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Soil survey for drainage projects

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Abstract: For a proper diagnosis of drainage problems one must have the appropriate soils information. The required soil data have to be of morphological, physical and chemical nature to relate to the hydrological problems. Soil mechanical interpretations and civil engineering aspects must also be kept. A survey of the water table is one of the most important parts of any drainage investigation. For a well-balanced drainage plan, the soil data will be include active gley phenomena, which give a reasonable idea of the fluctuations in groundwater levels. Reduced soil materials, Gr, that are permanently saturated have a characteristic gleyic colour and the horizon Gr must be present in the first 50 cm of the soil profile. Gleysols can be used for arable cropping, provided the groundwater table is lowered or groundwater seepage from the uplands is intercepted. A common soil survey offers soil data only for a depth of 1 to 1.5 meter. For hydrological calculations it is necessary to know the composition of the subsoil, even to depths of 50 to 100m. For tile drainage, it is necessary to know the characteristics, to a depth of at least 4 to 5 meters. For a drainage plan, the following soil data will be required: active gley phenomena, permeability, available water, salinisation and sodication problems, rippening; maturation. The drainage specialist will find the sensitivity analysis a useful tool in guiding the required soil and geohydrogeological investigations, which differ from project to project, and in working out alternative solutions regarding the use of pipe drains or ditches, drain depth, etc.

Keywords: soil, gley, survey, drainage, hydromorphic properties.

1. INTRODUCTION

For a proper diagnosis of drainage problems, as for the planning and design of irrigation and drainage projects, one must have the appropriate soils information. Without such information neither diagnosis nor plans are based solidly upon reality. The required soil data have to be of morphological, physical and chemical nature to relate to the hydrological problems, but they must also allow interpretation in agronomical terms in connection with the increased yields that can be expected after drainage improvements have been made. Soil mechanical interpretations and civil engineering aspects must also be kept in mind, as they have a bearing on the costs of executing the plan.

The soil information must be given in as quantitative and exact a manner as possible. This is true not only for the situation existing at the time of survey, but holds equally well for any changes in soil conditions – favourable or unfavourable – that may occur after drainage.

A survey of the water table is one of the most important parts of any drainage investigation. Information obtained by soil borings and water table measurements is needed on the source of the water, its movement, quality and quantity, and the cyclic trend of the water table (Hagan, 1970). If artesian pressure is discovered from deep water - bearing strata, relief well may be needed.

Where rainfall is a factor influencing the rise of the water table, surface drains may be indicated to remove excess water. If seepage from an adjacent canal or reservoir can be detected, an interceptor drain may solve the problem. If the source of excess water is over irrigation, a tile grid system is needed. If the drainage water is good quality, plans can be made for its reuse for irrigation purposes.

For a well-balanced drainage plan, the soil data will be include active gley phenomena, which give a reasonable idea of the fluctuations in groundwater levels, and enable conclusions to be drawn about the occurrence of any excessively high groundwater levels.

Gleysols, or soils with gleyic properties, are either permanently or temporarily wet and reduced at shallow depth.

Reduced soil materials, Gr, that are permanently saturated have a characteristic gleyic colour pattern (white to black or bluish to greenish) in the soil matrix, and the horizon Gr must be present in the first 50 cm of the soil profile (SRTS - 2012). A reduced soil is one in which redox reactions have caused reduced forms of O, N, Mn, Fe or S to be present in soil solution. Common reduced forms found include: H_2O, N_2, Mn^{2+}, Fe^{2+} and H_2S (Rogobete, 2007).

Oximorphic properties apply to soil materials in which reducing and oxidizing conditions alternate, as is the case in the capillary fringe zone and surface horizons of soils (Gox) with fluctuating groundwater levels.

The oximorphic properties are evidenced by the presence of reddish brown (ferrihydrite), orange

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(lepidocrocite) or bright yellowish brown (goethite) mottles. In loamy and clayey soils, the iron(hydr)oxides are concentrated on aggregate surfaces and walls of larger pores, like old root channels which in extreme cases can be entirely filled with such oxides, while cores still show reduction colours. (Bridges and co.).

Gleysols can be used for arable cropping, provided the groundwater table is lowered or groundwater seepage from the uplands is intercepted. Special precautions must be taken in case of Thionic Gleysols, which may acidify irreversibly upon oxidation after drainage (Deckers and co., 1998).

Trafficability usually is a problem with Gleysols; if the soil is cultivated in too wet a condition, soil structure is likely deteriorate (Driessen and Dudal, 1991).

2. MATERIALS AND METHODS

This article will present and discuss of drainage problems in the low plane of Banat. The paper relies on a detailed soil survey effectuated during about 10 years by OSPA – Timis and also of authors in some researches, effectuated in the field or in laboratory.

3. RESULTS AND DISCUSSIONS

To put it very generally, the purpose of soil surveys is to give information about soils.

A common basis is found in the study of soil profile for a detailed soil map, with an average scale (1:10000) of the final map. Such a detailed map shows mapping units or units of classification of a low rank. Few of these maps, if any, are produced for drainage planning.

There are often discrepancies between the scale of a soil map and the scale required for a drainage plan.

The latter will be on a scale of 1:5000, thus coming under the category of detailed soil maps. If necessary, the soil maps can be enlarged to the desired scale, wich is pedologically not justified but offers advantages in a drainage design.

A common soil survey offers soil data only for a depth of 1 to 1.5 meter, like in this soil profile from Cruceni.

Mollic Gleysols, semihistic (Gleiosol cernic, semihistic, SRTS - 2012)

0-27cm, Amg - mollic horizon; brown blackish, granular structure, mottled clay loam;

27-55cm, AmGr - mollic horizon; dark brown mottled clay loam with moderate subangular blocky structure; gleyc properties;

55-68cm, ACGr - dark grey bluish, mottled clay loam with moderate subangular blocky structure; gleyc properties;

68-150cm, CnGr - grey mottled clay loam.

Table 1 Analytical data

Horizons / Properties	Amg	AmGr	ACGr	CnGr
Clay, %	33,7	40,6	35,4	35,3
Silt, %	24,8	25,7	21,0	21,3
Bulk density, g/cm^3	1,20	1,35	1,48	1,44
Field capacity, %	25,50	24,24	23,16	22,54
Ksat, mm/h	5	0,80	1,50	0,65
pH	6,05	7,17	7,67	7,39
Humus, %	4,32	2,58	1,98	-
Pmobile, ppm	20,8	3,79	1,65	-
Kmobile, ppm	147	114	103	-
BSP	77,92	83,60	85,75	-
CECs	26,59	23,55	21,18	-

From the description above it will be clear that the quantitative data required for drainage planning and design are generally not adequately available in existing surveys. Specific surveys must be conducted to supplement the existing information. Carrying out specific surveys might be useful is likely to be the most rewarding and most economic policy. Therefore, it is important for the drainage engineer to have a good understanding of the methodologies that are current in soil science (Childs, 1969).

The existing soil maps show observations only for a depth of 1.0 – 1.5m, but this is not sufficient for the planning of main and subsidiary drainage. For hydrological calculations it is necessary to know the composition of the subsoil, even to depths of 50 to 100m (Rogobete, Tărău, 1997).

For tile drainage, it is necessary to know the characteristics, to a depth of at least 4 to 5 meters. Knowledge of the characteristics of soil to a great depth is also necessary for the calculation of seepage and subsidence. In the soil maps is the localization of areas with excess of water and generally also the indication of areas where subsidence problems are to be expected.

The available data, from soil map and the accompanying report, usually show quite clearly the existing problems of the different soils, but give only restricted information for ways and means of designing of land drainage (Rogobete, 1994).

A good soil profile offers the potential possibility for an unhampered root development and crop growth. Profile irregularities are also of importance in drainage, causing abnormal root development, and they influence the permeability. They can impede drainage and the result may be waterlogging and a too shallow root zone.

For a drainage plan, the following soil data will be required:

1. Active gley phenomena, which give a reasonable idea of the fluctuations in groundwater levels. Thus, a survey can show, fairly reliably, areas with serious waterlogging, minor waterlogging, or no waterlogging at all. Gley symptoms do not form when waterlogging occurs during rather short periods of only a few weeks, because gley formation is a chemical reaction and consequently takes time. On the other hand fossil reduction symptoms may remain visible in soils which have been drained for a long time, symptoms can remain visible in the soil for centuries. In some situations is difficult to decide whether the gley symptoms are fossil or recent.

2. Permeability

The ability of a soil to allow flow of a fluid through it. The term is also used, sometimes, to describe the ability of soils to allow penetration of plant roots. A ***permeable layer*** is a general term for soil or underlying rock layers having a relatively high permeability for water. When such a layer is water – saturated, this term is somewhat similar to the term aquifer, as used in hydrogeology. A more specific term, is used mainly in drainage studies, describing a layer having saturated hydraulic conductivity 5-10 times higher than that of the surrounding layers.

Hydraulic conductivity is a value characterising the property of soil to allow mass flow of water under the influence of a difference in water potential. In the Darcy equation, hydraulic conductivity is a factor that represents the flux of water through a unit area under the influence of a unit potential gradient. It has the dimensions of a velocity (e.g.cm s^{-1} or m day^{-1}). Saturated and unsaturated hydraulic conductivity are distinguished.

Measurements of hydraulic conductivity carried out with the augerhole method in order to get reliable data. The augerhole method allows the permeability to be determined to a depth of a few meters. Sometimes a knowledge of the properties of the deeper subsoil is necessary. We then have to make use of geohydrological observations and measurement techniques to depths of about 100 meters. With these techniques the depth of the aquifer and its hydraulic conductivity can be measured, giving an idea of the transmissivity of the subsoil.

Transmisivity is the product of hydraulic conductivity, average for a water-bearing layer, and the depth of this layer (kDvalue). Transmissivity is a measure of flow under unit gradient through the entire depth of the given layer. Sometimes is used by some authors for the A parameter in the Philip equation of infiltration.

Many soil profiles are heterogeneous in the upper parts of the subsoil due to geological or pedogenetic evolution. Geological heterogenic layers can be sand, gravel, clay and peat deposits and rocks.

Examples of heterogenic layers of pedogenetic nature are impeding Bt horizons and various pans as fragipan, duripan, hardened laterite.

3. Available water

The part of the soil water that can be taken up by plant roots and used by plants, being above the permanent wilting point or above the 15 – bar water retention tension, and its upper limit is field capacity or the corresponding water retention. The amount of water within the range of available, moisture content represents the available water capacity or ***available moisture – holding capacity***. It is usually considered equal to the difference between field capacity and the permanent wilting point. In most soils, its value varies between 10 and 15% (w/w). On the moisture characteristic curve, it corresponds in many soils to the difference in moisture content between water retention at 0.10 – 0.33 bar and at 15 bars.

4. Salinisation and sodication problems

Salinisation is a process of increasing the soil soluble content up to more than that of the normal soils (>0.08 – 0.1%). It commonly takes place following an upward capillary movement of water from a saline groundwater. Various salinity classes are recognised in different methodologies, identified by EC values: non – saline (<2dSm^{-1}), very slightly saline (2-4dSm^{-1}), slightly saline (4-8dSm^{-1}), moderately saline (8-16dSm^{-1}) and strongly saline (>18dSm^{-1}).

Sodication or alkalization is a process whereby the soil exchangeable Na content is increased due to substitution in the adsorbtion complex of divalent cation, mainly Ca^{2+} and Mg^{2+}, by Na^{2+}. Combined with other processes, it may lead to development of alkalized horizons of a specific columnar or massive structure, of dark colors and of solonetzisation.

The most commonly used parameters quantifying soil sodicity are the ESP and the SAR.

ESP - exchangeable sodium percentage, expressed as a percentage of the CEC of the respective soil. It characterizes the intensity of soil sodicity. The ESP of 15% is generally accepted as being the critical value for the division of soils into sodic and non-sodic.

SAR - sodium adsorbtion ration. A parameter representing the ratio of soluble Na to soluble divalent cations (Ca and Mg) in a soil saturation extract or in irrigation water:

$$SAR = \frac{[Na^{+}]}{\sqrt{\frac{[Ca^{2+}] + [Mg^{2+}]}{2}}} \quad (1)$$

where the total Na, Ca and Mg concentrations are expresses as $meqL^{-1}$. The SAR is useful in evaluating soil ESP, and consequently soil sodicity or in estimating the hazard of sodicity development when a specific irrigation water is used. It is also a diagnostic criterion for natric horizons. In solving already existing salinity-alkaly problems it is necessary to predict the possibilities of desalinization and de-alkalinization under improved drainage and irrigation conditions.

5. Rippening; maturation

A set of physic-chemical and biological processes that occur within soils and sediments, originally deposited under water, after embankment and drainage. The main processes in the concept of ripening are the result of loss of water including irreversible shrinkage, formation of cracks, subsidence, mineralization of organic matter, oxidation of reduced compounds (mainly of Fe) and development of aerobic types of microorganisms.

Ripening index (n value) defined in Dutch literature, showing the stage of development of the ripening process following drainage of formerly submerged soils:

$$n = \frac{w - \frac{Si + S}{S}}{C + 3\,OM} \qquad (2)$$

where w is the moisture content, Si is the silt content, S is the sand content, C is the clay content and OM is the organic matter content (all in %).

High values of the ripening index usually >0.7 describe soils under submergence conditions and not ripened.

It has been made clear that even though information on soils is available, supplementary studies will often have to be made to satisfy the requirement of the technical plan.

It should be born in mind that drainage can influence the soil conditions, either favourably or unfavourably. The evaluation of future soil conditions is one of the main points to be considered, in order to improvement the deterioration of some properties.

Van Beers (1976) have been summarized the theory and practice of drainage equations. When using equations based on steady – state conditions, one should realize that such conditions seldom occur in practice. Nevertheless the equations are extremely useful, because they make it possible:

-to design a drainage system which has the same intensity every here even though quite different hydrological conditions (transmissivity values) occur in the area

-to carry out a sensitivity analysis, which gives one a good idea of the relative importance of the various factors involved in the computations of drain spacings.

In the following drainage situations, for instance, there is only one possible equation that can be used for the different hydraulic conductivity:

K1>K2: a highly pervious soil layer above drain level and a poorly pervious soil layer below drain level; only Eq.Hooghoudt

K1<K2: a heavy clay layer of varying thickness overlying a sandy substratum; only Eq.Ernst

K3>K2: the soil below drain level consists of two pervious layers, the lower layer being sand or gravel (aquifer); only Eq.Ernst.

In the last time, a generalized equation has been developed which covers all K1/K2 ratios. This new equation, Hooghoudt-Ernst, is based on a combination of the approach of Hooghoudt (radial flow only for the flow below the drains) and the equation of Ernst, for the radial flow component.

For most drainage situations with a barrier (only K2D2 - transmissivity) a simplified equation and Graph can be used.

4. CONCLUSIONS

A sensitivity analysis reveals the relative influence of the various factors involved: the permeability and thickness of the soil layers through which groundwater flow can occur (depth of a barrier), wetted perimeter of drains, depth of drains, etc.

This analysis will indicate whether approximate data will suffice under certain circumstances or whether there is a need for more detailed investigations. The drainage specialist will find the sensitivity analysis a useful tool in guiding the required soil and geohydrogeological investigations, which differ from project to project, and in working out alternative solutions regarding the use of pipe drains or ditches, drain depth, etc.

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