Evaluation of the Equi pF Release Curve Apparatus

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1. Objective

The Equi pF device was placed at the disposal of the department of Site Evaluation and Soil Conservation in order test functionality, suitability for daily use, and potential use of this novel device. For that purpose several tests with samples of various texture and origin were carried out. The results were analysed regarding their features of water retention and water conductivity. In addition to the evaluation of the functionality, range of application and market opportunities of the device were analysed.

2. Materials and Method

Seven samples of five materials, mainly sands, were examined. The samples FS and SG are substrates of natural composition; the other samples are mixtures of sand, silt (coarse clay), and clay. Table 1 shows an overview of the samples.

Tab.1: Basic properties of the samples

no.	name	type	volume	height	bulk density	texture		
			cm³	mm	g/cm³	Sand	Silt	Clay
1	FS1	packed	380	50	1,60	97,0	1,5	1,5
2	SGI	packed	365	49	1,55	92,7	5,1	3,2
3	Su2	packed	380	50	1,71	60,4	34,6	5,0
4	SGII	undisturb ed.	380	50	1,55	92,7	5,1	3,2
5	SGIII	undisturb ed..	554	100	1,73	92,7	5,1	3,2
6	Su1	packed	760	100	1,62	88,1	9,9	2,0
7	Sl1	packed	380	50	1,61	71,8	20,0	8,2

For the preparation of packed samples, wet soil with the required bulk density was pressed into testing cylinders. The samples Su1 and Sl1 were conditioned after packing; specifically they were saturated twice and then dried by evaporation.

The unaffected samples SGII and SGIII were taken from a ground exploration in a park at approximately 1 m below ground surface. The sample SGII was collected with an original testing cylinder of the Equi pF device with a height of 5 cm. The sample SGIII was collected with a cylinder with a diameter of 8,4 cm and a height of 10 cm.

The samples were put on a ceramic plate according to the recommendations in the manual. When we expected problems with the surface-to-surface contact between the ground and the plate during the tests FS1, Su2 and SGI, we covered the plate with a thin layer of silt before setting up the soil samples.

The testing cylinders for tests 1 to 4 were covered with the original acrylic glass plate of the Equi pF device.

Since we expected evaporation losses, the remaining samples were closed with a PVC-lid and sealed with modelling clay.

During the experiments with the samples Su1 and Sl1, four Minitensiometers (diameter 4 mm) were vertically installed and the tensions were recorded by a data-logger. After finishing the experiments, the samples were weighed and re-weighed after having been dried for 24 hours at 105 °C.

3. Results

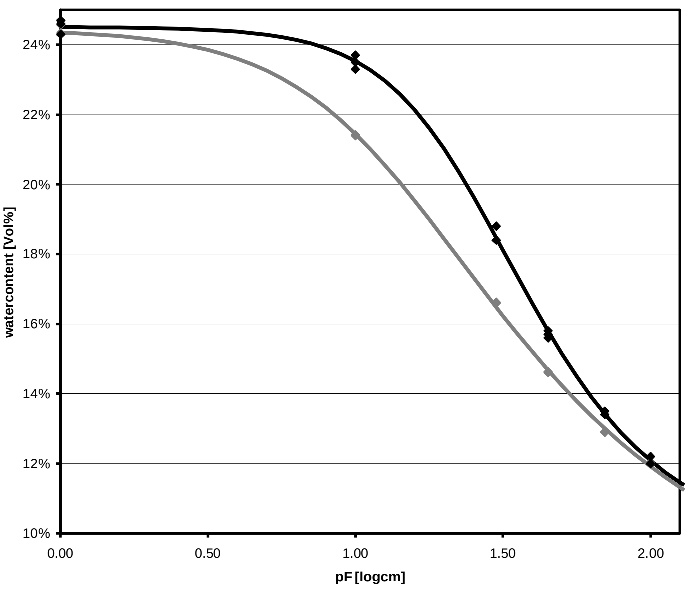
See the datasheets in the appendix (available on request).

4. Evaluation

4.1. Water retention capacity

During the saturation of the samples with a 0 cm water column, between 60 – 80 % of the arithmetical total volume of thepores were filled with water. The duration of a drain cycle (including 5 – 6 steps) took between 1 to 3 days; the rewetting and saturation process took between 3 and 6 days.

Regarding the retention function, almost all samples showed anextremely strong hysteresis between watering and de-watering.



	Drying (black)	Wetting (grey)
θ_s [-]	0.245	0.244
θ_r [-]	0.095	0.077
α [1/cm]	0.0402	0.0761
n [-]	2.247	1.700

Fig. 1.: Fit of Mualem van Genuchten parameters of sample Su1

The results of each watering and drying cycle were reproducible in different ranges. The sample Su1 showed almost identical values and curve progressions.

The samples SGII and SGIII also showed similar curve progressions, but with differences regarding the water content in each cycle. It is obvious that

- The greatest divergence appears in the last saturating step.
- The highest water content occurs in the last de-watering cycle.
- The sample SGIII shows unrealistic values.

The origin of these discrepancies is not known, though they may partly be explained by evaporation losses. Samples SG1 and FS1 showed very different curve progressions. The curve progressions differed clearly in each single cycle. Since those samples were packed and unconditioned, there is likely a process of pore compression and contraction. This error did not occur at the unconditioned samples SGII and SGIII. Also, conditioning the packed sample (Su1, S12) prevents this effect. It is also likely that these progressions could be due to not allowing sufficient time for each suction step to reach equilibrium.

By means of minitensiometers the adjustment of the matric potential was examined during the tests with the samples Su1 and Sl1. It became evident that the matric potentials are achieved according to the selected suction power, and therefore a hydraulic balance is set up (see Fig. 2 and 3).

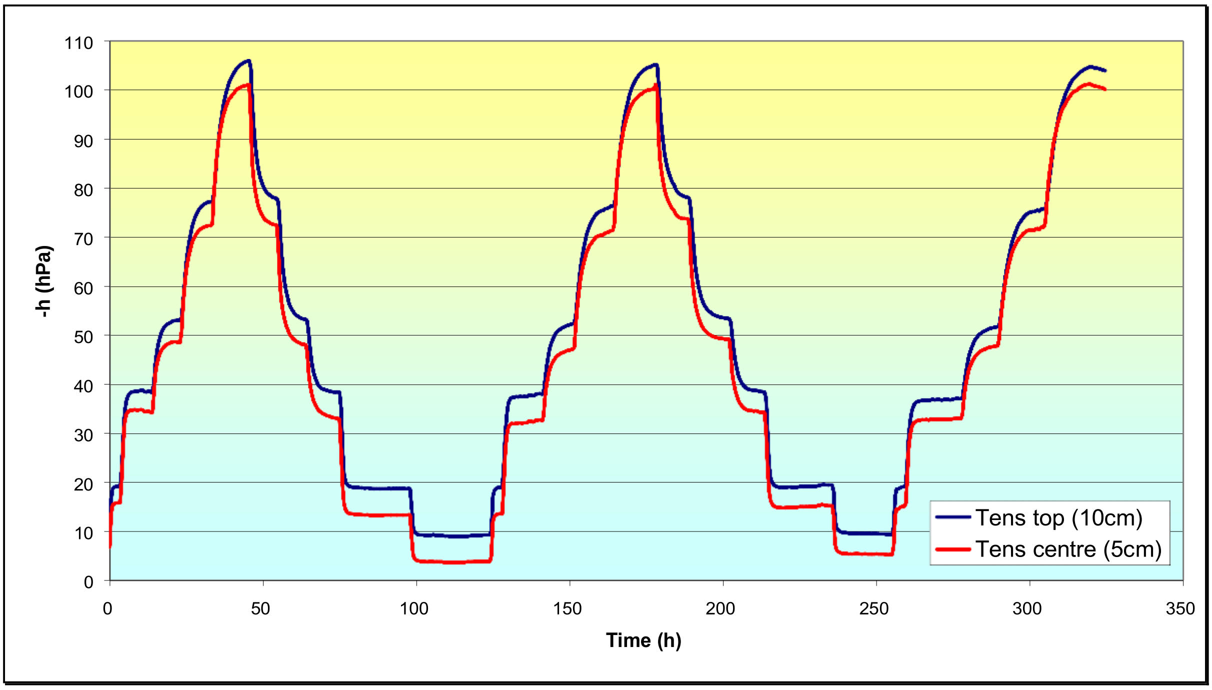


Fig. 2.: Timeline of the tensiometer values in the experiment with sample Su1

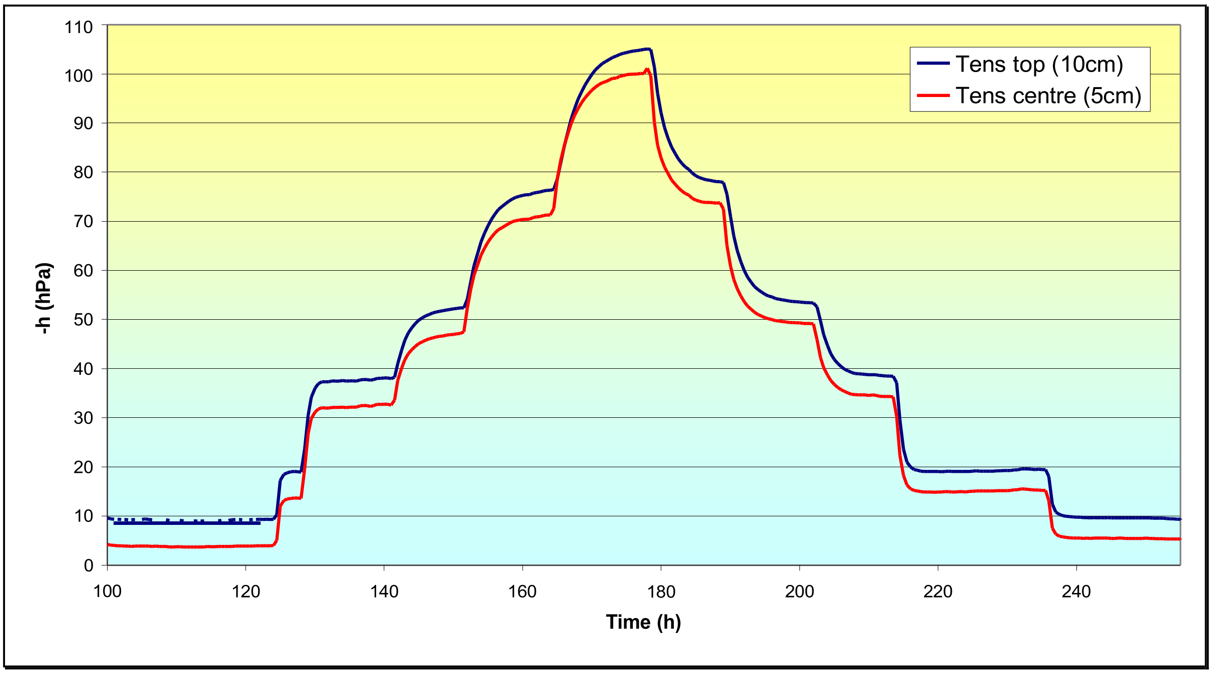


Fig. 3.: Timeline of the tensiometer values in the first drying/wetting cycle of sample Su1

4.2 Waterflux

The water fluxes which were provided by the device for the samples SGI, SGII and SGIII were analysed. Flow rates in the rage of 0,001 – 10 cm per hour were measured. Figure 4 shows the temporal process of watering and drying cycles of samples SGII and Su1. As expected, the highest fluxes appear at the beginning of each step (with high hydraulic gradients) and at low matric potentials. During the wetting cycles, the water flows decline constantly. On the contrary, while drying the flows show steps in the curve.

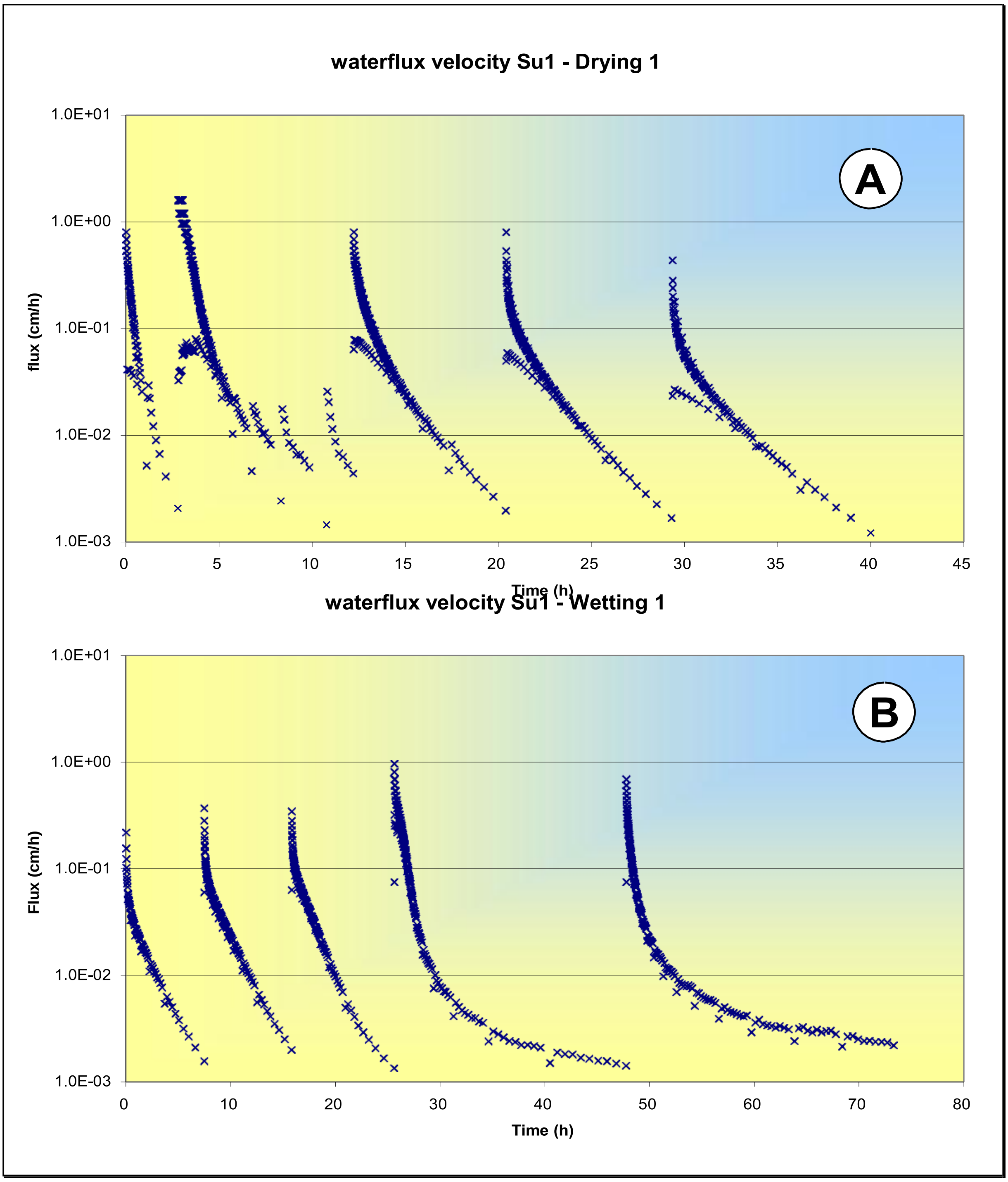


Fig. 4: Outflux (A) and Intflux (B) velocities of sample Su1

Regarding the curve of the cumulative inflow and outflow, all cycles of sample Su1 are very similar. Noteworthy variances only appeared during the first two steps of de-watering. Following that, the reproducibility is almost as good as the water retention function. For sample SGII, the first step in the drying and wetting cycle is clearly different from the following steps. The difference is not explicable.

5. Conclusions

5.1 Application

The Equi pF device allows a very simple, quick and smooth execution of experiments. Preparation as well as execution of a measurement requires little effort. In one case the experiment had to be cancelled, because the second de-watering sequence stopped at sample Sl1. The reason could not be detected. The data of the experiments were quickly available and were easy to evaluate.

5.2 Functionality

The outstanding feature of the Equi pF device is that it is capable of determining the hydraulic behaviour of soil with great accuracy, high resolution (regarding suction and time) as well as exactly reproducible wetting and drying cycles (hysteresis behaviour). It offers a unique insight into the hydraulic behaviour of soil. At the same time the usual errors and disruptions due to repeated weighing of samples did not occur.

Similarly, the program flow guarantees exact adjustment to balance. Due to the nature of the device, the range of measuring is limited to coarse pores allowing a clear determination of water retention only for sandy soil. For examining soil with a higher clay or silt content, further steps of drying have to follow, specifically in pressure cups. A characterisation of the hydraulic conductivity of soil is easy to carry out with the Equi pF device by means of the measured water flow. Nevertheless, an exact determination of ku-values and derivation of hydraulic parameters can not be carried out.