The 7th Conference of the International Soil Tillage Research Organization, Sweden, 1976.

ALTERNATIVES FOR PLOUGHING

C. van Ouwerkerk
Institute for Soil Fertility, Haren (Gr.), The Netherlands

ABSTRACT

Experimental evidence from 8 years' research on alternative tillage systems shows that, at least in a wide rotation, ploughing is not always needed to obtain good growth. Alternatives may vary from non-ploughing (for cereals) to deep cultivating (for root crops). In any case a good seedbed must be prepared, rapid and uniform emergence being prerequisite to high yields.
Alternatives for ploughing may be incorporated into a system of rational tillage, aiming at maximum net profit from the farm for the duration of the (intensified) crop rotation.

Ploughing is the main part of the tillage system and, therefore, an integral part of the modern farm management which aims at maximizing net profit from the farm for the duration of the crop rotation (Van Ouwerkerk, 1974). This goal may be achieved by intensification of the crop rotation - to maximize gross yield per ha - and by rationalization of tillage practices - to minimize total production costs, of which roughly 15% may be charged to soil tillage.
The modern plough is reliable but slow: maximum forward speed is about 7 km/h (Poesse and Van Ouwerkerk, 1967). Modern, powerful tractors >100 HP make the use of very wide, multi-body ploughs possible. However, apart from the fact that these ploughs are not easy to handle, they pay only on very large farms, which are uncommon in The Netherlands. Therefore, alternatives for the plough are currently sought actively.
In selecting an alternative, one must be clear about the objectives. The primary objective of ploughing is loosening the soil and restoring its homogeneity. Secondary objectives are incorporation of crop residues, mixing of organic and mineral fertilizers with the soil, control of weeds and of pests and diseases (Kuipers, 1963).
Insight into the practical possibilities and the fundamental background can be gathered from the results of research on alternative tillage systems carried out during 1968-1975 (Bakermans *et al.*, 1974; Van Ouwerkerk, 1976).

TILLAGE SYSTEMS

In general, any tillage, especially ploughing, has a loosening effect on soil structure while traffic has a compacting effect. According to the extent to which loosening effects are incorporated and compacting effects are tolerated, four different tillage systems can be distinguished (table 1).
In the *traditional* system the soil is loosened deeply and intensively each year by ploughing. However, in spring the soil is usually compacted to the extent that the loosening effect is completely nullified.
The experimental *loose-soil husbandry* tries to improve this situation

Table 1. Tillage systems.

Loosening effects	Compacting effects	Denomination
+	-	loose-soil husbandry
+	+	traditional tillage
-	-	rational tillage
-	+	zero-tillage

by maximizing the loosening effect and by minimizing compaction through rationalization of traffic, irrespective of costs.
In its full sense *zero-tillage* means that any tillage whatsoever (seedbed preparation included) is omitted (Bakermans and De Wit, 1970). However, for potatoes this is impractical as mechanical lifting is impossible without proper ridges. Therefore, by way of concession, a seedbed is made by full-width rotovating to a depth of 7 cm. In this system compaction of the soil predominates. As a consequence soil structure soon becomes homogeneous, dense and hard (Van Ouwerkerk and Boone, 1970; table 2).

Table 2. EHF "Westmaas" (1968-1971) - Pore space (%, v/v), averaged over 4 years and 5 crops.

Depth (cm)	Tillage system		
	traditional	zero	rational
2-7	49.5	45.9	48.9
12-17	46.7	44.0	45.6
22-27	46.3	44.7	45.5

Rational tillage is distinct from the other three systems in that it aims at increasing the efficiency of soil tillage in a technological and economical sense to maximize net profit, averaged over the duration of the crop rotation. Therefore, frequency, depth and intensity of soil loosening are made to correspond to the specific demands of the individual crops in the rotation with respect to soil structure and weeds. In practice this simply means that tillage in its broader sense (i.e. including traffic over the field) is restricted to a rational or a reasonable extent. This may be a reduction to nought (as for cereals), but also ploughing to 25 cm (as for sugar beet). It is self-evident that one tries to safeguard the loosening effect as much as possible by rationalization of traffic (combined cultivations, wide implements etc.).

EXPERIMENTS

Our first experiment (ZWZH 1310) was conducted during 1968-1971 in a fairly wide, five-year rotation, viz.,alfalfa or ryegrass - sugar

beet - winter wheat + ryegrass - potatoes - barley or oats + ryegrass. In this experiment rational tillage was compared with traditional tillage and zero-tillage (table 2). The experiment was laid out on a light clay soil (27% clay; 3.0% o.m.).
In 1971 a new experiment (Ws 38) was started on a heavy loam soil (21% clay; 2.9% o.m.). Here rational tillage is being compared with loose-soil husbandry and zero-tillage in an also fairly wide, four-year rotation, viz., sugar beet - barley + ryegrass - potatoes - winter wheat + ryegrass. The essential features of the three systems are shown in table 3.

Table 3. EHF "Westmaas" - Tillage systems compared since 1971.

Crop	Tillage system		
	loose-soil (A)	zero (B)	rational (C)
winter wheat	plough 20 cm + sowing (1 pass); no seedbed prep.	cultivator 6 cm + sowing (1 pass); no seedbed prep.	cultivator 15-20 cm + sowing (1 pass); no seedbed prep.
sugar beet	plough 25 cm seedbed prep. + sowing (1 pass)	- direct drilling	plough 25 cm seedbed prep., sowing (2 passes)
spring barley	cultivator 8 cm plough 20 cm seedbed prep. + sowing (1 pass)	cultivator 3 cm - direct drilling	cultivator 8 cm cultivator 15-20 cm seedbed prep., sowing (2 passes)
potatoes	plough 25 cm N-fert. + seedbed prep. + planting + ridging (1 pass)	- rotovator 7 cm + planting (1 pass) row-rotovating + ridging (1 pass)	plough 20 cm seedbed prep., planting (2 passes) row-rotovating + ridging (1 pass)

With respect to soil structure results until now were similar (table 2, fig. 1) for both experiments, mainly due to the fact that wheelpath or bed systems (Kouwenhoven, 1975) could not yet be fitted into the loose-soil system.
Differences in total pore space between systems A (loose-soil husbandry) and C (rational tillage) were only slight at the 2-7 cm depth. At a depth of 12-17 cm A was equal to or slightly better than C (effect of seedbed preparation) while at a depth of 22-27 cm A nearly always had a larger pore space than C (effect of working depth). With zero-tillage (system B) soil structure was much worse: at 2-7 and 12-17 cm depth it approached the maximum density for this soil (pore space 39%, v/v). In the 22-27 cm layer, not prone to compacting effects, pore space was somewhat higher.

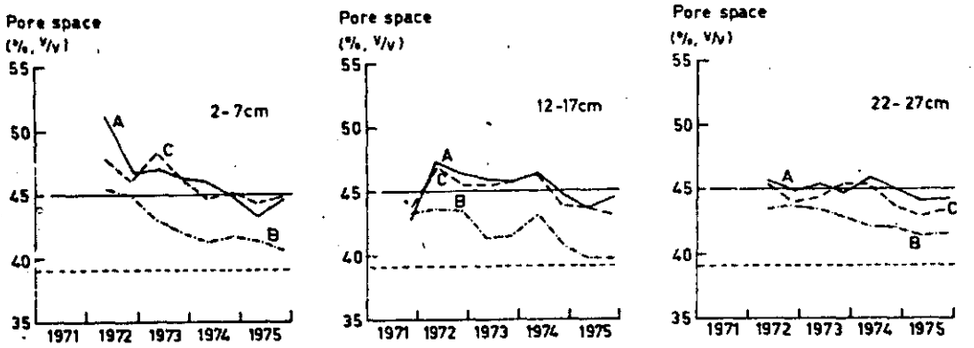

Fig.1. EHF "Westmaas" (1971-1975) - Pore space, averaged over 4 crops. A = loose-soil husbandry; B = zero-tillage; C = rational tillage.

It is striking that, in all systems, pore space decreased in the course of time and even in systems A and C fell below the critical level for this soil (pore space 45%, v/v; air content at pF 2.0 about 10%, v/v). However, this trend was due mainly to the effect of bad weather conditions during autumn and winter 1974/1975. Thanks to the subsequent fine, dry summer, distinct signs of recovery could already be noted in the autumn of 1975.
Averaged over the years there were no significant differences in yield level between systems A and C for the crops studied.
With zero-tillage, the yield level was clearly lower, especially with root crops. Experimental evidence suggests that actual differences between systems A and C were due mainly to differences in quality of the seedbed or in amount and aggregate diamater of the loose soil in the potato ridges. With respect to zero-tillage it can be stated that negative effects of poor soil structure predominated. These negative effects may be compensated, at least partly, by preparing a good seedbed and by increased nitrogen dressings.

To what extent these results will hold for extremely narrow rotations is being studied in new field trials. Preliminary results indicate that further intensification of the crop rotation and a higher net return are possible only if labour-saving alternatives for ploughing and other important parts of the tillage system are introduced.

ALTERNATIVES FOR PLOUGHING AND RATIONAL TILLAGE

Alternatives for ploughing depend on crop rotation, soil type, and climate. Moreover, in my opinion, the alternatives should contribute as much as possible to the net profit from the farm for the duration of the crop rotation.
The most promising alternative for ploughing found so far is the modern rigid-tined cultivator or chisel plough which produce about the same intensity of loosening as the moldboard plough. However, depending on the way of soil breaks up between the tines, the effective averag working depth of a cultivator is up to 5 cm shallower than the depth of the tines. Therefore, below 20 cm depth one has to reckon with a denser soil than with ploughing. Hence, it is not advisable to continue cultivating to this depth for many years. As a cultivator does not invert the soil, green crops cannot been turned under properly. Therefore, they have to be killed chemically. When they have produced much bulk, a shallow pre-treatment with a full-width rotovator has to be added. As these are costly, time consuming measures, ploughing is

preferred in this case. For the same reason the spading machine is now obsolete in Holland. The non-inverting action of the cultivator has the big advantage that potatoes lost at harvest stay in the topsoil where they have the best chance of being frost-killed (Lumkes, 1974). However, not inverting the soil means also that sugar beet tops and leaves as well as rhizomatous weeds stay near the surface. Hence, for spring cereals and sugar beet, seedbed preparation, serving also as mechanical weed control, is indispensable. Also later, intensive weed control has to be continued.

Generally, there are no objections to replacing ploughing by cultivating. However, in some cases a part of the zero-tillage system may serve as an alternative. For instance, in the narrow crop rotation sugar beet - winter wheat + ryegrass - potatoes, deeply loosening of the soil may not be necessary for winter wheat. When excessive rutting has not occurred the wheat can be drilled easily with a triple disc machine. Other possibilities are using a semavator or broadcasting the seed and working it under with a spring tined cultivator. After potatoes, however, it is imperative to level the surface and to mix the fine soil created at harvest with coarser material from beneath to re-establish contact with the subsoil and to create enough storage capacity for water. This is accomplished in one pass with the rigid-tined cultivator, provided 6 to 10 HP per tine is available. After winter wheat ploughing is preferred, as outlined before.

Along these lines alternatives for ploughing may be found and incorporated into a system of rational tillage. While not denying that high yields are rightly looked upon as the basis for a high net profit, it is a matter of weighing costs and returns to determine to what extent the specific demands of crops with respect to soil structure and weeds may be met.

REFERENCES

Bakermans, W.A.P. and Wit, C.T. de, 1970. Crop husbandry on naturally compacted soils. Neth. J. Agric. Sci. 18: 255-246.

Bakermans, W.A.P., Boone, F.R. and Ouwerkerk, C. van, 1974. Nieuwe grondbewerkingssystemen. Ervaringen te Westmaas, 1968 t/m 1971. Bedrijfsontwikkeling 5: 639-649.

Kouwenhoven, J.K., 1975. Beddenteelt voor aardappelen? Bedrijfsontwikkeling 6: 845-851.

Kuipers, H., 1963. The objectives of soil tillage. Neth. J. Agric. Sci. 11: 91-96.

Lumkes, L.M., 1974. Aardappelen als onkruid. Proefstatn.Akkerbouw, Publ. 15: 21-25.

Ouwerkerk, C. van, 1974. Rational tillage, Com. Etud. Agric. Environ., 1974, C.R. Séances - Bull. Rech. Agron. Gembloux, hors sér. 1974, pp. 675-709.

Ouwerkerk, C. van, 1976. Rationele grondbewerking, in verband met de structuur van de grond en de groei van het gewas. Landbouwkd. Tijdschr. 88, in press.

Ouwerkerk, C. van, and Boone, F.R., 1970. Soil-physical aspects of zero-tillage experiments. Neth. J. Agric. Sci. 18: 247-261.

Poesse, G.J. and Ouwerkerk, C. van, 1967. Ristervorm en ploegsnelheid. Publ. Inst. Landbouwtech. Ration. 103: 60.