TESTING AND CALIBRATING SWAP MODEL FOR FIELD-MEASURED MOISTURE PROFILES IN A BRAZILIAN LATOSSOL

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ABSTRACT: The start point for a reliable use of pesticide leaching models is to have an accurate description of the water flow. The pesticide leaching model PEARL uses the SWAP model to describe the water flow and has never been tested under Brazilian conditions. The aim of this work was to test and to calibrate the SWAP model to describe moisture profiles in a Brazilian very clayey typical dystroferric Red Latossol in Dourados, Mato Grosso do Sul State, Brazil. The SWAP model was tested in one experimental field of 0.09 ha cultivated with soybean and soil profiles were sampled eight times between December 2006 and October 2007. SWAP input values (i.e. soil water retention curves and meteorological data) were based on in-situ measurements. Simulations with the uncalibrated soil water retention curves resulted in moisture profiles that were too wet between 0-10 cm depth for all sampling dates. After calibration of water retention curves, there was a good improvement in the simulated moisture profiles that were within the range of measured values for almost all depths and sampling dates.
KEYWORDS: water flow model, simulation, inverse modeling.

INTRODUCTION: Environmental fate modeling of pesticides is an important tool to assess the risks of groundwater contamination by pesticides used in agriculture. Many countries (i.e. USA and European Union members) have been using pesticide leaching models (e.g. PEARL model) to support authorities in decisions about pesticide registration based on simulation outputs (VANCLOOSTER et al., 2000). In Brazil, authorities are not using these models to assess the risks of groundwater contamination by pesticides although there is an urgent need for this. The PEARL model (LEISTRA et al., 2002) uses the SWAP model (VAN DAM et al., 1997) to describe water flow. The start point for a reliable use of these models is to have an accurate description of the water flow. VANCLOOSTER et al. (2000) state that pesticide leaching models should not be used if hydrological component is not reliable because pesticide fluxes will be assessed wrongly if soil water fluxes are wrongly predicted. Until now, SWAP model has not been tested under Brazilian conditions. The aim of this work was to test and to calibrate the SWAP model to describe moisture profiles in a Brazilian very clayey typical dystroferric Red Latossol in Dourados, Mato Grosso do Sul State.

METHODOLOGY: SWAP model describes water flow using Darcy equation for one-dimensional, vertical and transient flow. The combination of the Darcy equation with the conservation equation results in the well-known Richards's equation. The soil water retention curve is expressed by the van Genuchten model given by:

$$\theta(h) = \theta_r + \frac{\theta_s - \theta_r}{(1+|\alpha h|^n)^{1-1/n}} \quad (1)$$

where h is the pressure head (cm), θ is the soil water content (cm^3 cm^{-3}), θ_r is the residual soil water content (cm^3 cm^{-3}), θ_s is the saturated soil water content (cm^3 cm^{-3}) and α (cm^{-1}) and n (-) are fitting parameters. The SWAP model was tested in one experimental field (30 m long and 30 m wide) cultivated with soybean located at Embrapa Western Region Agriculture (22° 16' 26'' S, 54° 48' 50'' W), in Dourados, Mato Grosso do Sul State. The experimental field consisted of 100 subplots of 3m long by 3 m wide. The soil is a very clayey typical dystroferric Red Latossol. The average clay (g kg^{-1}) and sand (g kg^{-1}) contents were, respectively, 630 and 245 at 0-10 cm, 663 and 229 at 10-20 cm, 697 and 212 at 20-40 cm, 713 and 195 at 40-100 cm depth. The average soil organic matter contents (g kg^{-1}) were 33.4 at 0-10 cm, 29.6 at 10-20 cm, 22.7 at 20-40 cm, 16.9 at 40-60 cm, and 11.3 at 60-100 cm depth. Soil profiles were sampled eight times on December 18, 2006, January 26, 2007, March 23, 2007, May 17, 2007, June 27, 2007, July 31, 2007, September, 12, 2007, and October 30, 2007. On each sampling date four subplots were randomly selected and each subplot was sampled only once during the duration of the experiment. One pit (1 x 1 x 1 m) was dig on each selected subplot and soil cores were collected from 0-10, 10-30, 30-50, 50-70, and 70-100 cm depth. All samples were put in a hermetic box and transported to the laboratory for determination of the moisture content by drying to a constant weight at 105°C for 24 hours. Three undisturbed soil cores (5.5 cm of inner diameter and 4 cm height) were taken at five different depths (0-10, 10-30, 30-50, 50-70, and 70-100 cm) for determination of the soil water retention curve in only one pit of the experimental field. These undisturbed soil cores were saturated in the laboratory and submitted to pressure heads of 100, 330, 500, 1000, 3000, 5000, 10000, and 15000 cm using Richards pressure chamber. Soil water retention curves were described by fitting the van Genuchten model (Eq. 2) to the measured data using the RETC optimization program. Meteorological data as input for SWAP model were obtained from the meteorological station at Embrapa Western Region Agriculture, which is located about 500 m from the experimental field. The potential evapotranspiration rate was estimated based on the Penman-Monteith method. The calibration of the SWAP model using the moisture profiles was carried out using the package PEST (DOHERTY, 2000) and the objective function (Φ) to be minimized was:

$$\Phi(\boldsymbol{b}) = \sum_{n=1}^{N} \sum_{m=1}^{M} \left(\left(y_{meas}\,(t_n, z_m) - y_{sim}\,(t_n, z_m, \boldsymbol{b}) \right) \cdot w \right)^2 \qquad (2)$$

where $\boldsymbol{b}$ is the vector with the fitting parameters, y_{meas} is the measured soil water content in the soil profile at time t and depth z (cm^3 cm^{-3}), y_{sim} is the simulated soil water content in the soil profile at time t and depth z (cm^3 cm^{-3}) for the corresponding set of $\boldsymbol{b}$ parameters and w are the weighting factors (-). We used a weighting factor of 1.0 for all measurements in the calibration procedure. Model performance was assessed by graphical display and by the normalized root-mean squared error (NRMSE) and the modeling efficiency (ME) given by:

$$NRMSE = \sqrt{\sum_{i=1}^{n} (P_i - O_i)^2 / n} \Big/ \bar{O} \qquad (3)$$

$$ME = \frac{\sum_{i=1}^{n} (O_i - \bar{O})^2 - \sum_{i=1}^{n} (P_i - O_i)^2}{\sum_{i=1}^{n} (O_i - \bar{O})^2} \qquad (4)$$

where P_i is the simulated value, O_i is the measured value, $\bar{O}$ is the average of the measured values and n is the number of values. Optimal values of NRMSE and ME are zero and one, respectively.

RESULTS AND DISCUSSION: Four soil moisture profiles that represent almost the full range of moisture profiles for all sampling dates are shown in Figure 1. The variability in the average measured moisture profiles was high. The range of the average plus and minus two times the standard deviation was as high as 0.2 m^3 m^{-3}. Simulations with the uncalibrated soil water retention curves resulted in moisture profiles that were too wet between 0-10 cm depth for all dates and also between 10-50 cm depth for 27 June 2006. These deviations between measured values and uncalibrated simulations suggest that the soil hydraulic characteristics measured in the laboratory were not representative for our experimental field. This lack of representativeness may have been caused by inadequate handling of spatial variability given the fact that all measurements of soil water retention curves were carried out using cores sampled from a single pit in the experimental area. Site-specific laboratory measurements using samples from one or two locations of an experimental area were also found to be insufficiently accurate to simulate moisture profiles (SCORZA JÚNIOR & BOESTEN, 2005). After calibration of n, α and θ_r parameters (van Genuchten model in Eq. 1), there was a good improvement in the simulated moisture profiles (Figure 1). The simulated moisture profiles were within the range of measured values for almost all depths. Optimized soil water retention curves for two depths are shown in Figure 2 that resulted in a decrease of water retention. Table 1 shows that the calibration procedure improved the NRMSE and ME values for all sampling dates. The negative ME value at 17 May 2007 indicates that the simulation of moisture profiles at this date was worse than the others. This result is also confirmed by NRMSE value of this sampling date that was the highest one for all sampling dates.

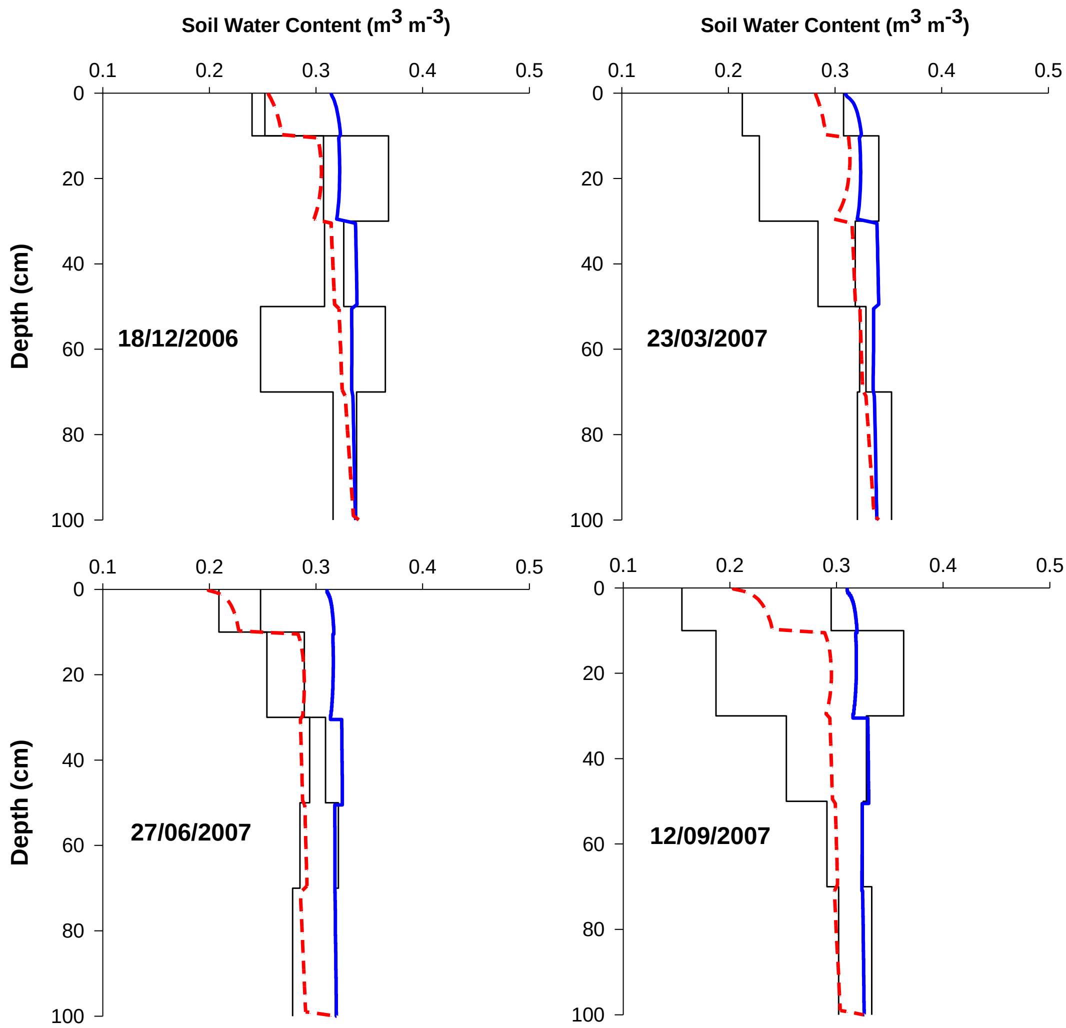

FIGURE 1. Measured and simulated moisture profiles at the experimental field in Dourados, MS, Brazil. The area within the solid black lines is the range of the measured averages plus and minus two times the standard deviation. Solid blue and dashed red lines are uncalibrated and calibrated simulations, respectively.

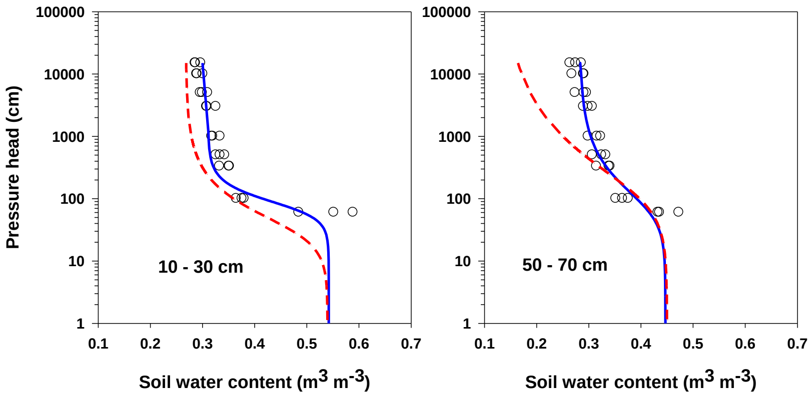

FIGURE 2. Soil water retention curves for 10-30 cm and 50-70 cm layers at the experimental field in Dourados, MS, Brazil. Points are measured values using Richards pressure chamber and solid blue and dashed red lines are uncalibrated and calibrated curves, respectively.

TABLE 1. Normalized root-mean squared error (NRMSE) and modeling efficiency (ME) of simulated moisture profiles for uncalibrated and calibrated simulations.

Dates	Uncalibrated		Calibrated	
	NRMSE	ME	NRMSE	ME
18 Dec 2006	0.09	-0.43	0.06	0.50
26 Jan 2007	0.05	0.59	0.05	0.60
23 Mar 2007	0.12	-0.55	0.06	0.62
17 May 2007	0.15	-4.80	0.08	-0.69
27 Jun 2007	0.16	-1.62	0.04	0.81
31 Jul 2007	0.05	-0.66	0.01	0.91
12 Sep 2007	0.17	-1.26	0.04	0.87
30 Oct 2007	0.09	-2.47	0.02	0.83

CONCLUSION: Calibration of the soil water retention curves was necessary to obtain a good simulation of the moisture profiles using SWAP model in a Brazilian soil.

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