Soil Physical Description of the Root Zone

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The qualities of a soil as a medium for plant growth depend chiefly on soil construction and how it is affected by various factors. The soil construction, i.e. its texture, organic matter content, structure, porosity and pore distribution in the different horizons, can be studied and described in the field while soil samples can be extracted and analyzed.

The extent of a soil physical examination must of course be related to its original aim. The number of replicates taken or the number of tests performed is often restricted because many tests are time-consuming and expensive. The tests which normally form part of a physical analysis of soil on experimental sites in Sweden are described below. There follows a discussion on which of these tests should receive priority in the physical investigation of a soil in view of their practical applications.

During the last 30 years comprehensive soil physical investigations have been performed at the Department of Soil Sciences for about 250 profiles. Most of these investigations have been performed in connection with research projects and large field experiments. Thus the sites are not in the first hand selected to represent different soil types. But soil physical investigations have been carried out for most types of arable soils and we therefore have a good view of the physical status of soils.

Results are published in a series of reports which also detail methods of investigations and presentation /JOHANSSON et al., 1985/. Methods are described by ANDERSSON /1955, 1962/, /See JOHANSSON et al., 1985/. Methods are JOHANSSON /1964/ and JOHANSSON et al. /1985/.

Physical characterization of experimental sites

The soil physical investigation carried out at an experimental site at present usually consists of the following:

- Description of the soil profile /≤ 1.0 m depth/ and its surroundings, according to FAO /1977/.
- Extraction of 2-4 undisturbed soil samples from each 0.10 m level down to 1.0 m depth /using cylinders with 0.10 m height and 0.072 m diameter/.
- Extraction of approximate 1 kg loose soil from each 0.10 m layer.

- Extraction of a vertical profile to 1.0 m depth in a metal box 1.0 m high, 0.25 m broad and 0.05 m deep and 4 horizontal cross-sections in boxes 0.45 m long, 0.25 m wide and 0.05 m deep.

The cylinder samples are used in a series of laboratory tests. Loose soil material is used in mechanical analysis and to determine density of solids and physical wilting point /water content at 150 m water column/. Soil cross-sections are photographed. They are usually retained for teaching and demonstration purposes.

The following measurements are carried out on undisturbed soil samples in cylinders:

- Moisture content at various soil moisture tensions. The number of tension steps and the size of increment between steps is chosen according to soil type.
- Cultivated wilting point by growing sunflower and wheat /WIKLERT, 1964/.
- Saturated hydraulic conductivity.
- Dry bulk density.

Results of tests allow calculation of materiality, porosity and moisture content at sampling. Furthermore, a soil moisture retention curve and water tension /w_t/ curves can be drawn for each 0.1 m layer. The relationships between moisture content and water retention are used to construct drainage equilibrium /w_{dr}/ curves /JOHANSSON, 1964/.

The results of a soil physical investigation as described above are usually reported as a brief descriptive text with photographs of vertical and horizontal cross-sections and a table and four diagrams as shown below /Table 1, Figures 1, 2, 3 and 4/.

Water tension curves /Fig. 3/ show the relationship between applied tensions and water content in the soil profile. Each curve shows the volume percentage of water /= mm water per 0.1 m horizon/ remaining in the pores of respective soil horizons at the particular tension. It also shows the volume of air which enters the pores. The water tension curves provide an indirect picture of pore size distribution in the different layers of the profile. Thus $w_{t,0.05}$ corresponds to an equivalent pore diameter of 0.6 mm, $w_{t,0.5}$ to an equivalent pore diameter of 0.06 mm etc.

Drainage equilibrium curves /Fig. 4/ show the moisture content of the profile at matric tensions equivalent to certain drainage or water table depths. Thus, if the water table lies 2.0 m below the soil surface, the mean tension in the upper 0.1 m horizon will be 1.95 meter water column /m wc/, in the 0.1-0.2 m horizon it will be 1.85 m wc, etc. The w_{dr} -curves thus give a picture of the water holding capacity of the soil profile at different water table depths.

As a complement to the analyses mentioned above, macro- and microaggregate analysis /WIKLERT, 1962/ can be carried out, as can measurement of air permeability at different tension steps and of shrinkage at each tension step and after drying of 105 ^{o}C.

A method to measure air permeability on undisturbed soil cores has been in routine use at the Department for twenty years /ANDERSSON, 1969/. In recent years methods have also become available for testing air permeability in the field /GREEN and FORDHAM, 1975/ and for measuring diffusion coefficient on undisturbed soil cores /EDLING, 1986/. Equipment is also available for measuring oxygen flux and redox potential /ARMSTRONG and WRIGHT, 1976/. A simple hand-held penetrometer /ANDERSSON et al., 1980/ is also available at the Department. This allows soil strength to be measured at 3 cm intervals to 45 cm depth.

Table 1

Main physical characteristics of a soil profile on silty clay /Ålbo, 1979/

Depth, cm	Solids	Pores	Mositure content, vol %										Dry bulk density	Density of solids	Saturated hydraulic conductivity, cm/hour
	vol %		tension, m wc								wilting point	at sampling	g/cm³		
			0.05	0.5	1.0	2.0	4.0	6.0	50	150					
0– 10	51.5	48.5	44.1	37.7	36.3	34.9	34.1	33.6	19.0	10.8	13.2	36.1	1.35	2.61	6.8
10– 20	57.5	42.5	39.4	36.4	35.4	34.5	33.9	33.4	23.6	13.2	18.7	35.9	1.51	2.62	2.4
20– 30	59.3	40.7	39.3	37.0	36.2	35.5	34.9	34.4	22.3	13.2	15.8	36.1	1.57	2.64	4.2
30– 40	57.7	42.3	40.6	38.1	37.6	36.5	35.7	35.0	28.2	19.7	23.2	36.8	1.54	2.66	10
40– 50	57.5	42.5	40.1	38.5	37.9	37.1	36.2	35.5	24.9	16.9	22.8	37.6	1.53	2.67	25
50– 60	57.9	42.1	41.4	40.3	39.9	39.4	38.6	38.1	24.8	17.7	21.4	39.4	1.56	2.69	0.02
60– 70	57.0	43.0	41.9	41.0	40.5	40.0	39.4	39.0	17.1	12.7	20.7	40.3	1.54	2.70	0.003
70– 80	55.3	44.7	44.6	43.2	42.8	42.4	41.8	41.3	22.8	16.1	22.7	42.5	1.49	2.69	0.02
80– 90	55.8	44.2	43.0	41.3	40.7	40.3	39.7	39.1	18.0	12.8	16.4	40.2	1.50	2.69	0.80
90–100	56.1	43.9	43.5	42.8	42.4	42.2	41.8	41.3	22.0	15.0	20.5	42.0	1.50	2.68	0.03
Total /mm/	565.6	434.4	417.9	396.3	389.7	382.8	376.1	370.7	222.7	148.1	195.4	386.9			

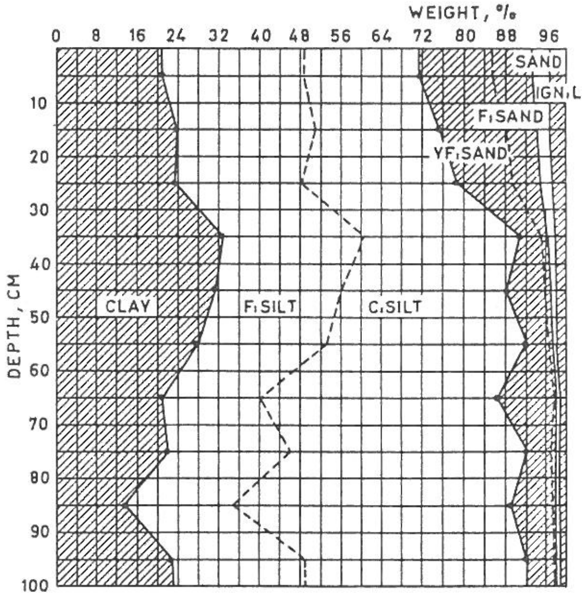

Fig. 1

Mechanical composition and loss of ignition /Ålbo, 1979/

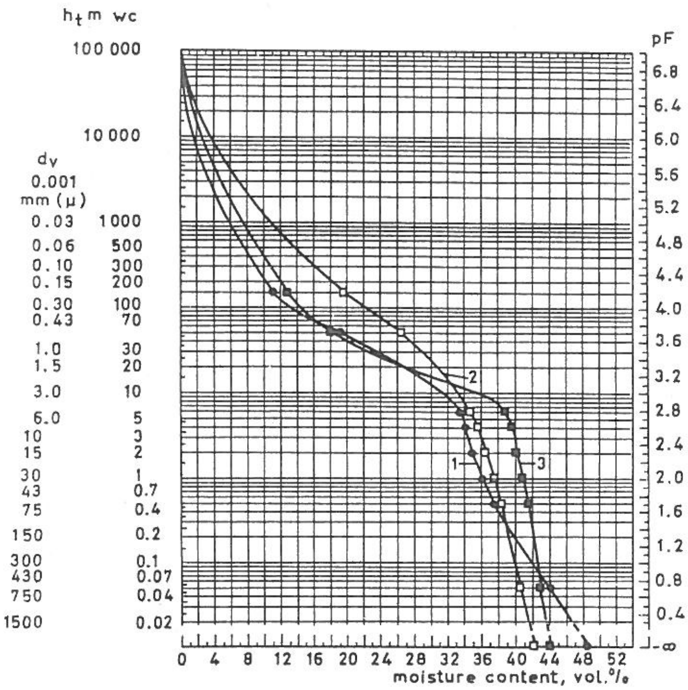

Fig. 2

Soil moisture retention curves /Ålbo, 1979/. 1: layer 0.10–0.20 m; 2: layer 0.30–0.40 m; 3: layer 0.80–0.90 m

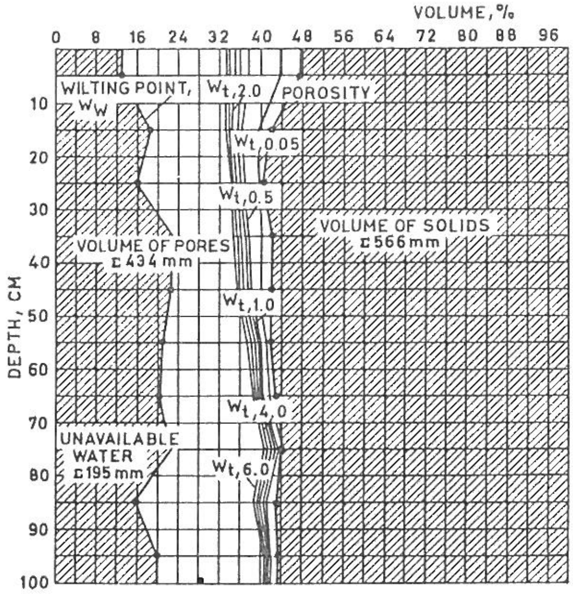

Fig. 3
Volume relations and water tension curves /Ålbo, 1979/

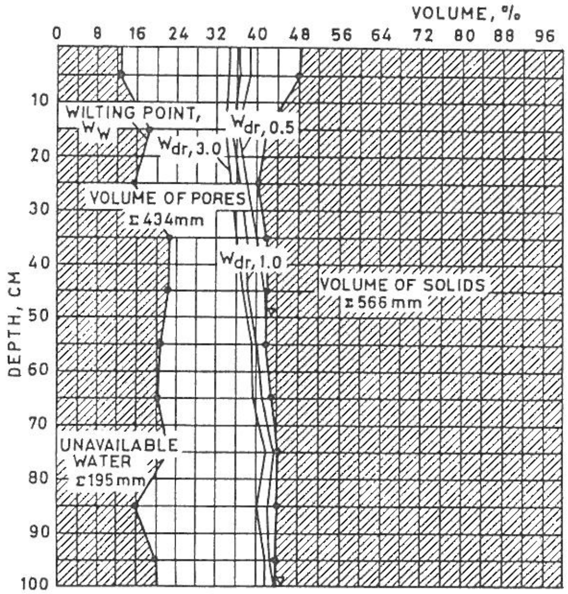

Fig. 4
Drainage equilibrium curves /Ålbo, 1979/

Soil physical investigations as described above are for example carried out on sites where root development and water use are to be studied. At the Department, methods have been developed for studies of root development and distribution in the soil. Direct studies and measurements in the field - in vertical cross-sections provided by walls of inspection pits - have dominated in recent years /JOHANSSON and GUSTAFSSON, 1988/. Soil moisture content is mainly determined gravimetrically, and neutron probe apparatus is used for complementary volumetric measurements.

Physical characterization as related to practical growing

In Sweden we have a discussion how to examine soil physical conditions for practical purposes and how to follow changes of soil physical conditions in fields within and between years. A full soil physical examination is rarely of value except for research purposes. Of course, results from an examination can be used to predict properties and functions of soils which have not been investigated.

For practical purposes, determination of a soil's physical character and its function must often be of a limited nature. The tests performed should be decided according to the information required. The number of replicates per area can be adapted after known degree of variability in the soil. The number of layers sampled can be adapted according to how the soil profile is constructed.

Mechanical analysis is a relatively cheap test which does not have to be repeated. However, it only gives information on the material and not on the soil structure so it has to be complemented by other tests. A good complement is a soil description carried out for example according to FAO guidelines /FAO, 1977/. Assessment of the root profile - root depth, distribution and density - of a crop and the determination of soil moisture distribution at the end of the growing season can give valuable information on how the soil profile functions and also how much of the soil is involved in the Soil-Plant-Atmosphere system.

In irrigation for agriculture it is important to know how the crop root system develops and how much plant available water can be retained in the root zone of the crop. Thus, one needs to know the moisture retention ability of the different layers at the prevailing groundwater level and the fraction of the water content which is available to plant roots /above biological wilting point/. Since both these parameters can vary greatly with soil structure it is recommended that they should be measured on each individual site.

Seasonal changes in the weather and changes in land use affect the physical properties of the soil and its function every year and also in the longer term. Soil texture, however, remains relatively unchanged from year to year. Changes in physical properties are more apparent in the upper layers of the profile.

Changes in physical properties within a year and between years can be followed in different ways. Practical methods are e.g. inspection of rooting at the end of the growing season, measurement of permeability of the soil to air and water, measurement of infiltrability and of soil strength.

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