SPATIAL VARIATION OF SOIL PROPERTIES AFFECTING YIELD

Cs. FARKAS[1] – *A. RISTOLAINEN*[2] – *L. ALAKUKKU*[3]

1. Research Institute for Soil Science and Agricultural Chemistry, of HAS, Budapest, Hungary
2. MTT Agrifood Research Finland, Soils and Environment, E-House, 31600 Jokioinen, Finland 3. University of Helsinki, Dept. of Agrotechnology, Finland

Introduction

Application of precision agricultural techniques enables the management of different within-field areas with different input levels (Németh et al, 2003). To obtain the economical and environmental benefit from this technology, it is important to have information about the spatial and temporal variation of soil properties affecting yield quantity and quality (Orfánus and Nagy, 2002), and, consequently, transport of elements in the soil-plant-atmosphere system and food chain. Measurement and mapping of spatial distribution of soil physical and hydrophysical properties, affecting the spatial pattern of soil water balance elements is expensive and laborious. Hence, simulation models that incorporate the physical-based knowledge of the processes in the soil-water-plant-atmosphere system (Štekauerová et al., 2002; Hagyó et al., 2005) can be used for this purpose. Our aim was to characterize the within field variability of the soil water regime of a heavy clay soil in Southern Finland, using the scaling option of the SWAP simulation model.

Materials and methods

The two experimental fields (J1 and J2), with a size of 3 hectares each, were located at Jokioinen in S-W Finland. The soils with clay content varying between 0.32 and 0.82 g g^{-1} were classified as very fine Typic Cryaquept. In the autumn of 2002 (field J2) and 2003 (J1), large undisturbed soil cores with a diameter of 0.15 m and length of 0.60 m were taken from 30 and 21 locations of the J1 and J2 fields, respectively. Samples were cut into three parts representing functional layers of the soil: plough layer (0-0.20 m), plough pan (0.20-0.35 m) and subsoil (0.35-0.60 m). Soil water retention curves were determined at 0, 0.1, 1.0 and 150 m suctions. Soil hydraulic conductivity was measured in the 0-1.0 m suction range.

In the spring 2002 a *monitoring station* for soil water content was grounded to field J1. The TDR sensors measured changes in soil water content four times a day at the depths of 0.1-0.4, 0.4-0.7 and 0.7-1.0 m. During 2002-2004, soil moisture content was measured twice a month with a Trase-TDR at the depths of 0-0.30 m and 0-0.60 m at 30 (J1) and 21 (J2) points co-located with soil sampling positions. Crop height and leaf area index were monitored according to the development stage of the barley crop on a weekly basis.

The SWAP simulation model (versions 2.02 and 3.03) (Van Dam, 2000) was fit to the study area. Details of model parameterisation are given in Farkas et al. (2004). Model calibration was performed against soil water content data, recorded in 2002-2004 at the monitoring station of the J1 field. The incorporation of the hysteresis option was investigated. Model adaptation was achieved by tuning of model parameters. The method, suggested by Addiscott (1993) was used to assess the accuracy of the model fitting. The reference level of accuracy was set 0.05.

The within field spatial distribution of soil water balance elements was evaluated, using the inbuilt scaling option of the SWAP model. The mean (reference) pF-curves for the study areas (J1 and J2) and scaling factors, representing the deviation of each individual curve from the mean one, were calculated according to (Clausnitzer et al., 1992). Providing the parameters of the reference curve and the scaling factors, SWAP generates the soil hydraulic

DOI: 10.1556/CRC.34.2006.1.39

functions for each scaling factor value and the corresponding water balance. Field average soil water dynamics were characterized by simulating the soil water content using the scaled average pF-curves. Averaged throughout the field soil water content values were used as reference data. For describing the within field variability, five locations were chosen, corresponding to the main points (min, max, 25%, 50% and 75%) of the cumulative probability function of the scaling coefficients of the topsoil layer, to represent the spatial variability of soil hydrophysical properties. For these sites, individual model runs were performed to study the effect of spatial inhomogeneity of soil physical properties on spatial distribution of the soil water balance elements. Two simulation experiments were carried out for each of the sites: with SWAP 3.03, which is able to take into account the spatial variability of all the soil layers, and with SWAP 2.2, considering the spatial distribution of the pF-curves in the topsoil only.

Results and discussion

Model calibration against measured data (monitoring station) was successful. The mean differences between the measured and simulated values were below 5%. The error levels in individual profiles were somewhat higher, but still the water content dynamics measured in fields could be presented satisfactorily. These results are presented in Farkas et al. (2004).

We found, that incorporating the hysteresis option of the SWAP 3.03 model slightly improved the simulation results (Figure 1., left) of the field average soil water content. The mean differences (MD) were by 0.01 lower for the 0-30 and 0-60 cm depths when considering the hysteresis phenomena in the flow process. Scaling the pF-curves in all the three soil layers (SWAP 3.03) improved the simulation results in the 0-60 cm layer compared to model runs, when the pF-curves were scaled for the topsoil only (SWAP 2.02) (Figure 1, right).

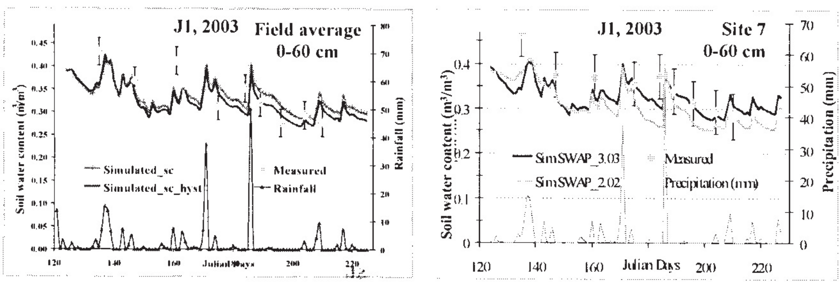

Figure 1. Measured and simulated soil water content dynamics by 1) using (Simulated_sc_hyst) and avoiding (Simulated_sc) the hysteresis option (left) and 2) scaling the soil hydrophysical properties for all the three soil layers (Sim SWAP_3.03) and for the topsoil only (Sim SWAP_2.02) (right)

According to the scaling coefficients of the topsoil, the spatial variability of soil physical properties was larger in case of J2 field (the scaling factor varied between 0.2 and 2.7) than for J1 field (0.3 and 1.5), which reflected the greater variability of J2 field (topsoil) in soil texture, organic matter content and soil hydrophysical data.

Strong relationship between the scaling factors and simulated by SWAP 2.02 actual transpiration values for fields J1 and J2 were found (Figure 2). Within field differences between the simulated transpiration values exceeded 35 mm.

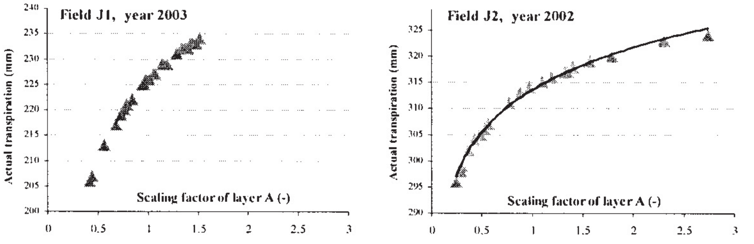

Figure 2. Relationship between the scaling factors and estimated actual transpiration values for the study fields when scaling the soil hydrophysical functions of the topsoil only

These results, however, corresponded to simplified cases, when the pF-curves of the topsoil (layer A) were scaled only. To obtain a more sophisticated description of the relationship between the soil hydrophysical properties and crop yield, all the three soil layers were scaled further, using the SWAP version 3.03. Profiles, selected to characterize the within field variability of soil properties for the J2 fields, using the cumulative probability function of the scaling factors are shown in Table 1. The multivariate regression coefficient, R, between the three scaling factors (layers A, B, C) and simulated transpiration values were 0.70. Concerning the correlation separately for each layer, poor relationship was found for the layer A. The R values were 0.74 and 0.88 for layers B and C, respectively.

Table 1. Soil profiles and corresponding scaling factors, selected to represent the spatial variation of soil hydrophysical properties of the J2 field.

Layer		MIN	25%	50%	75%	MAX
A	Profile No.	24	26	11	5	27
	Scaling factor	0.32	0.85	1.14	1.34	1.51
B	Profile No.	1	22	9	11	19
	Scaling factor	0.31	0.55	0.93	1.45	2.31
C	Profile No.	21	17	8	18	6
	Scaling factor	0.27	0.70	0.91	1.17	3.27

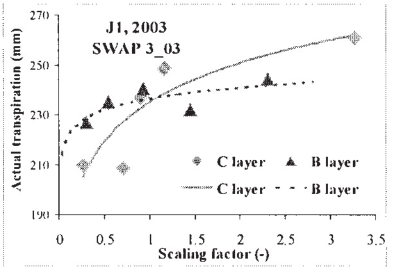

Figure 3. Relationship between the scaling factors and estimated actual transpiration values for the subsoil layers of the J2 field.

Conclusions

We concluded, that the soil hydrophysical database, constructed for the Jokioinen experimental site was suitable for calibration and spatial extension of the SWAP simulation model. The spatial distribution of the soil water regime could be characterized satisfactorily by the scaling option of the model. Using this method, the soil physical background of the within field variation of yield can be characterized for supporting precision agricultural applications in order to provide sustainable crop production and safe food.

Acknowledgement

Authors acknowledge the support of the Hungarian Science and Technology Foundation (SF-3/03), of CIMO, Finland (KM04-1776) and the material assistance of HNSF grants (OTKA T042996 and T048302) and OM-4/064/2004 "NKFP" grants. A. R acknowledges a grant from August and Aino Tiura foundation. F. Cs. is a grantee of the János Bolyai Research Scholarship of the Hungarian Academy of Sciences.

References

Addiscott, T., 1993. Simulation modelling and soil behaviour. Geoderma, 60. 15-40.

Clausnitzer, V., et al., 1992. Simultaneous scaling of soil water retention and hydraulic conductivity curves. Water Resour. Res., 28:19-31.

Farkas, Cs., et al., 2004. Simulation modeling of soil water regime of a heavy clay soil in Southern Finland. Proceedings of the 12th International Poster Day on Transport of water, 2004 November 25, Bratislava. 2004; CD-ROM.

Hagyó, A. et al., 2005: Hydrophysical properties and evapotranspiration elements of a heavy clay grassland soil. Cer. Res. Com., 33:217-220.

Németh, T. et al., 2003. Integrated GPS and Internet based GIS applications for the support of agricultural advisory systems. In: Schnug E, et al., (eds.): "Fertilizers in context with resource management in agriculture', CIEC, Debrecen (ISBN 963 9274 44 5) 2003; 30-37.

Orfánus, T. and Nagy, V. 2002. Variability of soil moisture in the field with heterogeneous soil cover. In: Gaál K. K. (ed.): CD Proc. 29th Scientific Days in Mosonmagyaróvár, Mosonmagyaróvár, 2002, s. 1CD.

Štekauerová V. et al., J. 2002. Using of pedotransfer functions for assessment of hydrolimits. Plant Production, 48:407–412.

Van Dam, J., 2000. Field-scale water flow and solute transport. Ph.D. thesis, Wageningen University, the Netherlands, 167 p.