A VISUAL METHOD OF SOIL STRUCTURE EVALUATION

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1. Introduction

The concept of soil structure is as complex as the architecture of a house, man's health or the brewing quality of barley. Handling of these concepts in applied scientific research requires a quantitative characterization which can be obtained generally in two different ways :

a. by measuring several aspects of the concept (for instance in the case of soil structure : total pore volume, pore size distribution, aggregation, etc.) and summarizing the results of these measurements as a single value using an empirical formula or a statistical method;

b. by observing a series of visible features, giving a general impression, which on ground of experience results in a quantitative evaluation.

The first method is objective, easy to define and the different aspects can be measured in a distinct and accurate way. These measurements of soil structure however take a lot of time per sample. A great number of samples per plot is necessary as soil structure in the field generally shows great heterogeneity in a direction parallel to the soil surface and as mixing of undisturbed samples is impossible. Summarizing the results of such measurements in the form of a single value which characterizes soil structure is difficult since the relative quantitative importance of each aspect is rather obscure as well as the way in which the aspects must be combined.

The second method is a subjective one and can be learned only by practice under the supervision of an expert. In agriculture it is well known as a method of evaluating soils, crops, cattle, etc. A great advantage is the short time needed per object. Usually the result is expressed as a value on a simple scale, say 1, 2, ..., 10, in which case the accuracy of one and the same expert will often be about a half or a quarter of a point. A disadvantage of the method is the possibility that the level and the width of the scale used by a certain expert can vary in course of time. Hence a series of evaluations made over a short period by one and the same observer gives the best results. Experience shows however that the variation of the scale, with a trained observer is quite small.

In the study of soil fertility two different techniques of field experiments are used : the ordinary one, based on the ceteris paribus principle and a special one, working with a series of plots, scattered over a region and differing in several factors. When studying the relation between soil structure and plant growth the first method is only applicable to a certain extent, as it is not always possible to change on a field the single factor of soil structure. Therefore the second method must be used and this generally requires a large number of structure determinations. Hence the research worker will look for a simple way of obtaining quantitative information on soil structure.

Ferwerda (4) in 1946 tried to characterize soil structure by means of a visual evaluation method on a series of arable fields on which the farmers were giving different dressings of stable dung. He estimated the mean size of the aggregates, the cohesion of the soil particles and the porosity of the aggregates. These aspects and others were summarized in a general structure evaluation, the so-called St-number. Usually the method was applied to the plough-layer of arable land. The method has been modified somewhat on the grounds of experience, and it appears that an estimation of the St-number is sufficient.

2. The method.

By means of a spade little pits are dug on several places (say 5 to 10, depending on the size and heterogeneity of the plot) in the soil under investigation. From a non-compressed wall of each pit a soil block, about 10 cm thick and to the depth of the plough-layer, is cut off. This soil block is somewhat loosened by hand and the St-number is estimated by considering the following features :

a. *Size of the aggregates.* The best aggregate-size is obtained if about one half of the natural aggregates has a diameter greater or smaller than 2 mm. Often it is somewhat difficult to recognize the natural aggregates. Therefore the soil block must be loosened carefully.

b. *Shape of the aggregates.* Rounded and porous aggregates are considered to be favourable. Angular or prismatic and dense ones indicate a poor structure.

c. *Cohesion of the soil particles.* This aspect is evaluated by crushing the aggregates between the finger tips under normal moisture conditions. If it is almost impossible to crush the aggregates soil structure will be very poor. A favourable cohesion is about a third of this maximum value. Very low cohesion forces are unfavourable. Under dry conditions a false impression can be obtained, for instance dry dispersed silt soils of marshlands give very hard aggregates.

d. *Porosity of the aggregates.* This is estimated by observing the faces of cracks. Rough and porous faces are favourable, smooth and dense ones indicate a poor structure.

e. *Porosity of the entire plough-layer.* A porous top soil is advantageous.

f. *Root development.* Density and regular development of the root system are judged. Poorly structured soils have usually a moderate or poorly developed root system with roots growing chiefly in cracks and wormholes. Local branching of roots often indicates dense layers. A well developed and regular root system is usually associated with a good soil structure.

g. *Dispersion of the soil surface.* Pronounced dispersion of the soil surface is unfavourable.

Based on these observations a St-number is estimated on a scale from 1 (very poor structure) to 10 (ideal structure).

The most favourable time for the visual evaluation of structure is in spring before the soil is cultivated or in autumn immediately after harvest. On fields with tracks of tractors, wagons, etc. structure in and outside the tracks is evaluated. By estimating the total surface of the tracks a mean St-number can be obtained.

If the topsoil shows distinct layers with different soil structures each layer is treated separately. By taking into account the thickness of the layers a mean St-number can be computed.

3. Short description of some soil structures with different St-numbers

It will be clear that the evaluation of soil structure by the method described above must be learned in the field. Some examples however may illustrate the method.

a. *Clay and loam soils*

St = 1 Plough-layer consists entirely of big clods. Smooth and dense crack faces. In several places evidence of reducing conditions. Roots only in cracks.

St = 3 Plough-layer consists of big, dense aggregates. Smooth crack faces with very few visible pores. Roots only between the aggregates. St = 3 can also be evaluated for a topsoil, which is very dense below a depth of 6 cm and has an upper layer of 6 cm with angular, dense aggregates.

St = 5 Frequently there are two layers; a toplayer, 7 to 8 cm thick, with small, rather porous aggregates (nearly crumbs) and a rather dense lower part of the plough-layer. It is also possible that the entire topsoil consists of big, somewhat porous aggregates, with rather smooth crack faces.

St = 7 The greater part of the plough-layer consists of porous crumbs, which are partly combined into porous aggregates. Occasionally more dense clods are found.

St = 9 The entire plough-layer consists of nice, porous crumbs. Very few dense aggregates.

b. *Sandy soils*

St = 1 Single-grained structure. No cohesion of the soil particles. May occur on sandy soils poor in humus.

St = 3 Very little cohesion of the soil particles. Therefore only a few aggregates and these have a very low stability. Often a loose top layer of any cm lies on the collapsed and compacted lower layer of the top soil.

St = 5 Cohesion of the soil particles is slight. Often the plough-layer consists of a top horizon of 7 to 8 cm depth with moderate aggregation and a collapsed, dense lower layer. On sandy soils rich in humus St = 5 may occur if the entire topsoil consists of big and rather dense aggregates.

St = 7 Almost the entire plough-layer consists of porous and rather stable crumbs. Occasional dense aggregates.

St = 9 The entire ploughing layer consists of stable, porous crumbs and very few dense aggregates.

4. Results

Twelve years' experience with the method described above in soil structure research and regional investigations on soil fertility at the Institute for Soil Fertility, Groningen, (Netherlands) has demonstrated its value (2, 3, 5). It appeared that relationships could be found between the St-number on the one hand and measured aspects of structure (e.g. aggregate size, air content, consistency (1)) as well as crop yields, on the other. When yields were related to soil structure in regional investigations better results were obtained by using St-numbers than by using aggregation indices, due to the strong correlation between the latter and clay content.

Summarizing it can be concluded that visual evaluation of soil structure as described in this paper is suitable for quantitatively characterizing the structure of arable soil, especially if a great number of determinations is required. It is also possible by a similar method to evaluate soil structure of grassland. As on grassland however structure is better characterized by the porosity of the soil than by the aggregation obtained when the soil is broken up, attention must be given principally to a visual evaluation of porosity.

LITERATURE

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SAMENVATTING

Een visuele methode voor de waardebepaling van de bodemstructuur

Bodemstructuur als fysische factor voor de vruchtbaarheid vraagt een kwantitatieve omschrijving. Het begrip bodemstructuur is echter veelzijdig en kan slechts door een reeks van verschillende parameters bepaald worden. Daarbij komt nog, dat in het veld de bodemstructuur in een richting, evenwijdig met het oppervlak, zeer heterogeen is. Het gevolg is dat per veld een groot aantal metingen nodig is voor de waardebepaling van de bodemstructuur.

Ook neemt het aantal te onderzoeken velden sterk toe, wanneer, zoals het in kleiarme gronden dikwijls het geval is, het niet mogelijk is een structuurproefveld aan te leggen.

Daarom moeten de veldmethoden voor de waardebepaling van de bodemstructuur eenvoudig, snel en aangepast zijn aan routinewerk. Verschillende jaren ervaring hebben ons geleerd een visuele methode op te stellen steunende op de grootte, vorm en porositeit van de aggregaten, de aaneenkitting van de gronddeeltjes, de porositeit van de bovenste grondlaag, de wortelontwikkeling en het toeslibben van de bodemoppervlakte. Volgens deze criteria kan de waarde van de structuur uitgedrukt worden in een schaal gaande van 1 tot 10, die aanwendbaar is in het onderzoeken van de vruchtbaarheid van landbouwgronden.

RESUME

Une méthode visuelle pour l'évaluation de la structure du sol

La structure du sol, en tant que facteur physique de fertilité, requiert une caractérisation quantitative. La notion de structure du sol étant plutôt complexe, celle-ci ne peut être déterminée que par un groupe de différents paramètres. En outre, l'état structural au champ est horizontalement très hétérogène, ce qui explique le grand nombre de déterminations par parcelle, nécessaire à l'évaluation de l'état de la structure. Ce qui plus est, le nombre de parcelles à étudier peut augmenter fortement lorsqu'il s'avère impossible d'aménager des parcelles expérimentales, comme c'est souvent le cas pour les sols peu argileux. Par conséquent, les méthodes d'évaluation de la structure doivent être simples et rapides pour la pratique et adaptables au travail de routine.

L'expérience acquise au cours de nombreuses années a montré qu'une méthode visuelle, classant l'état structural de 1 à 10, peut fort bien convenir pour les études de fertilité des sols arables. Cette méthode visuelle comprend : l'examen des dimensions, formes et porosité des agrégats, le degré de cimentation des particules du sol, la porosité de toute la couche arable, le développement des racines et le degré de glaçage en surface.

ZUSAMMENFASSUNG

Eine visuelle Methode zur Beurteilung der Bodenstruktur

Ein quantitativer Ausdruck für die Bodenstruktur als physikalischer Fruchtbarkeitsfaktor ist notwendig. Der Begriff „Bodenstruktur" ist aber komplex und kann nur durch eine Serie von verschiedenen Parametern bestimmt werden. Dazu kommt, dass im Felde die Bodenstruktur in einer Richtung, die parallel zur Bodenoberfläche steht, stark heterogen ist. Die Folge ist, dass zahlreiche Bestimmungen an ein und derselben Stelle für eine Bodenstrukturuntersuchung notwendig sind.

Auch die Zahl der zu untersuchenden Felder nimmt stark zu, wenn es nicht möglich ist (wie es in tonarmen Böden oft der Fall ist), Versuchsfelder anzulegen.

Die Methoden für die Bodenstrukturbeurteilung müssen deswegen einfach, schnell in der Praxis anwendbar und auch geeignet für Serienarbeiten sein. Mehrjährige Feldversuche haben uns gezeigt, dass es möglich ist, eine visuelle Methode aufzubauen, die eine Strukturbeurteilung in einer Gradation von 1 bis 10 erlaubt, und die für die Fruchtbarkeitsbeurteilung von Ackerböden zweckmässig ist. In dieser Methode werden die Grösse, die Form und die Porosität der Aggregate, die Zementation der Aggregate, die Porosität der ganzen oberen Bodenschicht, die Wurzelentwicklung und die Verkrustung an der Oberfläche berücksichtigt.