Characterization of the Temporal Evolution of Soil Hydraulic Properties Under Anthropomorphic Conditions By X-Ray Tomography.

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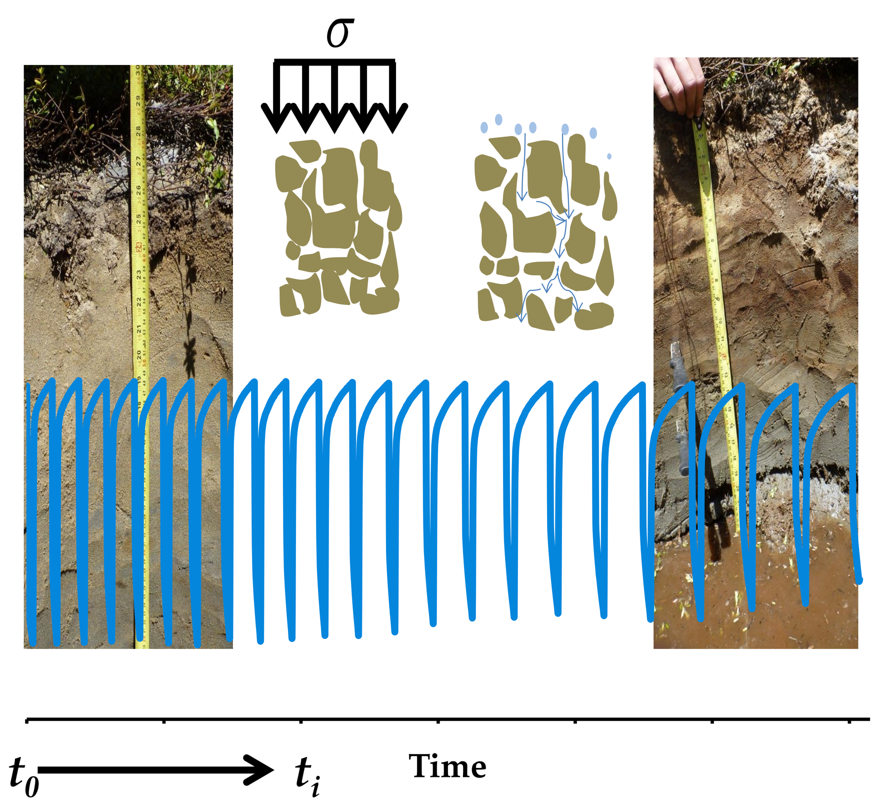
Introduction

- Installation of a drainage system
- Anthropic layering of the natural sequence of soil strata
- Potential changes of soil hydraulic properties induced by irrigation and water table control
- Reduction of drainage capacity
- Natural consolidation (drainage and recharge cycles), filtration and clogging of soil pores by colloidal particles

Anthropic Genesis

Consolidation & Migration



- Tomography imagery allows the study of a number of physical processes occurring in soils (Wildenschilds 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 of 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 lysimetres
- Measurements of inflow and outflow

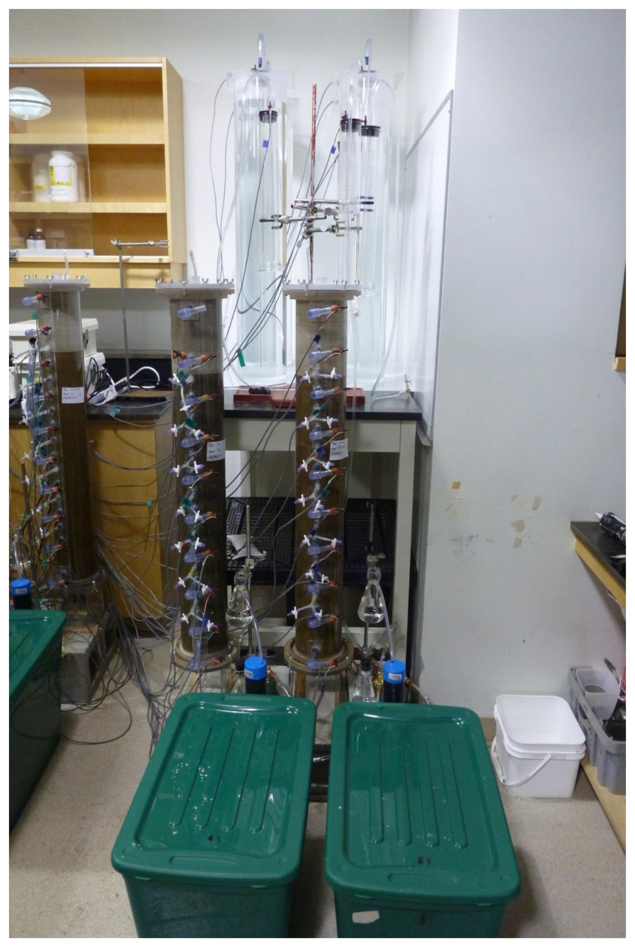


Figure 1. Experimental setup

Tomographic analysis

- The study was realised at *Laboratoire Multidisplinaire de Scanographie du Québec de l'INRS-ETE.*
- Medical CT scan. Type Somatum Volume Access (Siemens, Oakville, ON, CA).
- Energy level of 140, 120, 100 and 80 keV
- Resolution of a voxel: 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 the 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 the Chan and Govindaraju (2004) model
- Model of Mualem (1976) for dual porosity model

$$Ksc = Ks \frac{\phi_c^3 (1-\phi)^2}{\phi^3 (1-\phi_c)^2}$$ (Or *et al*., 2000)

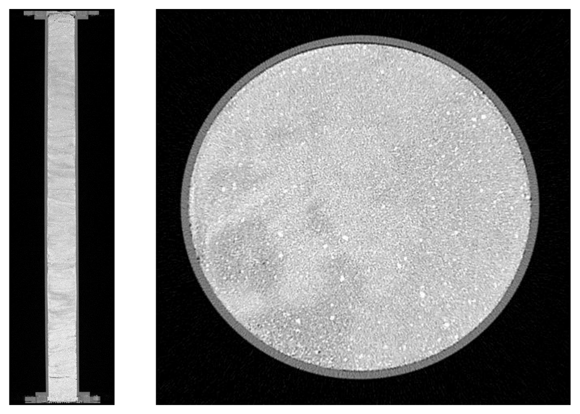


Figure 3. Vertical and horizontal slices

Analysis of pressure head time series with the continuous wavelet transform

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

Conclusions

- Use and analysis of Medical CT scans clearly illustrates the dynamics of anthropomorphically-driven impacts of water management on drainage.
- The results indicate an important modification of soil properties caused by consolidation and transport of particles.
- Recharge cycles and drainage processes take longer.

Results

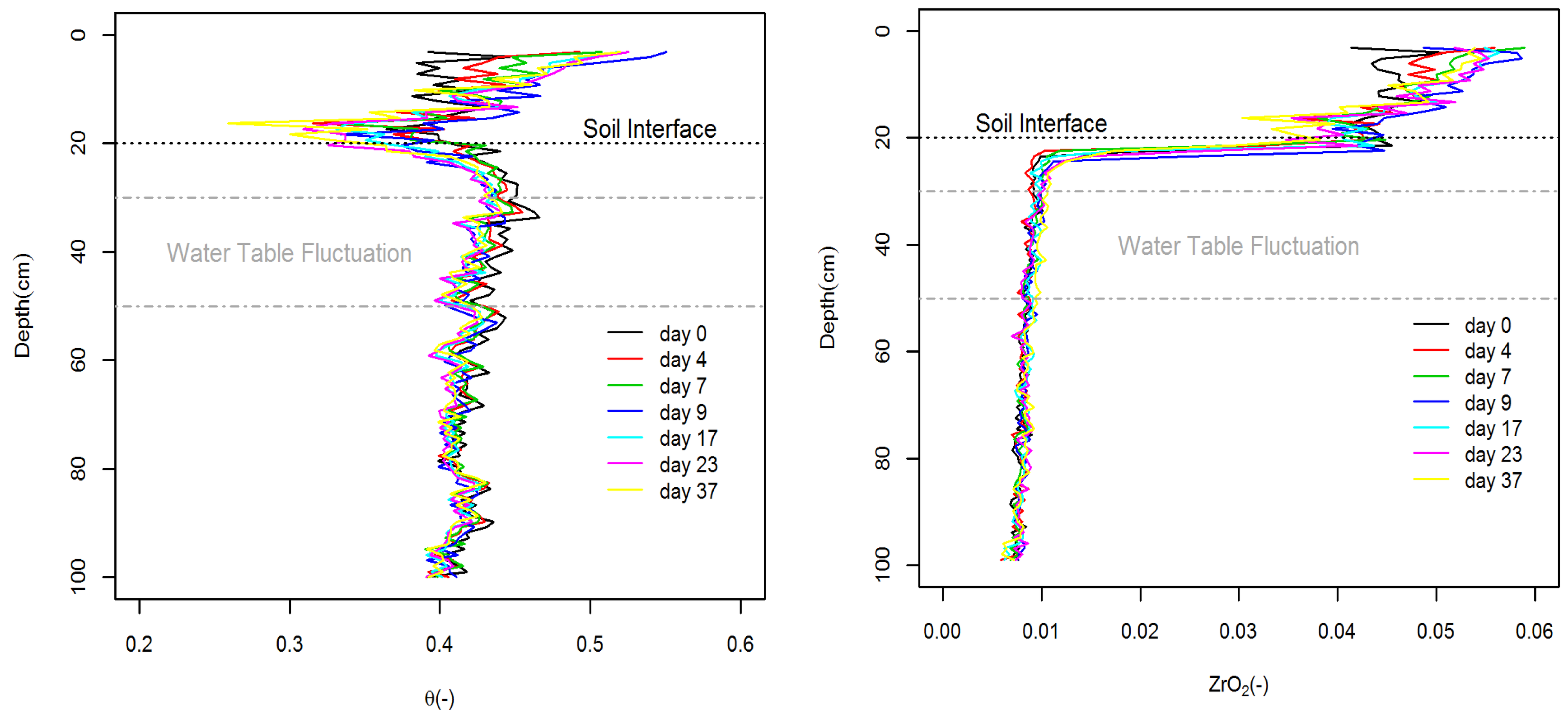


Figure 4. Profile of porosity and concentration of ZrO_2

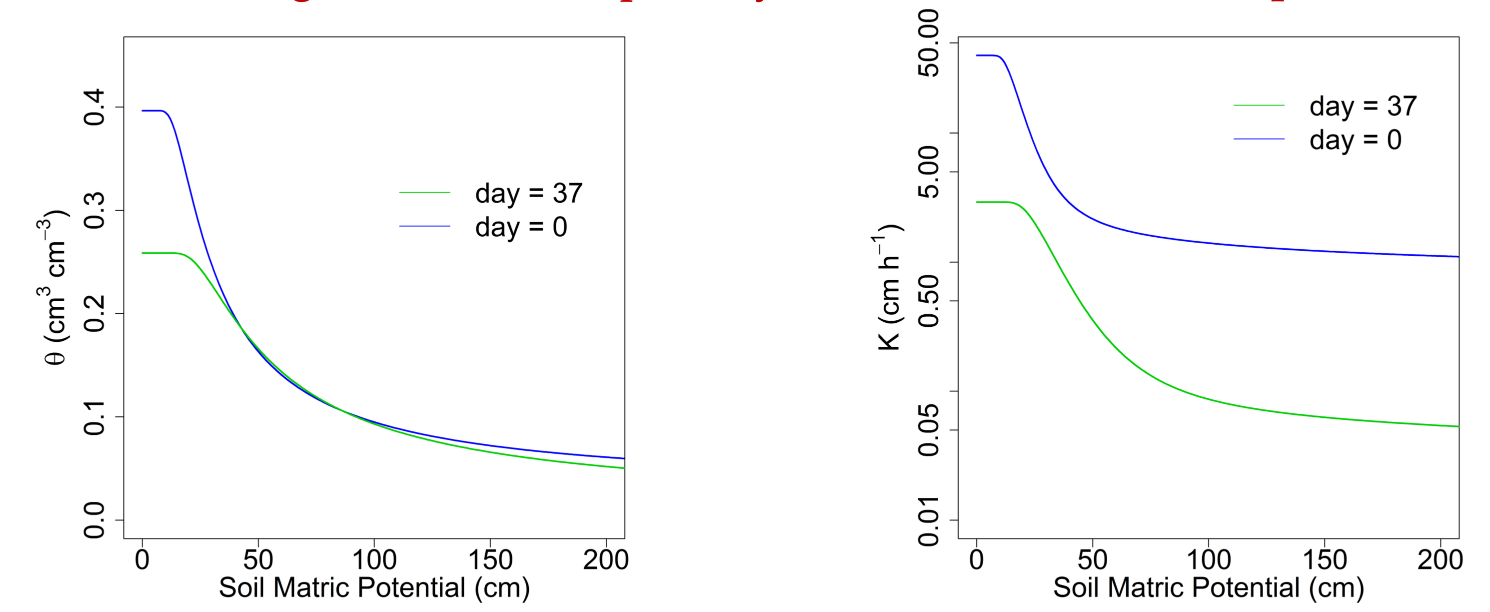


Figure 5. Soil retention and hydraulic conductivity curves at a depth of 17 cm at day = 0 and at day = 37

- 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).
- Reduction of the porosity caused by consolidation and particle transport (Figure 4).
- Substantial 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-drainage cycle contains two dominant wavelets (two blue bands) (Figure 6).
- Wide band = recharge and narrow band = drainage (Figure 6)
- Recharge and drainage cycles are longer (Figure 6) (duration of the recharge-drainage cycle increases on average by 7.9% per cycle)

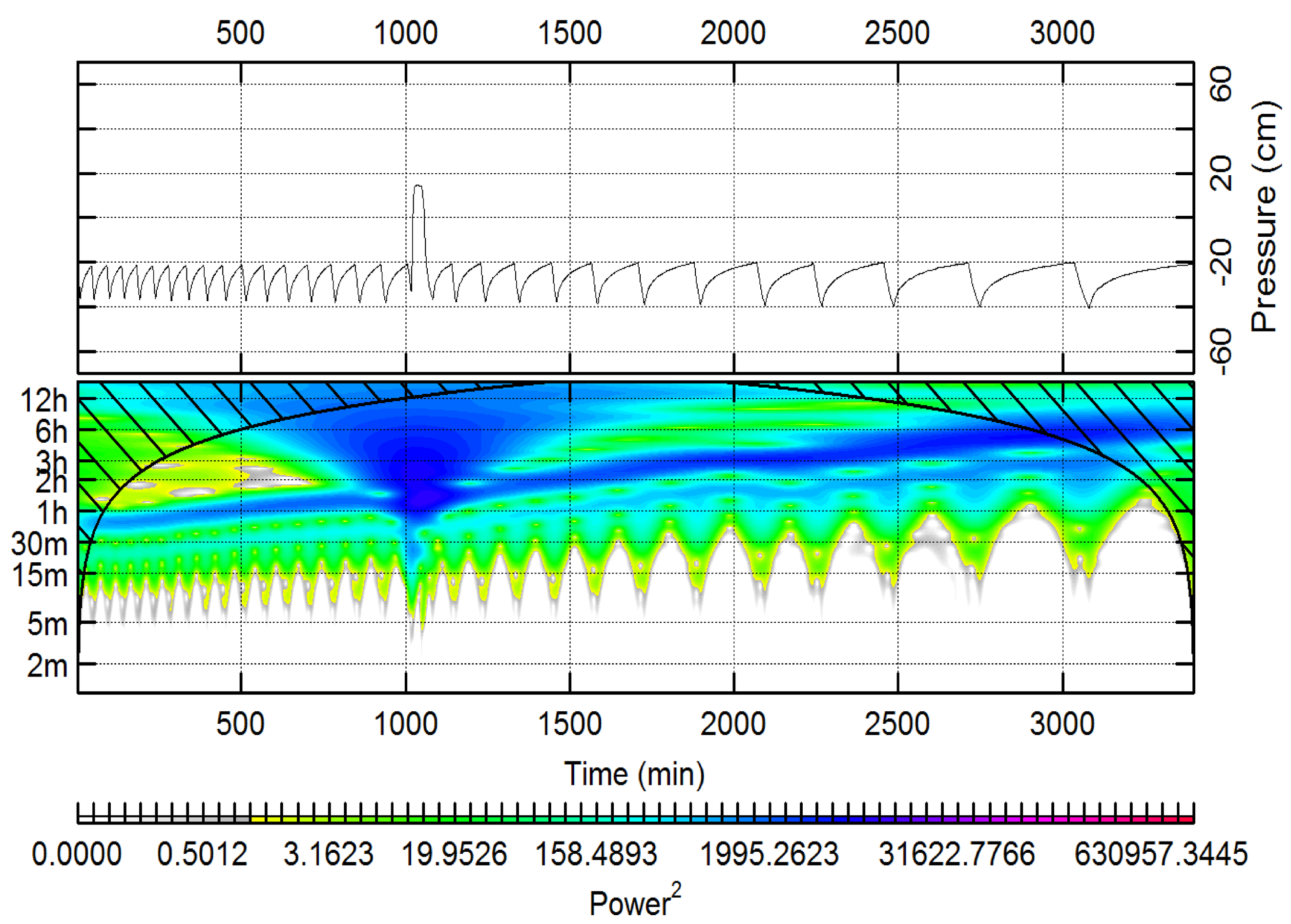


Figure 6. Pressure head at a depth of 17 cm as a function of time and continuous wavelet transform.

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