VALIDATION OF HYDRUS 1D MODEL IN SELECTED CATCHMENT OF SLOVAKIA

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Soil water content is very important for agricultural practice. Direct measurements of the soil moisture are being replaced by mathematical simulations and models step by step. One of the most used models for the simulation of the soil moisture is HYDRUS 1D model. This paper deals with HYDRUS 1D validity check in the Nitra River Catchment. Three different localities in the Nitra River Catchment (Malanta, Kolíňany and Dolné Naštice) were chosen for model validity check. Both, measurements and modelling of soil moisture, were made for these localities in three years (8/2011 - 8/2014). The evaluation of model validity was performed by calculation of the correlation coefficient and count of comparisons with variance of 15%. The correlation coefficients of measured and simulated data were between 0.67 and 0.95. Data comparisons with variance of 15% among measured and simulated data were between 79 to 100%. Based on these results we can declare that HYDRUS 1D model is valid for the conditions of Slovak catchments.

Keywords: HYDRUS 1D, soil moisture, simulation, model validation

Global climate has changed dramatically in recent years. These changes influence every sphere of our lives, including agriculture. Difficulties with soil cultivation are caused by changes in average annual temperature and average annual rainfall. Soil water content and soil moisture are changing too. Soil water content in vadose zone is an important resource of water for plants. Water and solute movement in the unsaturated zone is an incredibly complex process due to the heterogeneous nature of soil and variable atmospheric boundary conditions at the soil surface over a short time period (Saifadeen and Gladnyeva, 2012). Knowing the amount and the dynamics of the soil water content, we may predict and react to the current climatic conditions of the environment in time (Jurík and Kaletová, 2014).

Realization of field soil moisture monitoring could be characterized as extremely time and money consuming (Kaletová et al., 2012; Šimůnek et al., 2012a). Because of this, we use mathematical models and simulations. The use of models and information systems is supported by increasing development of technologies (Leitmanová et al., 2014). Mathematical simulation is a modern tool for exact determination of desired parameters. Numerical models are increasingly used to predict or analyze the water flow and contaminant transport processes in the subsurface, including the vadose zone (Šimúnek, van Genuchten and Šejna, 2012b). Many of the authors used HYDRUS 1D model for the simulation of soil moisture (Burger and Látečka, 2005; Kaletová et al., 2012; Joris and Feyen, 2003; Šimůnek, et al., 2012c; Zeng, Su and Wan et al., 2009).

We need to do validity check of mathematical models due to their frequent use to obtain the soil moisture data. This paper is focused on the validity of outputs from the mathematical model HYDRUS 1D.

Material and methods

The HYDRUS 1D numerical model is widely used to simulate water flow and solute transport in variably saturated soils and groundwater. HYDRUS 1D software can be used to simulate such processes as precipitation, irrigation, infiltration, evaporation, transpiration, soil water storage, capillary rise, deep drainage and groundwater recharge (Šimůnek, van Genuchten and Šejna, 2012b).

Model validity check was performed by comparing measured data and HYDRUS 1D simulation outputs. Measured and simulated data from three different regions of the Nitra River Catchment (Malanta, Kolíňany and Dolné Naštice) in three different time periods (1. 8.–31. 10. 2011 for locality Malanta, 10. 6.–10. 8. 2014 for locality Kolíňany and 10. 1.–10. 2. 2014 for locality Dolné Naštice) were chosen for the comparison.

The Nitra River Catchment is the sub-catchment of the Váh River Catchment area. The Nitra River is located entirely in the Slovak Republic. Area of the Catchment is 5,080 km². The Nitra River Catchment is mainly agricultural land (61% of the area) and forest land (30% of the area). There are Rendzic Leptosols in the northern part and Chernozems, Mollic Fluvisols and Brown soils in the southern part of our Catchment (Landscape Atlas of the Slovak Republic, 2015; Jarabica et al., 2003; Šimanský, Tobiašová and Chlpík, 2008).

Soil moisture was measured in 20 and 40 cm depths of soil profile by the sensor 10HS (Decagon Devices). These sensors use frequency domain reflectometry (Decagon Devices, 2014). The evaluation of model validity was performed by calculation of the Pearson's correlation

coefficient (1) and count of comparisons with variance of 15%. Soil samples were taken from selected localities in the Catchment for determination of soil properties. Samples were analysed to obtain retention curves of soil. Data from the analysis were used as an input data of the HYDRUS 1D model.

$$\rho_{X,Y} = \frac{cov(X,Y)}{\sigma_X \sigma_Y} \qquad (1)$$

where:
cov – the covariance
σ_x – the standard deviation of *X*
σ_y – the standard deviation of *Y*

Results and discussion

Three localities with different climatic and soil conditions were chosen for validity check of HYDRUS 1D model. Both, measurements and modelling of soil moisture, were made for these localities. We chose different time periods (1. 8.–31. 10. 2011 for locality Malanta, 10. 6.–10. 8. 2014 for locality Kolíňany and 10. 1.–10. 2. 2014 for locality Dolné Naštice) for this comparison.

The correlation coefficients of measured and simulated data were between 0.67 and 0.95. Coefficient *r* = 0.60 to 0.79 is considered as strong and *r* = 0.80 to 1.0 as a very strong relationship (Clay, 2008). Count of comparisons with variance of 15% was a second parameter which was evaluated. Count of comparisons with variance of 15% between measured and simulated data was between 79 to 100%.

Table 1   Correlation of measured and simulated data of soil moisture in locality of Malanta

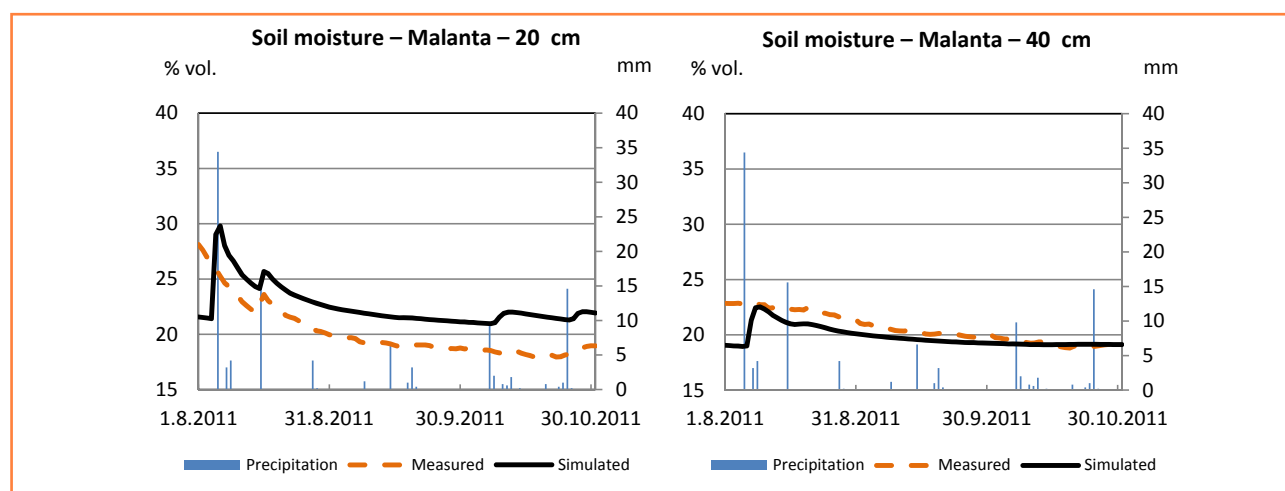| Time period	Count of comparison (each depth)	Count of comparisons with variance of 15%		Count of comparisons with variance of 15% (%)		Correlation coefficient	
		20 cm	40 cm	20 cm	40 cm	20 cm	40 cm
1. 8. –31. 10. 2011	92	73	86	79.35	93.48	0.67	0.75

Figure 1   Measured and simulated data of soil moisture in the locality of Malanta
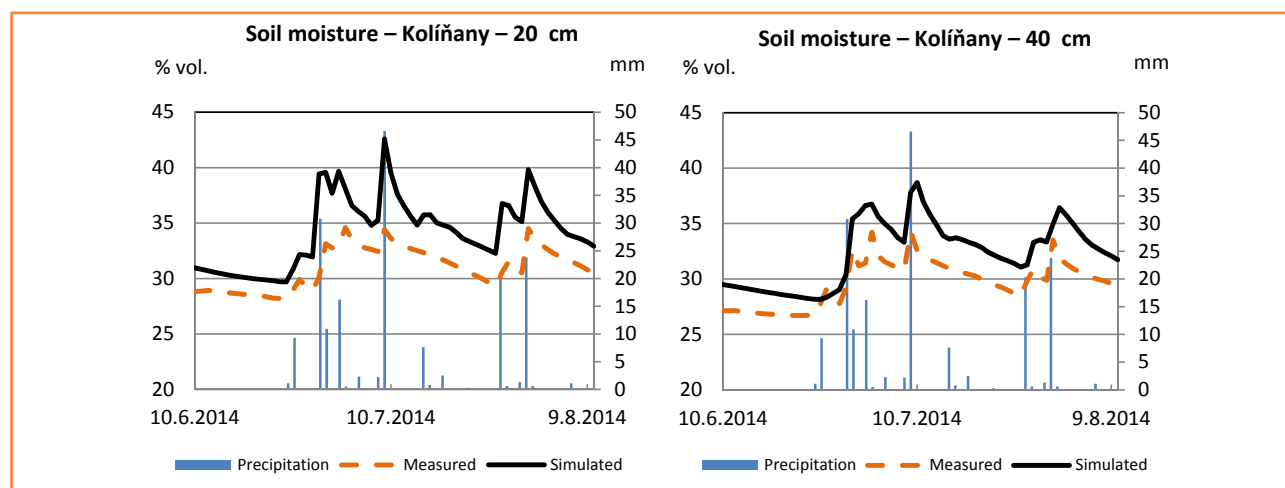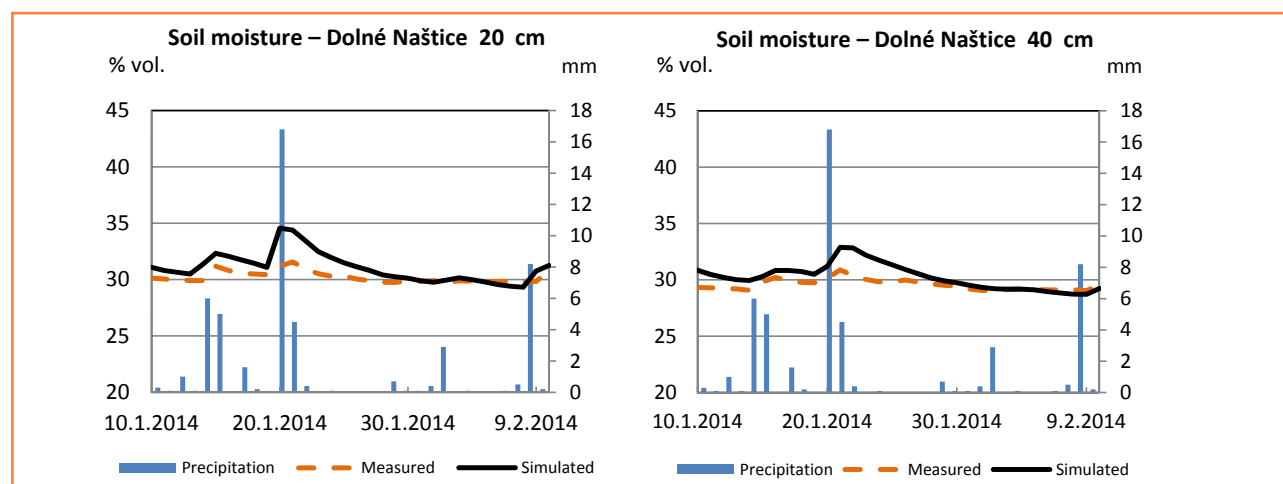

Figure 2   Measured and simulated data of soil moisture in the locality of Kolíňany

Table 2   Correlation of measured and simulated data of soil moisture in the locality of Kolíňany

Time period	Count of comparison (each depth)	Count of comparisons with variance of 15%		Count of comparisons with variance of 15% (%)		Correlation coefficient	
10. 6.–10. 8. 2014	62	20 cm	40 cm	20 cm	40 cm	20 cm	40 cm
		51	58	82.26	93.55	0.90	0.95

Table 3   Correlation of measured and simulated data of soil moisture in the locality of Dolné Naštice

Time period	Count of comparison (each depth)	Count of comparisons with variance of 15%		Count of comparisons with variance of 15% (%)		Correlation coefficient	
10. 1. –10. 2. 2014	32	20 cm	40 cm	20 cm	40 cm	20 cm	40 cm
		32	32	100.00	100.00	0.90	0.88

Figure 3   Measured and simulated data of soil moisture in the locality of Dolné Naštice

Figures from 1 to 3 and tables from 1 to 3 show the comparisons of measured and simulated soil moisture data.

We can declare that our simulations are valid due to values of the correlation coefficient. Many authors have similar research outputs from HYDRUS 1D model validity check. For example, according to Haishen et al. (2009) the soil water content predicted with HYDRUS was found to be in good agreement with experimental measured data.

Conclusion

As direct soil moisture monitoring is time and money consuming, indirect methods of soil moisture measurement are considered very important nowadays. The aim of this paper was to evaluate one of the most used mathematical models for soil moisture simulation – HYDRUS 1D model. Validity check of HYDRUS 1D model was performed by calculation of the correlation coefficient and count of comparisons with variance of 15%. Based on our results, we can say that HYDRUS 1D model can be used for soil moisture simulation in conditions of the Slovak Republic. Outputs of the soil moisture simulation in various conditions obtained by modelling could be a good basis for landscape planning or an interesting extension for information systems about landscape (Muchová et al., 2016). As an example of practical application we can mention the information system for land consolidation OKTOPUS (Leitmanová et al., 2013) developed by our faculty.

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