Water Flow and Solute Transport to Tile Drains in Upland Fields

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1. Introduction: Although leaching of nitrates and pesticides is of greatest concern on sandy soils under high rainfall and irrigation regimes, more field research is needed to determine the potential for groundwater contamination under other soil and climatic conditions as well. The understanding of water flow and solute transport through variably saturated soils is crucial to improve agricultural practices and to lead to a sustainable agriculture. Current approaches to modeling of water flow and solute transport in variably saturated porous media are mainly based on Richard`s equation for soil water dynamics and on the convection-diffusion equation for solute transport. Solving these equations requires the soil hydraulic functions $\theta(h)$ and $K(h)$ or $K(\theta)$, where θ is soil water content, h is pressure head, and K is the hydraulic conductivity as a function of θ or h.

In irrigated agricultural areas, crop production is being threatened not only by traditional problems such as waterlogging and salinity, but also more recently by concerns regarding its potentially damaging effects on the environment. It is common practice to use subsurface drainage systems to lower the water table in areas with shallow ground water table and to limit soil salinization. Tile drains are popularly used in many agricultural fields for draining excess water from the vadose zone to sustain optimum soil water contents for crop production and maintaining low levels of soil salinity and other contaminants.

In Japan, as paddy fields are transformed to grow upland crops there is the need to investigate the fate of nutrients in such soils due to their peculiar nature. This will help to put in structures that will increase agricultural production on such soils and also check pollution of surface and underground waters before they reach environmentally dangerous proportions.

The objective of the present study are to (1) simulate water flow and solute transport processes numerically in two-dimensional tile-drained field, and (2) interpret and predict quantity and quality of outflows from tile drains for the purpose of reducing the pollution of surface and ground water supplies.

2. Materials and Methods: The study will be conducted on a volcanic ash soil at the experimental site of the National institute for Rural engineering. The soil is naturally moderately drained and subsurface plastic drain pipes (tubes) will be installed to a nominal depth of 75 cm from the surface; and at 10, 20 and 40 meter spacing with virtually no slope gradient (see Figure 1). The length of the drain is 70 meters and the outlets are directed into an observation ditch where the outflow is measured and sampled for nutrient analysis. Other parameters to be observed include the soil water content, pressure head and the water table height.

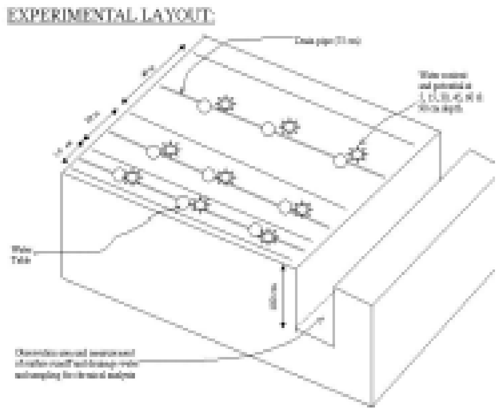

Fig. 1. Experimental Layout

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Description of Numerical Model and Domain: The simulations will be performed using the model developed by Simunek et. al., (1999). Briefly, the model is a two-dimensional, deterministic model simulating unsaturated-saturated water flow and solute transport, subject to root water uptake, drainage, and various fluxes at the soil-atmosphere interface due to different climatic conditions. The water movement and solute transport are modeled by numerical solutions to Richard`s equation and convection-diffusion equation, respectively, using the Galerkin finite element method, subject to the appropriate initial and boundary conditions. The model can simulate the processes that couple irrigation practices, land use, evaporation, transpiration, and soil water extraction by roots, with vadose zone and groundwater flow and transport. The model can also predict changes in water table elevations and water quality due to agricultural management strategies. The details of the model can be found in Simunek et. al., (1999)

3. Model Parameters: Some of the hydraulic parameters which are relevant to the simulation process are presented in Table 1. It can be seen that the second layer has a very low conductivity value compared to the others and this can slow down the movement of water into the lower layer considerably. Also, the saturated water content for the second layer is quite high, meaning it will take some time to store sufficient water in this zone before there is movement downwards. Since the drainage pipe is located in this layer we expect that there will be some outflow which will be measured and compared with the simulation results. It is important to point out that the lateral conductivity of the soil was of the same order (10^{-4}) for all the layers and therefore does not pose any significant problem. Other hydraulic parameters would be collected later. Relevant crop parameters will be collected during the period of experimentation together with climatic parameters.

Table 1: Some Hydraulic Properties of the Soil

Soil layer (vertical)	θ_s	K_s (cm h^{-1})	ρ_b (g cm^{-3})
1st (0 – 40 cm)	0.62	1.16	0.83
2nd (40 – 90 cm)	0.73	0.25	0.62
3rd (90 + cm)	0.68	4.01	0.56

4. Expected Results: The results will promote an understanding of the flow processes involved in water and solute movement. This will allow for the determination of the effects of land-use, fertility practices, water management practices and other practices and their distribution within the field, on water quality and pollutant loading at the outlet.

References:

Simunek, J., M. Sejna, and M. T. van Genuchten, The HYDRUS-2D software package for simulating two-dimensional movement of water, heat, and multiple solutes in variably saturated media, Version 2.0, Rep, IGWMC-TPS-53, 251 pp., Int. Ground Water Model. Cent., Colo. Sch. Of Mines, Golden, 1999.