Session 1 : Alternative and innovative approaches for characterising the pollution level and pollution hasard of water ressources

Louvain la Neuve / 21-22 octobre 2004

Passive capillary pan samplers : an efficient system to monitor in-situ percolation fluxes in soils.

System presentation and estimation of measurement uncertainties

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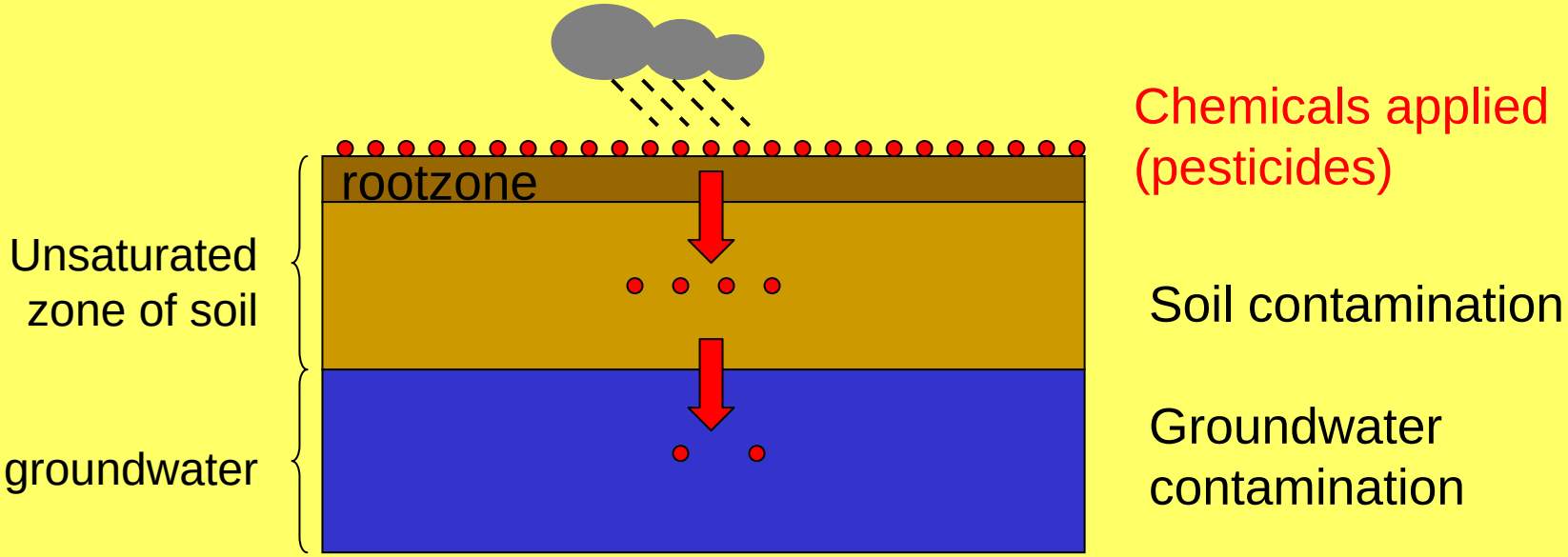
THE SCIENTIFIC CONTEXT :
Measurement of water and solutes percolation fluxes in the unsaturated zone of soils

Many interests in hydrology :

- groundwater recharge
- mass balance for a specific layer
- <u>leaching hazard for chemical contaminants</u>

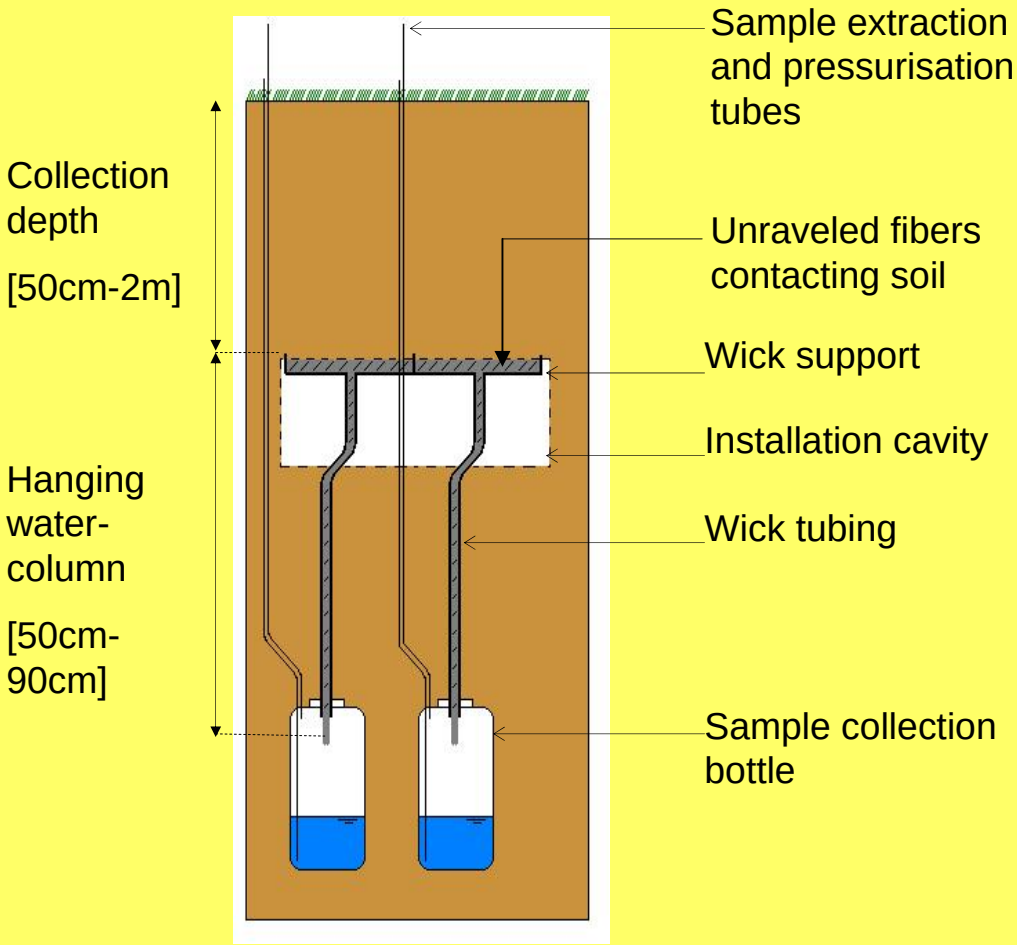


THE TECHNICAL CONTEXT :

Few field technics :	**Poorly representative measures :**
•Tensiometry	Local (spatial variability), C_{FLUX} needed, K-h needed (source of uncertainty)
•Suction cups lysimeter	Local (spatial variability), $C_{RESIDENT}$, flow distortion, concentration effect.
•Weighing lysimeter	Soil destruction (stabilization period), flow pattern distortion, cost)
•Zero tension pan sampler	h=0 ⇒undersampling (e≈50%), flow distortion (divergent flows)

PRESENTATION OF THE PASSIVE CAPILLARY SAMPLER

Typical design of a passive capillary sampler (PCAPS)



Photography of a sampler during installation under a banana tree.

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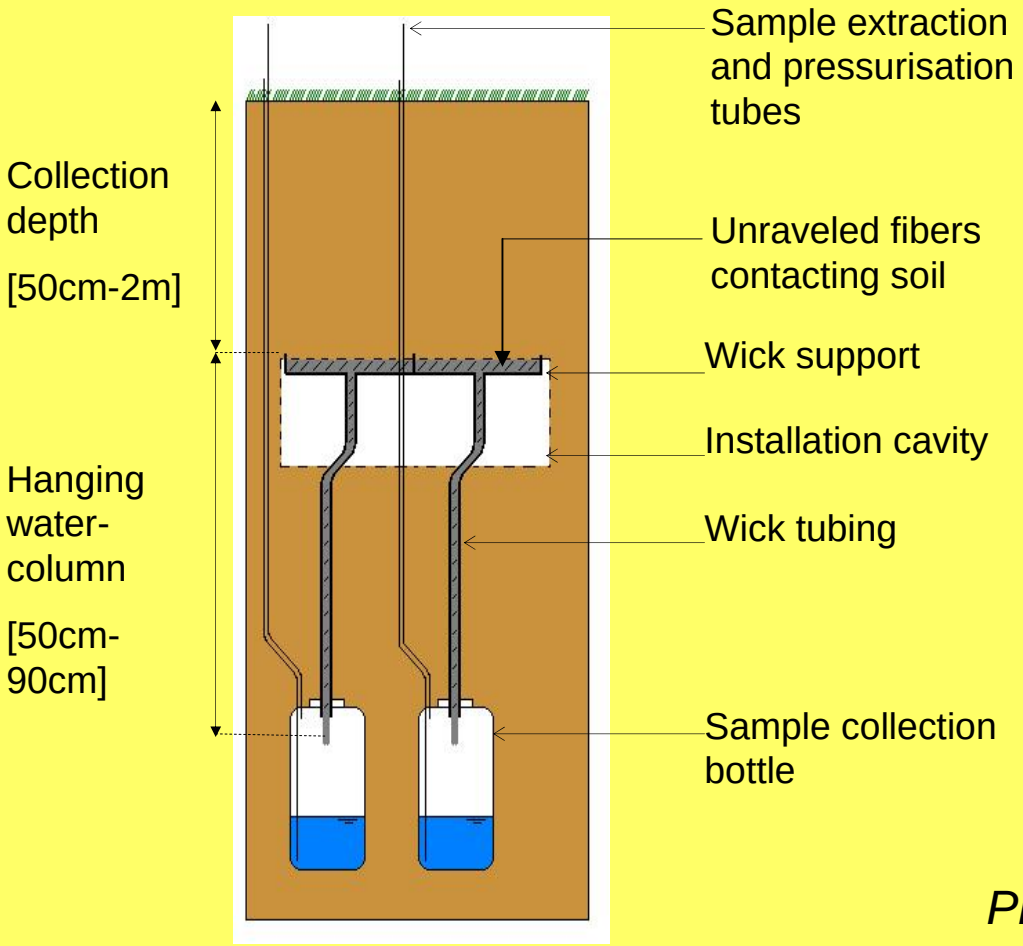

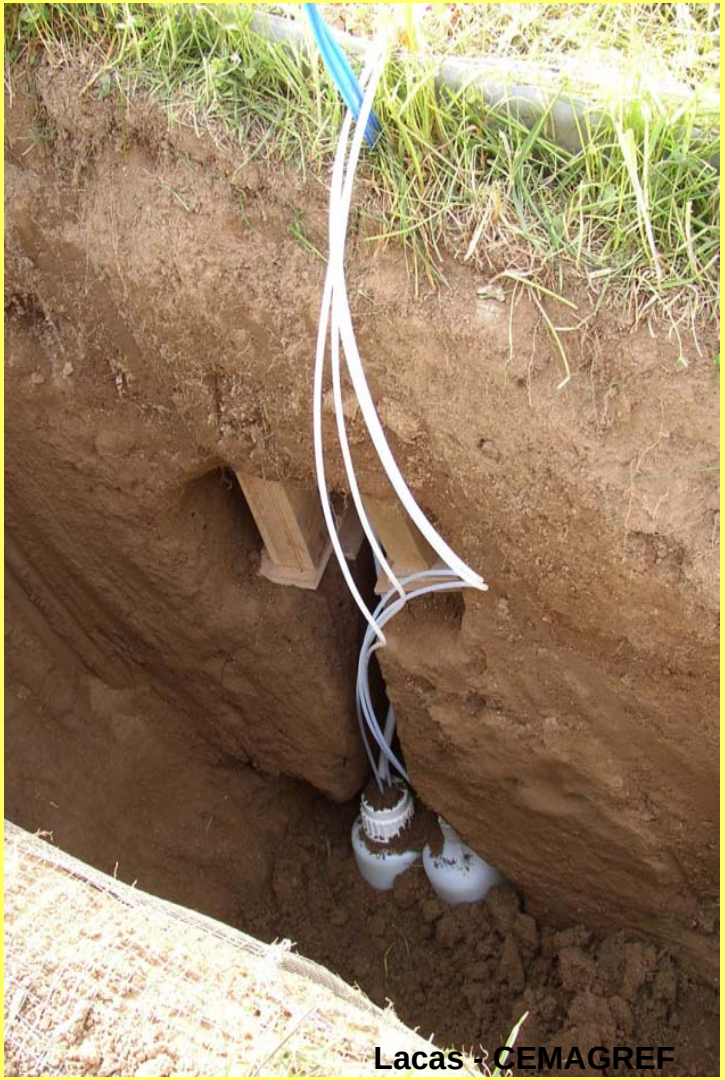

Photography of the sampling bottles and extraction tubes – lysimeter installed under a grassed zone.

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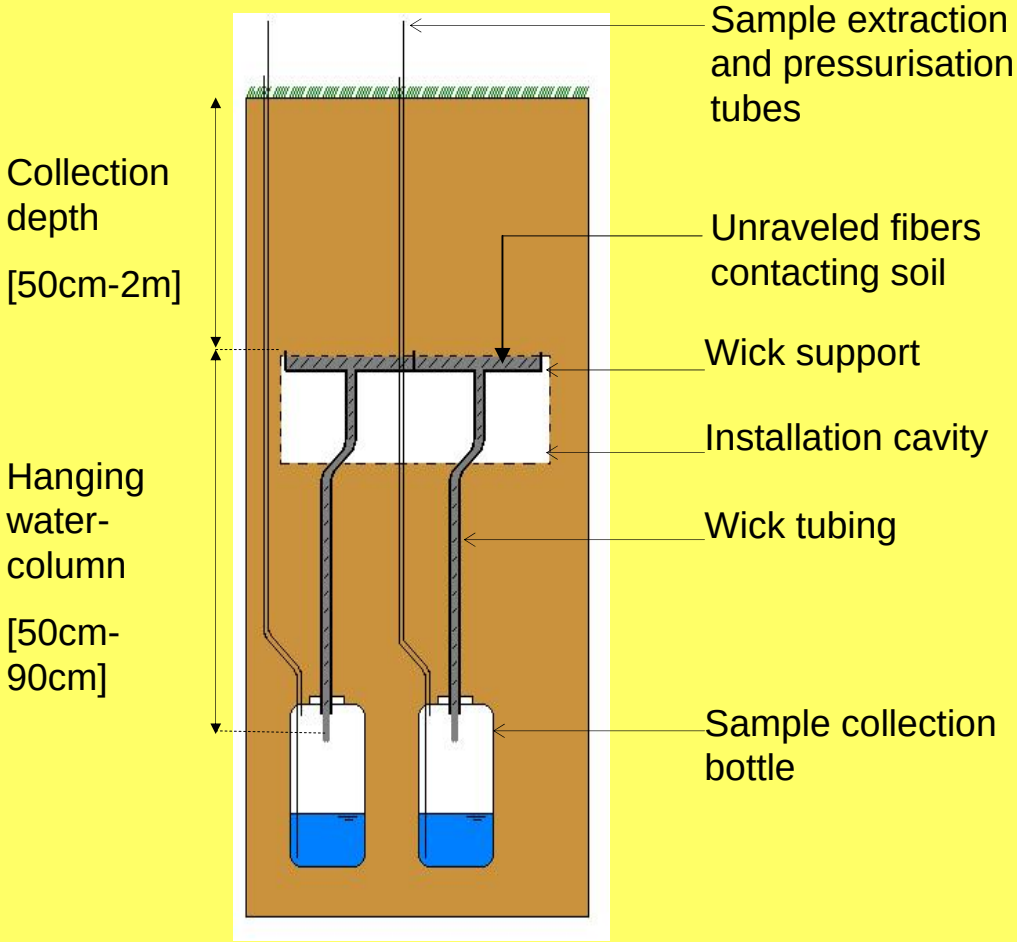
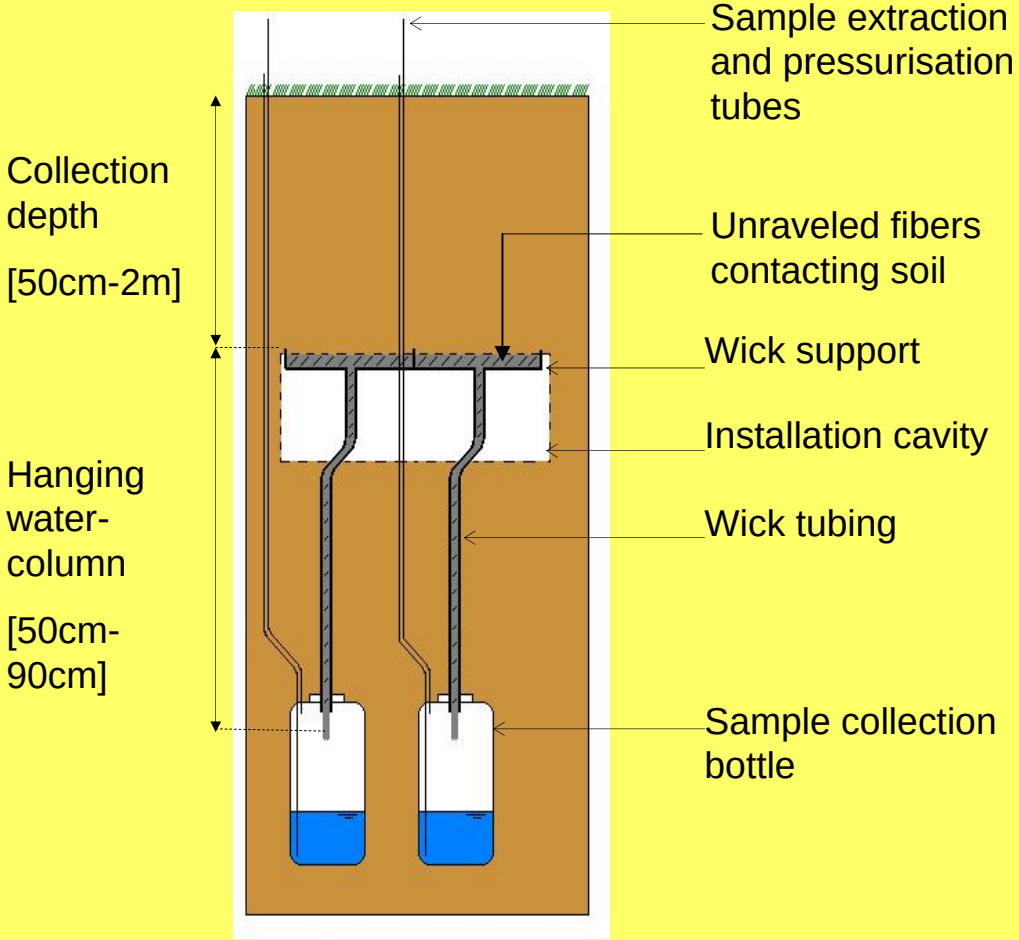


Photography of a wick lysimeter with two cells before installation – unraveled fibers

PRESENTATION OF THE PASSIVE CAPILLARY SAMPLER

Typical design of a passive capillary sampler (PCAPS)

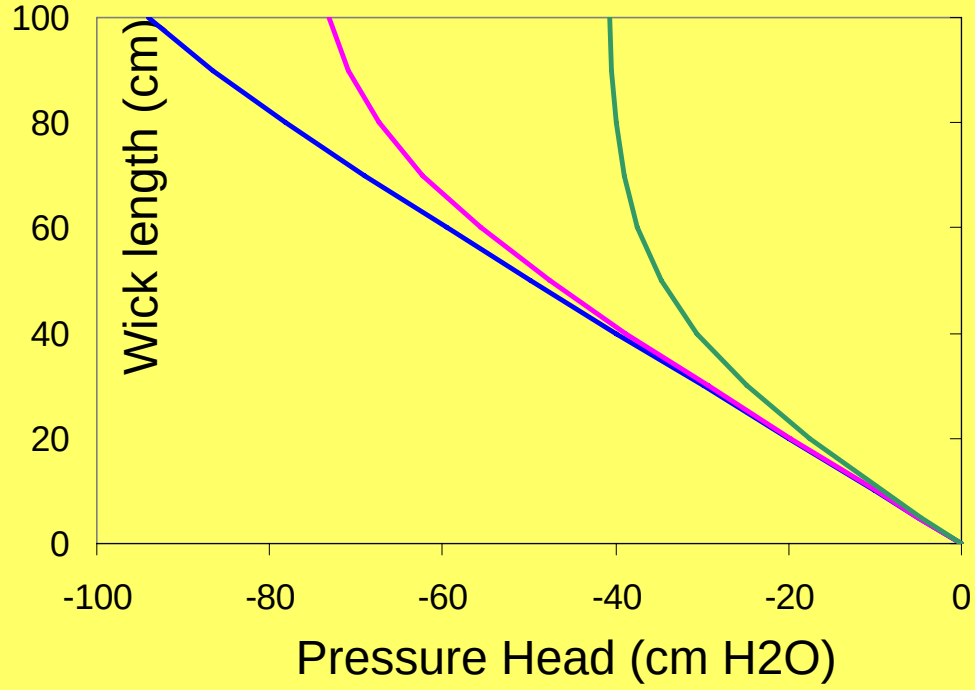


Photography of the lysimeter in contact with the overlying soil – the collector is pressed into the soil by wood blocks

HOW DO PCAPS COLLECT SOIL FLUXES ?

Typical pressure head profiles within a fiberglass wick under different soil flux intensities.

Succion exerted on the overlying soil by a 100cm long wick



Soil flux :

q_s=0,1cm/h

q_s=0,01cm/h

q_s=0,001cm/h

Wick conductivity :

Ksat = 460cm/h

Collection area :

227 cm^2

Wick area :

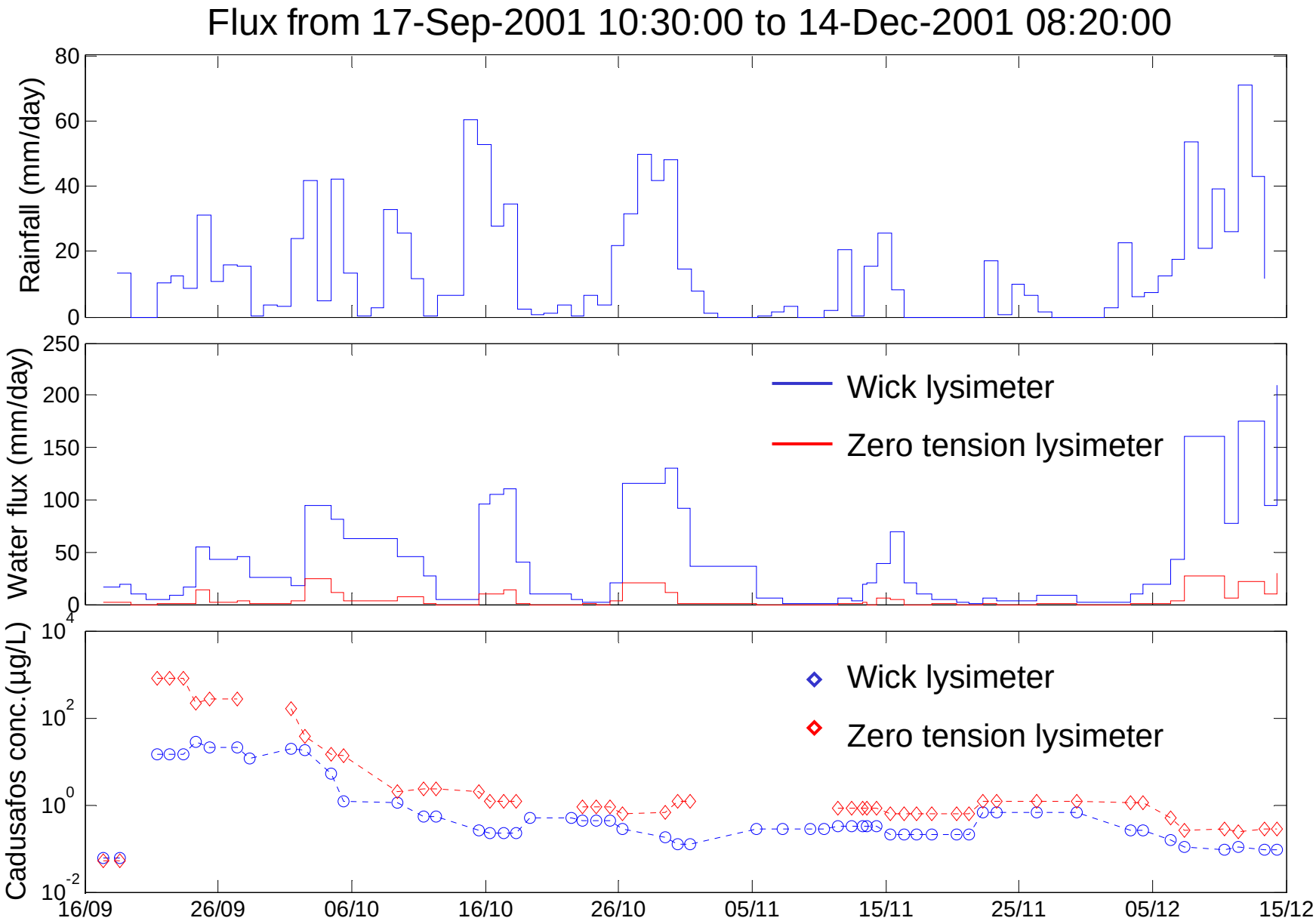
0,7 cm^2

CARACTERISTICS OF THE PCAPS MEASURE

- Unsaturated and saturated fluxes (macropores and matrix)
- Non-disturbed soil volume
- Significant area (typic. 900cm^2).
- No divergent flows
- Continuous sampling
- Non sorbing material
- No additional delay nor dispersion in solute breakthrough
- Well suited for field studies (no external vacuum generator needed, cheap materials)

Very representative measurement of leaching (e≈100%)

EXAMPLE OF MEASUREMENTS (Guadeloupe)



PCAPS MUST BE DIMENSIONNED

In order to achieve a minimal disturbance of the native flow regime,

the wick material, wick length, wick number and the collection area have to be dimensioned

so that the "*soil pressure vs. flow*" conditions of the wick match those of the soil.

Analytical equations have been proposed in the literature :

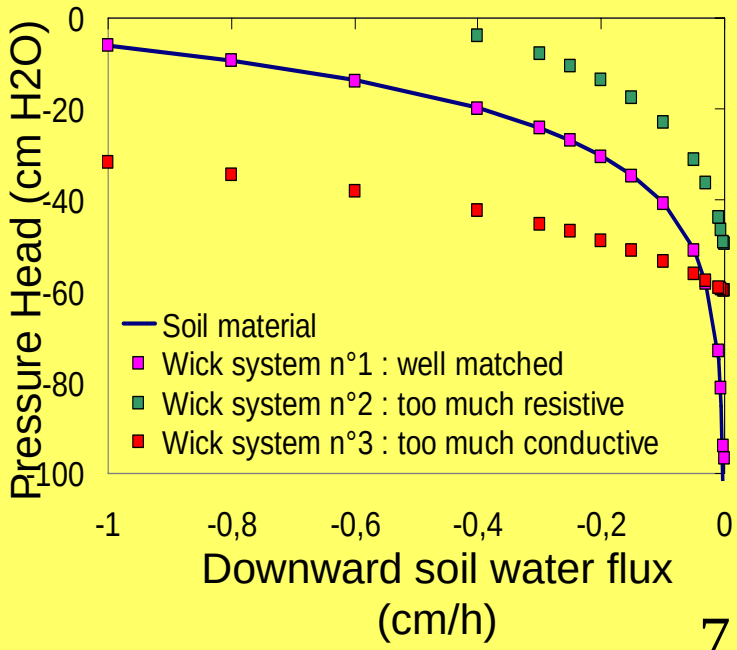
- Holder et al. (1991)

$$number\ of\ wicks = \frac{K_{s\,soil} \times Plate\ area}{K_{s\,wick} \times Wick\ area}$$

- Knutson and Selker (1994)

$$h_s = \frac{1}{a_s} \ln\left[\frac{-q_s}{K_{sat}}\right] \qquad K(h) = K_s \quad e^{ah}$$

$$h_{wick} = \frac{1}{a_w} \ln\left[\exp(a_w L_w)\left(q_s \frac{A_s}{A_w K_{wsat}} + 1\right) - \left(q_s \frac{A_s}{A_w K_{wsat}}\right)\right]$$



QUESTION OF MEASUREMENT UNCERTAINTY :

PCAPS are widely used to determine percolation fluxes…

but there isn't any data on the measurement uncertainty.

two main sources of errors :

•theoretical hypothesis underlying the analytical equations proposed by Knutson and Selker (1994) to dimension PCAPS.

(unit gradient in soil, permanent flow, 1D flow, Gardner model)

•experimental errors associated to parameters used for dimensioning or associated to the PCAPS installation procedure in field.

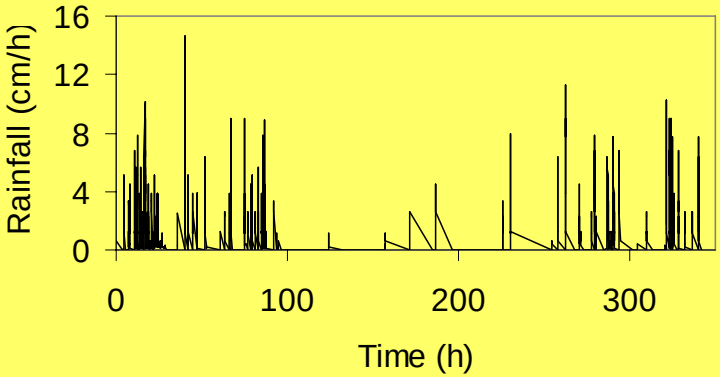
(soil Ks, wick Ks, wick length, effective collection area…)

ERROR ANALYSIS : A NUMERICAL METHODOLOGY

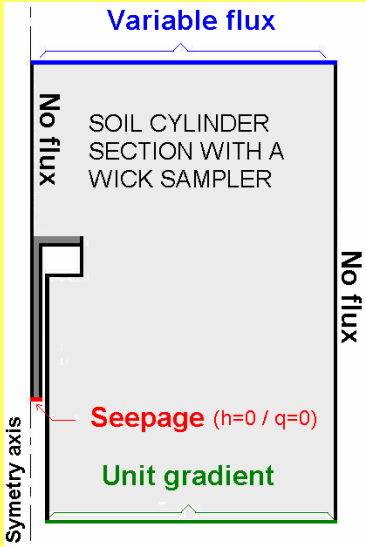
We used the Hydrus 2D code (Simunek et al., 1999), solving the Richards equation without hypothesis for simulating two-dimensional unsaturated flow,

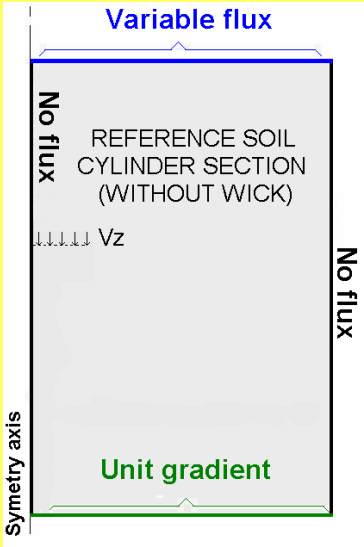
to analyze the deviations of a *soil-instrumented* system in comparison to an *undisturbed system*, in realistic conditions.

Surface condition applied



Boundary conditions used for « soil with a wick sampler » and « reference soil ».

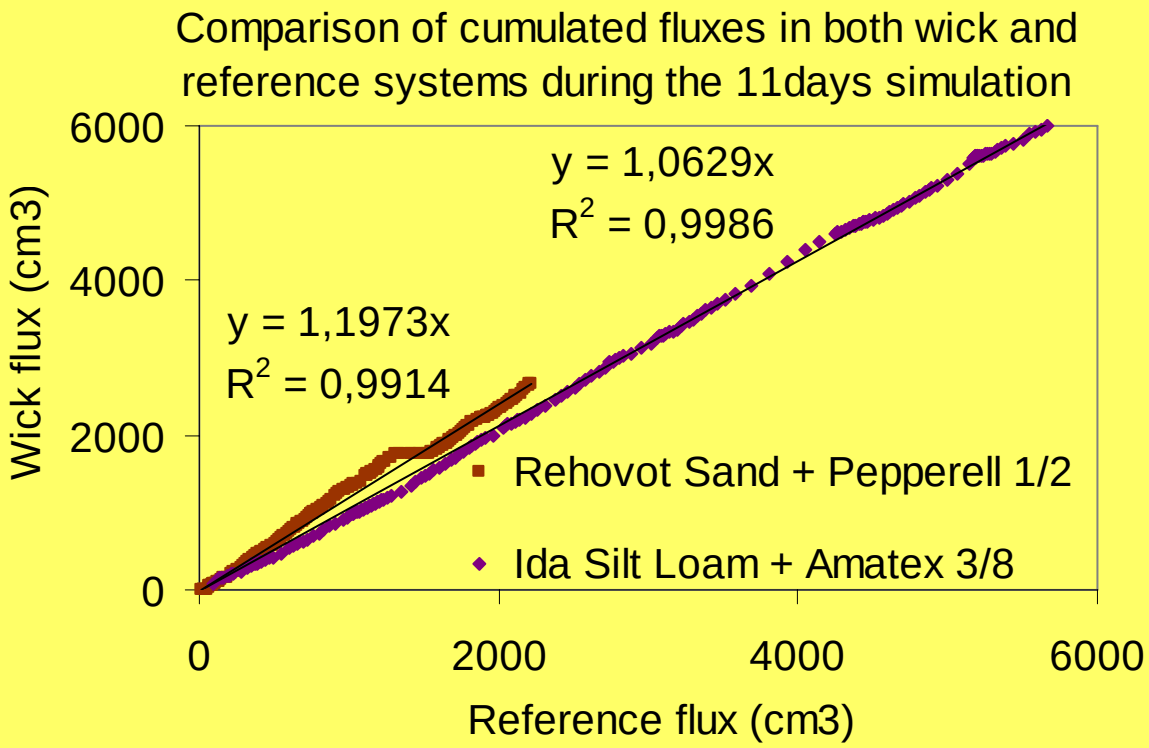




ERROR ANALYSIS : RESULTS 1

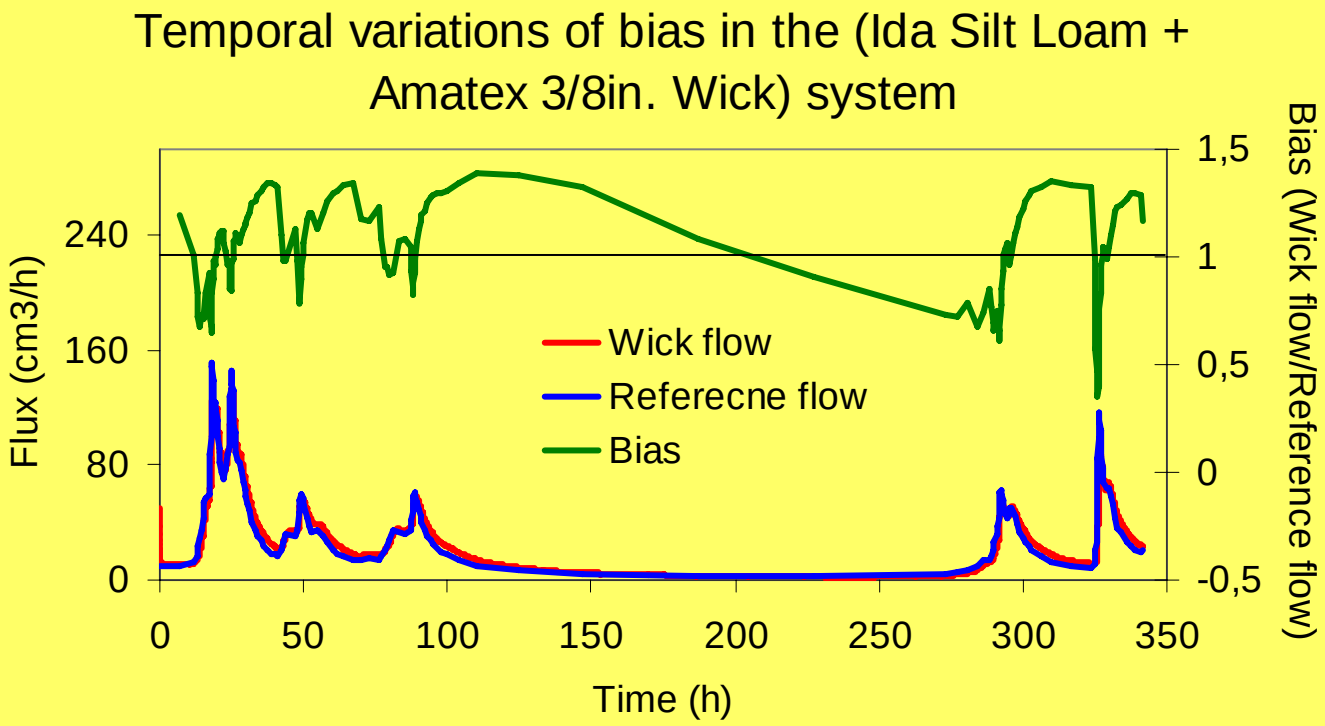
• no significant bias on the wick-extracted volumes with Ida Silt Loam (2%)

•The small bias observed with Rehovot Sand (19%) is due to the fact that soil and wick properties couldn't be perfectly matched.



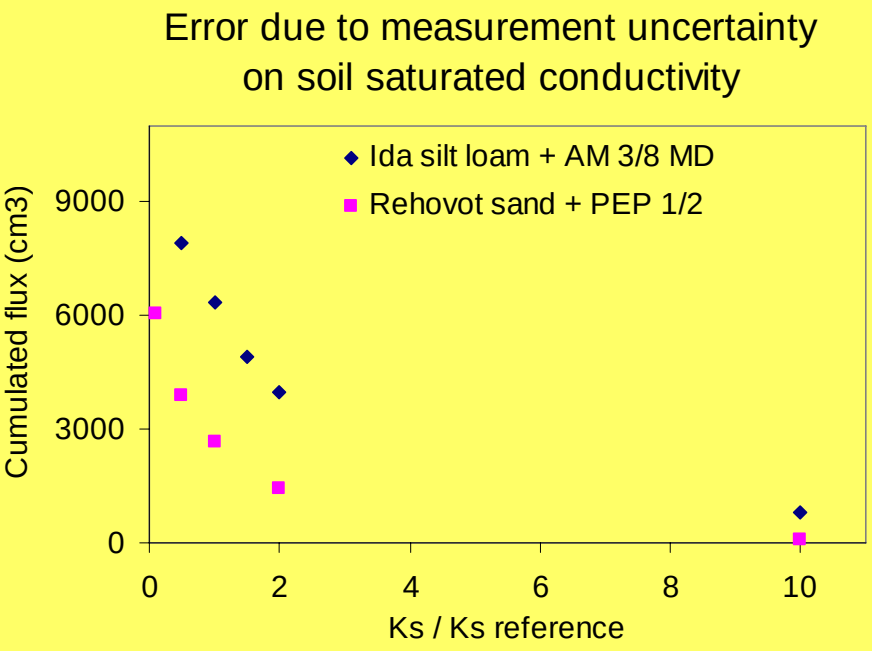
ERROR ANALYSIS : RESULTS 2

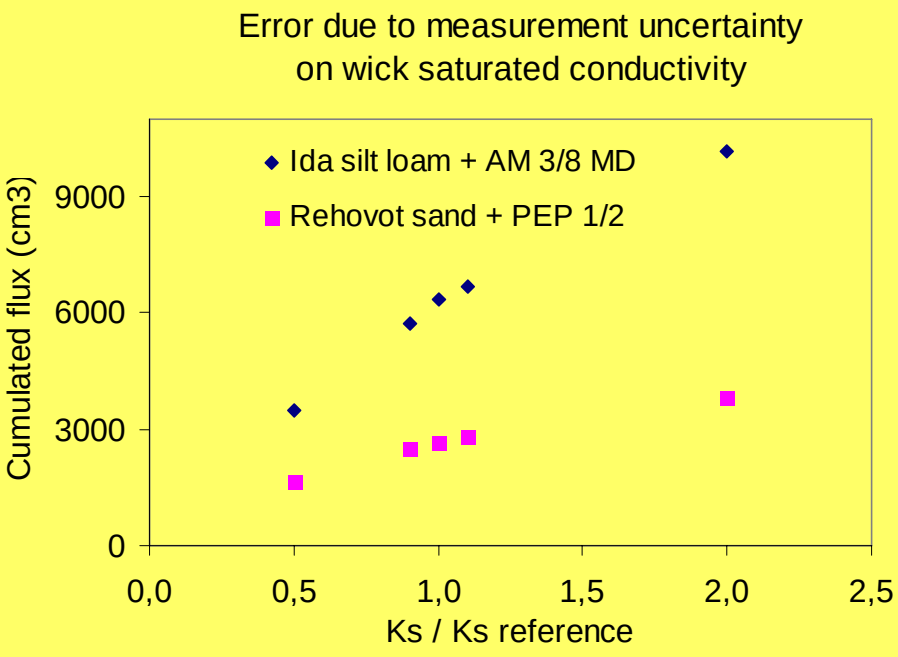
•However, the bias can be significant for short time scale measurements



ERROR ANALYSIS : RESULTS 3

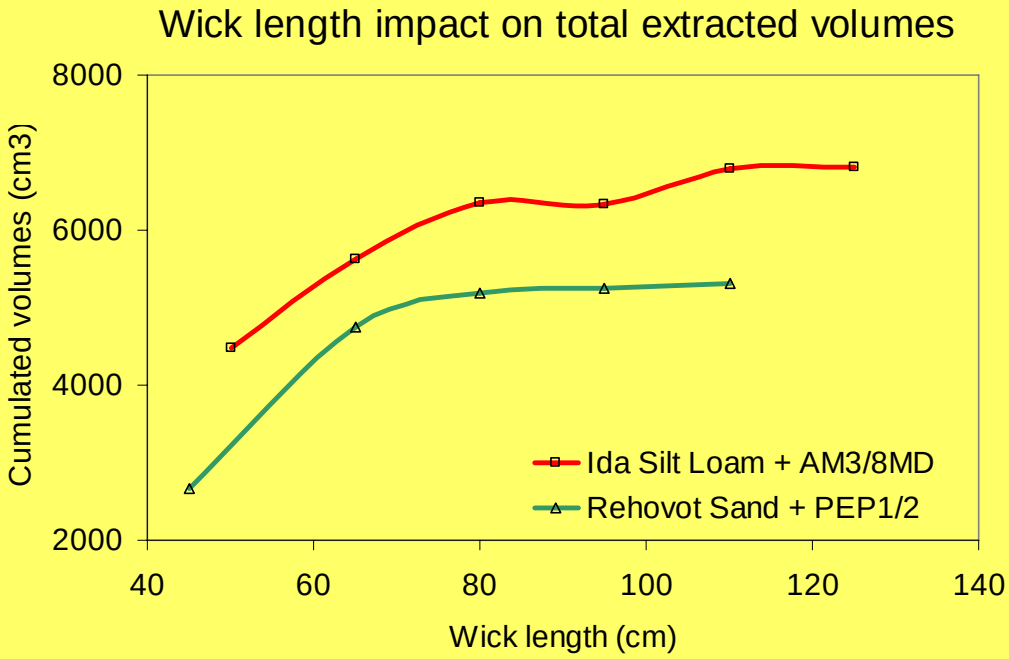
•The typical uncertainties about the hydraulic properties of both soil and wick materials can induce large deviations of wick-extracted volumes





ERROR ANALYSIS : RESULTS 4

•An error made on the wick length can have a large impact on extracted volumes



CONCLUSIONS

- PCAPS are attractive systems that permit a representative measurement of in-situ leaching fluxes (C_{FLUX} and water flux) in the unsaturated zone.

- The hydraulic conductivities of both soil and wick must be measured accurately to have a reliable estimation of flux. Attention should also be taken at the wick length.

- Analytical methods proposed in the litterature to dimension the lysimeter are relevant for Gardner type soils and large time-scale measurement

- A 2D numerical simulation approach should be used in most cases to accurately evaluate the PCAPS efficiency and the measurement bias. It allows to post-correct measured percolation fluxes

Thank you !