Investigating spatio-temporal variability of soil moisture in a small farmland: from point to catchment scale

Tailin Li, Nina Noreika, Jakub Jeřábek, Josef Krasa, David Zumr, Tomáš Dostál[1]

[1]Faculty of Civil Engineering, Czech Technical University in Prague, Prague, Czech Republic

EGU General Assembly 2020

Summary

This study aims to investigate the spatio-temporal variability of moisture content in the topsoil of the Nučice catchment, the Czech Republic. To accomplish this, we analysed the temporal dynamics of point soil moisture measurements. Also, we conducted seven detailed field surveys with Hydrosense II probes (Campbell Sci., UK) to measure the spatial moisture distribution at the hillslope-scale, and field-scale. Among all the surveys, we applied geostatistical method (kriging interpolation) with the measured data to identify the spatial patterns of the topsoil moisture content across the field. Besides, we applied hydrological modelling (MIKE-SHE) to simulate the temporal dynamics of soil moisture content at the catchment.

Study area

The study was conducted at the Nučice experimental catchment, the Czech Republic (Figure 1). The catchment (0.531 km^2) has the average elevation of 401 m a.s.l. (ranging from 382 to 417 m a.s.l.) and the average slope of 3.9% (varying between 1% and 12%). The climate condition at the catchment is humid continental: the average air temperature is 6 ℃ with the annual mean precipitation of 630 mm and annual mean evapotranspiration of 500 mm.

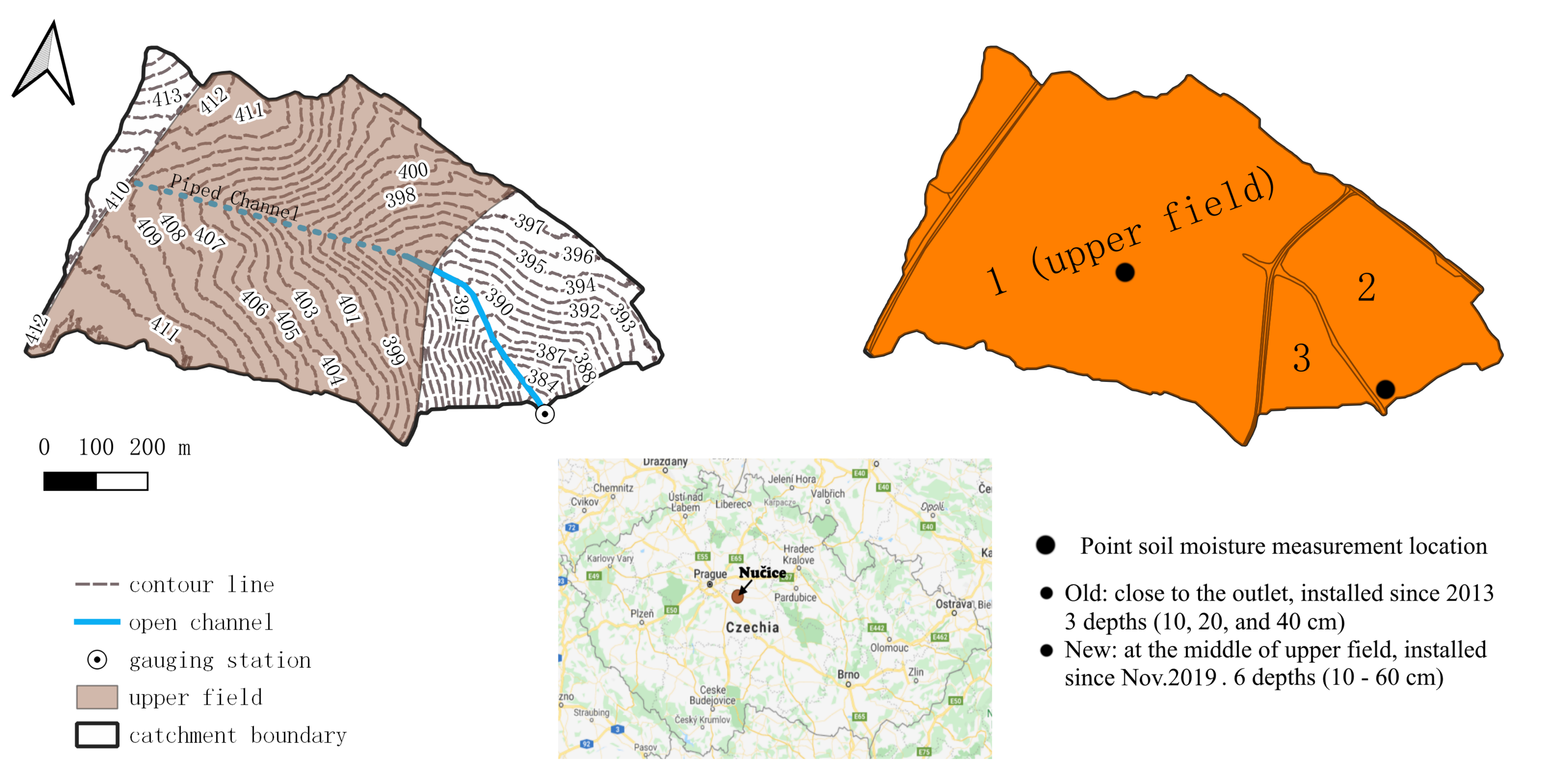

Figure 1: Location of the Nučice catchment

The catchment is mainly covered by farmlands and divided into 3 separated fields (Figure 1) with slightly different agricultural operations conducted during the soil moisture surveys. The upper field covers much larger portion of the catchment and contains only one homogeneous farmland cultivated by one farmer using the same cultivation method.

Method

Temporal dynamics:
Two observation points:
1. Close to the outlet, installed in 2013, 3 depths (10, 20, and 40 cm). Some data gaps between the observation.
2. At the middle of the upper field, installed in Nov.2019, 6 depths (10-60 cm)

Spatial variation:
Number of surveys: 7 detailed field surveys (Table 1) with Hydrosense II probes
Measurement period: Autumn 2019 - Spring 2020 (Table 1)
Measurement depth: 12 cm (topsoil)
Interpolation method: Ordinary Kriging (Equation 1 and 2 were applied to compute the variograms for the Kriging interpolation)

$$\gamma_s(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} (\theta_i - \theta_{i+h}) \quad (1)$$

$$\gamma_e(h) = c_0 + c_1 \left[1 - \exp\left(-\frac{h}{r}\right)\right] \quad (2)$$

Hydrological modelling:
Modelling tool: MIKE-SHE (fully distributed model)
Simulation Period: 01-01-2014 – 12-31-2014
Timestep: 1 hour
Calibration indexes:
1. Runoff
2. Soil moisture (with the observation close to the outlet)

Results

Point measurements (11.17.2019-01.16.2020)

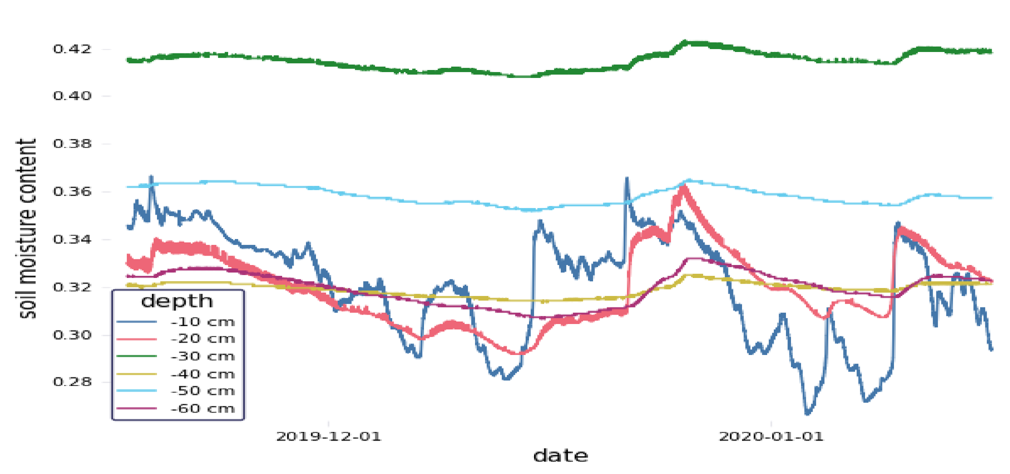

Figure 2: Soil moisture temporal dynamics (upper field)

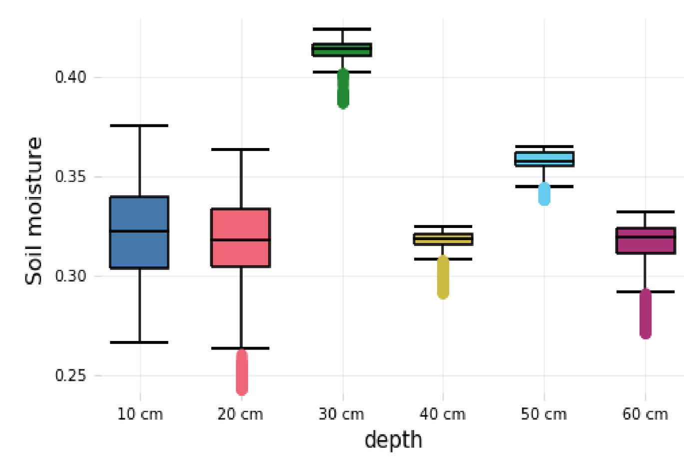

Figure 3: Boxplot (upper field)

Table 1. Summary of the field scale distributed topsoil moisture surveys

Date	number of points	mean soil moisture	standard deviation	scale	7 days antecedent rainfall (mm)	mean temperature (°C)
2019-10-01	1011	19.24	4.54	field	8.80	15.28
2019-10-09	1274	30.93	4.56	whole catchment	24.40	8.28
2019-10-09 (upper field)	1025	30.95	4.49	field	24.40	8.28
2019-11-06	159	24.22	4.95	hillslope	5.50	5.77
2019-11-20	93	33.88	4.74	hillslope	9.10	6.08
2020-01-16	1168	28.49	4.51	field	1.10	2.17
2020-03-19	2043	32.21	4.75	field	2.60	7.29
2020-03-27	936	28.14	6.94	whole catchment	2.00	1.13
2020-03-27 (upper field)	295	32.09	4.96	field	2.00	1.13

Hill-slope and catchment scale measurements

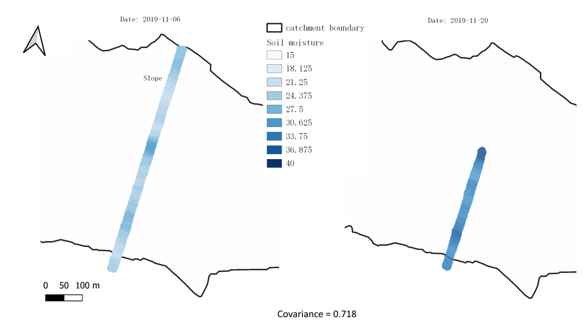

Figure 4: Hillslope scale

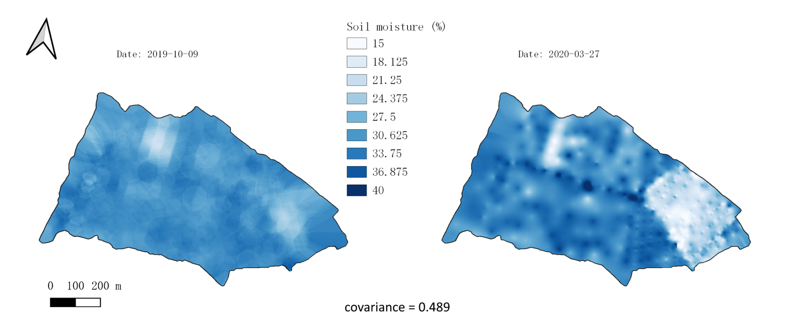

Figure 5: catchment scale

Field scale measurements

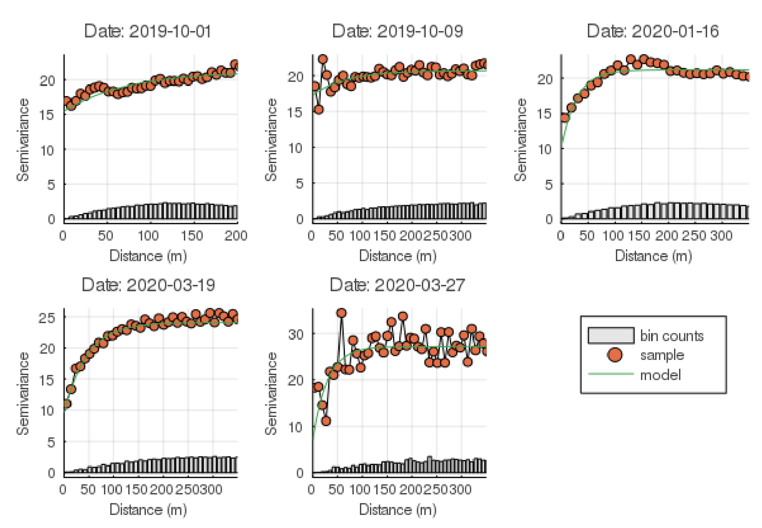

Figure 6: Variogram

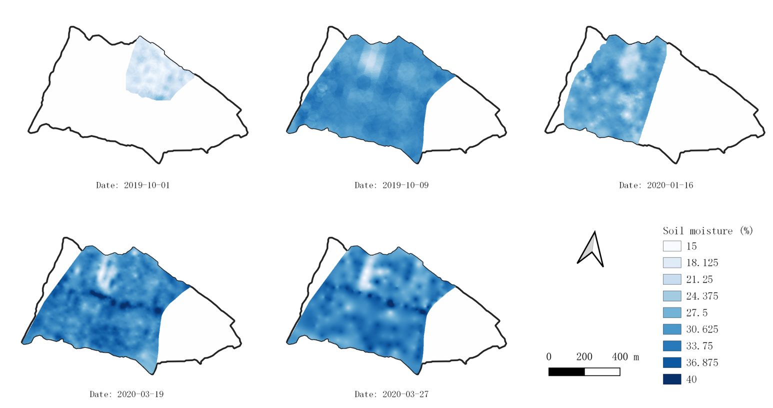

Figure 7: field scale

Simulated soil moisture dynamic with observation

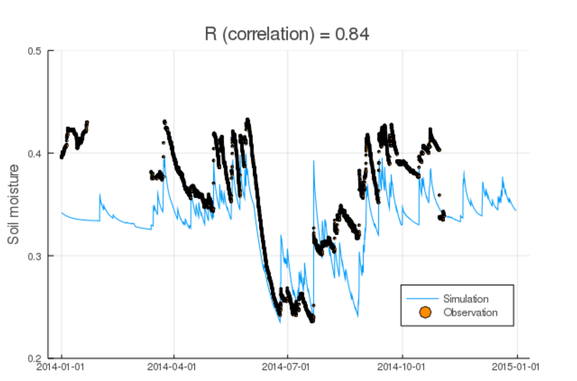

Figure 8: 10 cm Depth

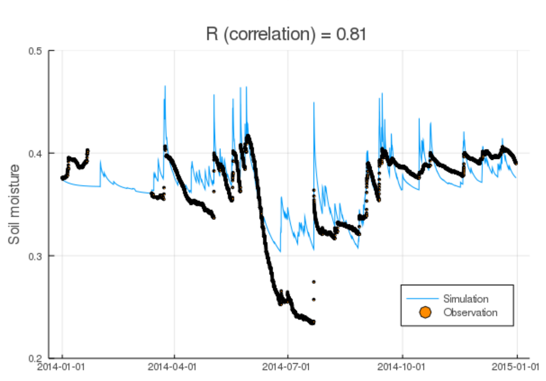

Figure 9: 20 cm Depth

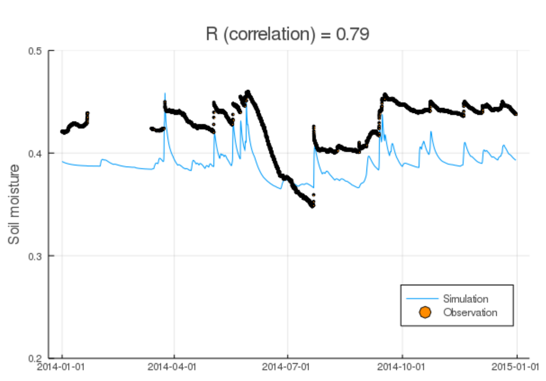

Figure 10: 40 cm Depth

Discussion and conclusion

1. For the point observations, the top soil has a relatively higher temporal variation than the subsoil. However, the soil moisture at the depth of 30 cm has the lowest variation and highest mean soil moisture. It could be a compact soil layer at this depth, which should be considered in the hydrological modelling.
2. For the field surveys with Hydrosense probe, the topsoil moisture content at the catchment is highly dynamic. The spatial mean soil moisture was highly related to the antecedent climate condition. Also, the similarities between the spatial patterns were controlled by the scale/extend of the surveys, the time gap between the surveys, and the land-use/vegetation cover changes.
3. In the MIKE-SHE model, the observation fitted better with the simulation in the top layer than the deeper layer.
4. Future surveys at same extent and spatial resolution should be conducted regularly and combined with other measurements (e.g. remote sensing) and MIKE-SHE model need to be further calibrated.

tailin.li@fsv.cvut.cz