MECHANICAL ASPECTS OF CULTIVATION

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Tillage can be defined in various ways. One definition is that tillage is the preparation of the soil for planting and the process of keeping it loose and free from weeds during the growth of crops (Smith 1965). One can also say that the ultimate aim of tillage is to manipulate a soil from a known condition into a different desired condition by mechanical means (Gill & van den Berg 1967). More specifically, the objectives of tillage can be listed as:

(i) to loosen the soil for maximum rainfall, root and air penetration;

(ii) to turn under and mix stubble or other materials;

(iii) to destroy weeds and prevent their re-growth;

(iv) to loosen the soil and prepare a proper seedbed for planting;

(v) to leave the soil surface resistant to erosion;

(vi) to destroy insects, their eggs and breeding places.

Seedbed preparation usually consists of ploughing followed by some pulverising action by disc harrow, possibly followed again by a spring-tooth or spike-tooth harrow. Often the soil is left to dry out for long periods between operations, resulting in cloddy seedbeds. In an attempt to break down the clods, additional, often useless and expensive operations, might be carried out with only one guaranteed result — loss of soil moisture, something which we in South Africa can hardly afford.

Tillage operations can account for up to two-thirds of the power and labour required to produce crops such as maize and groundnuts. Any device or system which will prepare seedbeds with less power and labour must therefore be of distinct advantage to the farmer. It is also of extreme importance that he understands the operating characteristics, the applicability and the performance of the various tillage machines.

Instead of broadly defining tillage as above, one should then perhaps, like Hunt (1973), rather consider optimum tillage as being that amount which maximises the return from the crop to be planted. He defines an economical seedbed as one that:

(i) discourages weed growth;

(ii) has a minimum amount of energy expended in its preparation;

(iii) causes the least amount of damage to the soil by wheel traffic;

(iv) prepares as a seedbed only, the soil adjacent to the eventual seed position.

In fact one should thus only do what is absolutely necessary and guard against any over-cultivation. Every tillage operation should be critically analysed and questions such as the following should be asked:

- what is the aim of the operation?
- why is this necessary?
- why must it be done at a particular time?
- why use a particular machine system to do it?
- what are the alternatives to each of the above?

One must guard especially against the all too prevalent habit of doing things simply for fashionable or historical reasons.

The rest of this paper will concern itself with ways and means of reducing the amount of energy expended in the preparation of seedbeds by choice of machine systems and optimum machine operation.

Tillage tools are mechanical devices to apply forces for the pulverization, cutting, inversion or movement of the soil. There are many types of tillage machinery. Some would be satisfactory under one set of conditions but quite unsatisfactory under others. These implements can be broadly classified into primary or secondary tillage equipment. The first class would include implements such as ploughs and subsoilers to break and loosen deeply, with harrows, pulverizers, cultivators, etc classed as secondary tillage tools.

As an example of primary tillage equipment, the ordinary mouldboard plough will be discussed in some detail.

The plough is still the most common and important implement used to achieve the primary goals of tillage. Some type of plough already existed thousands of years ago. In the Bible we read that Elisha was found "ploughing with 12 yoke of oxen before him" (Kings 19:19). Iron ploughs materialized in England at the end of the 18th century and a hundred years later large 10 to 15 bottom ploughs, pulled by huge steam tractors were common. The integral tractor-mounted plough was developed in the early 1940's by

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Ferguson. Since that time no real significant change has occurred in basic plough design.

Used correctly, the standard mouldboard plough still has a place in agriculture. It lessens weed competition compared to other methods such as rotary tillage or disc machines which tend to stir and mix soil and trash.

A plough, or for that matter any other tillage tool, moving at uniform velocity is subjected to three main forces, ie gravity, pull to maintain motion and total soil reaction. The total soil reaction can be broken up into useful and parasitic forces (Bainer, Roy, Kepner & Barger, 1955). The useful forces are those that the tool must overcome in cutting, breaking and moving the soil. The parasitic forces are those that act upon stabilizing surfaces such as the landside and sole of ploughs or upon supporting runners or wheels.

Factors such as type and shape of mouldboard, sharpness of share, overall adjustment, depth and width of cut, soil type and condition and speed, all affect the draught of ploughs. The total draught will thus vary widely from field to field. A breakdown of the components of the total draught of a plough would give something like 18 per cent due to friction (parasitic), 34 per cent in turning the furrow slice and 48 per cent in cutting the slice.

Friction forces, although impossible to eliminate entirely, can be reduced by correct adjustment and hitching of the implement. This is one draught component over which the operator does have considerable control. Too often, however, when a particular tractor seems incapable of handling an implement satisfactorily, not because the implement is basically too big but because it is badly adjusted resulting in excessive power requirement, the easy solution is adopted, namely to hitch a bigger tractor.

Draught is affected by the speed of ploughing. As shown in Table 1 (Smith, 1965), increased speed will result in increased draught.

TABLE 1 Draught of mouldboard ploughs for various speeds, expressed as percentage of the draught at 1,6 km/h

	Soil type.	
Speed (km/h)	Clay loam	Loam
1,6	100%	100%
3,2	114	117
4,8	128	–
6,4	142	126

For a general-purpose mouldboard plough a speed increase from 3,2 to 6,4 km/h will thus increase draught by about 25 per cent, varying with soil. The increased draught, due to speed is probably applied to that part of the total which is required for turning and pulverizing. This varies with speed from less than one-third to about one-half of the total draught within the range of 3 to 5 km/h.

The sharpness of shares is especially important when ploughing sod, rooty soil or hard and/or dry soil. Gill & van den Berg (1967) found that the effect of wear on the angle of sharpness and specific draught resistance of ploughs was as shown in Table 2.

TABLE 2 Effect of wear on draught of mouldboard ploughs

Soil	Area ploughed ha	Specific draught ressitance kg/cm^2	Increase in draught %
loam	0	0,50	0
	1,95	0,59	18
	4,88	0,63	26
	6,9	0,66	32
sand	0	0,31	0
	2,44	0,35	13
	5,70	0,37	19
	12,2	0,40	29

The increase in draught due to decreasing sharpness of the blade would be due to larger forces required to cut the furrow slice.

Draught is also affected by depth of tillage. The relationships shown in Figure 1 have been established between draught and depth for various soils. (Gill & van den Berg, 1967.) These data indicate that depth of operation can be increased up to 12,5 cm in most soils without an appreciable increase in specific draught.

To illustrate that depth of operation also affects the draught of implements other than mouldboard ploughs, the data of Table 3, compiled from work done on a five bottom chisel plough (or ripper), can be studied. (Gill & van den Berg.)

TABLE 3 Draught requirements of a chisel plough at various depths

Depth of operation cm	Draught force kg	Specific draught kg/cm^2
8,3	507	0,61
18,3	1 259	0,73
28,3	2 159	0,75
33,6	3 264	0,91
35,2	3 338	0,94
40,6	4 334	0,97
43,8	5 200	0,96

From this data it can be seen that the specific draught of rippers also increases with depth.

The width of cut of a tillage implement also affects specific draught. However, considerable work still needs to be