STUDY ON THE ESTIMATION POSSIBILITIES OF THE SOIL HYDRAULIC CONDUCTIVITY

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Introduction

The most important elements of the soil water regime – water retention and hydraulic conductivity – are known to play an important role in the fate and transport of organic and inorganic compounds in the soils. They determine the air and water management, biological activity and nutrient management of the soil (Várallyay, 2005). The knowledge of the soil hydraulic properties has one of the most important effect on the success of plant production (Baser *et al.*; 2004, Rajkainé and Szundy, 2004; Farkas *et al.*, 2005).
Earlier studies (Makó *et al.*, 2005) proved that soil water retention characteristics can be reliably estimated for soil subtypes using the grouped means of texture and humus content categories of soil maps. In the current work we study predicting possibilities of soil hydraulic conductivity from data of soil maps and cartograms as readily available information. For these studies we used the database of the Hungarian Soil Information and Monitoring System. For estimating of soil hydraulic conductivities we used the TALAJTANonc 1.0 software (Fodor and Rajkai, 2005).

Methods

The Hungarian Soil Information and Monitoring System (HSIMS) database used includes data of 1023 soil profiles. In the database there are information, among others, on particle size distribution, bulk density, water retention data, organic matter and carbonate content, soil types for 3115 layers (TIM, 1995). Since the HSIMS database does not contain data of measured hydraulic conductivity (K_{sat}) we were not able to test directly the goodness of the outworked estimations. As an alternative control, conductivity values ($K_{sat,c}$) were calculated by the Campbell method (Campbell, 1974) (see later). Worth to mention, that the Campbell's method gives the minimum hydraulic conductivity of the measured value because it characterises the water conductivity of the soil matrix without considering its macro pores (Rajkai, 2004). However, in our study we considered the $K_{sat,c}$ calculated by Campbell – as an accepted method in the international literature – as a reliable substituting value of K_{sat}.

The data set was divided into two parts with a quasi-random procedure in order to get an “evaluation database” containing 67% of the whole database, and a “test database”. According to former studies the most deterministic soil parameters of the K_{sat} are the soil particle-size data and the bulk density. Unfortunately the basic soil maps and cartograms contain no direct information for the bulk density of the soils. The soil subtype codes we used to generate ten bulk density groups – called “density types” – by the help of the hierarchical cluster analysis (SPSS, HCA), for the soils of the “evaluation database”.

Beside bulk density category generation three further grouping were made applying the categories of the soil maps for:

1. Soil texture (7 classes).
2. Soil texture (7 classes) and “density type” (10 types) (44 groups).
3. Soil texture (7 classes), “density type” (10 types) and organic matter content (2 classes) (74 groups).

For each group of the “evaluation database” the mean values of the measured sand % (0,02-0,2 mm), silt % (0,002-0,02 mm), clay % (< 0,002 mm), bulk density and organic matter content were calculated according to the above three grouping points of view. The calculated mean values were used to estimate the mean saturated hydraulic conductivity (m/s) as typical value for each group. Calculations have been carried out with the TALAJTANonc 1.0 software (Fodor and Rajkai, 2005). This software calculates the $K_{sat,c}$ with the Campbell’s pedotransfer function (Campbell, 1974) from the bulk density, sand-, silt- and clay % of the soil.

The same grouping procedure as for the “evaluation database” was done for the “test database” as well. The calculated MEAN $K_{sat,c}$ values of the groups in the “evaluation database” were adjoined to the groups of the “test database” – which were created in a similar way like in the “evaluation database”. To control the goodness of the group value estimation (MEAN $K_{sat,c}$), the conductivity values ($K_{sat,c}$) were calculated for each soil sample of the “test database” by the Campbell method and compared with the mean values of the soil groups. The difference between the $K_{sat,c}$ and the MEAN $K_{sat,c}$ values were evaluated.

The goodness of the prediction – the estimated hydraulic conductivity on the basis of the group mean values – was evaluated in two ways: (1.) the estimated value was considered reliable when the difference between the estimated and calculated value was less than 1 in logarithmic scale (Fodor and Rajkai, 2004; Schaap and Leij, 1998); (2.) the estimated value was considered reliable when the difference between the two values was less than 0,5 in logarithmic scale. In order to indicate the goodness of estimation the number of the “good” estimations was expressed as percentage of all samples of the “test database”.

In a supplementary study the effect of bulk density on the hydraulic conductivity’s estimation was also carried out. The bulk density was calculated by the TALAJTANonc 1.0 software based on the method by Rawls (1983). Soil bulk density is estimated from the organic matter content, sand-, silt- and clay % of the soil.

Results and discussion

Results of the present analyses show that the estimation efficiency of soil hydraulic conductivity does not improve considerably if more soil properties are used to generate the groups. (Table 1.). In case of the stronger evaluation method (if the difference between the estimated and calculated value was less than 0,5 in logarithmic scale) the estimation efficiency for the groups containing more soil parameters (soil texture class, density type and organic matter code) increased only 5%.

Table 1. The estimation efficiency in the case of the three different grouping methods evaluating by the above mentioned two ways.

The way of creating the groups	Estimation efficiency (%)	
	1st evaluation	2nd evaluation
1. soil texture class	91 %	61 %
2. soil texture class and density type	92 %	64 %
3. soil texture class, density type and organic matter code	92 %	66 %

Finally we compared the MEAN $K_{sat,c}$ and the characteristic Hungarian standard values (Várallyay et al. 1980) which showed the following: (1.) in case of course textured soils the calculated values are lower than the characteristic ones; (2.) for the more clayey soils the calculated values are higher than the characteristic ones. The reason of the differences can be the outcome of that the Campbell method does not consider the soil macro pores, and in case of soils with high clay content the error of the bulk density measurement can play role.

Based on the calculated hydraulic conductivity values derived from the HSIMS database, it can be assumed that the soil hydraulic conductivity can be estimated reliably from soil texture codes of the soil map.

It was also found that bulk density estimation by Rawls (1983) is insufficient to replace the mean bulk density values of soil groups. The efficiency of the hydraulic conductivity estimation decreased to 78-79% in the 1st evaluation and to 49-50% the 2nd evaluation in case of applying estimated values instead of calculated group mean ones.

For estimating hydraulic conductivity value of soil categories the Campbell and the Rawls estimation methods used in the TALAJTANonc program was suitable.

Conclusions

By the introduced method for soil hydraulic conductivity – which is extremely variable in space and time (Várallyay, 1972) – reliable estimation can be given on the basis of soil texture category codes of soil maps and cartograms. Compared to the mean values of the measured bulk densities estimated by the Rawls method were not reliable. The mean bulk density of measured ones for each soil group resulted more precise hydraulic conductivity estimation. The reason of it can be the difference between the used databases and the various laboratory methods. Checking the functional reliability of the estimated K_{sat} values is a next task.

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