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ASSESSMENT OF STRUCTURE IN AGRICULTURAL SOILS. RESULTS OF A MULTILATERAL COOPERATION PROJECT BETWEEN AUSTRIA, CZECH-REPUBLIC, HUNGARY, POLAND AND SLOVAK-REPUBLIC

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A b s t r a c t. Soil research institutes from 5 countries (Austria, Czech-Republic, Hungary, Poland, Slovak Republic) cooperated during 2 years in the assessment of structure in agricultural soils. The project was financed by the Austrian Governement and coordinated by the Institute of Soil Research of the University of Agriculture in Vienna, Austria.

The cooperation was organized on the base of 4 workhops and each partner institution analysed typical and representative soil of each country with general methods standarized within the research group and used by all partners as well as by specific methods only used by individual institutes.

The investigations resulted in a large number of data, characterizing a broad spectrum of soils. The most important result of this project is a classification of specific physical, chemical and biological methods for the description of different soil functions related to structure, aiming of soil as a porous medium, transport medium, transformation medium and biological habitat. Moreover, the applicability of these methods under specific and site conditions (eg., texture, salt content, water regime etc.) was analyzed.

K e y w o r d s: classification of soil structure parameters, methods for description of soil structure

INTRODUCTION

One of the most influential factors for agricultural production and environmental protection is soil structure. This was underestimated for a long time, because soil chemical parameters were regarded as more important. Fortunately, this view has changed within the last few years.

The concept of soil structure, which can be investigated by different methodological approaches, has several aspects and reflects the soil as a porous system and biological habitat in which specific transport and transformation processes occur and where the scale of investigation is defined by the specific methodological approach.

The concept of soli structure has many aspects. A comprehensive definition was given by Brewer [1], defining soil structure as 'the physical constitution of solid soil materials as expressed by the size, shape and arrangements of soil particles and voids and its associated properties'.

There are many accepted methods for determining soil structure parameters, and individual laboratories have adapted those methods in response to particular needs, depending on circumstances and requirements. Because soil structure is never static, methods suitable for specific circumstances may be without result when applied elsewhere.

It seems to be impossible to define a single or unique set of methodological procedures for all soil. A broad range of soil structure studies reveals a large number of very different methodological approaches, because most scientists only measure such parameters which they consider relevant for their particular targets.

Therefore, numerous publications focussing on structure exist, but still no internationally standarized and comprehensive set of methods for its qualitative and quantitative assessment. The reason for this is the enormous variability of soil parameters, which are better targeted by reference methods than by standard methods.

Based on such an analysis of the actual state of the art, the following partners worked together for two years in order to proceed in this matter:

- Institute of Soil Research of the Agricultural University of Vienna, Austria;
- The Department of Irrigation and Drainage of the Faculty of Civil Engineering, Czech Technical University of Prague, Czech Republic;
- The Research Institute of Soil Science and Agricultural Chemistry in Budapest and the Research Institute of Karcag, Hungary;
- The Institute of Agrophysics and the Department of Soil Science of University of Agriculture, Lublin, Poland;
- The Soil Fertility Research Institute, Bratislava, Slovak-Republic.

MATERIAL AND METHODS

The cooperation activities were guided by 4 workshops (Vienna/Austria, Lublin/Poland, Prague/Czech-Republic, Karcag/Hungary) within 2 years. Moreover, for these workshops the structure of different soil types was analyzed with different methodological approaches in each country.

Investigated soils

The investigations were carried out on typical soils of each cooperating country within a wide spectrum ranging from very light textured (Fuchsenbigl/Austria) to very heavy textured (Karcag/Hungary) soil, thus giving important information on how soil structure parameters may vary under different site and soil conditions. The soils used in the experiments are described in detail under the 'specific' methods and in other papaer [3].

Methods

A general problem within international sceitific cooperation is the harmonization of methodological approaches in order to avoid that different countries measure the same soil parameters in a different way, e.g., using different equipments. Since the uniformity of methods is the main basis for any comparison of results, the methodology to be used was defined in the first workshop.

The methods were subdivied into 'general' methods, which were carried out by all cooperating partners, and 'specific' methods, which were used only in those institutions which disposed of the relevant technical facilities.

'General' methods

As 'general' methods, the following were chosen:

Physical analyses:

- Particle size distribution
- Bulk density
- Particle density
- Total porosity
- pF-curve and differential porosity

Chemical analyses:

- pH-value
- Organic matter
- Electrical conductivity
- $CaCO_3$-content
- Cation Exchange Capacity (CEC) and exchangeable cations

'Specific' methods

The 'specific' mthods used by individual institutions in different countries were cited below, together with the investigated soil types.

AUSTRIA (Vienna):

a) Specific methods:

- Mineral composition of the fine earth
- Clay mineral distribution in the fine earth
- 'Free' Fe-, Al-, Mn-oxides
- Saturated hydraulic conductivity
- Soil aggregate stability

b) Investigated soils (FAO):

- Chernozem
- Cambisol

CZECH-REPUBLIC (Prague):

a) Specific methods:

- Measurement, modelling and spacial variability of water infiltration.

b) Investigated soils (FAO):
- Chernozem

HUNGARY (Budapest/Karcag):
a) Specific methods:
- Tension infiltrometry
- Swelling and shrinking
- Microaggregate analysis
- Mathematical description of pF-curves

b) Investigated soils (FAO):
- Fluvic Gleysol, cultivated
- Fluvic Gleysol, uncultivated
- Vertic Gleysol, deep loosened
- Vertic Gleysol, without loosening
- Orthic Solonetz, uncultivated
- Orthic Solonetz, ameliorated and cultivated

POLAND (Lublin):
a) Specific methods:
- D/D_o, ODR, redox potential
- Air permeability
- Enzyme activities
- Microbial counts
- Respiration rate
- Specific surface area
- Micromorphometrical analysis
- Method of thermal properties calculation
- Pore size distribution by Hg-porosimetry
- Compaction test
- Water retention and k_{unsat} by TDR

b) investigated soils (FAO):
- Orthic Luvisols.

SLOVAK-REPUBLIC (Bratislava):
a) Specific methods:
- Micromorphological analysis (soil thin sections)

b) Investigated soils (FAO):
- Calcaro-haplic Phaeozem
- Calcaro-gleyic Phaeozem

RESULTS AND DISCUSSION

Classification of soil structure parameters based on 4 soil functions

Soils are complexe substrates with numerous functions. By assessing soil structure the functional aspects of soils can be divided as follows:

1) Soil as porous medium
2) Soil as transport medium
3) Soil as transformation medium
4) Soil as biological habitat

It seems clear that the methodological approaches used for soil structure assessment depend mainly on the specific target chosen.

Therefore, the diagnostic value of each single method for assessing soil structure parameters varies in relation to the soil function which has to be evaluated. The 'general' and 'specific' methods used in the cooperation project were classified as follows (the numbers in parentheses refer to the 4 above mentioned soil functions, see also Table 1).

Site description (1,2,3,4) (including parent material, climate, water regime, temperature regime, soil utilization, crop rotation, relief, etc.).

Soil description (1,2,3,4) (classification of soil types based on national systems should be translated, if possible, into FAO-UNESCO-system).

Soil sampling (1,2,3,4) (time, replications, dimensions, location).

Inherent soil properties

Particle size distribution (1,2,3)
Particle density (1)
Specific surface area (1,2,3,4)
pH (H_2O, KCl, $CaCl_2$) (2,3,4)
Electrical conductivity (1,2,3,4)
$CaCO_3$(1,2,3,4)
Organic matter (2,3,4)
CEC (2,3,4)
Exchangeable cations (2,3,4)
Clay mineralogy (1,2,3,4)
Total mineralogy (3,4)
'Free' Fe-,Al-, Mn-oxidies (1,2,3,4)

Structural state parameters

Bulk density and porosity (1,2,3,4)
Standard bulk density (1,2,3,4)
Bulk density of aggregates (1,2,3,4)
Swelling and shrinking of soils (1,2,4)
Soil water retention (pF) (1,2,3,4)

Water, air and energy flow parameters

Solute, air and energy transport (1,2)
Saturated hydraulic coductivity (1,2)
Unsaturated hydraulic conductivity (1,2)
Bypass flow (1,2,4)
Air diffusion (1,2,3,4)
Air permeability (1,2,3,4)
ODR - oxigen diffusion rate (3,4)
Eh - redox-potential (3,4)

Soil strength and stability

Compaction test (1,4)
Penetration resistance (1,4)

Soil morphology

Soil thin sections (1,2,3,4)
Morphometric caracterization of thin sections (1,2,3,4)
Submicroscopy (1,2,3,4)
Macropore continuity (1,2)

Soil biology

Enzymatic activity ((2),3,4)
Respiration rate (3,4)
Meso- and macrofauna (1,2,3,4)
Rooting system (1,2,3,4)

Applicability of methods in relation to specific soil characteristics

The application of methodology on a very wide spectrum of different soils allowed to give a differentiation of the applicability of single methods with respect to specific soil characteristics.

Methods with unlimited applicability

- Particle size distribution
- Particle density
- pH
- Organic matter
- Electrical conductivity
- CEC and exchangeable cations
- Total and clay mineral composition
- 'Free' Fe-, Al-, Mn-oxides
- Redox-potential
- Specific surface area.

Methods with limited applicability, which can still be improved

- Thin and thick sections for heavy soils because of impregnation problems;
- Infiltration rate, saturated and unsaturated hydraulic conductivity, bulk density, water retention, pore size distribution and porosity for swelling and cracking soils;
- Air permeability and gas diffusion coeficient for loose sands and for shrinking soils.

Methods with limited applicability, which cannot be improved

- Aggregate stability for heavy soils and for salt affected soils;
- Air permeability and gas diffusion coefficient for light and heavy soils;
- $CaCO_3$ content in dolomitic soils.

Biological and biochemical methods which need a standardization of soil physical conditions before application

- Enzyme activities
- Respiration rates
- Microbial counts.

FUTURE TASKS

The identification, evaluation and quantification of soil structure functions as an important factor for sustainable biomass production and environmental protection should be a main future task. Further investigations and methodological improvements are necessary in order to elaborate one or more international sets of methods for the qualitative and quantitative assessment of soil structure.

REFERNCES

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Table 1. Applicability of soil analytical methods for specific soil functions

Analytical methods (parameters to be determined)	Applicability of soil functions such as			
	Porous Medium	Transport Medium	Transformation Medium	Biological Habitat
Site description	+	+	+	+
Soil description	+	+	+	+
Soil sampling	+	+	+	+
Inherent soil properties				
Particle density	+			
Particle size distribution	+	+	+	
Specific surface area	+	+	+	+
Electrical conductivity	+	+	+	+
$CaCO_3$	+	+	+	+
pH (H_2O, KCl, $CaCl_2$)		+	+	+
Organic matter		+	+	+
CEC		+	+	+
Exchangeable cations		+	+	+
Clay mineralogy	+	+	+	+
'Free' Fe-, Al-, Mn-oxides	+	+	+	+
Total mineralogy			+	+
Structural state parameters				
Bulk density and porosity	+	+	+	+
Standard bulk density	+	+	+	+
Bulk density of aggregates	+	+	+	+
Soil water retention (pF)	+	+	+	+
Swelling and shrinking	+	+		+
Water, air and energy flow parameters				
Solute, air and energy transport	+	+	+	+
Sat. hydraulic conductivity	+	+		
Unsat. hydraulic conductivity	+	+		
Bypass flow	+	+		+
Air diffusion	+	+	+	+
Air permeability	+	+	+	+
Oxigen diffusion rate			+	+
Eh - Redox - potential			+	+
Soil strength and stability				
Compaction test	+			+
Penetration resistance	+			+
Soil morphology				
Macropore continuity	+	+		
Soil thin sections	+	+	+	+
Morphometric characterization of thin sections	+	+	+	+
Submicroscopy	+	+	+	+
Soil biology				
Enzymatic activity		+	+	+
Respiration rate			+	+
Meso- and macrofauna	+	+	+	+
Rooting system	+	+	+	+