration considerably, and can result in increased crop yields (Stevens, 1988). The disadvantage of full-surface cultivation, however, is that draft force requirements are likely to be high under relatively dry soil conditions, while in moist conditions too fine a tilth may be obtained, hence increasing the risk of water and wind erosion and accelerated formation of a new crust. Furthermore, multi-tined implements tend to sweep surface residues off the field when these get stuck between the tines and the tines are then unable to penetrate very deeply. Besides, quite strong and durable cultivators are required, with rigid tines that are well fixed to the frame.

Ripping is working the soil in a narrow strip. It requires relatively low draft force. Implements used should combine strength and durability with simplicity, ease of operation and low production costs (Figure 10). Rippers can be used for opening a line in which to hand-plant directly afterwards.

Table 4: Labour requirements for direct ridging plus hand planting and traditional hand planting on flat untilled land for cowpeas on sandy soil in Niger

Operation	*Direct ridging and planting (hours/ha)*	*Traditional planting on untilled land (hours/ha)*
Ridging (4 hour/ha for a team with 2 operators)	8	n/a
Making holes with planting hoe	n/a	9
Hand planting	9	12
Total	**17**	**21**

Source: Stevens (1988)

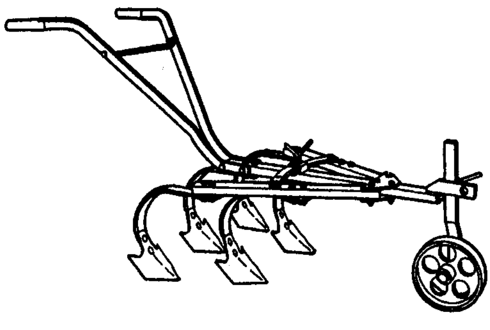


Figure 5: Houe Manga *cultivator*

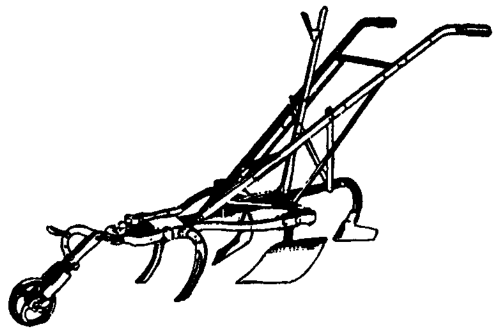


Figure 8: Adjustable cultivator with hiller blades

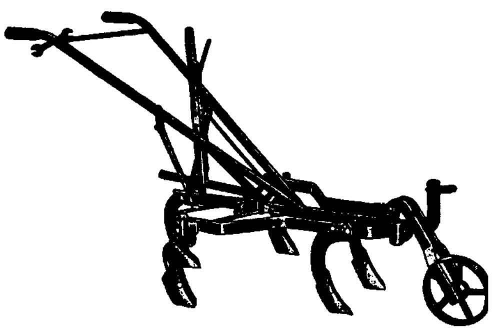


Figure 6: Adjustable cultivator with chisel tines

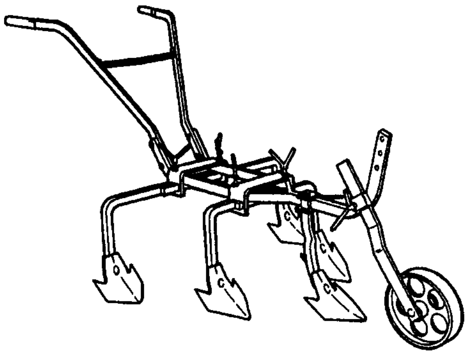


Figure 9: Cultivator on multipurpose toolbar

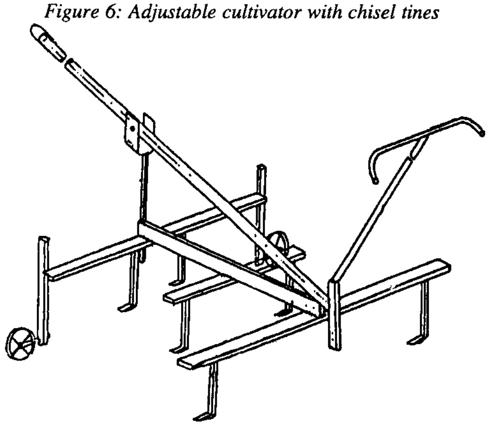


Figure 7: Mbeya Oxenization Project over-the-row cultivator (Source: Shetto and Kwiligwa, 1989)

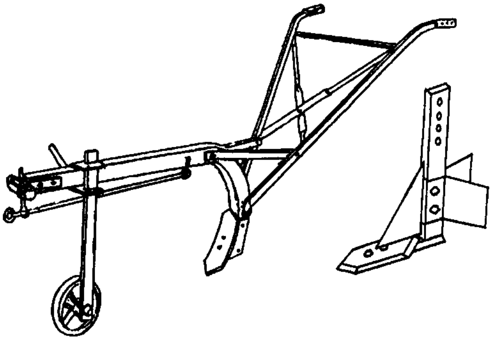


Figure 10: Plow beam fitted with ripper tine (left) and Konni ripper tine (Source: Kruit, 1991)

Ripping enhances water infiltration and favours crop growth and yield compared with direct planting on untilled land (Stevens, 1988). It is a good technique to bring degraded and abandoned fields back into cultivation (Kruit, 1991). It is fast and does not delay planting, compared with hand planting in untilled land (Stevens, 1988). It even enables earlier planting than can be obtained with plowing.

A big disadvantage of ripping is the poor weed control between crop lines at the beginning of the season. A cultivator could control early weeds, but the soil may still be too hard. The weed problem is less serious in more arid areas where weeds cannot grow abundantly because of drought. Another disadvantage is the increased risk of soil erosion by water on sloping land, especially on crust forming soils. In Zimbabwe, ripping is recommended only on fields having a good mulch cover. However, in the semi-arid area near Masvingo, Vogel (1991) reported that sheet erosion losses on ripped plots without mulch were only moderate (less than the critical level of 5 t/ha), while yields were slightly higher than on tied-ridged plots but slightly lower than on plowed plots. In more humid areas ripping should only be applied on soil protected by mulch. During wet periods, low soil temperature and poorer aeration may stunt crop growth. Ripping is not recommended on heavier soils because of water infiltration and weed problems.

Comparison of weed control methods

Shortage of labour capacity

Most farmers weed by hand, using a variety of well-developed traditional hand hoes (Raulin, 1984). Weeding is widely recognised as a serious bottleneck in crop production: in many cases the farm labour available for weeding determines the final area that can be harvested. It is quite common for the workforce to be unable to cope with the weeds on all the fields, so parts of the crops become overgrown and have to be written off: even on fields that have not been abandoned, yields are considerably reduced by inadequate weeding. In a literature review on weeding research, Shetto and Kwiligwa (1989) describe the decisive impact that proper weed control has on crop yields and total production. The answer to the weeding problem of many households in an increase in labour capacity, which can be provided by draft animals.

Weeding with animal traction

All too often the development of animal traction technology in an area seems to halt after plows and carts have been introduced. Animals are rarely used for weeding in Africa, even in areas where plowing has been practised for generations. Planters and weeding implements are used in some areas, but sales of such implements are only a fraction of those of plows. Several factors may account for this low interest in planters and weeders. Perhaps development programmes have given too much emphasis to plowing. Perhaps it is the men in farming households who generally take major decisions but they themselves are not very involved in weeding operations. Perhaps it is just too costly to invest in more than one implement. Probably the answer is a combination of such factors. Nevertheless, draft animals do provide a clear opportunity to alleviate the problem of labour shortage for weeding.

One study of maize weeding in the southern highlands of Tanzania compared different weed control systems involving combinations of hand labour and animal draft power (Kwiligwa, Shetto and Rees, 1994). Table 5 highlights the main results of this study. The labour requirement for weeding was reduced tremendously when weeding was

Table 5: Comparison of weeding systems for maize in the southern highlands of Tanzania, 1989/90

Weeding system	*Weed dry weight 70 days after planting (t/ha)*	*Maize yield gain*[1] *(t/ha)*	*Weeding labour input (hours/ha)*	*Weeding labour productivity (kg/hour)*	*Variable weeding costs*[2] *(TSh/ha)*	*Overall net profit*[3] *(TSh/ha)*
1 Hand} 2 Hand} = *farmers' practice* 3 None}	6.4	3.1	184	17	22 000	31 000
1 Hand} 2 Hand} = *recommended practice* 3 Hand}	3.8	3.5	227	15	32 000	25 000
1 Cultivator 2 Cultivator 3 Ridger	8.7	1.4	42	33	9 000	26 000
1 Cultivator (early) 2 Cultivator (early) 3 Cultivator (early)	8.0	1.1	49	22	9 000	23 000
1 Cultivator + hand (intra-row) 2 Cultivator + hand (intra-row) 3 Ridger	4.6	3.3	120	28	16 000	38 000
LSD (5%)	2.0	1.5	10			

[1] *Maize yield gain over yield of unweeded control plots which was 1.9 t/ha*
[2] *Cost calculations based on open market prices and costs for 1989/90 season. Figures in Tanzanian shillings (Tsh)*
[3] *Based on maize price of Tsh 13 200 per tonne (US$ 1 ≈ TSh 150)*
Source: Kwiligwa, Shetto and Rees (1994)

entirely with animal draft implements instead of hand hoes. However, in these circumstances yields dropped as well, as a result of poor weed control within the crop rows. Weeding earlier (at maize heights of 5, 25 and 45 cm instead of 10–15, 45 and 90 cm) did not improve this situation. With additional hand labour for within-row weeding, yields were again back at normal level. This was of course at the expense of some of the gained reduction in labour input. Nevertheless the system of animal traction weeding with additional hand labour led to a 65% increase in labour productivity, and a 23% higher net benefit, compared with farmers' practice of hand weeding twice. It is interesting to note that the recommended practice of weeding three times instead of twice gave only a slightly higher yield, but in financial terms led to a 19% decrease of the overall net benefit.

In other trials by the same research team in Tanzania, herbicides were found to reduce labour requirements even more than using animal traction. Herbicides led to yields comparable with the best manual and animal traction techniques, and therefore resulted in enormous labour productivity. Nevertheless the high cost of herbicides meant that the overall profitability of the herbicide treatment was no greater than some other weeding treatments (Shetto and Kwiligwa, 1989).

Reducing additional hand labour

A farmer with animal traction and much land but with little labour could simply cultivate all the land quickly with animal power. The farmer could accept the loss in yield caused by the within-row weeds as total production and net benefit would probably be higher than that when hiring additional hand labour.

It would seem that improved implements and working methods could dramatically reduce the need for additional hand weeding (or the use of herbicides) without reducing yields.

In the weeding comparison study in the southern highlands of Tanzania, mentioned above, an over-the-row cultivator, developed by the Mbeya Oxenization Project (Figure 7), was compared with the more common adjustable inter-row cultivator (Figure 6). No remarkable improvements were observed for the prototype over-the-row cultivator, although the short yoke that goes with any over-the-row cultivator seemed to improve the teamwork of the oxen, as compared to the long yoke used with inter-row cultivators (Kwiligwa, Shetto and Rees, 1994).

Cultivators

The use of cultivators for weeding is most appropriate for early weed control on smooth, clean fields. Weeding with cultivators becomes troublesome on land heavily infested with weeds, particularly when the implement has many short tine shanks; clods of soil and uprooted weeds get stuck between the tines and the cultivator starts acting like a rake, not penetrating the soil any more, but just sweeping the gathered ball of soil and weed mass forward. The same problem occurs in fields with high levels of crop residues (which are desirable in conservation tillage systems). Another disadvantage of the cultivator is the rather complex design, as compared to ridgers and plows. In practice this results in bulky tools which are often poorly assembled and which generally cannot be set as specified.

Adjustable cultivators

The most common cultivators in eastern and southern Africa are all more or less successful versions of the well-performing Safim design (see examples in Figures 6 and 8). All are meant to be adjustable in working width during operation without the need to stop. A serious disadvantage of most cultivators found in the region is their poor durability; moulded shanks break easily, tines made of mild steel wear and bend after a short period of use, and the frames are not strong enough for most of the conditions under which they are used.

Cultivators on multipurpose toolbars

In francophone West Africa cultivators are usually attached to multipurpose toolbars (Figure 9). The durability and performance of these implements are mostly good, but they are not easily adjustable during operation. The overall working width and the distance between the tines must therefore be set before weeding begins. Hence, for maximum working efficiency inter-crop row distances should be as regular as possible; if crop row distances are irregular, fewer tines can be used, or a narrower working width must be set and two passes are needed along each row. On some types of multipurpose toolbars the tine shanks are attached to the frames with clamps. This system avoids the need for spanners to adjust the tines, but there are two serious disadvantages: the clamps add to the weight of the implement and, if not perfectly produced, their grip tends to loosen during use. It is very common for tines to fall out unexpectedly, even though they were carefully tightened a moment earlier.

The *Houe Manga*, developed in Burkina Faso (Figure 5), seems to offer a compromise between the above mentioned disadvantages of cultivators on toolbars and the complexity of Safim adjustable cultivators.

Hiller blades

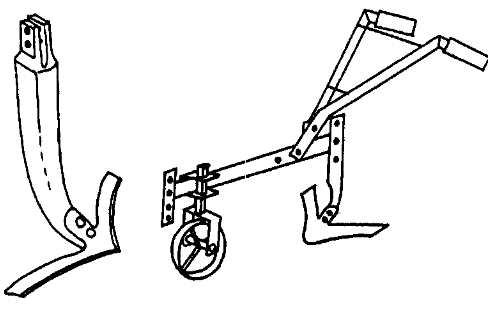
A pair of hiller blades attached to an adjustable cultivator (Figure 8) can be used to cover weeds within crop rows. It performs excellently when used under the proper conditions for cultivators, leaving an almost completely weed-free field. If any tall weeds remain, they can be rapidly pulled out by hand. This adjustable cultivator with hiller blades is widely used and appreciated by farmers in Zimbabwe. The Animal Draft Power Research and Development Programme in Zambia has also found such cultivators are also easily accepted by farmers once they have seen them working.

Ridging

Ridging is a fast and simple weeding method which, like plowing, can cope with crop residues, big weeds and relatively high weed densities. Ridgers and plows are reasonably easy to use on fields with tree stumps and shrub remains. Ridging covers weeds within the crop rows, but ridging early in the season runs the risk of covering seedlings as well as weeds. It would require good management to use a ridger or a plow effectively for first weeding on flat land; weeding must be done early enough to prevent unacceptable yield reduction and build-up of weeds, but not so early that the crop may be damaged. When the crop is planted on ridges this might be less of a problem. Hence ridging is particularly recommended as a technique for the second weeding.

As noted in a previous section relating to direct ridging, there are two main types of ridgers—the type used in francophone West Africa (Figure 2) and the Safim-type (Figure 3). During weeding demonstrations organized by the Animal Draft Power Research and Development Programme in Zambia two weeding implements proved popular—the West African ridger and the adjustable Safim cultivator fitted with hillers.

Figure 11: Sweep tine (left) and Konni donkey hoe (Source: Kruit, 1991)



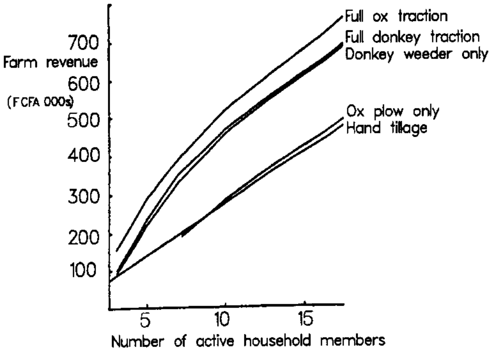


Figure 12: Increases in farm revenue with animal traction for different farm sizes in Burkina Faso. Source: Sanders (1985) after W Jeager (1984)

The West African ridger's simplicity and ease of handling are quite remarkable. It does a proper weeding job with good coverage within the plant lines for crop row distances of up to about 90 cm. However, if the soil is hard and dry, penetration, and hence effective working width, are reduced. The ridger cuts a clearly edged furrow which some farmers dislike. The wings can be easily adjusted; each one pivots around a bolt turning simultaneously either outwards and downwards, or inwards and upwards. This enables effective (re-)ridging at different inter-ridge distances and prevents damage to the ridges by the wings during re-ridging at small inter-ridge distances. This is unlike the Safim ridger (Figure 3) with its horizontally turning wings on hinges. Nevertheless, the Safim type ridger, although heavy to pull and handle, suppresses weeds effectively, leaving behind a flat, large furrow with no edge at the ridge base.

Weeding with donkeys

Weeding with donkeys has great potential on light soils in semi-arid areas, and should be encouraged further. In many of these areas crops are rapidly hand planted in untilled land as early as possible. The limiting labour bottleneck occurs at the first weeding (Sanders, 1985). Kruit (1991) recommends the introduction of donkey weeding with a relatively cheap and simple sweep tine of 35 cm width, originally intended for groundnut lifting, mounted on a toolbar (Figure 11). The graph in Figure 12, from an economic study in Burkina Faso, reported by Sanders (1985), clearly illustrates how attractive donkey weeding can be.

Conclusions

Improving tillage involves changing complete systems. Changes in tillage necessitate changes in working methods and in subsequent farming operations (planting, weeding, harvesting). It may take a long time before there are observable improvements in soil properties, yields and costs. Practical and simple solutions are required, with appropriate and durable implements and easy and well-proven methods. However, the systems must be flexible, for farmers benefit most when they adapt and refine implements and techniques to their particular, ever-changing conditions.

Ridging, and especially tie-ridging, has good potential for soil and water management, particularly in subhumid regions and on heavier soils in semi-arid areas. Ridges reduce waterlogging and soil loss and facilitate drought survival. In semi-arid regions, ridging on sandy soils reduces wind erosion problems but may lead to crop failure if ridges dry out before roots reach ground water.

Ripping is very fast and improves water infiltration in semi-arid areas, but may not control weeds adequately. Both ridging and ripping require less labour than plowing (and less than direct hand planting on untilled land). Nevertheless further adaptive research is necessary to develop ridging and ripping systems well adapted to the farmers' needs.

Weeding with animal traction is much faster than hand weeding and is physically lighter (benefiting all people including women, children and the elderly). Animal power makes the timely weeding of all fields possible, with benefits for labour productivity and production. Animal-drawn weeding techniques are more cost-effective than herbicides and are more likely to be available to smallholder farmers. Animal-drawn weeding techniques should eradicate weeds within crop rows at an early stage to reduce the need for additional hand-weeding. Cultivators with hiller blades are useful tools for this. It is not essential to have a cultivator that can be adjusted while weeding, although this can be useful where rows are irregular. Excessive vegetation or crop residues can cause problems for cultivators which tend to act as rakes. This is less of a problem for ridgers, which ideally combine ease of use with reliability and durability. However, ridgers cannot be used easily when the crop is still small. Ridgers are ideal weeding implements on both flat and ridged fields, but are less effective in dry conditions, and where crops are widely spaced (80–90 cm). Rapid progress in weed control in the region is more likely to come from familiarising farmers with existing methods of animal-powered weed control rather than from further research programmes.

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