The objectives of soil tillage

Introduction to the conference-theme

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Introduction

Soil tillage research is becoming more and more popular in recent times. To some of us it may seem to be a new topic, a field of interests not yet discovered. However in reality, soil tillage research is one of the oldest branches of agricultural research. For many years it was by far overshadowed by the progress made in chemical and biological research branches, but it never disappeared entirely. Therefore the research worker in the field of soil tillage should be aware of his *historical background,* he should know that he is continuing the work of many preceeding colleagues.

Nevertheless the present revival indicates that there is a new situation. The more practical research branches will be stimulated only if there it a reason for it and especially because improvements are expected or are judged to be necessary. Therefore it is also true that the research worker on soil tillage should be aware of his *new situation.*

A common aspect of classical and modern tillage research is, that both wish to improve soil tillage practices. "To improve" means to do it in a better way, so this implies that we know the difference between a good and a bad job, that we know the objectives of our work. The objectives of soil tillage are the guide line for research planning in this field and that is the reason we chose it as our conference theme.

Classical objectives

It is very interesting to read what our ancestors and older colleagues wrote about the objectives of soil tillage. The first remarkable thing is, that far too much has been written, to believe the objective to be self-evident. In the nineteenth century the most common argument was that the soil should be made fertile by tillage operations. In the twentieth century this argument disappears in scientific papers although it lives on, up to now quite unperturbed, in non- agricultural literature. In the newer concepts in the first half of our century there is a remarkable confusion of arguments. The main objective, the fertility of the soil, is sometimes described in terms of a favourable physical condition and weed control, or summarized in the idea of a high crop yield. On the other hand arguments like "the soil should be loosened", "the top layer should be turned over", "clods should be broken" or "manure should be ploughed in" are encountered as well.

These types of arguments are sometimes arrayed in a confusing manner, but the great men in tillage research generally showed a marked preference and so two different lines can be distinguished. One is often indicated as the more scientific, the fundamental line, starting from the final objective, e.g. from the high crop yield, and searching for the factors influencing the growth. The other line is the practical one, starting from the possibilities, e.g. the loosening of the soil, or the

possibility to turn over the top layer and searching for the results of these changes. This difference was at the cradle of scientific soil tillage research. In the last decade of the 19th century DEHÉRAIN in France published his work on soil cultivation in his "Annales Agronomiques" (1). It can be summarized as follows: His first idea was that nitrogen might be the most important factor. Some experiments he did, seemed to prove this more or less, but perhaps he did not feel at ease with his results and a few years later he supposed that the air content of the soil might be decisive. However, his experiments on this subject made him reject this idea. Finally he suggested water might be the most important factor and this was affirmed by his experiments, at least in his own eyes.

At the same time WOLLNY published his famous series on soil physics (2). He studied the influence of spading depth and found that a greater depth gave a higher yield and the influence of hoeing which gave a higher yield, partly by weed control partly by another factor, perhaps aeration?

DEHÉRAIN and WOLLNY approached their subject from opposite directions. They did not appear to understand each other at all. If we follow the evolution of the German line, which is by far the most continuous one in Western Europe it is instructive to compare the chapters on soil tillage in two famous handbooks on soils issued about 1930 (3, 4). Both follow about the same scheme and start with a part on the objectives of soil tillage. In the first book Prof. ROEMER of Halle writes the chapter on soil tillage. Its objective should be to raise the *natural productivity* of the soil to a higher level than under natural conditions. This can be done by loosening the soil, by mixing in organic and artificial manure and by turning over the toplayer to prevent colloidal materials to be washed out and to kill weeds. However, one should be careful not to damage the *microbial activity* of the soil. He briefly discusses the influence of tillage operations on the soil. This is done as follows:

There is a physical action: soil crumbs should be formed for good water- and air supply; a biological action: the microbial activity should be as high as possible, and a chemical action in which the main point is the carbondioxyde production of the microbes. All this is summarized in his statement: the principal point of tillage is to get a good tilth.

In the second book Prof. TORNAU of Göttingen is the author on soil tillage. He agrees with his colleague in many points but it is remarkable to see that after his introduction in which he clearly states that soil physics is the central theme, he writes twenty pages on the physical aspects concerning water-, air- and thermal properties of the soil, one page on the chemical aspects, of which practically no data is available and two pages on biological reactions as carbondioxyde production and nitrogen mineralization. Only after this main point we find the next point termed practical purposes, where the loosening of the soil is demonstrated on disturbing dense layers and where the mixing in of different substances and the turning over of the toplayer is discussed. His final point on the objectives is soil structure, where e.g. mechanical properties of the soil are discussed and finally soil tilth.

We see that the authors are much closer together than WOLLNY and DEHÉRAIN, as both cover the same range of topics, but there is still a marked difference in approach. ROEMER first stresses the action of the tillage operation itself and its final objective is to reach a good tilth, which, it stands to reason, will result in a good crop. TORNAU's first and principal point is the physical behaviour of the soil in its

relation to plant growth. This physical behaviour of course is influenced by the tillage operation and it has something to do with soil tilth.
If we continue this German line we'll find GÖRBING and his school as a side branch of ROEMER's line with such a strong stress on soil tilth that we automatically think VON NITZSCH to be the straight successor in TORNAU's line. Yet I believe that this is an undeserved limitation of our view on the work of VON NITSZCH, as he really showed the possibility to characterize the result of tillage operations in terms related to crop growth. Today, twenty five years after his work on "Better tillage" (5) was issued, we need of course not accept all the details found there but if we realize that the man of the laboratory methods here describes his many results on practical fields where not only the soil, but also the crop is studied, both lines of research are seen to touch each other in one man.
Summarizing I believe, that one of the most important things we'll have to learn from our predecessors in soil tillage research is, that it is not worth while to bother about a fundamental aproach or a practical one. There is a long chain between the tillage operation and crop response and all phases will have to be studied simultaneously.

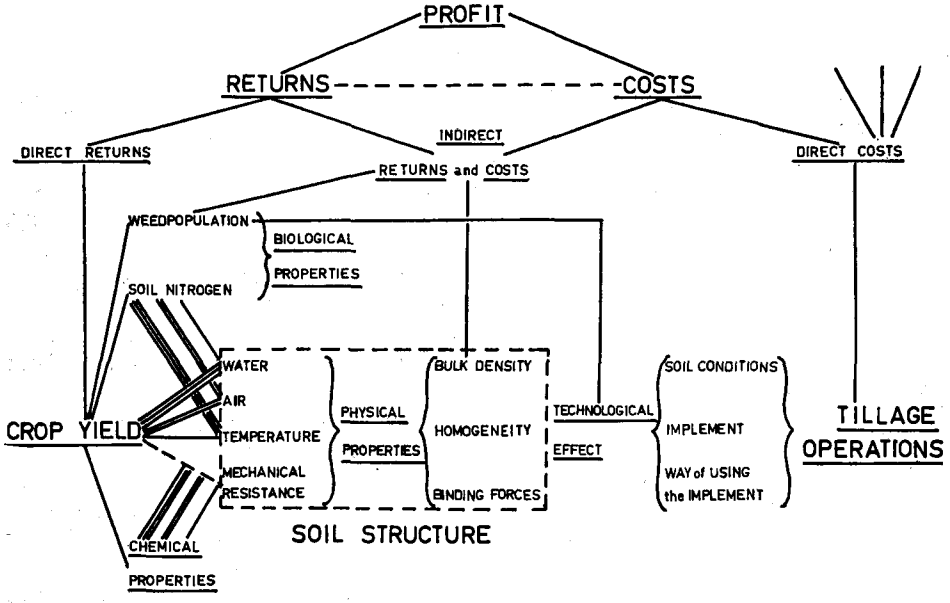
New objectives

The next point to discuss is what is the new aspect in our present situation, that revived soil tillage research. The mechanization of our farm work changed rural life so fundamentally that we need not to be imaginative to discover here the driving force of the new activities. More energy is available in bigger units, principally in a rotational form and at a price depending on other principles than formerly. New tools are constructed and sold to the farmers by tradesmen. We should keep in mind that the character of this development of farm mechanization is a growth process. Where farm mechanization was successfull, it developed, where it was difficult it lagged behind. Agricultural practices suited to mechanization became much more attractive than the less suited ones and so agricultural practices and farm mechanization mutually influenced each other.
This is our new situation: there is an industry interested in constructing well-selling machines, and an agriculture interested in relatively high productions at low production costs. The reason for using agricultural machineries is not a technological one, it is not in the first place to get a better quality of the work, but an economical one. In practice this means that there is no discussion about whether mechanization should go on or not, but only how it should be done. *Through this situation soil tillage is linked up with all the other agricultural practices as a part of the production process from which its right of existence is derived.* That means that the objectives of soil tillage will be found in practice not only in the "classical" group, which is directly related to the crop yield but also in the other agricultural practices as a decrease of production costs has the same effect for the farmer as an increase in production. E.g. if a farmer succeeds in saving an expensive chemical weed spray by an effective cheap tillage operation, it is more realistic to say that the objective of the tillage operation was to decrease the production costs than that it was meant to increase crop yield.
Although we are free to choose for our scientific work the "classical" objective, the high yield in quantity or quality as the only point of interest, I believe that

our present situation makes it necessary to study as well the other aspect, the relation between tillage and production costs.
On the one hand this aspect increases considerably the number of subjects to be kept in mind, but on the other it strongly facilitates the judgement about certain practices and implements and it offers a good opportunity to realize for ourselves, that soil tillage is not a very specialized topic, but is a field in which different agricultural aspects play a joint role. Soil tillage is as well a *crop* management operation as an atttempt to regulate *soil* physical conditions. One might even say, it is an application of tillage implements. Finally it is an agricultural operation. That means that many aspects are involved and that at present the *economical* aim will be the final one.

Scheme of objectives

I should like to finish this introduction by discussing a scheme of the relation between the different aspects involved in discussing the objectives of soil tillage. (Fig. 1).



We start from the most commonly accepted base for agricultural production by describing the final objective as a *financial profit,* being the difference between the production *costs* and *returns,* which of course depend on each other to a certain extent. Returns and costs are both devided in direct and indirect ones. Direct returns depend on crop yield, indirect ones on the lowering of production costs. Direct costs are caused by the tillage operation itself, indirect ones by raising other production costs. It stands to reason, that the direct costs do not depend only on the tillage operation itself. A certain practice may be cheap for one farmer and expensive for another.

If we try to analyse the relation between the tillage operation and the yield we see that the operation will result primarily in a *technological effect,* which will depend on 1) soil conditions at the time of operation (soil type, pore space, water content, binding forces, the way in which organic materials are mixed through the soil etc.), 2) the implement and 3) the way in which it is used (working depth, speed, intensity).

This technological effect can be described as a change in the *weed population,* in some cases even as a direct mechanical influence on the crop and always as a change of the soil *physical conditions.*

A change in the weed population may have an influence on the indirect costs and returns by saving a spray or by making it necessary. It may also effect crop growth if the change is not compensated by chemical methods.

The same is true for a change in soil physical conditions. This may influence the production costs e.g. by facilitating potato harvest, or sugarbeet thinning. Of course it is not necessary to start our reasoning at the tillage operation itself. If we start on low production costs we can say: a mechanical harvest is the only possible way to keep the production costs at a reasonable level. If the costs of soil tillage operations should be raised to make the unfavourable influence of the mechanical harvest on the soil tolerable, it means that these expenses for tillage operations are primarily justified by lower production costs.

Of course a change in soil physical conditions can also influence crop growth. A big problem however lies in the fact, that the terms that will be suited to characterize the technological effect are not the same as those that will be chosen to characterize the relation with the crop.

To characterize the technological effect one can choose terms like bulk density, homogeneity and soil strength.

A term like homogeneity will have many aspects as it will be used to characterize not only the degree of mixing with foreign substances, the cloddiness of the soil or the roughness of the surface, but also the presence of certain layers or of certain compaction patterns. For these quite different aspects different standards should of course be used.

All these terms however will bear no direct relationship to plant growth. For plant reactions we'll have to study water-air-thermal- and strength properties of the soil. Only if we succeed in relating those two types of terms with each other we'll be able to detect a causative relation between soil tillage and plant growth.

The relation between water-, air- and thermal properties of the soil and plant growth may be very complicated, but yet generally speaking we can say that relatively much data is available. However we must take into account that these properties will not only have a direct influence on crop growth but also an indirect one by changing either biological soil properties (i.e. nitrogen mineralization) or chemical ones (i.e. manganese reduction under wet conditions).

If we remember that crop yield is the result of growth during a rather long period in which plant reactions may vary with type of plant and stage of development when environmental conditions are constant and in which more-over these environmental conditions themselves will change continuously, then it is clear that practical advice on soil tillage based on the idea that a higher crop yield will be obtainable will be influenced strongly by intuition.

The task of the research on this subject will be in the first place to schematize and in the second to qualify the theoretically many times infinite number of possible

reactions into practicable reaction patterns, and probably it will finally, in the third place, be possible to provide quantitative relationships.
Schematizing may be done mainly on theoretical considerations. Qualification means to indicate which relations are very important under certain conditions, which are rather important and which not al all. This will imply the use of exact data and a lot of practical experiences. Quantification finally, may only be possible for special types of research work.
One of the aimes of our conference will be to contribute to this schematization and qualification. The first day we'll concentrate on the "classical" objectives, the relation with crop growth. The second we'll stress the relation with the other agricultural practices.

LITERATURE

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