Characterization of spatiotemporal variability of soil hydraulic properties under drainage and recharge cycles by X-ray tomography.

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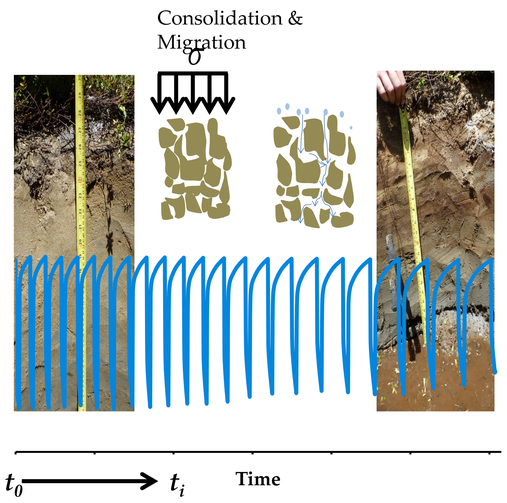
Introduction

- Installation of a drainage system
- Anthropic layering of the natural sequence of soil strata.
- The soil hydraulic properties may change under the influence of irrigation and water table control.
- Reduction of drainage capacity
- Natural consolidation (drainage and recharge cycles), filtration and clogging soil pores by colloidal particle

Anthropic Genesis



- Tomography imagery allows to study a number of physical processes occurring in soils (Wildenschild and Sheppard, 2013).

Objective

- The main objective of this work is to analyze the temporal evolution of hydrodynamic properties of a sandy soil during repeated drainage and recharge cycles using a medical CT-scan.

Material & Methods

Experimental design

- Fluctuation of water table between 35 cm and 55 cm below the soil surface.
- Boundary condition at the bottom layer
- −5 cm at the bottom during drainage and +76 cm during recharge.
- Simulation of precipitation (9 cm of pressure head at the top)
- 2 valves, 1 Mariotte bottle 18.2 l, 1 Mariotte bottle 1000 ml
- 10 tensiometers and 7 lysimeters
- Measurements of inflow and outflow

Figure 1. Experimental setup

Tomographic analysis

- The study was realized at *Laboratoire Multidisplinaire de Scanographie du Québec de l'INRS.*
- Medical CT scan of type Somatum Volume Access (Siemens, Oakville, ON, CA).
- Energy level of 140, 120, 100 et 80 keV
- Resolution of a voxel was 0.1x0.1x0.6 mm

Figure 2. Medical CT scan

Determination of the concentration

Beer-Lambert law

$$I = I_0 \exp(-\mu x) \qquad HU = 1000(\mu - \mu_w)/(\mu_w - \mu_a)$$

- Discrimination of phases by Procedure proposed by Rogasik *et al.* (1999)

Sand concentration

$$C_s = \frac{Hu_1 Hu_{Zr2} - Hu_2 Hu_{Zr1}}{Hu_{Zr1} Hu_{m2} - Hu_{Zr2} Hu_{m1}}$$

ZrO_2 concentration

$$C_{Zr} = \frac{Hu_1 Hu_{m2} - Hu_2 Hu_{m1}}{Hu_{Zr1} Hu_{m2} - Hu_{Zr2} Hu_{m1}}$$

Porosity $\phi = 1 - (C_s + C_{Zr})$

Soil hydraulic properties

- Modification of model of Chan and Govindaraju (2004)
- Model of Mualem (1976) for dual porosity model
- Explained in detail at poster 1523

Analysis of pressure head time series with the continuous wavelet transform

$$W_m(s) = \sum_{m'=0}^{N-1} y_m \psi^* \left[\frac{(m' - m)\delta t}{s} \right]$$

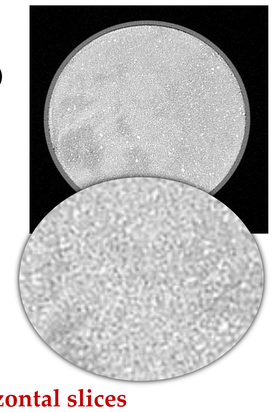


Figure 3. Horizontal slices

Conclusions

- Using and analyzing Medical CT scans clearly illustrated the dynamics of anthropomorphic-driven impacts of water management on drainage.
- The results indicated an important modification of soil properties caused by consolidation and transport of particles.
- Recharge cycles and drainage processes are longer.

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Results

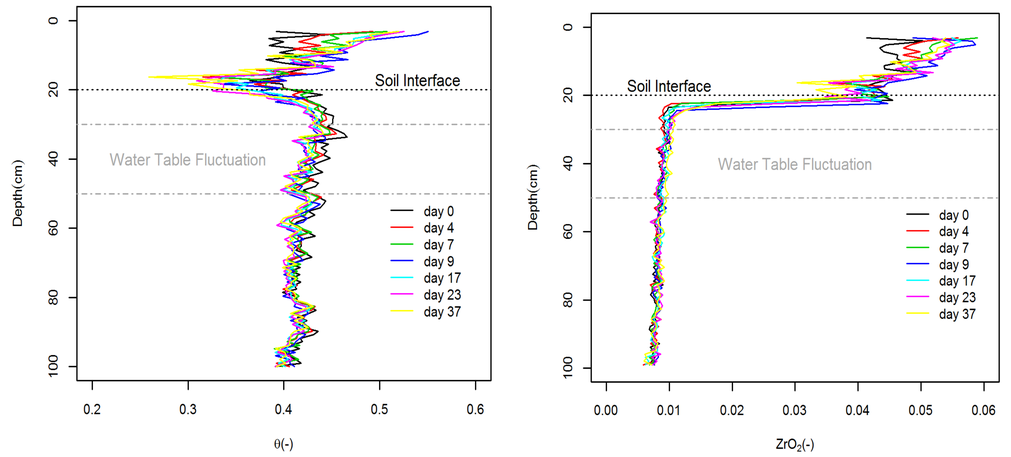

Figure 4. Profile of porosity and concentration of ZrO_2

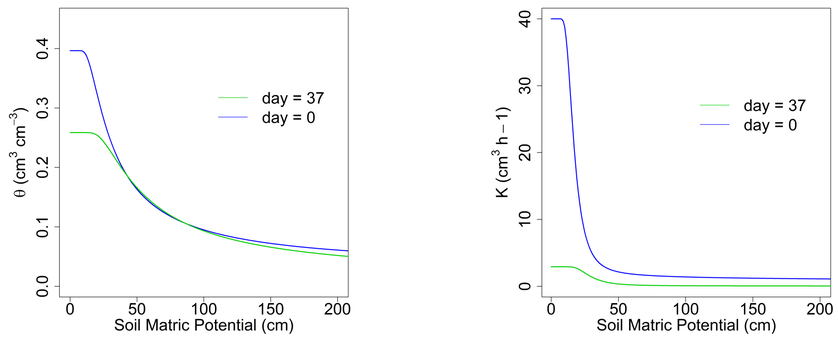

Figure 5. Soil retention and hydraulic conductivity curves at 17 cm of depth at time day = 0 and at time day = 37

- Consolidation at the interface and in the water table fluctuating zone (figure 4).
- Accumulation of fine particles (ZrO_2) under the interface and on top of water table fluctuating zone (figure 4).
- High reduction of the porosity caused by consolidation and particle transport (figure 4).
- High modification of the soil hydraulic properties (figure 5).
- Evolution of the soil affected the dynamic of pressure head at a depth of 17 cm (figure 6).
- Recharge and drainage cycles are longer (figure 6).

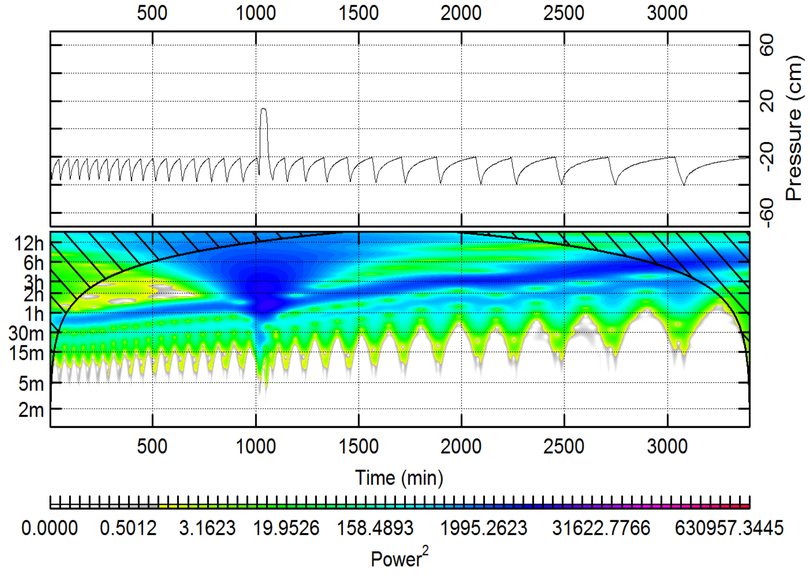

Figure 6. Pressure head at a depth of 17 cm as a function of time and continuous wavelet transform.

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