Two-Dimensional Simulation and Parameters Optimization of Soil-Water Flow from Field Experiments of M'Nasra Area (North-West Morocco)

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Abstract

Determination of soil hydrodynamic parameters at field scale is of great importance for modeling soil water dynamics and for agricultural water management. Modeling of water flow and solute transport in the unsaturated soils requires knowledge of many parameters associated with the water content *θ(h)*, hydraulic conductivity *K(h),* The experimental determination of some of these parameters in the laboratory or in-situ requires expensive equipment and requires significant time. The main objective of this work is to optimize the hydrodynamic parameters of unsaturated soil by using the two-dimensional numerical software HYDRSUS-2D model with different boundaries conditions at the soil surface to simulate water flow. Soil water content samples, collected from the area of M'nasra in north western of Morocco, were used to deduce the optimized values of hydrodynamic parameters $\theta_r, \theta_s, n, \alpha$ and k_s. The results show that HYDRUS-2D model simulated water flow through the root zone depths satisfactorily.

Keywords: Soil, hydrodynamic parameters, HYDRUS 2D, water content, hydraulic conductivity.

1. Introduction

The soil is a porous medium with variable saturation, it presents a place of exchange and transfer. Such processes depend on the conditions of the environment: properties of the soil and solutes for example. The understanding of the processes occurring in the soil requires the analysis of the different physical and chemical characteristics of the soil. The aim of this study is the simulation of the variation of fluxes in the soil as a function of time in 2D. In the literature, there are several relationships for fitting experimental data to these functions. In the present case, we used the module of van Genuchten (1980), for its simplicity. This approach of adjustment, allows us to draw the curves of the water content for the purpose of calculating the hydrodynamic parameters $\theta_r, \theta_s, n, \alpha$ These parameters will be used later in the simulation by the Hydrus 2D software to plot the water content versus time curves at each soil depth.

2. Mathematical model.

The Two-dimensional vertical model in the unsaturated water flow equation is expressed as Richards's equation as follows:

$$\frac{\partial\theta}{\partial t} = \frac{\partial\theta}{\partial h}\frac{\partial h}{\partial t} = \frac{\partial}{\partial x}\left(K(h)\frac{\partial h}{\partial x}\right) + \frac{\partial}{\partial z}\left(K(h)\left(\frac{\partial h}{\partial z} - 1\right)\right)$$

Where *K* is the hydraulic conductivity [L/T], z is the soil depth (taken as positive downwards) [L], and t is the time [T]. Based on the initial and boundary conditions, Richards' equation was solved using the finite element method with an implicit scheme for time discretization. The discretized Richards' equation was resolved with a Fortran The HYDRUS 2D model as described above.

To solve Richards' equation, the water retention function *θ(h)* and the hydraulic conductivity function *K(h)* must be defined. We used the hydraulic model of the van Genuchten Mualem-type equations given by:

$$\theta(h) = \theta_r + (\theta_s - \theta_r)[1 + |\alpha h|^n]^{-m}$$

$$K(h) = K_s S_e^l \left[1 - \left(1 - S_e^{1/m}\right)^m\right]^2$$

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

in which *θs* is saturated water content; *θr* is residual water content of the soil; h the soil water pressure head; k_s is saturated hydraulic conductivity, α, n, and m $m = 1 - 1/n$

are shape parameters**.** S_e is the effective saturation and *l* is an empirical parameter that was estimated by Mualem to be approximately 0.5 for most soils.

3. HYDRUS-2D

The HYDRUS2D model is a software for the simulation of water flow, heat and solute motion in two-dimensional variably saturated media. The program solves the Richard equation in 2D. The 2D flow equation is the following modified form of the Richards equation:

$$\frac{\partial\theta}{\partial t} = \frac{\partial}{\partial x_i}\left[K\left(K_{ij}^A \frac{\partial h}{\partial x_j} + K_{iz}^A\right)\right] - S$$

θ is the water content by volume $[L^3 L^{-3}]$
h is the pressure charge [L].
S is a term sink $[T^{-1}]$
xi (i = 1,2) are the spatial coordinates [L].
t is the time [T].
K_{ij}^A Are components of a tensor K^A dimensionless anisotropy.

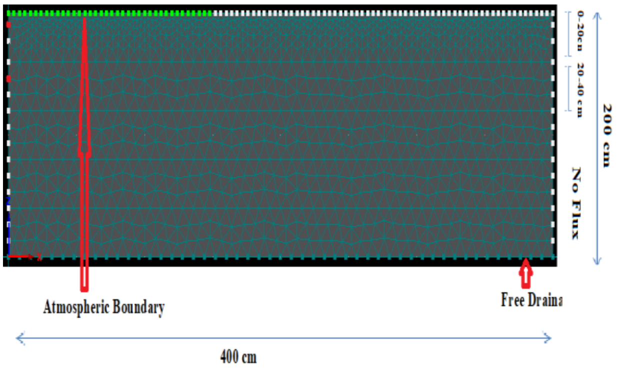
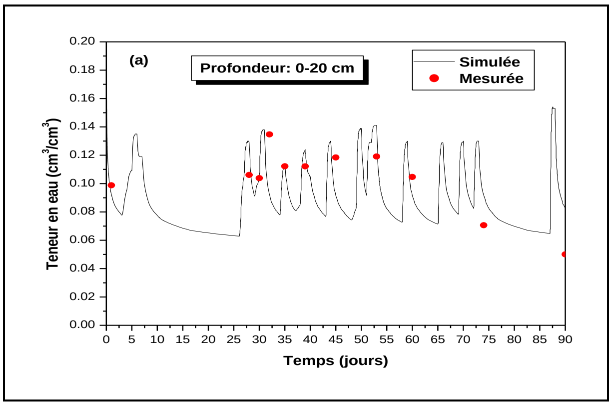


Figure 1: Geometric domain of HYDRUS-2D modeling with observation nodes, and boundary conditions for soil-water

4. Simulation results

Figure 2 shows the measured and simulated water profiles during the three months of monitoring for different soil depths (0-20cm, 20-40cm). All the experimental tests were carried out under field conditions and in the absence of vegetation (no crops or weeds).



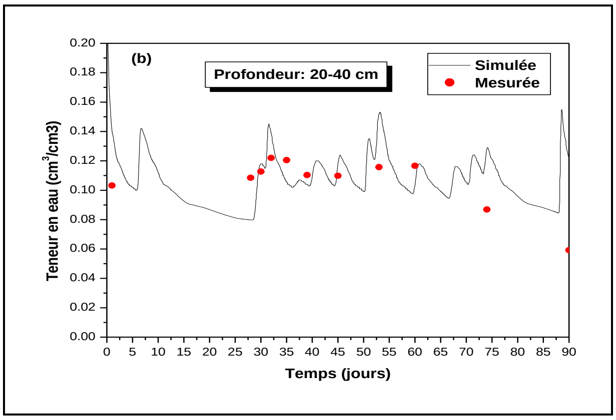


Figure 2: comparison of numerical simulations and experimental values of the volume water content at the depth scale: (a) :0-20cm et (b) :20-40cm.

For this sandy soil, we notice that the gravity potential is more dominant than the horizontal pressure potential gradients. It can be seen that at the different levels of the soil profile, the volumetric water content is generally characterized by small variations, especially in the lowest depths the two horizons near the surface (0-20cm) and (20-40cm) represent the level where the variation of the water content is the most important (Fig. 2(a) et Fig. 2(b)). Water content variations are observed just after each rainfall or irrigation. Soil reaction time to precipitation (or irrigation) is very short. This is due to the nature of the soil studied, which is of sandy texture characterized by a low retention capacity, high drainage potential and has a low initial water volume.

In this part of the simulation, the soil chosen in this study is considered as homogeneous, the values of the hydrodynamic parameters of Van Genucheten were estimated by the average value of these four depthsThe results of the hydrodynamic parameters ($\theta_r, \theta_s, n, \alpha$) for these depths are shown in Table 1.

Table 1: Hydrodynamic parameters calibrated by the plot-scale modeling method

Paramètre	0-20 cm	20-40 cm
$\theta_r(cm^3cm^{-3})$	0.045	0.045
$\theta_s(cm^3cm^{-3})$	0.43	0.43
$n(-)$	2.68	2.68
$\alpha(cm^{-1})$	0.145	0.145

4. Conclusion

We simulated the variation of the water content as a function of time for each depth interval of sandy soil by the Hydrus 2D model, and then we compared the simulated water content curves with the measured ones. This allows us to determine the values of the hydrodynamic parameters sought **(**θ_r, θ_s, n, α**)**.

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