Application of Hydrus-2D to reproduce soil water redistribution and to detect Zero Flux Plane (ZFP)

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1. Introduction:

Comprehensive analysis of three simulations by using Hydrus-2D sets has been performed to examine the potentiality of detecting of the zero flux plan (ZFP) in unsaturated zone. Three different cases have been carried out. First, simulations of one-dimensional flow, with drainage face and zero evaporation rate. Second, the simulations of one-dimensional flow, with 25 cm/day evaporation rate and finally, the simulation of one-dimensional flow with both evaporation and precipitation occurred simultaneously. Other Three different laboratory experiments with simulations have been conducted independently. Two of them to study the drainage case only and the third, to study ZFP. There was reasonable agreement between measured and simulated results derived by Hydrus-2D. The model study indicated that the Hydrus-2D could be a good tool to examine the zero flux plan movement. In addition, Hydrus-2D could be used to study and investigate the salt movement and accumulation in vadose zone and to implement in other application.

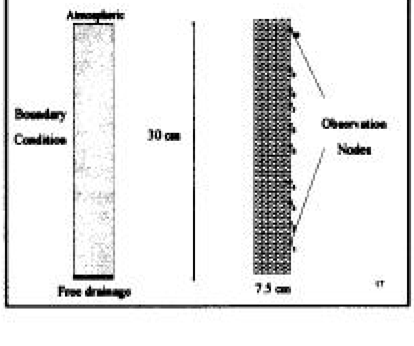
2. Materials and tools

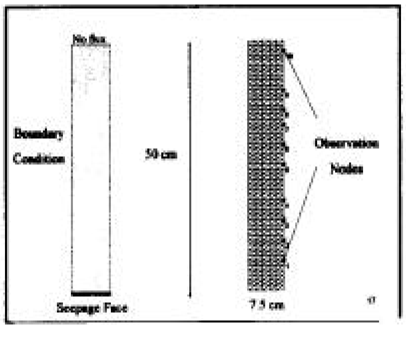
Three different types of soil have been used in the experiment. Tottori sandy soil, Tachikawa loam soil and volcanic ash soil. The bulk densities of them are 1.63, 0.43 and 0.63 (g/cm3) respectively. The water content are 2%, 131% and 80% correspondingly. The model used in this study is Hydrus-2D. It is a Microsoft windows based modeling environment for analysis of water flow and solute transport in variably saturated porous media. It includes the two-dimensional finite element model for simulating flow and solute transport in variably saturated media.

3. Method

3.1 Simulations: Three main simulations cases of one-dimensional flow with drainage face and zero evaporation, and with evaporation rate 25cm/day and finally, with precipitation and evaporation occurring simultaneously. The soil used is sandy loam soil and the initial pressure is ranged from -40 at the top to -10 in the bottom for these tests. First, the one-dimensional flow in a column of 30cm length with drainage face only has been carried out. The boundary conditions, nodes distribution, geometry and finite element mesh are shown in Figure 1. The second case has the same features as shown in Figure 1. but with evaporation rate 25 cm/day. Finally, with same conditions as above, the simulation of one-dimensional flow with both evaporation and precipitation has been performed but the evaporation rate is 25cm/day; the precipitation rate is 10 cm/day with free drainage face at the bottom and atmospheric face at the top.

3.2 Experiments: Three laboratory experiments have been conducted with simulations to examine reliability of Hydrus-2D simulations and to study ZFP. First two experiments, concerning the drainage only and no evaporation allowed, were carried out using both Tottori sand and Tachikawa loam soil respectively. A column with 10 acrylic rings with 4 cm height and 7.5 cm diameter, in addition to 5 acrylic rings with 2 cm height have been used. The total length is 50cm. Seepage face to the bottom with no evaporation allowed form the top surface. Total potential and temperature have been measured by tensiometers and thermo couples respectively.





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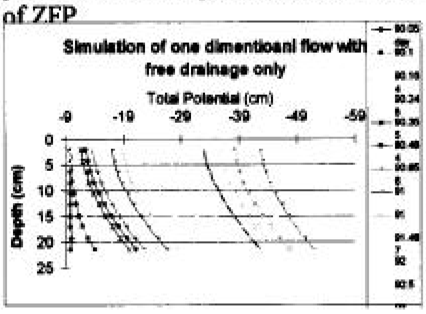
The boundary conditions, nodes distribution, geometry and finite element mesh is shown in Figure 2 The main feature are shown in Figure 3. The third experiment was carried out to detect the ZFP with both drainage and evaporation occurred simultaneously. A column with 11 acrylic rings with 2 cm height and 7.5 cm diameter in addition to 8 acrylic rings with 1 cm height. The total length is 30cm. Seepage face at the bottom whereas the top end is exposed to electric light, 150w, 20 cm apart, as a thermal source, to produce evaporation. Total potential and temperature have been measured by tensiometers and thermo couples. The soil type, the evaporation rate and water flow parameters for these three cases are shown in table 1

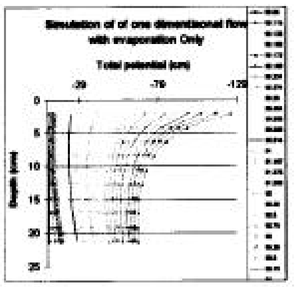
Case	Soil Type	Time	E.	(θr)	(θs)	(n)	(α)	K_s
Drainage	Tachikawa loam	2days		0.62	0.71	0.04	6.60	0.12
	Tottori sand	2days		0.03	0.30	0.03	9.95	1.24
Evaporation	Volcanic ash		15.0	0.45	0.75	2.28	0.13	0.06
Drainage & evaporation	Volcanic ash	2days	15.0	0.45	0.75	2.28	0.13	0.06

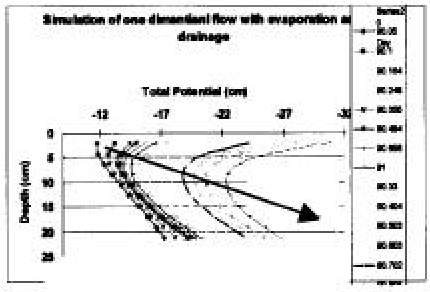
Table 1 The features of soils used in Experiments and simulations
(θr) Residual soil water content (θs) Saturated soil water content (E mm/day) Evaporation.
(n), (α) Parameters in soil water retention function (K_s cm/min) saturated Hydraulic conductivity

4. Results and discussion

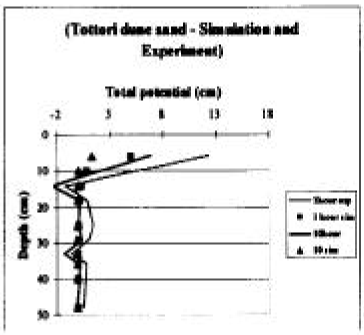
Figures 4, 5 and 6, and, show the simulations of one-dimensional flow, with drainage face and zero evaporation rate, with 25 cm/day evaporation rate and both evaporation and precipitation. The total pressures via depth have been established. From the Figure 4, it is clear that the rate of decrease in total potentials at the bottom is higher than these ones at the top. In contrast, Figure 5 shows that the rate of decrease in total potentials at the top is higher than these ones at the bottom. In Figure 6, we can observe easily the movement of ZFP

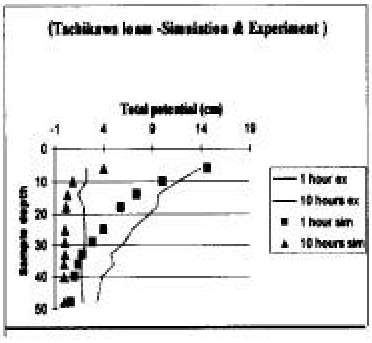






To evaluate the results obtained from Hydrus-2D, the total potential for different soils, Tottori sand and Tachikawa loam and volcanic ash soil have been drawn from both experiments and simulations results. The potential lines after 1 and 10 hours, through the depth of 50cm are shown in Figures 7 and 8. The results demonstrated in Figure 9. give a reasonable agreement between simulations and experiment results except for surface zone.





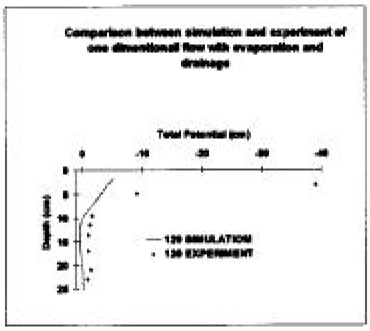


Fig. 9. Results comparison of drainage and evaporation case.

5. Conclusions

Hydrus-2D is not valid to over saturated soil
Hydrus-2D is a good tool to observe and detect ZFP
Careful experiment and simulation could be reasonable means to measure and control salt accumulation.