Water Flow and Solute Movement in Volcanic Ash Soils

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1. Introduction: Although leaching of nitrates and pesticides is of great concern on sandy soils under rainfall and irrigation regimes, more field research is needed to determine the potential for groundwater contamination under other soil and climatic conditions as well. Volcanic ash soils (Andisols) contain allophane, imogolite, and other poorly crystalline materials as dominant clay minerals and carry variable surface electrical charge which gives it the propensity to adsorb otherwise inert electrolyte anions such as Cl^- and NO_3 (Katou et. al. 1996). In view of the intensive arable production practiced on Volcanic ash soils in Japan, solute (anion) transport processes through unsaturated volcanic ash soils is of considerable agricultural and environmental interest. Understanding contamination of groundwater by plant nutrients requires the precise prediction of their fate, including transport by rain and irrigation waters (both off-field and through the soil), chemical transformation and decay, and uptake.

The overall objective of this study is to quantify nutrient and sediment concentrations in subsurface drainage flow from a volcanic ash soil under typical agricultural management practices. The specific objectives are to (1) establish concentration and total amounts of nutrients and sediments in the drainage outflow in a volcanic ash soil, and (2) simulate water flow and solute transport processes numerically.

2. Materials and Methods:

The study was conducted on a Kanto loam soil (volcanic ash) located at the experimental site of the National Institute for Rural Engineering. Samples of the soil were taken in a grid at 10 m intervals to determine the inherent physical properties, which would become relevant later in simulation studies. Drainpipes were installed in the field at 60 cm depth with drain spacing of 10 m and directed to an outlet that was used to monitor outflow. The total area of the field plot is 30 m by 50 m. Other parameters monitored in the field included the soil matric flux (tensiometers) and the groundwater level. The tensiometers were installed at different depths in three sets (that is, at 1, 3, and 5 m from one side of the drainpipe). Atmospheric conditions were monitored from the meteorological station located on the grounds of the Institute. Carrot was used as the test crop because it is widely grown in this region and its fertilizer requirement is also high.

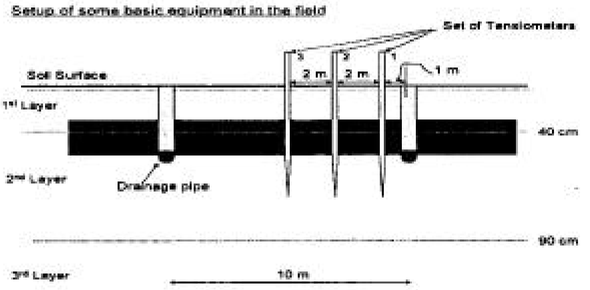

Fig. 1. Setup of some basic equipment in the field

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Keywords: water flow; solute movement: volcanic ash soil;

3. Results and Discussion: Some physical properties of the soil are presented in Table 1 (a and b). There is a compacted zone at the 30-60 cm depth (see Table 1. b).

This will have effect on water flow through the soil profile as confirmed in Figure 2 where the suction pressure is generally high at 50 cm depth for the first two sets of tensiometer (i.e., 1 and 3 m from the drainpipe).

Table 1: Some physical properties of the soil

a.

Soil layer (cm)	ρ_b (g cm^{-3})	θ_s	θ_r	Ks (cm h^{-1})	α (cm^{-1})	n
0 - 40	0.80	0.65	0.41	1.16	0.029	1.77
40 – 90	0.57	0.72	0.45	0.25	0.035	1.38
90 +	0.55	0.68	0.34	4.01	0.032	1.54

b.

Depth of Soil (cm)	Soil Hardness/Strength
10	15.9
20	16.6
30	19.2
40	20.7
50	20.2
60	18.5
70	16.7
80	15.4
90	15.2
100	15.7

Generally, the suction pressure in the soil followed the same trend irrespective of measurement location. The difference between the suction pressure at location one and two at the 15, 30, and 70 cm depths could be attributed to the fact that set one was close to the drainpipe which was installed to a depth of 60 cm.

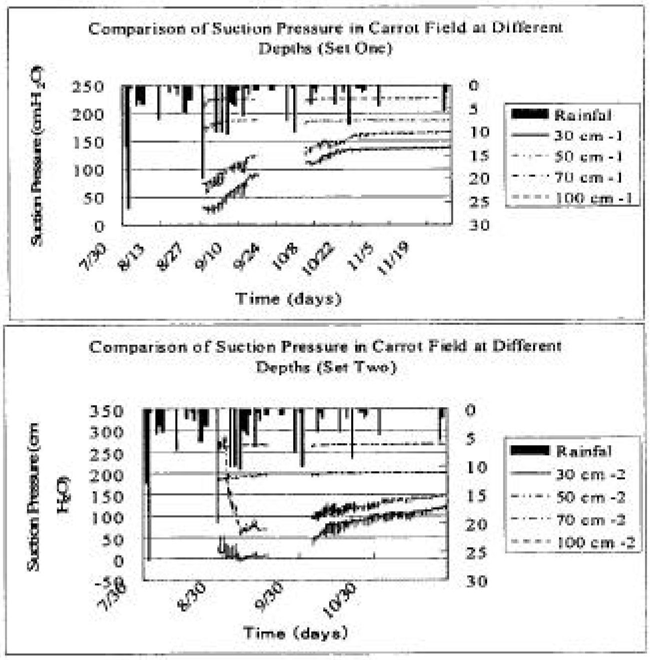

Fig. 2. Suction in Carrot Field at locations one and two (i.e., 1 and 3 m from drainpipe)

Groundwater level as monitored during the experiment was on the average at about 2.2 m from the surface of the soil. For this reason there was no outflow and this has impacted negatively on one of the stated objectives. There is the need therefore to investigate further the geology of the area to ascertain why the groundwater could not rise high as expected.

Analysis of the soil before and after the growth of carrot however, indicated an accumulation of nitrate nitrogen (NO_3) in the second layer of the soil profile. But this is only the beginning and more work needs to be done to confirm this phenomenon. Also, a simulation study has just begun and it is hoped that modeling could be used to monitor the fate of water and solute transport in volcanic ash soils successfully.

4. Conclusion: Preliminary results from the study are interesting and further work is need to clarify the mode of transport of water and solute in volcanic ash soils.

References: Katou, H., B.E. Clothier, and S.R. Green. 1996. Anion transport involving adsorption during transient water flow in an Andisol. Soil Sci. Soc. Am. J. 60:1368-1375.