Simulation of Nitrate Transport in Soil Using HYDRUS-1D

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Abstract: In recent years, nitrogen fertilizer consumption in agriculture, accumulation and movement of salts in soils and modeling their movement have received extensive attention, But in using these substances, there should be a balance between the production increase and the quality of agricultural products, in this phanamena, undesirable effects, such as environmental pollution and soil and ground water contamination maybe occur. Sugar cane is a perennial plant during its period of rapid growth is the need for water and nitrogen fertilizer. The purpose of this paper is to simulate nitrate in soils under sugarcane planting using the HYDRUS- 1D model. The results show can be seen that the model could provide good estimates of nitrate in the soil under sugarcane cultivation.

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1. Introduction

Water is an important factor for crop production especially for rapeseed and maize in arid and semi-arid regions. Partial root drying irrigation by alternate furrow irrigation (AFI) and drip irrigation is an appropriate procedure for management of deficit irrigation in these regions. In these irrigations method, deep percolation and surface evaporation reduce and less water is used (Sepaskhah and Hosseini, 2008; Ahmadi et al., 2010).

Nitrogen (N) plays an important role in crops grown with supplementary irrigation (Tavakoli and Oweis, 2004). It is important to use an optimum amount of water and nitrogen for best management of crop production in arid and semi-arid regions because the application of an excess amount of water causes nitrogen leaching below the root zone (Gheysari et al., 2009; Wang et al., 2010), and causing economic losses for farmers.

Nitrate is the primary source nitrogen and to continue plant life is essential. For this reason fertilizers Nitrogen-containing chemical used to improve plant growth. When the amount of nitrate in the soil surplus to requirements, Leachied into the groundwater and surface water. Therefore simulation of nitrate transport is necessary in the fields. Wang et al. [Wang et al., 2010] detected the leaching of accumulated N under heavy rainfall, high irrigation rate in growing season and with different amounts of initial accumulated N. Ramos et al. [Ramos et al., 2011] successfully simulated water and solute transport in two multicultural experiments, in which water with different salinity and nitrogen concentrations was used. The model of transient water flow and nitrogen transport were established by Kurtzman et al. [Kurtzma et al., 2013] to calibrate the data of two vadose zone profiles in the sandy-loam soils. Simulation models are appropriate tools for identifying best irrigation and N fertilization management. Different simulation models were used to evaluate the N fertilizer movement to groundwater (Li and Ghodrati, 1994; Jala et al., 1994; Ersahin and Karaman, 2001). The purpose of this paper is simulate nitrate in soils under sugarcane planting using the HYDRUS- 1D model.

2. Material and Methods

A field experiment was carried out in the Agricultural Research Department of Karoon Agro industry at Khuzestan province (32 5 N, 48 43 E, alt., 60 m), in southwestern Iran from September 2000 to March 2002. The region represents semiarid and subtropical climatic conditions with very hot summers and fairly cool winters (Fig. 1).

3. Physical model

The numerical simulation package HYDRUS [11] was used to simulate the process of water flow, solute transport, heat transport and root water uptake. For solute transport, the advective-dispersive transport in the liquid phase is regarded as gaseous phase. The governing equation of water flow can be calculated by Richard’s Equation [12]:

Table 1. Physical properties of soil at the experimental site

depth (cm)	clay	silt	sand	soil texture
0-30	21.8	51.78	26.42	si-l
30-60	21.8	51.78	26.42	si-l
60-100	21.8	51.78	26.42	si-l

Table 2: Chemical properties of soil at the experimental site

depth (cm)	Nitrogen	ph	sar	na	ec (ds/m)	Organic materials
0-30	0.03	7.7	1.41	1.63	1.7	0.7
30-60	0.07	7.5	1.69	2.74	1.9	0.6
60-100	0.09	8	1.72	2.52	2.1	0.5

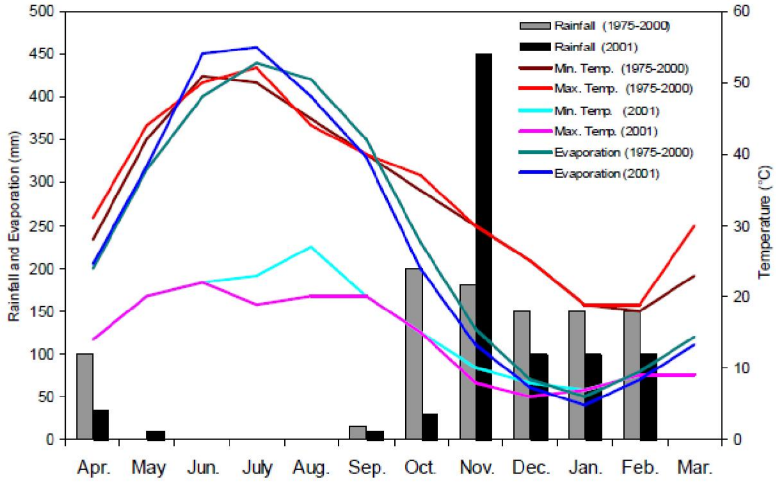

Figure 1. Mean of 25 years of monthly minimum and maximum temperature, total evaporation (mm) and rainfall values (mm) at Agric. Res. Center, Karoon Agro-industry, Khuzestan, Iran (the growth period of sugarcane is from April. to October

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

where θ is the volumetric water content, h is the pressure head, t is time, K is the unsaturated hydraulic conductivity function, S sink term, which represents the volume of water removed per unit time from a unit volume of soil due to plant water uptake [13]. Van Genuchten [14] used the statistical pore-size distribution model of Mualem [15] to obtain a predictive equation for the unsaturated hydraulic conductivity function in terms of soil water retention parameters. The equation of van Genuchten is:

$$\theta(h)=\begin{cases}\theta_r+\dfrac{\theta_s-\theta_r}{\left[1+|\alpha h|^n\right]^m} & h<0\\ \theta_s & h>0\end{cases}$$

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

$$m=1-\frac{1}{n},n>1$$

where θs and θr are the saturation water content and residual water content, α, n, Ks and l are parameters predicted by HYDRUS model. The pore-connectivity parameter l in the hydraulic conductivity function was estimated to be about 0.5. The classical solute transport equation is derived by the mass conservation equation, and the non-equilibrium equation is taken as:

$$\frac{\partial}{\partial t}(\theta C+\rho_b s)=\nabla(\theta D\,\nabla C)-\nabla(\theta u C)+WC_w+I$$

where C and s are respectively solute concentration in the liquid and solid phases, D is the dispersion coefficient tensor for the liquid phase, and ρ is the soil bulk density, u is pore-water velocity, W is liquid volume of somewhat introduced source sink term, Cw is fluid concentration of the introduced source sink term, I is other source sink terms. In order to solve equation (5), it is necessary to know the water content θ, and the other variables can be obtained from Richard's equation. The water content can be calculated by:

$$\theta R\frac{\partial C}{\partial t}(+\rho_b s)=\frac{\partial}{\partial x_i}\left(\theta D\frac{\partial C}{\partial x_j}\right)-\frac{\partial qC}{\partial x_i}+WC+I$$

Where q represents the outward fluid flux. Three types of conditions was implemented to describe system-independent interactions along the boundary conditions of the form:

$$h(x,y,z,t)=\psi(x,y,z,t)\quad \text{for}\quad (x,y,z)\in\Gamma_D$$

Specified flux (Neumann type)boundary conditions given by:

$$-\left[K\left(K_{ij}\frac{\partial h}{\partial x_j}+K_{iz}\right)\right]n_i=\sigma_1(x,y,z,t) \quad \text{for}\ (x,y,z)\in\Gamma_N$$

and specified gradient boundary condition

$$-\left(K_{ij}\frac{\partial h}{\partial x_j}+K_{iz}\right)n_i=\sigma_2(x,y,z,t) \quad \text{for}\ (x,y,z)\in\Gamma_g$$

Γ_D, Γ_N, Γ_g indicate Dirchilet, Neuman and gradient type boundary segments, respectively; Whereas third-type (Cauchy type) boundary condition is used to prescribe the concentration flux along a boundary segment Γ_C as follows:

$$-\theta D_{ij}\frac{\partial C}{\partial x_j}n+qnC=qnC_0 \quad \text{for}\ (x,y,z)\in\Gamma_C$$

In which *q* represents the outward fluid flux, *n* is the outward unit normal vector and C_0 is the concentration of the incoming fluid.

The parameters required for the simulation of nitrate using the HYDRUS- 1D model are: Bulk density, soil texture, Organic matter, The soil nitrogen, Irrigation water, Field capacity and Permanent wilting point.

Among the various parameters of hydraulic and solute transport model using sensitivity analysis, the main parameters were identified.

4. Results and discussion

Nitrate movement in the field and by using the HYDRUS- 1D model is shown in Figure 2. Relation between predicted and field is shown in Figure 3.

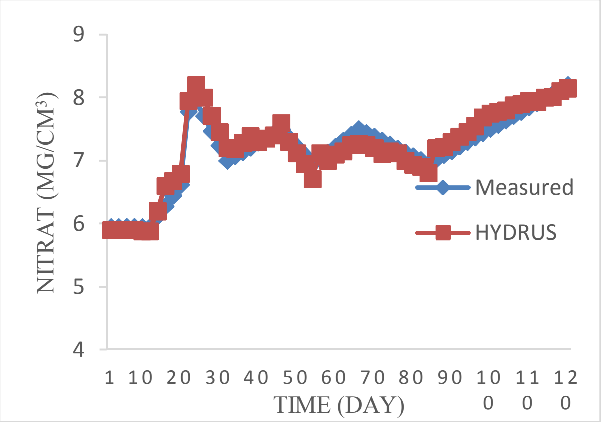

Figure 2. The results of the simulations to real data.

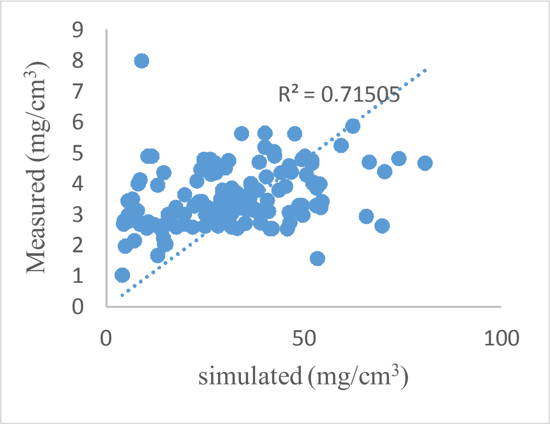

Figure 3. Relation between predicted and observed

According to Figure 2 can be seen that the model could provide good estimates of nitrate in the soil under sugarcane cultivation. With the increase in fertilizer also increases the amount of nitrate in drainage water, So it is necessary to avoid the dangers of the amount of fertilizer to be controlled.

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