THE 9TH CONFERENCE OF THE INTERNATIONAL SOIL TILLAGE RESEARCH ORGANIZATION, ISTRO, SOCIALISTIC FEDERAL REPUBLIC OF YUGOSLAVIA, Osijek 1982

SOIL STRUCTURE IN MODERN AGRICULTURE

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Abstract

A number of changes have taken place in agriculture in the last 10-20 years; more mechanization, a narrower crop rotation, and an increased use of chemicals. At first sight these changes must have a considerable, usually unfavourable, effect on soil structure. The results of annual investigations into soil structure confirm that indication.

Therefore, a study was made of the effect of various factors involved in modern farming on soil structure. The conclusion was that the decline in soil structure is not caused by a change in crop rotation or by the use of chemicals, but is mainly the result of more compaction due to the use of heavier equipment and insufficient restoration of the compacted soil through soil tillage.

Introduction

A number of changes have taken place in agriculture in the last 10 to 20 years. At first sight, these changes must have a considerable, usually unfavourable, effect on soil structure. The fact that soil compaction and deterioration of soil structure have often been a topic of discussion in recent years also points into that direction. The results of annual investigations into the structure of the top layer of farm fields and experimental fields confirm this indication, as is illustrated in fig. 1. It not only shows that structure varies from year to year due to weather conditions, but also that structure has been deteriorating during the last 10 years.

It was therefore decided to study how soil structure is affected by the various factors involved in modern farming and to search for means to prevent deterioration of soil structure.

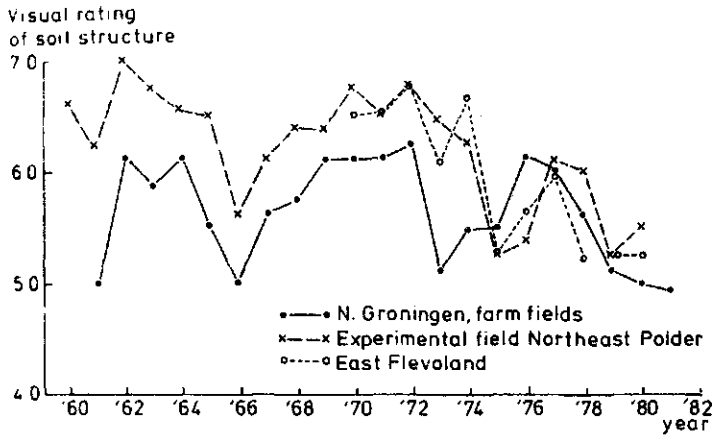

Fig. 1. Level of actual soil structure over several years.

Changes in agriculture

The most striking development in agriculture is *mechanization*, characterized by an increase in number and weight of implements. This change has been promoted by an increase in farm size and by high costs of labour. It resulted in new systems and new cropping techniques which make heavier demands both on the soil and on the management skills of the farmer.

Another change, especially in The Netherlands, is *narrowing of the rotations*. The number of crops decreased and the area under potatoes, sugar beet and corn increased. It is conceivable that this results in a reduced return of organic residues to the soil and more compaction as a consequence of the use of heavier machines under more unfavourable conditions, e.g. at harvest.

A third development is the increased use of chemicals like fertilizers, herbicides, and pesticides, and a decrease in organic matter supply. This development leads to a reduction in soil tillage and possibly to interference with the biological activity in the soil.

Measurement of the effects

Some of the effects are studied on experimental fields, for example those of heavy machines, fumigation, crop rotation, and organic manuring. The behaviour of soil structure of the top layer and the density of the subsoil in the course of time are measured on fields of commercial farms.

Soil structure is evaluated by a visual score and by determination of bulk density, pore space, air content and oxygen diffusion rate. Workability is characterized also by a visual score.

Compaction by machines

Driving a tractor a varying number of times over a sandy soil under different moisture conditions gave results as shown in fig. 2. As expected, an effect of number of runs and of moisture content was found. The conclusion reported in this study was that on sandy soils having a moisture tension of more than 125 cm, driving a tractor will give little harmful compaction. In actual farm practice, however, machines are often used under more unfavourable conditions and then the soil is strongly compacted. If compaction occurs in spring before the start of the growing season, plant growth will be impeded.

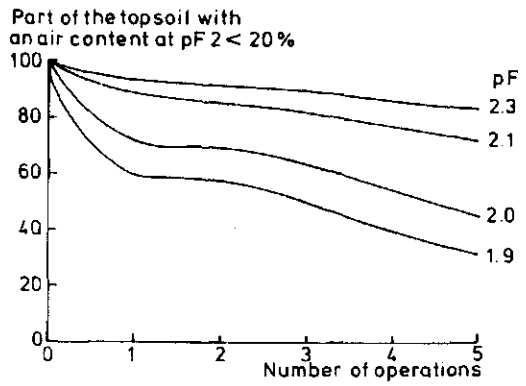

Fig. 2. Effect of driving with machinery - under different moisture conditions - on the actual structure of the top soil.

During harvest in late summer, strong compaction of clayey soils is found (fig. 3). The greater part of the field is occupied by tracks in which soil structure is very poor. In most years, subsequent soil tillage will undo this damage and thus the compaction will not be injurious.

An important question is to what depth compaction takes place. It is generally thought that the subsoil will be compacted by using heavy machines. However, on sandy and clayey soils we did not find an increase in density of the subsoil (fig. 4).

Effect of crop rotation

Twenty years of different crop rotations did not result in differences in organic matter content and workability in spring. Only small differences in actual soil structure were produced. With a larger proportion of sugar beet and potatoes in the rotation, soil structure deteriorated somewhat (table 1).

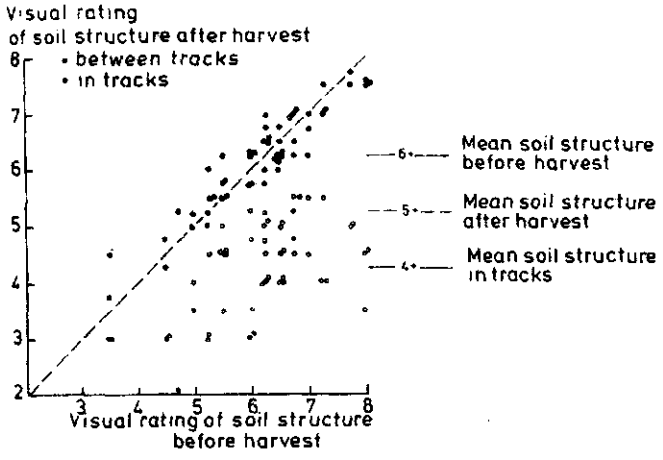

Fig. 3. Effect of driving with heavy machinery - during harvest - on the actual soil structure.

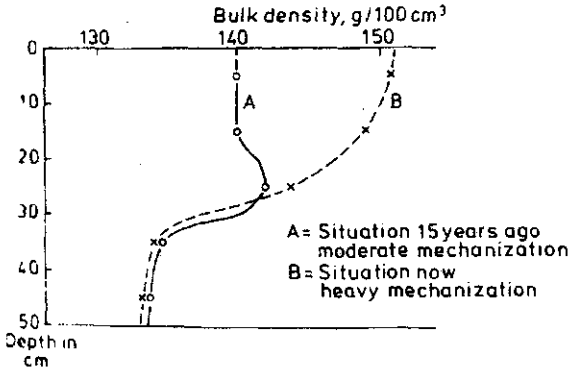

Fig. 4. Effect of mechanization on the density of the topsoil and of the subsoil.

In the Netherlands, the proportion of potatoes and sugar beet in the rotation rose from 27% to 43% in the last 20 years and, according to table 1, this will result in a soil structure deterioration of about 0.1 unit on the visual score scale.

Table 1. Influence of crop rotation on organic matter content, workability and actual soil structure.

Number of years with potatoes and sugar beet in six years	Organic matter content	Workability		Actual Structure	
		Visual score	Plasticity	Pore space	Visual score
0	3.04	5.0	28	54.2	6.2
1	3.00	5.1	30	54.0	6.2
2	3.05	5.1	31	53.4	6.1
3	3.04	5.1	29	53.1	6.0
4	3.01	5.1	32	53.1	5.9

Effect of chemicals

Chemicals like *fertilizers* and *pesticides* promote growth and increase yields. In general, this also means that larger amounts of organic residues are added to the soil.

Use of *herbicides* instead of mechanical weed control entails missing the effect of soil tillage. Especially after harvest, stubble plowing may be important in restoring the compacted soil.

Fumigation is not damaging to soil structure. This conclusion was reached in a study conducted on a sandy soil which was fumigated annually and on a clay soil that received a single treatment.

Organic matter content of the soil

It was expected that a number of factors in modern agriculture would cause a reduction in organic matter content of the soil. This is not the case, however, judging from the results of routine analyses in certain regions of The Netherlands (table 2).

Table 2. Soil organic matter contents in two regions.

% particles <16 µm	Wieringermeer			Northern part of Groningen		
	'41-'47	'50-'61	'76-'77	'69-'71	'72-'75	'78-'79
10	1,71	1,65	1,73	1,66	1,59	1,63
20	2,24	2,22	2,23	1,94	1,96	1,95
30	2,73	2,78	2,73	2,22	2,23	2,27

Evidently the amount of organic matter added to arable land was not lowered by the change in crop rotation or by substitution of fertilizers for organic manure. Another explanation may be that decomposition of the organic material is slowed down due to poorer aeration of the soil.

Factors responsible for soil structure deterioration

It was pointed out in the preceding that soil structure deterioration in The Netherlands, which occurs mainly in the top layer, is not caused by a decrease in organic matter content or by a more intensive use of chemicals; a minor contributing factor is a change in crop rotation. Thus, other factors like mechanization and soil tillage must be responsible for the decline in soil structure.

What happens in actual farm practice? Nowadays, during harvest, the soil is compacted more than it was a number of years ago. So more intensive soil tillage is needed to restore soil structure. But that is usually not done, for the following reasons: the season is too far advanced, lack of time, high cost of labour and energy, or the presence of a green manure crop. Usually the soil is autumn-plowed without a prior stubble tillage operation. Then, restoration of soil structure is incomplete, because only the top layer of 8-10 cm is brought into a good condition due to freezing and thawing and seedbed preparation, but the deeper layers are left untouched. The result is that we get a good, friable top layer and a cloddy, poorly aerated 10-25 cm layer.

How do we maintain good soil structure?

In the first place it is very important to keep the soil in a good condition with respect to drainage and lime status. Research has shown that, in general, it is economically justified to do so.

In the second place the farmer should try to prevent compaction as much as possible, but if he does not succeed, he should try to restore soil structure through more intensive soil tillage. To make this possible, potatoes and sugar beet should not be harvested too late, and seedbed preparation in spring should be done only when the soil is dry enough, so not too early. That is easy to say, but in every-day farm practice these measures are less obvious, because there are some disadvantages: yields may be somewhat lower, there may be problems with storage of sugar beet and industrial potatoes prior to delivery to the factory, organisation of the work may be more difficult and more expensive, and labour and fuel costs may be higher.

In view of the changed situation in agriculture and the changed ratio between yield and costs of production, a lower quality norm for soil structure may have to be accepted. This point needs more attention in the near future.