Effect of desiccation cracking on the fluid transfer process in agricultural soil

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1. Framework

- The studied soil is classified as Cutanic Luvisol, from agricultural field in Gembloux, Belgium.
- Undisturbed soil sample presents strongly heterogeneous with pre-existing cracks along the sample.
- **Goals :** Understading the impacts of cracks on the kinetics of evaporation and fluid transfer in the soil core during evaporation process.

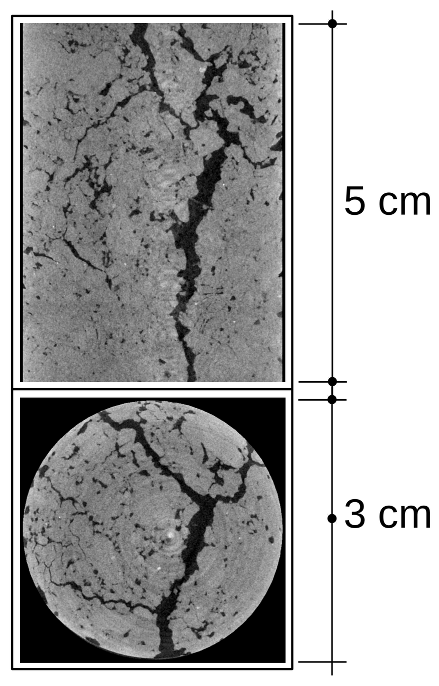

Fig.1 : A soil sample after drainage at 4 kPa

2. Evaporation test

- The HYPROP device (UMS GmbH, Munich, Germany) was used for the evaporation test on undisturbed soil samples.
- The device with soil core was placed in a chamber-drier designed in order to limit the variation of the ambient conditions (e.g., temperature, relative humidity).
- A digital camera was placed at 0.5m above the soil sample to capture the evolution of soil surface.

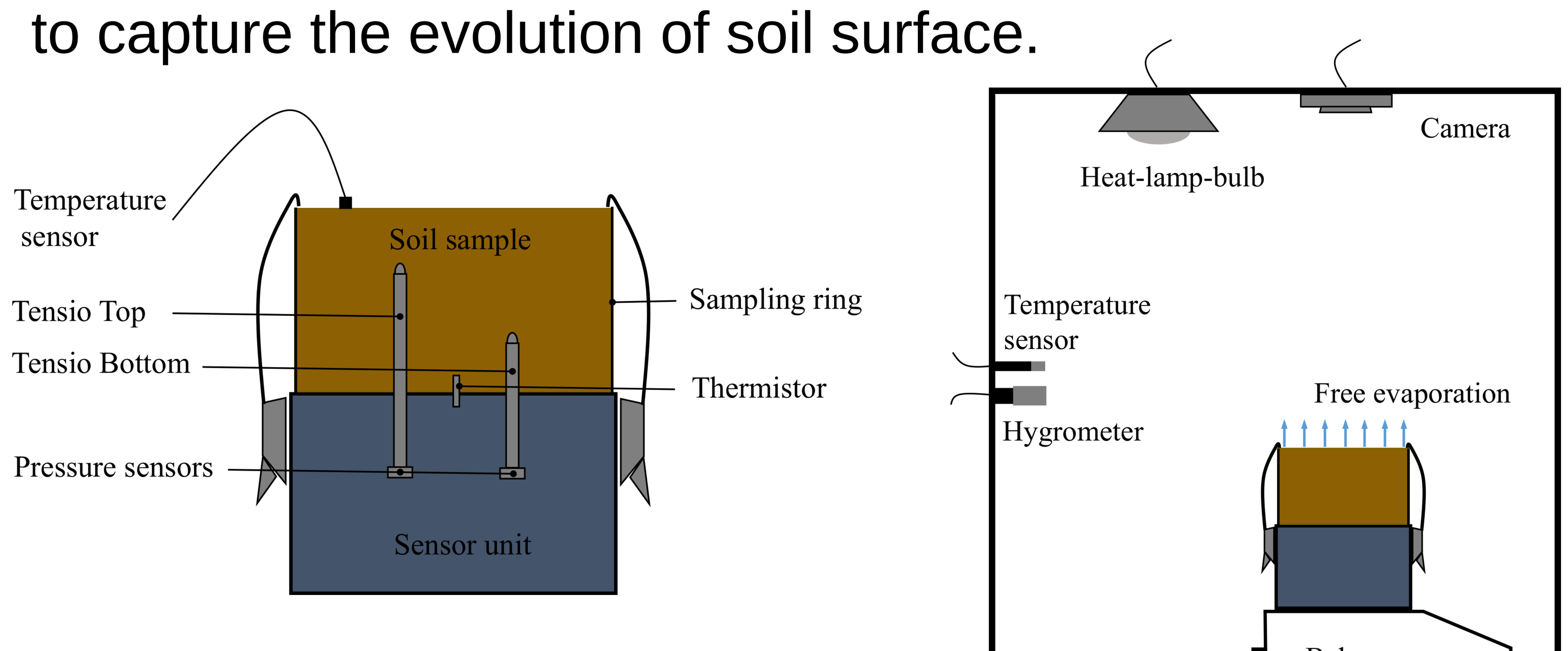

Fig.2 : HYPROP device and chamber-drier

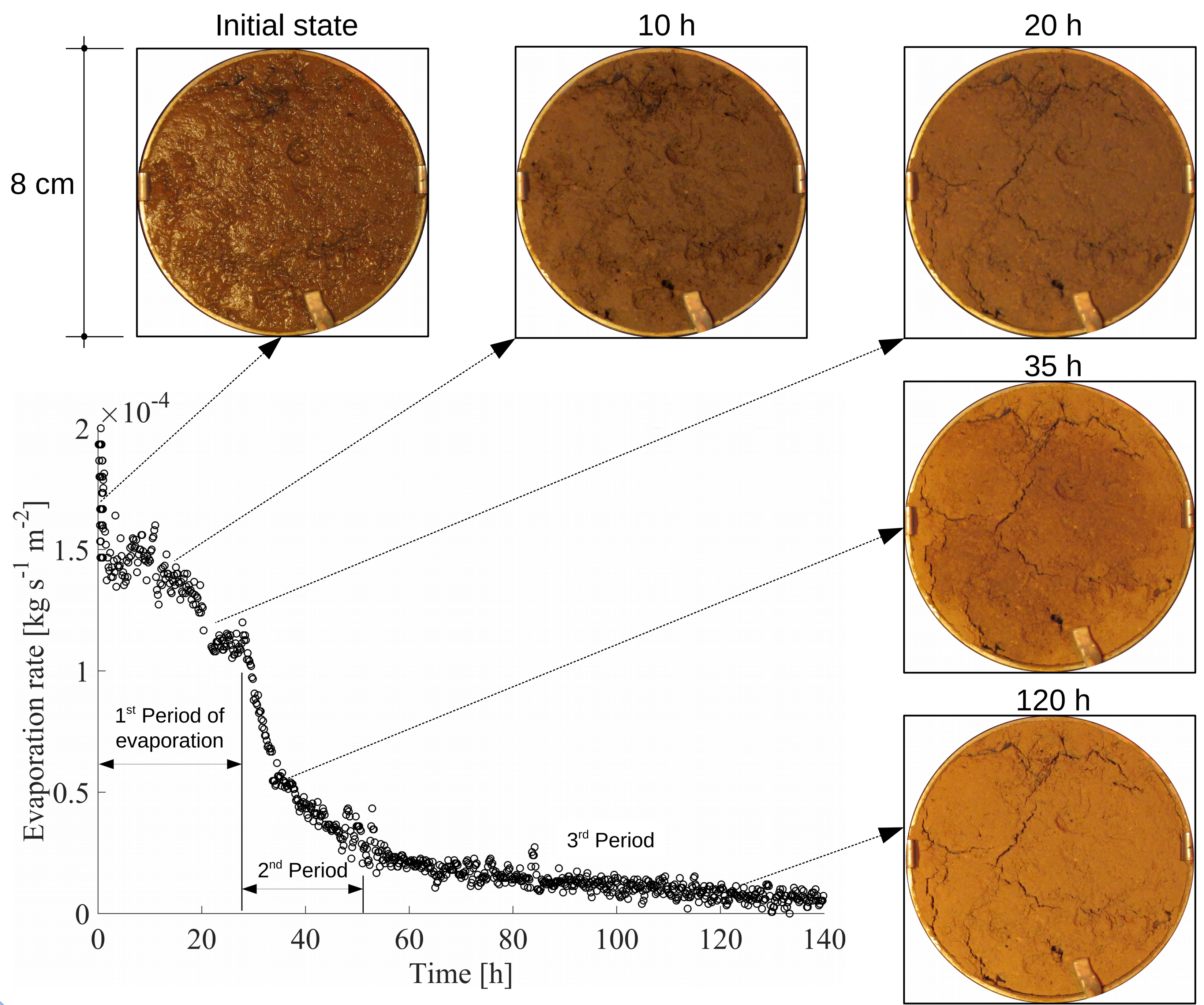

Fig.2 : Evolution of the evaporation rate with time

[1] Gerard, P., Léonard, A., Masekanya, J. P., Charlier, R., Collin, F. (2010). Study of the soil–atmosphere moisture exchanges through convective drying tests in non-isothermal conditions. *Int. J. Numer. Anal. Meth. Geomech.*, 34(12), 1297-1320.

[2] Olivella, S., Alonso, E. E. (2008). Gas flow through clay barriers. *Géotechnique*, 58(3), 157-176.

3. Numerical modelling

- The water and heat transfers are assumed to take place into a thin limit layer surrounding the porous medium [1].

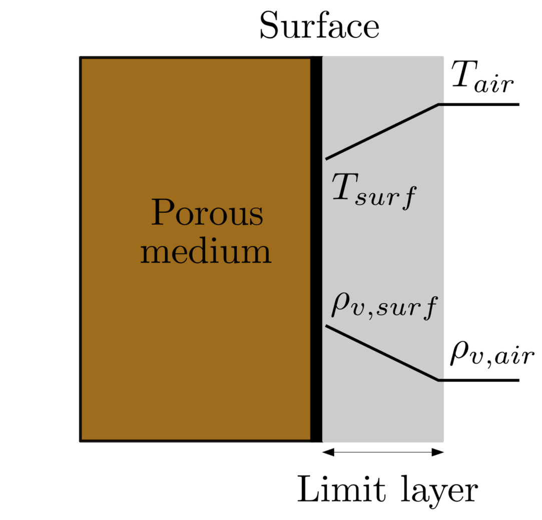

Fig.3 : Boundary layer model

- Vapour flux :

$$\overline{q} = \alpha_0 \, S_r^{surf} \, (\rho_{v,surf} - \rho_{v,air})$$

- Heat flux :

$$\overline{f} = L\overline{q} - \beta \, (T_{air} - T_{surf}) - R_n$$

- The mass and heat transfer coefficients α, β were determined from experimental data.

- The embedded fracture model was used to represent the development of the fractures in porous medium [2].

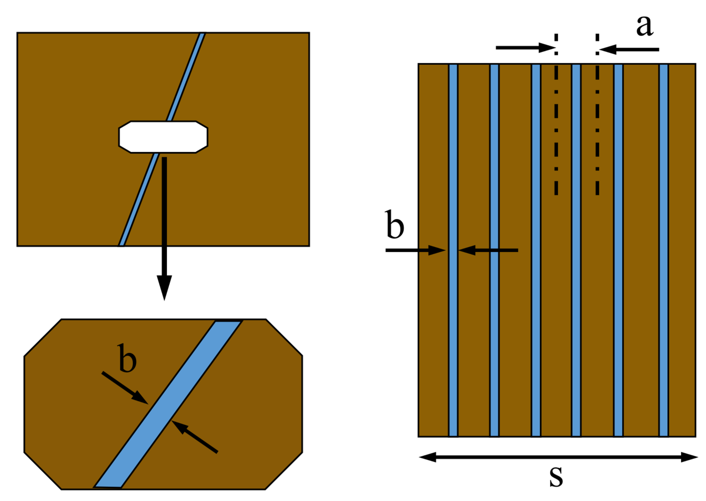

Fig.4 : Embedded fracture model [2]

- The intrinsic permeability of a fracture is related to its aperture and the deformation of the sample.

$$b = b_0 + \frac{s}{n}(\langle \varepsilon_n - \varepsilon_0 \rangle),$$

$$k_{fracture} = \frac{b^3}{12a} = k_0(1 + \lambda(\langle \varepsilon_n - \varepsilon_0 \rangle))^3$$

- The model introduced was used to reproduce the evaporation test.

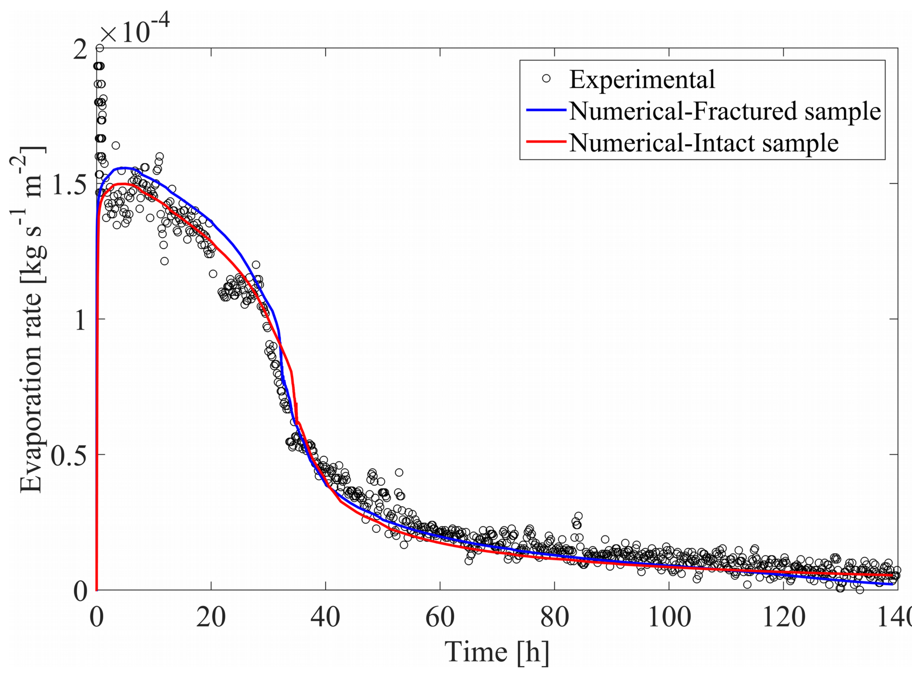

Fig.5 : Comparison of numerical and experimental evaporation rate

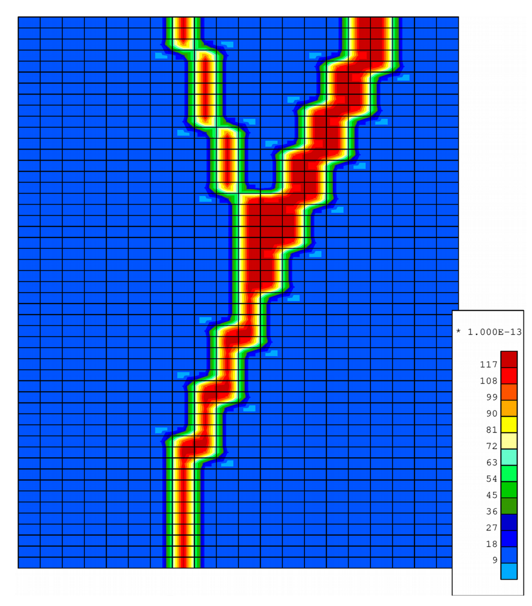

Fig.6 : Evolution of the intrinsic permeability in embedded fracture zones at t = 21h

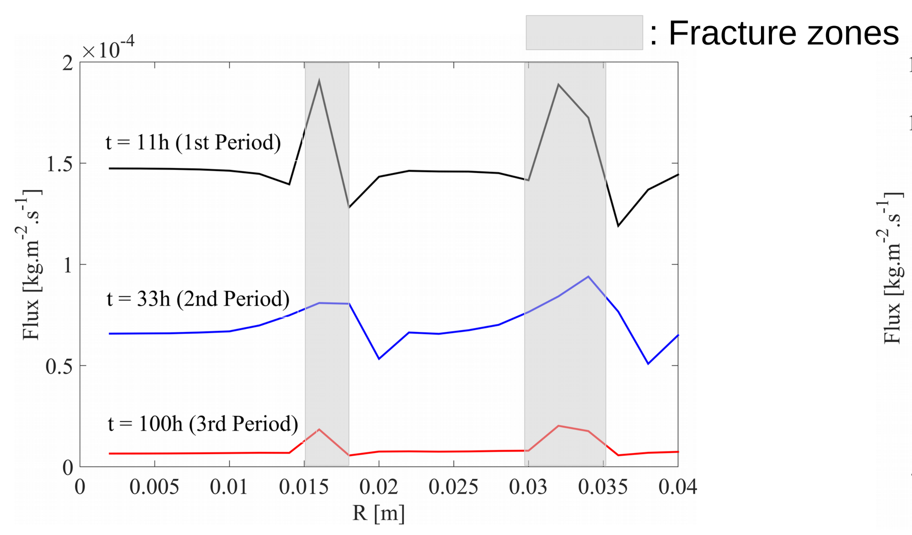

Fig.7 : Water advection flow through the soil surface

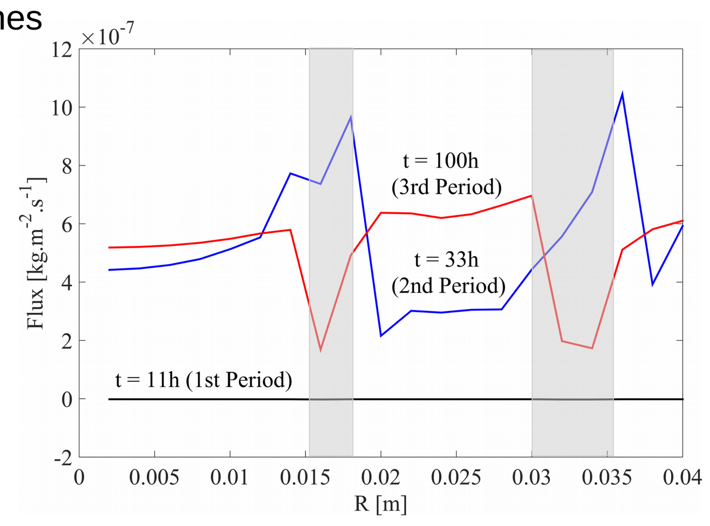

Fig.8 : Vapour diffusion flow through the soil surface

4. Conclusions

- Experimental observations show that most cracks occured during the first period of evaporation.
- Numerical results show that the existence of fractures only modifies slightly the evaporation rate in the first period of evaporation on small soil sample with size of HYPROP device.
- A continuum model is capable of modelling preferential flows developed in a fractured porous medium by using a simple concept of cracking development.

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