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USING TWO PEDOTRANSFER FUNCTIONS TO ESTIMATE SOIL MOISTURE RETENTION CURVES FROM ONE EXPERIMENTAL SITE OF SOUTH MORAVIA

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Abstract

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The soil moisture retention curves (SMRCs) were measured in laboratory conditions. The sand table and pressure extractor method were used to obtain a 9-point SMRCs for undisturbed soil samples taken from 20 cm depth. The data points of the individual retention curves were parameterized using the RETC computer program. For the same soil, the SMRCs were estimated by two models of pedotransfer functions (PTFs). In the first part of the study the Rosetta program with the model of artificial neural network (Schaap *et al.*, 1998) was used. The PTFs derived by Wösten *et al.* (1998) were used in the second part of the study. The reliability of selected PTFs models were tested on local soils from one site of the South Moravia. The quality of estimated retention curves was evaluated using the coefficient for correlation R between the measured and the estimated soil water content at several pF values and the root mean squared error RMSE. Of the two models of PTFs, which have been tested in the study, Wösten's model showed better agreement with the measured retention curves ($RMSE_{Sch} = 0.0383$ (cm^3.cm^{-3}), $RMSE_W = 0.0264$ (cm^3.cm^{-3})).

Keywords: soil moisture retention curve, soil hydraulic properties, pedotransfer functions, artificial neural networks

INTRODUCTION

Soil is one of the irreplaceable natural wealth of our country and form a characteristic component of the landscape. Intensive industrial production and agriculture cause the quality of our soil and water significantly to get worse and creates significant environmental damage. To prevent further soil degradation, it is necessary to assess the impact of agriculture with regard to overall water balance (soil water retention capacity, infiltration and surface runoff, evapotranspiration), using mathematical models to simulate the processes occurring in aeration zone. This zone is strongly heterogeneous, each modeling of transport in this area requires a significant amount of input data (soil hydraulic properties).

Input data required for simulation process in aeration zone is usually obtained from direct measurements in the field or using various laboratory techniques. Measurement of SMRC is time consuming and costly, necessary data are usually not available. Various SMRC estimation models have been proposed and used extensively to overcome this problem. Pedotransfer functions (PTFs) for the estimation of these important characteristics from more easily or routinely measured soil properties can serve as a valuable alternative to direct measurements, especially in environmental studies (Wösten *et al.*, 2001; Nemes *et al.*, 2006). Other, more easily determinable and available soil properties, such as particle-size distribution, soil bulk density and organic matter content, were used for the estimation of SMRC.

However, PTFs are not recommended for use outside the area for which they were derived (Wösten *et al.*, 1999). Thus, a source database containing locally measured data is always necessary (Nemes *et al.*, 2003). Several large databases for PTFs development have been built and are being updated on national as well as international level. The most important database for Europe is HYPRES – HYdraulic PRoperties of European Soils (Wösten *et al.*, 1999). PTFs derived from this database belong to the most widely used worldwide (McBratney *et al.*, 2011). Based on the structure European database HYPRES, with few modifications, was created Czech database HYPRESCZ (Miháliková *et al.*, 2013).

The preliminary study is focused on creating a small reference data set with locally measured soil hydro-physical properties that will be used to estimate of SMRCs. The two models PTFs were employed to their applicability for soil under study. From a number of concepts available, in the first part of the study method of SMRC prediction based on artificial neural networks model (Schaap *et al.*, 1998) was used with international databases Rosetta, which reflects agricultural and non-agricultural land used mainly in the U.S. and parts of Europe. In second part the Wösten's original model was selected, which was derived for European soils in general. Both PTF's models were tested on arable land from one region of the South Moravia.

MATERIALS AND METHODS

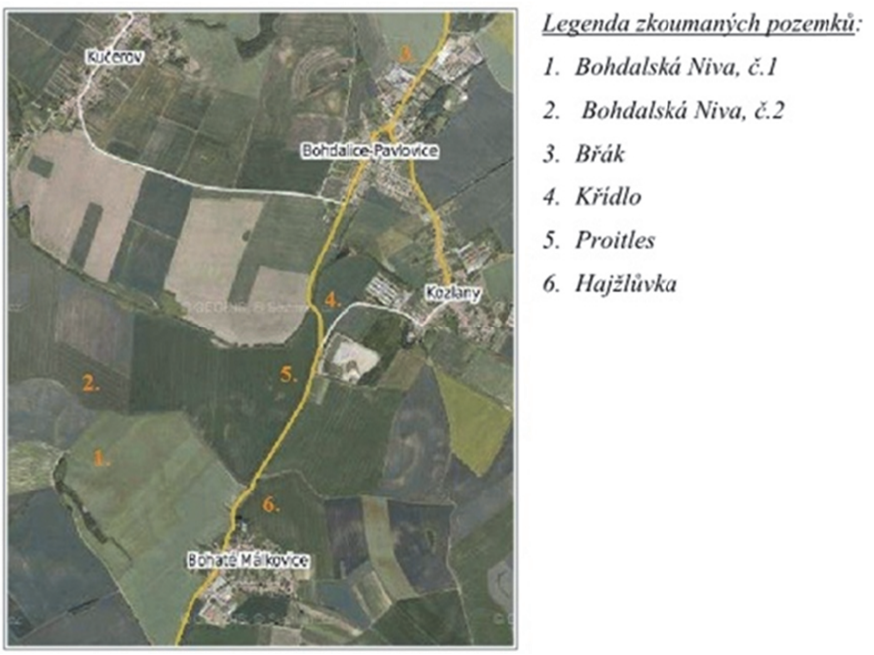
The experimental site is located in beet production area near the locality Bohaté Málkovice, Vyškov district. The experimental plot is part of the river basin Svratka. The average altitude is around 279 m above the sea level, with an average rainfall during the growing season 350 mm and with average temperature around 8.4 °C. The genetic soil representative is Haplic Chernozem/FAO and the pedogenetic substrate is loess. These soils are very deep with weakly acidic-alkaline soil reaction, with fine grey-wacked structure.

Experimental research was conducted on six plots with total area of 241 hectares; they are processed for long-term by different technologies of soil cultivation (the conventional ploughing to a depth of 22 cm and the reduced tillage – during autumn the cultivation of spring crops is done by vertical hoeing of soil to a depth of 20 cm), Fig. 1. The reduced tillage was applied to an area of 191 hectares and 50 hectares to the conventional tillage.

Predominant crop was spring barley (*Hordeum vulgare*) of other crops were represented winter oilseed rape (*Brassica napus subsp. Napus*) and sunflower (*Helianthus*).

The soil samples were taken from fifteen sampling probes, the depth of sampling was 20 cm. The soil profiles in these pits were very similar.

The undisturbed soil samples were used to obtain the data points $\theta(h)$ at pressure heads h of 0, –20, –60, –100, –220, –570, –980, –2 000 and –15 000 cm. The sand table method was used in range from –20 to –60 cm. The pressure plate extractors (Soil Moisture Eguipment, Santa Barbara, California, U.S.) were used for the pressure head range from 0.1 to 15 bars. The measured data points $\theta(h)$ for individual retention curves were parameterized, using the RETC computer program (van Genuchten *et al.*, 1991) to obtain the fitted parameters θ_r, α and n. Parameter θ_s has been replaced by the measured



1: *The situation of the selected site with experimental plots* saturated water content and was not fitted. Non-linear least square method was use to optimize the parameters of the van Genuchten equation (1980):

$$\theta(h) = \theta_r + \frac{(\theta_s - \theta_r)}{\left[1+(\alpha h)^n\right]^m},\ m = 1 - \frac{1}{n}, \tag{1}$$

where

$\theta(h)$........ soil water content as a function of pressure head h (cm³.cm⁻³),

θ_r............. residual soil water content (cm³.cm⁻³),

θ_s............. saturated soil water content (cm³.cm⁻³),

α, n, m.... empirical parameters.

The same undisturbed soil samples (15), in which retention curves were measured in laboratory conditions, were used to determine bulk density ρ_d, particle density ρ_s and particle size distribution curve. The particle size distribution curves were then determined by sieving for sand fraction and by Casagrande method for silk and clay fractions. The original particle-size distribution data were converted to the FAO/USDA categories. In the grab samples, the organic matter content was estimated by measuring total organic carbon. The wet acid oxidation method was used.

Basic information about the soil physical properties is summarized in Tab. I, obtained values are listed in the range from minimum to maximum.

The two PTFs were tested in this study. The artificial neural network model Rosetta (Schaap *et al.* 1998) was employed to obtain van Genuchten's parameters (θ_r, θ_s, α, n). Mass fractions of clay (0–2 µm), silt (2–50 µm), sand (50–2000 µm) and dry bulk density ρ_d were used as the parameters of predictions. The particle-size categories currently used in the Czech Republic were converted to the FAO/USDA categories. Using equation (1) were calculated points of SMRC in nine pressure heads h (h = 0, –20, –60, –100, –220,–570, –980, –2 000 and 15 000 cm). In the second part the method developed by Wösten *et al.* (1998), Wösten *et al.* (1999) and other European authors was selected.

All pF curves measured, fitted and estimated were plotted into graphs for a visual comparison. The reliability selected models was evaluated using R coefficient for correlation and root mean squared error RMSE.

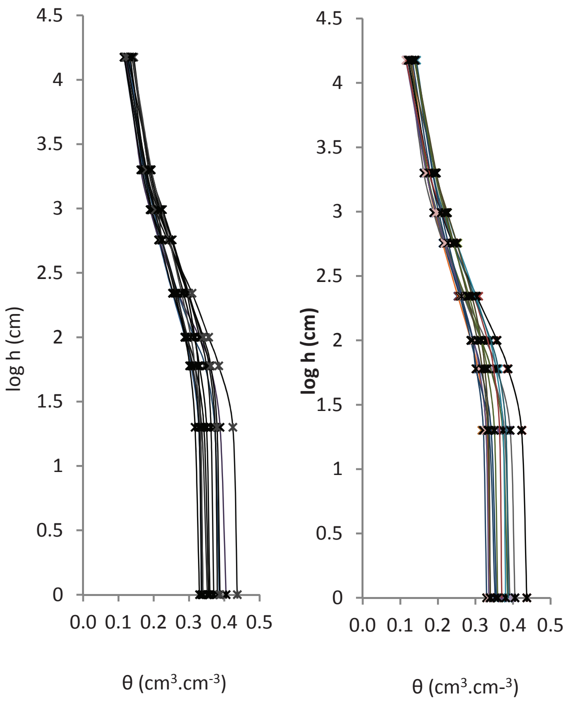
RESULTS AND DISCUSSIONS

The measured SMRCs, expressed as pF curves, and their individually parameterized counterparts corresponded well to one another, this is documented in Fig. 2. The measured points are indicated in both graphs.

For a visual comparison, graphs of individually fitted and estimated pF curves were plotted. Results comparing are shown in Fig. 3. This figure is composed of four graphs as follows: a) measured and fitted (output of RETC) pF curves for particular soil samples, b) PTF – estimated pF curves using the artificial neural network model Rosetta (Schaap *et al.,* 1998), c) PTF – estimated pF curves using the equations by Wösten *et al.* (1998), d) comparison of pF curves a), b), and c) for a one selected soil sample.

Quality of estimated retention curves was evaluated using correlation coefficient R and root of the means squared difference RMSE. Dependence of relationship between the measured and the estimated soil water content θ at several pF values using both PTF's is graphically presented in Fig. 4.

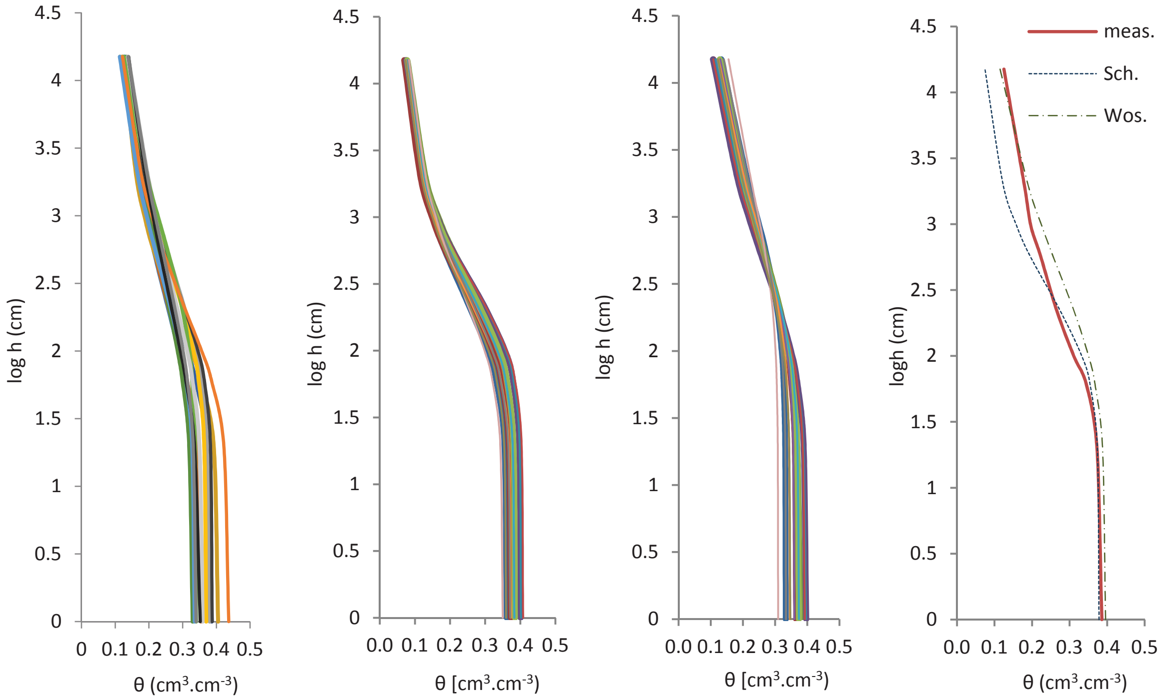
The calculated values of correlation coefficient R are not significantly different (R_{Sch} = 0.974, R_W = 0.963), showing a close correlation between measured and estimated data. The RMSE for both PTF's models is low ($RMSE_{Sch}$ = 0.03843 (cm³.cm⁻³), $RMSE_W$ = 0.0264 (cm³.cm⁻³)).



2: *Comparison of measured and fitted (using RETC computer program) pF curves*

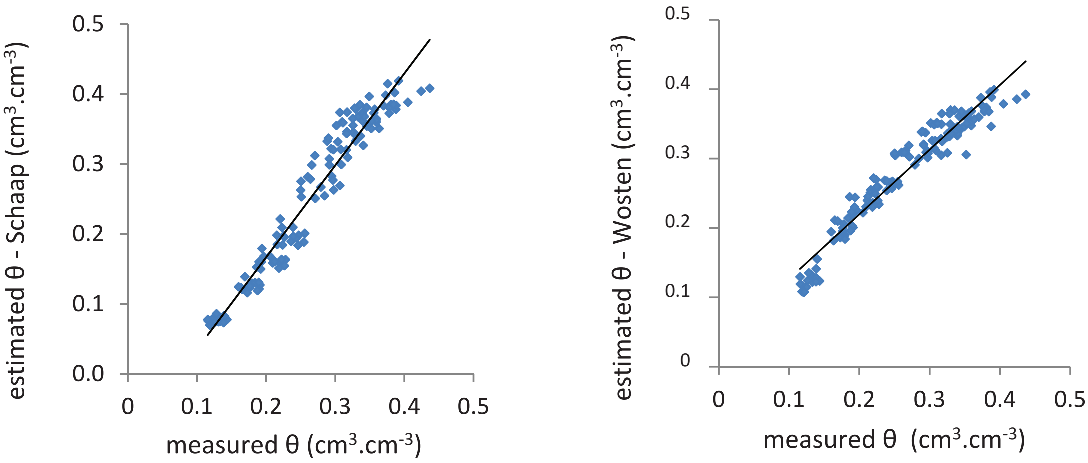
I: *Basic soil physical properties of tested plots*

site	particle density ρ_s (g.cm⁻³)	bulk density ρ_d (g.cm⁻³)	organic matter content (%)	USDA/FAO categories (%) clay	silt	sand	FAO/USDA textural triangle
B. Málkovice	2.54–2.56	1.49–1.79	1.7–3.01	8.7–14.7	75.24–81.18	6.02–12.91	silt, silt loam



a) b) c) d)

3: *Graphs of a) measured and fitted (using RETC) pF curves, b) pF curves derived from Schaap's model (1998), c) pF curves derived from PTF's according to Wösten et al. (1998), d) comparison of a), b), c) for a one selected soil sample.*



a) b)

4: *A1:1 correlation of the measured and the estimated soil water content at several pF values using both PTF's models, a) measured vs. estimated soil water content at several pF values predicted by Schaap's model (1998), b) measured vs estimated soil water content at several pF values by Wösten's model (1998).*

CONCLUSION

Based on processed small local reference data set with soil hydro-physical properties and measured retention curves in laboratory conditions, SMRCs were estimated using two PTF's models. The Wösten's model performs better, because the HYPRES database collects data from European soils, while databases Rosetta comes from U.S. soils. Quality and size of the input data sets are critical factors for a successful use of pedotransfer functions.

SUMMARY

The experimental site is located in beet production area near the locality Bohaté Málkovice, Vyškov district. The genetic soil representative is Haplic Chernozem/FAO and the pedogenetic substrate is loess.

Experimental research was conducted on six plots with total area of 241 hectares; they are processed for long-term by different technologies of soil cultivation (the conventional ploughing and the reduced tillage). Predominant crop was spring barley (*Hordeum vulgare*) of other crops were represented winter oilseed rape (*Brassica napus subsp. Napus*) and sunflower (*Helianthus*).

The soil samples were taken from fifteen sampling probes, the depth of sampling was 20 cm. The soil profiles in these pits were very similar.

The undisturbed soil samples were used to obtain the data points $\theta(h)$ at pressure heads of 0, –20, –60, –100, –220, –570, –980, –2 000 and –15 000 cm. Sand table and pressure extractor methods were used to obtain a 9-points of retention curve for undisturbed soil samples taken from 20 cm depth. The data points of the individual retention curves were fitted using the RETC computer program.

The same undisturbed soil samples (15), in which retention curves were measured in laboratory conditions, were used to determine bulk density ρ_d, particle density ρ_s, organic matter content and particle size distribution curve. The particle size distribution curves were then determined by sieving for sand fraction and by Casagrande method for silk and clay fractions. In the grab samples, the organic matter content was estimated by measuring total organic carbon. The wet acid oxidation method was used.

The retention curves were estimated by the artificial neural network model Rosetta (Schaap *et al.*, 1998) and the use of model of continuous PTF's by Wösten *et al.* (1998). Both PTF's models were tested on arable land from one region of the South Moravia.

The results of the comparison of fitted and estimated retention curves using both PTFs did not differ significantly, which is shown in Fig. 3. The estimation quality was assessed in terms of reliability with correlation coefficient R and root of the means squared difference RMSE. The correlation coefficient R for both PTF's models is high and demonstrates the close relationship between the measured and estimated soil water content θ at several pF values. Root of the means squared difference RMSE is low ($RMSE_{Sch} = 0.0383$ ($cm^3.cm^{-3}$), $RMSE_W = 0.0264$ ($cm^3.cm^{-3}$)). Selected simple PTF's models provide estimates of retention curves for the site with sufficient reliability.

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REFERENCES

MCBRATNEY, A. B., MINASNY, B., TRANTER, G. 2011. Necessary meta-data for pedotransfer functions. *Geoderma*, 160: 627–629.

MIHÁLIKOVÁ, M., MATULA, S., DOLEŽAL, F. 2013. *HYPRESCZ* – Database of the soil hydrophysical properties in the Czech Republic. *Soil and Water Res.*, 8: 34–41.

NEMES, A., SCHAAP, M. G., WÖSTEN, J. H. M. 2003. Functional evaluation of pedotransfer functions derived from different scales of data collection. *Soil Science Society of America Journal*, 67: 1093–1102.

NEMES, A., WÖSTEN, J. H. M., BOUMA, J., VÁRALLYAY, G. 2006. Soil water balance scenario studies using predicted soil hydraulic parameters. *Hydrological Processes*, 20: 1075–1094.

SCHAAP, M. G., LEIJ, F. J., VAN GENUCHTEN, M. T. 1998. Neural network analysis for hierarchical prediction of soil hydraulic properties. *Soil Science Society of America Journal*, 62:847–855.

VAN GENUCHTEN, M. T. 1980. A closed-form equation for predicting the hydraulic conductivity of unsaturated soils. *Soil Science Society of America Journal*, 44: 892–898.

VAN GENUCHTEN, M. T., LEIJ, F. J., YATES, S. R. 1991. *The RETC code for quantifying the hydraulic functions of unsaturated soils*. Riverside, California: US Environmental Protection Agency.

WÖSTEN, J. H., LILLY, A., NEMES, A., BAS, C. 1999. Development and use of database of hydraulic properties of Europen soils. *Geoderma*, 70: 169–185.

WÖSTEN, J. H. M., PACHEPSKY, Y. A., RAWLS, W. J. 2001. Pedotransfer functions: bridging the gap between available basic soil data and missing soil hydraulic characteristics. *Journal of Hydrology*, 251: 123–150.

WÖSTEN, J. H. M., LILLY, A., NEMES, A., BAS, C. 1998. *Using existing soil date to derive hydraulic parameters for simulation models environmental studies and in land use planning*. Final Report on the European Union Foundef Project. Wageningen.

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