Modeling Spatially Distributed Water Fluxes in an Andosol under Banana plant

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Introduction

Atmosphere

Humid tropical climate: 2.5 - 4.5 m water/year with intensities > 70 mm/h

Main stemflow around the pseudo-stem (**stemflow:** 20 to 45 times the incident rainfall)

Interface

slope > 10%

Plant

KNO$_3$ supply: massive and localized around the stem (400 kg N/ha/y 800 kg K/ha/y)

Interface

Soil

Spatially distributed drainage in depth of a volcamic ash soil (Andosol)

Objective : Modeling water flow using the **HYDRUS-2D model (Simunek *et al*., 1999)**, which simulates Darcian water flow in a two-dimensional domain in the unsaturated-saturated flow system

Materials and Methods

Richards Equation for water flow in variably-saturated soils

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

θ volumetric water content [L L^{-3}]
h pressure head [L]
z depth under the soil surface [L]
x horizontal distance [L]
t time [T]
K unsaturated hydraulic conductivity function [L T^{-1}]
S sink term [T^{-1}]

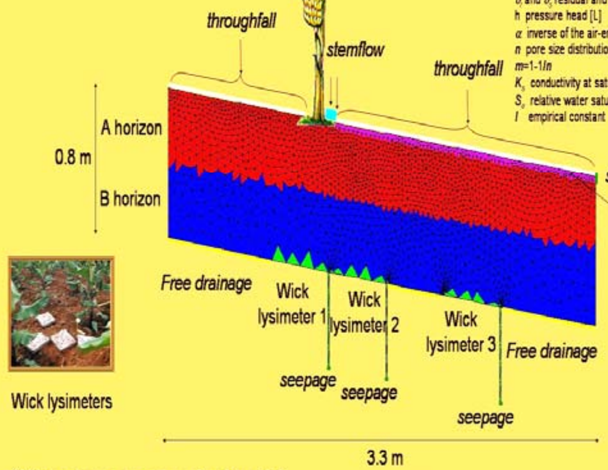
Water Retention and Hydraulic Conductivity functions (Wind measurements and infiltrometers)

Mualem (1976) and van Genuchten (1980)

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

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

θ_r and θ_s residual and saturated water contents [L^{3}L^{-3}]
h pressure head [L]
α inverse of the air-entry value [L^{-1}]
n pore size distribution index
m=1-1/n
K_s conductivity at saturation [L T^{-1}]
S_e relative water saturation $(\theta-\theta r)/(\theta s-\theta r)$
l empirical constant



Wick lysimeters

✓ Water fluxes measured using wick lysimeters
5 replicates of 3 positions with respect to stem location

✓ Pressure heads measured with tensiometers above each lysimeter at 3 depths (6, 25, and 55 cm)

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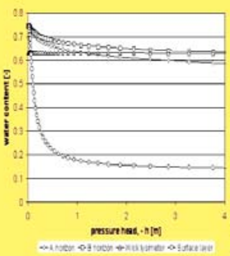
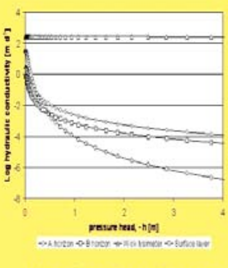
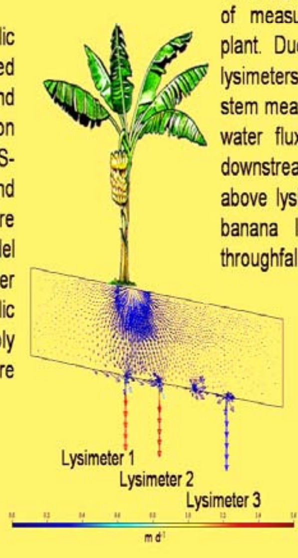
Results





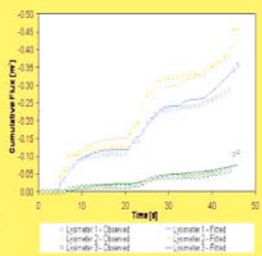
Water Retention and Hydraulic Conductivity functions

Effective soil hydraulic properties were obtained in the laboratory and using the inverse option provided in HYDRUS-2D. The tensiometric and lysimetric data were used in model calibration. Both water content and hydraulic conductivity considerably increase for pressure heads above -1 m.

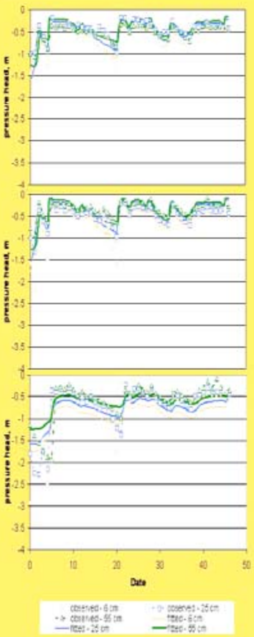


Flow velocity vectors under the banana stem after a rainfall event

Modeling reproduced the general trends of measured drainage under banana plant. Due to the impact of stemflow, lysimeters 1 and 2 under the banana stem measured more than 3 times larger water fluxes than lysimeter 3 located downstream from the stem. The zone above lysimeter 3 was sheltered by the banana leaves and received mainly throughfall.



Cumulative measured and simulated drainage in three lysimeters



Measured and simulated pressure heads above lysimeters 1, 2 and 3

Simulated drainage was validated:

✓ statistically using the coefficient of efficiency (E) defined by Nash and Sutcliffe (1970).

(E) L1=0.94
(E) L2=0.75
(E) L3=0.99

✓ comparing simulated pressure heads with those measured using tensiometers.

Conclusion

Numerical model reproduced well measured drainage in three lysimeters located at different positions with respect to the banana tree. The model inputs (e.g., soil hydraulic parameters) were either measured using laboratory and in situ experiments, or calibrated using pressure head and drainage measurements and the inverse procedure of HYDRUS-2D. Due to the focused stemflow, lysimeters 1 and 2 located under the banana tree received more than 3 times larger fluxes than lysimeter 3 located downstream from the stem. Further research should integrate water flow with solute transport, taking into account variable charge of the Andisol.

References:

Mualem, Y., 1976. A new model for predicting the hydraulic conductivity of unsaturated porous media. Water Resources Research, 12(3): 513-522.
Nash, J.E. and Sutcliffe, J.V., 1970. River Flow Forecasting through Conceptual Models - Part I: A Discussion of Principles. Journal of Hydrology, 10: 282-290.
Simunek, J., M. Sejna and M.T.van Genuchten. 1999. The HYDRUS-2D Software Package for Simulating Two-Dimensional Movement of Water, Heat and Multiple Solutes in Variably-Saturated Media. Version 2.0, IGWMC-TPS-53, International Ground Water Modeling Center, Colorado School of Mines, Golden, Colorado.
van Genuchten, M.T. 1980. A closed form equation for predicting the hydraulic conductivity of unsaturated soils. Soil Science Society of America Journal 44:892-898.

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