Seasonal variability of near-saturated hydraulic conductivity on cultivated soil

VLADIMIR KLIPA, DAVID ZUMR, MICHAL SNEHOTA

CTU IN PRAGUE, CIVIL ENGINEERING, THAKUROVA 7, 166 29, PRAGUE 6, CZECH REPUBLIC
e-mail: vladimir.klipa@fsv.cvut.cz

Technology Agency of the Czech Republic
GAČR CZECH SCIENCE FOUNDATION

Background

The soil structure and hydraulic properties of arable soils considerably vary during the year due to the periodical tillage and fertilization activities, soil compaction, plant and root grow, climate impact etc. The knowledge of the effect of temporal soil variability is essential when assessing water regime and associated dissolved substance transport in soils. The main aim of this contribution is to describe the temporal development of unsaturated hydraulic conductivity on arable land during a year. Newly developed automatic multi-point mini-disk tension infiltrometer (MultiDisk) was used for determination of near-saturated hydraulic conductivity.

Water level measuring principle

The cumulative infiltration is measured via changes of buoyant force acting on the vertical bar that is immersed in water in the reservoir tube (see Fig. 1). During the infiltration, changes of buoyant force are sensed using electronic load cell to which is attached the vertical bar.

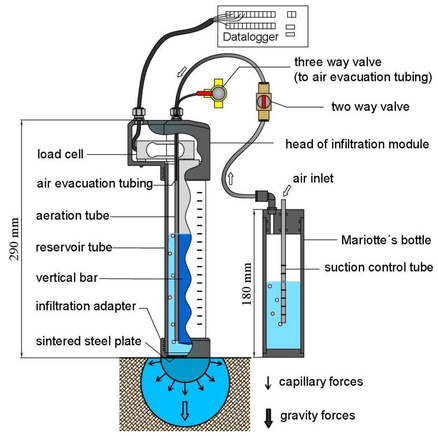

Figure 1 – scheme of automated minidisk infiltrometer module

Measuring equipment – MultiDisk (Generation I)

The automated multi minidisk tension infiltrometr (MultiDisk) consists of aluminum frame and a unit containing a datalogger and a battery.(see Fig. 2). In frame are held six infiltrometer modules which are divided into two triplets. Each triplet of infiltrometer modules is connected to a common control Mariotte´s bottle (suction adjustment).

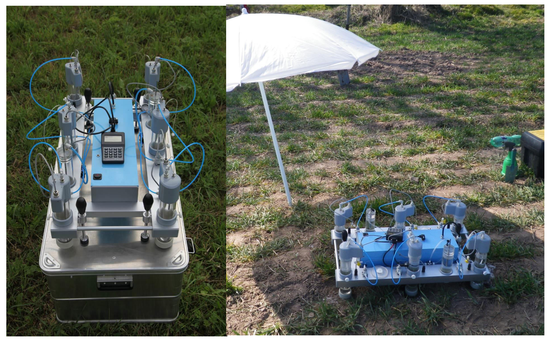

Figure 2 – MultiDisk (Generation I) in experimental catchment Nučice

Experimental agricultural catchment

Catchment

Area:	48.67 ha
Altitude:	410 m a.s.l.
Slope:	4 – 11 %
Land use:	Arable soil
Soil type:	Cambisol
Texture:	Loam – Clay loam

Van Genuchten model param.:
α = 0.048 cm^{-1} ; n = 1.312

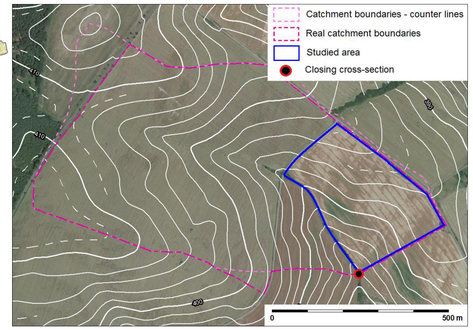

Figure 3 – Upper part of Konojedský stream – studied area is bounded by the blue line

Tension infiltration experiments

- 5 infiltration campaigns in total (i.e. 5x6 tension infiltrations)
- Set suction pressure head - h_0 = -3.0 cm
- Maximum 1 – 3 cm of soil were taken away

Figure 4 – 25.10.2012

Figure 5 – 22.4.2013

Table 2 – Infiltration campaigns

Fig. No.:	Date	Description of field conditions
4	25. 10. 2012	Young winter barley (few weeks after sowing)
5	22. 4. 2013	between postharvest stubble breaking and sowing
6	25. 7. 2013	full-grown oat (1 m high)
7	4. 10. 2013	after fresh postharvest stubble breaking
8	13. 3. 2014	stubble breaking sowed with winter wheat

Figure 6 – 25.7.2013

Figure 7 – 4.10.2013

Figure 4 – 13.3.2014

Results

Typical results of tension infiltration experiment carry out using single tension infiltrometer module are cumulative infiltration (brown line and dots) and mean infiltration rate (red line and dots) (see Fig. 9)

Near-saturated hydraulic conductivity $K(h_0)$ (cm.min^{-1}) is calculated using Zhang`s relationship (1997) [4] after determination coefficients $C_1$ (cm.min$^{-1/2}$) and $C_2$ (cm.min$^{-1}$) by fitting of measured cumulative infiltration $I$ (cm) using Philip`s equation (Philip, 1957) [3] as is shown in the Figure 9.

In equation [4], A_2 is dimensionless coefficient of which expression is dependent on magnitude of van Genuchten`s parametr n (-) (Dohnal et al., 2010).

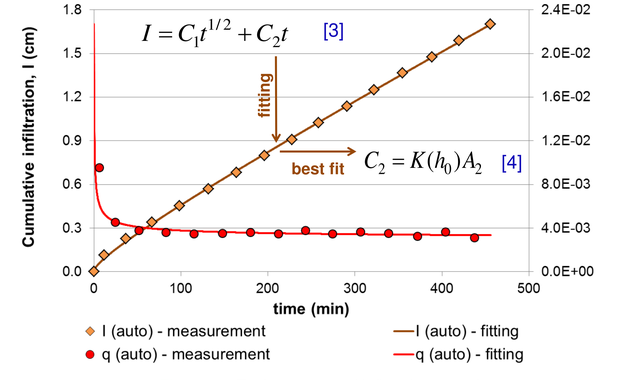

Figure 9 - Typical results of infiltration experiment

Table 2 – Summary of the average values of unsaturated hydraulic conductivity - $K(h_0)$, *initial* (θ_{init}) *and saturated* (θ_s) *water contents and bulk densities* - ρ_d

Date	$K(h_0)$	θ_{init}	θ_s	ρ_d
	(cm min^{-1})	(-)	(-)	(g cm^{-3})
25.10.2012	3.16 10^{-3}	0.33	0.43	1.54
22.4.2013	8.49 10^{-4}	0.23	0.50	1.30
25.7.2013	2.83 10^{-3}	0.15	0.45	1.40
4.10.2013	2.74 10^{-3}	0.37	0.44	1.39
13.3.2014	7.08 10^{-4}	0.27	0.53	1.25

- In April 2013 and March 2014 $K(h_0)$ is about one order of magnitude higher then in the remaining data sets. Bulk densities were low during these measurements.
- According values of bulk density and saturated water content, the lowest bulk density is determined in spring
- The figure 10 clearly shows, that $K(h_0)$ decreases in less compacted soil (low bulk density). This is probably caused by smaller number of small pores that take part in tension infiltration

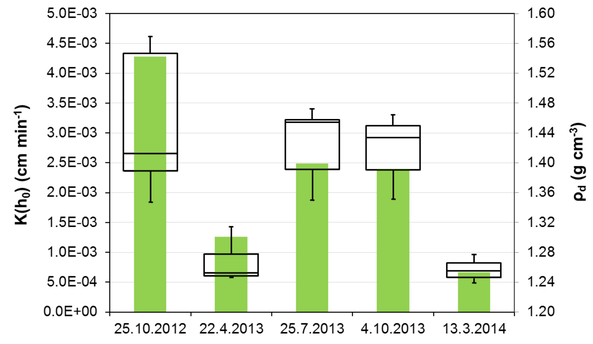

Figure 10 – Statistical evaluation of unsaturated hydraulic conductivity. The bottom and top of the box in the graph represents the 25% and 75% quartiles and the band inside the box represent median. Ends of whiskers represent minimum and maximum unsaturated hydraulic conductivity determined for each experiment. The green columns represent values of bulk densities.

Conclusion

- The instrument MultiDisk proved to be a reliable and efficient tool for the field work
- The connection was observed between unsaturated hydraulic conductivity and compaction of soil
- It is necessary to conduct more measurements to describe temporal variations of K.
- Future measurement will be supplemented with measurement of saturated hydraulic conductivity

REFERENCES

- *Dohnal, M., Dusek, J., Vogel, T., 2010. Improving Hydraulic Conductivity Estimates from Minidisk Infiltrometer Measurements for Soils with Wide Pore-Size Distributions. Soil Sci. Soc. Am. J. 74(3), 804-811.*
- *Philip, J.R., 1957. The theory of infiltration: 4. Sorptivity and algebraic infiltration equations. Soil Sci. 84:257-264.*
- *Zhang, R., 1997. Determination of soil sorptivity and hydraulic conductivity from the disk infiltrometer. Soil Sci. Soc. Am. J. 61:1024-1030.*

ACKNOWLEDGEMENTS

The contribution has been supported by research projects TA ČR No.: TA01021844, GA ČR No.: 13-20388P and SGS No.: SGS14/131/OHK1/2T/11