ANALYSIS OF DIFFERENT SOURCES OF VARIABILITY OF SOIL RELATED PARAMETERS AT FIELD SCALE FOR HYDROLOGICAL SIMULATIONS

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KEY POINTS:

- *Hydrological models require extensive soil parameters collection*
- *Soils to be characterized exhibit large variations in space and time*
- *Soil properties variability has implications on hydrological simulations*

1 INTRODUCTION

Infiltration as an important component of the hydrological cycle is controlled mainly by soil hydraulic parameters. Numerous methods that have been developed to measure or estimate these parameters exhibit different levels of confidence. Implemented field and laboratory procedures are expensive and time consuming particularly for soils with high clay content. Saturated hydraulic conductivity (KSAT) could be defined through direct field and laboratory measurements or derived from direct or inverse measurements (*Dane and Topp*, 2002).Soil water retention curve parameters are usually measured in the laboratory using suction tables and pressure chambers. This method is time consuming, with a high cost and its applicability is limited at relatively low water potentials due to the poor plate-soil contact (*Schinder et al.*,2012). As an alternative, numerical inversion of transient flow experiment such as multistep outflow and evaporation method has been implemented for soil hydraulic properties determination(*Peters and Durner*, 2008). Data evaluation methods of these experiments through data fitting or inverse modelling are based on minimizing the difference between optimized and observed parameters (Iovino and Romano,2004). For any indirect or direct estimation method of soil water retention curve parameters fits to a selected parametric equation. Many empirical models exists in the literature (*Gardner*, 1958; *Brooks & Corey*, 1964; *Campbell*, 1974; *Clapp & Hornberger*, 1978; *van Genuchten*, 1980; *Hutson & Cass*, 1987; *Russo*, 1988) but Brooks and Corey (BC) (1964) and Van Genuchten (VG)(1980) are the most used models to describe soil water retention curve implemented especially within pedotransfer functions. In recent years many pedotransfer functions (PTFs) were developed, due to the short comings of direct and indirect methods. These functions started to be widely used under the condition of required validation of their applicability through some direct measurements (*Durner & Lipsius*, 2005). Adding to the uncertainty that may be induced from the selection of parameter determination method , soil parameters are subjected to temporal (during a cropping cycle) and spatial variability. Due to biological processes and agricultural management practices : tillage , irrigation , fertilization and harvest ; soil properties are subjected to diverse physical and chemical changes that leads to a non-stability in term of water and chemical movements within the soil as well to the groundwater. Many researchers have focused their studies on quantifying effect of tillage on soil properties (*Green et al*. 2003, *Mapa et al.* 1986). Others tried to assess the effect of wheel traffic on infiltration (*Ankeny et al*. 1990, *Defossez et al*. 2003). Fewer studies were carried out to evaluate the impact of agronomic practices on soil properties as well on soil water movement within the vadoze zone(*Ndiaye et al*.2007). Better understanding of the effect of different sources of uncertainty of soil hydraulic parameters could improve hydrological simulations accuracy.

2 MATERIAL AND METHODS

The study site is a maize field (45°13’31.70’’ N, 9°36’26.82 E) located in Northern Italy-Lombardy region. This field belongs to the Consortium of Muzza Bassa Lodigiana. This site is a surface irrigated field that covers an area of 6ha. Experimental measurements were carried out from 21 April 2015 to 16 September 2015. This site was taken as case study of the SEGUICI project, aimed at experimenting soil moisture forecast for irrigation scheduling. Both meteorological data and soil moisture were monitored. The field was equipped with an eddy covariance and meteorological stations. Sentek probe together with three TDR probes were inserted at different soil depths. During several field visits soil samples were collected at different points (A01, A02, A03 and A04), at different soil depths (0cm, 20cm, 40cm). We limited our soil parameter monitoring to the first 40 cm of the soil, since the top soil in more susceptible to variability due to agronomic practices then deeper layers. For each soil sample we carried out several tests to assess the saturated hydraulic conductivity (KSAT) , soil water retention curve parameters (SWRC) , bulk density (BD) , particle size distribution (PSD) and organic matter content (OM). The selection of sampling points was aimed to assess the spatial variability of soil properties as well to assess the effect of cropping practices at different locations of the field (near to the irrigation canal (A02), at the middle of the field (A01) and at the extremity of the field (A03)). The point A04 was selected from an uncultivated part of the field, since 8 years, in order to assess the effect of agronomic practices on soil properties as compared with other points of the field located within the maize cultivated part for more than 25 years. Several methods were applied for the measurement of the saturated hydraulic conductivity. The experiments with Guelph permeameter were performed together with laboratory falling head measurements using the UMS-KSAT on undisturbed soil samples. Soil water retention and hydraulic conductivity curves from the evaporation method were fitted to different unimodal and bimodal parametric equations (BC, VG-UNI, VG-BI, KOSUGI-UNI, and KOSUGI-BI). Collected soil parameters (PSD,BD and OM) were used to assess the validity of different pedotransfer function for the study area.

3 RESULTS AND DISCUSSION

3.1 Determination method uncertainty

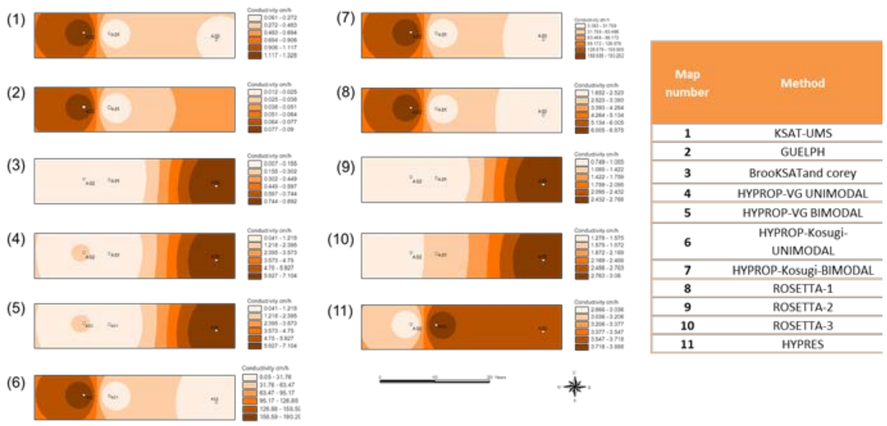

Figure 1. Saturated hydraulic conductivity maps from different tested determination methods

As shown in Figure1, some applied methods for KSAT determination yielded non-representative maps of this parameter for the study area. Thus, the method used to determine the saturated hydraulic conductivity is considered as a source of variability of this parameter among many other factors of variability (i.e: land use , agronomic practices). Field and laboratory measurements that are usually considered as the most accurate determination methods may also exhibit a certain level of error, depending on the study site conditions, sample collection and disturbance , and instrument installation. From this study, field measurements were time consuming and underestimated with one order of magnitude KSAT values. Van Genuchten unimodal gave better prediction of this parameter as compared with other fitted parametric equations. Pedotransfer functions for such field scale studies though without calibrations were able to give a good prediction for the saturated hydraulic conductivity. ROSETTA's textural classes based model was also able to give a good prediction, but the use of such a model would not be applicable for a field with fully developed crop or after any agronomic practice since it doesn't consider any other factors that impacts the KSAT such as Bulk density or organic matter, while other models of ROSETTA-MODEL 2, ROSETTA-MODEL 3 and HYPRES gave acceptable predictions with more input requirements. Results of HYPROP tests were fitted to

Brooks and Corey and Van Genuchten. Resulted water retention curve parameters were compared with different pedotransfer functions. Results showed that the pedotransfer function developed by (Wὂsten et al., 1999) gave better predictions of SWRC parameters among the other tested ones, as compared with laboratory determined SWRC.

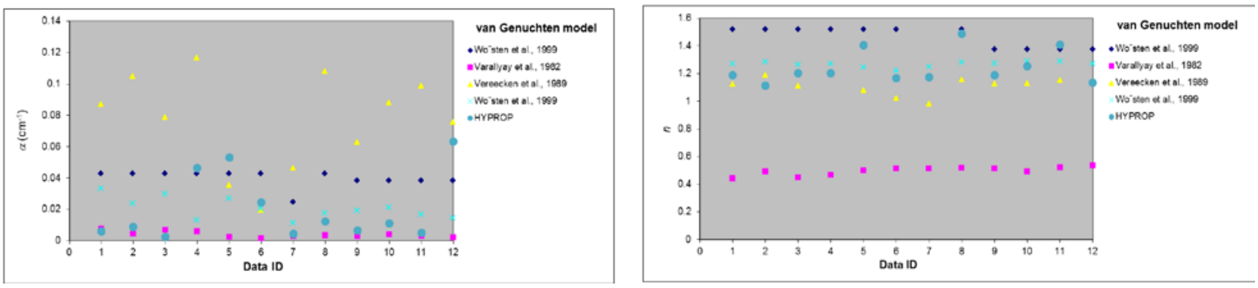

Figure 2. Comparison of some soil water retention curve parameters as determined by pedotransfer functions and HYPROP

3.2 Spatial and temporal variability

Soil properties showed changes during the cropping cycle. KSAT and the organic matter content increased , while the bulk density decreased. Assessment of results of the evaporation method showed as well variability of soil water retention curve vertically , horizontally and as well temporally. This variability was higher for samples taken from rows (under-plants) than the one taken from the inter-rows(between plants lines). These variations are induced probably due to roots development, biological activities and wetting /drying cycles. A04 , as taken from an uncultivated part of the field presented the highest KSAT value in the first campaign due to grass roots and earthworms that were absents in the other cultivated part. Concerning the SWRC , comparison between the different tested samples at different depth and at different locations , showed that the available water was less in depth since soil was more compacted in these layers. This result could explain the shallow rooting depth of maize in the study area. Field capacity and wilting points were as well subjected to temporal variability since they decreased considerably between the first and second campaign. In the last field campaign, after harvest, soil properties were more homogenous then the previous measured ones. The results of performed soil properties measurements allowed us to conclude the existence of synergic effect between these parameters. The use of such time-variable parameters for hydrological simulations would improve the quality of prediction of soil moisture. Temporal and spatial variability assessment of soil parameters is expensive and time consuming , for this reason few studies only have addressed this aspect. Meanwhile, this kind of measurements will allow us to select more representative parameters for field conditions.

4 CONCLUSIONS

In this study some direct and indirect methods for deriving soil hydraulic properties were tested. Taking into consideration laboratory measured parameters as reference allowed us to assess the uncertainty induced from other tested methods. HYPRES pedotransfer function predictions of SWRC and KSAT for this study area showed good performances. Our results revealed as well the temporal and spatial dynamic of soil properties. Neglecting this variability could introduce more uncertainty into model simulations. The propagation of uncertainty from input parameters to hydrological model outputs should be evaluated.

Acknowledgements This work has been partly funded by Regione Lombardia in the framework of the SEGUICI project "Smart technologies for water resources management for civil consumption and irrigation". The authors would like to thank the staff of LPM laboratory of Politecnico di Milano for their collaboration in determining organic matter content.

REFERENCES

Ankeny, M.D., T.C. Kaspar and R. Horton. Characterization of tillage and traffic effects on unconfined infiltration measurements. Soil Science Society of America Journal 54: 837-840, 1990.

Brooks, R.H., and Corey A.T. Hydraulic properties of porous media. Hydrol. Paper 3. Colorado State Univ., Fort Collins, CO, USA.

Campbell, G.S., 1974. A simple method for determining unsaturated conductivity from moisture retention data, Soil Sci. 117(6):311-314, 1964.

Clapp, R. B. and G. M. Hornberger. "Empirical Equations for Some Soil Hydraulic Properties," Water Resources Research, 14: 601-604 , 1978.

Dane, J.H. and C. Topp. Methods of Soil Analysis. 1st Edn., Soil Science Society of America, Madison, WI, ISBN-10: 089118841X, pp: 866, 2002.

Durner, W. and Lipsius, K. Determining soil hydraulic properties, in: Encyclopedia of Hydrological Sciences, edited by: Anderson, M. G., chap. 75, John Wiley & Sons, Chichester, UK, 1121– 1143, 2005.

Défossez, P., Richard, G., Boizard, H. and O'Sullivan, M.F. Modeling change in soil compaction due to agricultural traffic as function of soil water content. Geoderma, 116: 89-105, 2003.

Gardner, W. Some steady-state solutions of the unsaturated moisture flow equation with application to evaporation from a water table, Soil Sci., 85, 228 – 232,1958.

Green, T.R., L.R. Ahuja and J.G. Benjamin. Advances and challenges in predicting agricultural management effects on soil hydraulic properties. Geoderma 116: 3- 27, 2003.

Hutson, J.L. & Cass, A. A retentivity function for use in soil-water simulation model. J. Soil Sci., 38, 105-113, 1987.

Iovino, M., Romano, N. Inverse modeling of evaporation and multistep outflow experiments for determining soil hydraulic properties: a comparison, RIVISTA DI INGEGNERIA AGRARIA, 2, 51-62, 2005.

Mapa, R.B., L. Santo and R.E. Green. Temporal variability of soil hydraulic properties with wetting and drying subsequent to tillage. Soil Science Society of America Journal 50: 1133-1138, 1986.

Ndiaye, B., Molenat, J., Hallaire, V., Hamon, C.G.Y. "Effects of agricultural practices on hydraulic properties and water movement in soils in Brittany (France)". J. Soil & Tillage Res. 93, 251-263, 2007.

Peters, A., and Durner,W. Simplified evaporation method for determining soil hydraulic properties. Journal of Hydrology 356 (1), 147-162, 2008.

Russo, D. Determining soil hydraulic properties by parameter estimation: On the selection of a model for the hydraulic properties. Water Resour. Res., 24(3), 453-459, 1988.

Schindler, U., Muller, L., da Veiga, M., Zhang, Y., Schlindwein, S. Hu, C. Comparison of water-retention functions obtained from the extended evaporation method and the standard methods sand/kaolin boxes and pressure plate extractor. Journal of Plant Nutrition & Soil Science, 175, 527–534, 2012.

Van Genuchten, M. A closed-form equation for predicting the hydraulic conductivity of unsaturated soils. Soil Sci. Soc. Am. J. 44:892-898,1980.