Detailed temporal and spatial topsoil moisture content changes in a small agricultural catchment in the Czech Republic

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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. The spatial patterns were mainly compared with topographic indexes (e.g. elevation, slope, and index of connectivity). Also, we connected the measured soil moisture data with meteorological data to understand the changes of topsoil moisture content with the variation of precipitation and air temperature. We found The spatial mean soil moisture was highly related to the antecedent climate condition. However, the spatial topsoil moisture changes showed a low correlation with geomorphological indexes (elevation, slope, and hydrological index of connectivity). Therefore, the geomorphological indexes cannot be used to anticipate the topsoil moisture distribution 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.

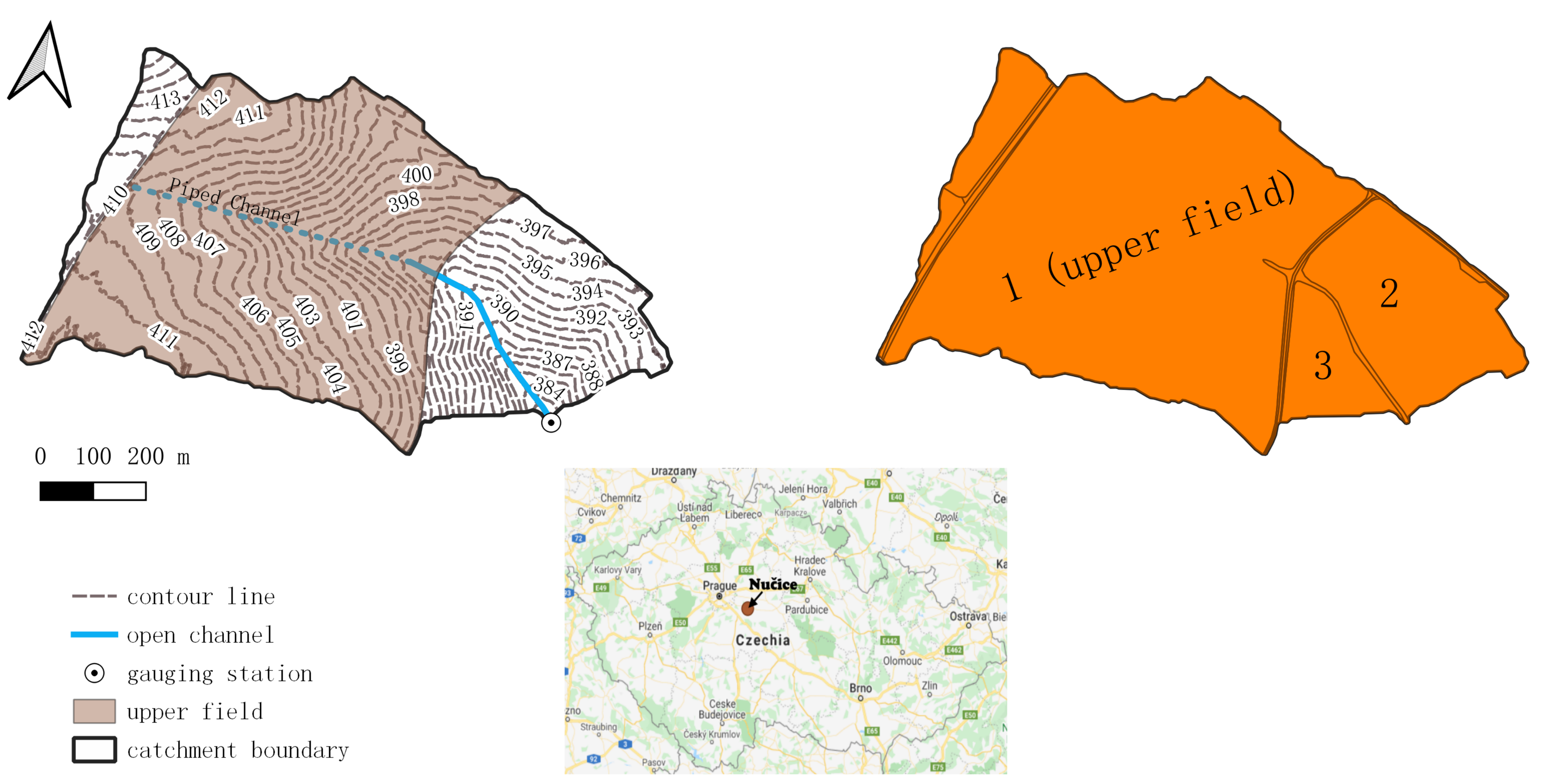

Figure 1: Location of the Nučice catchment

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

Spatial variation:

Number of surveys: 7 detailed field surveys (Table 1)
Measurement period: Autumn 2019 - Spring 2020 (Table 1)
Measurement devices: Hydrosense II probes (Campbell Sci., UK)
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 connectivity index

Software: SedInConnect
Based on DEM of the catchment with 1-meter spatial resolution

Results

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

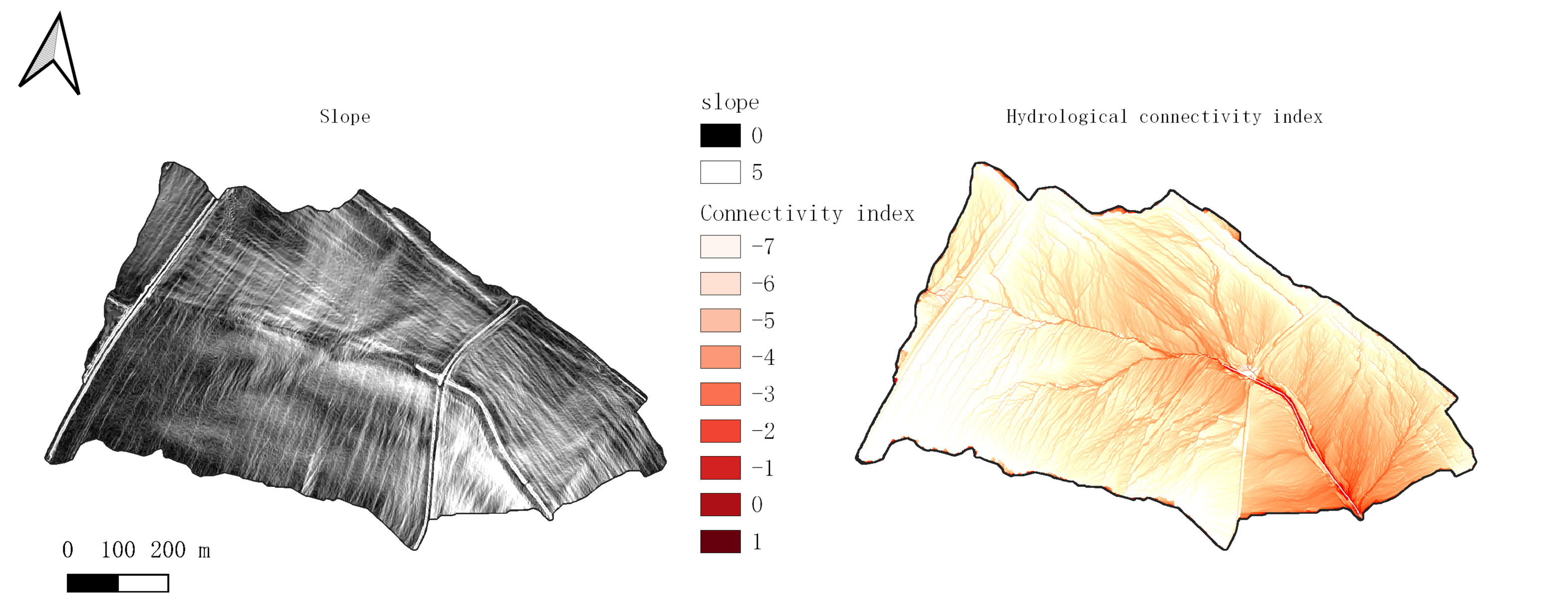

Figure 2: Slope and index of connectiviy

Hill-slope and catchment scale measurements

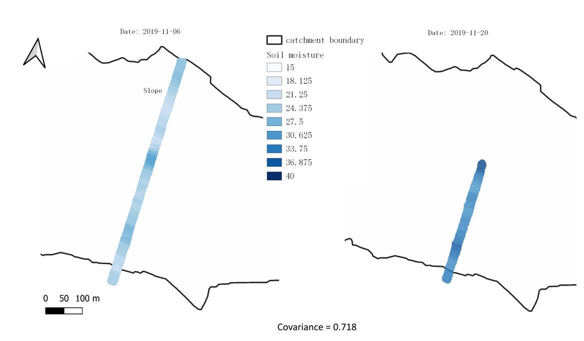

Figure 3: Hillslope scale

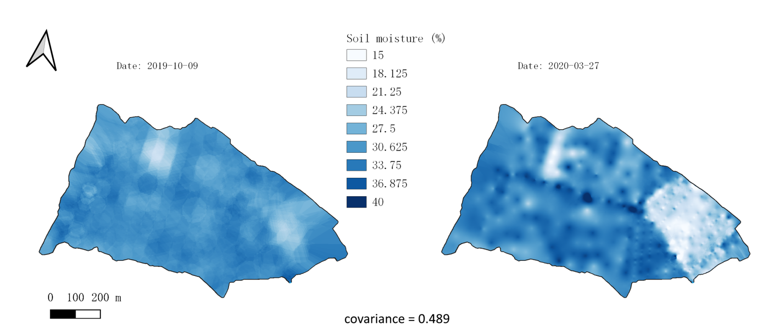

Figure 4: catchment scale

Field scale measurements

Table 2. Correlation between soil moisture and geomorphological indexes

Measurement Date	correlation (with slope)	correlation (with connectivity index)	correlation (with elevation)
2019-10-01	0.041	0.063	-0.209
2019-10-09 (upper field)	-0.056	0.003	-0.111
2020-01-16	-0.011	0.033	-0.077
2020-03-19	0.002	0.043	-0.107
2020-03-27 (upper field)	0.082	0.184	-0.216

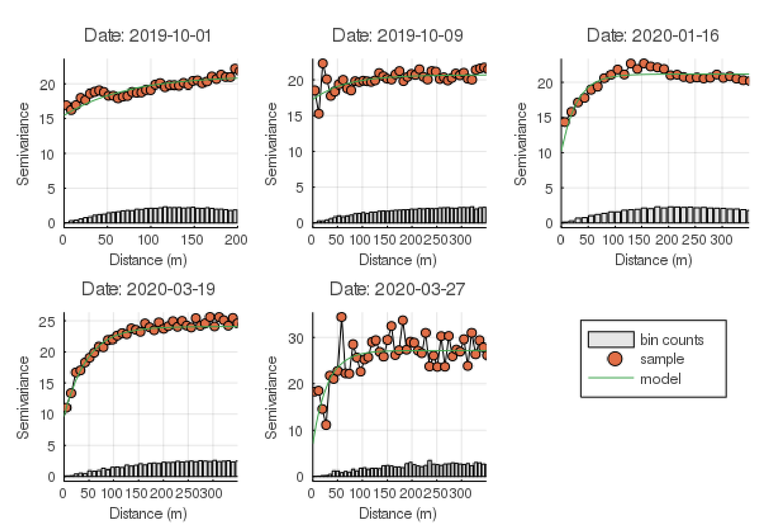

Figure 5: Variogram

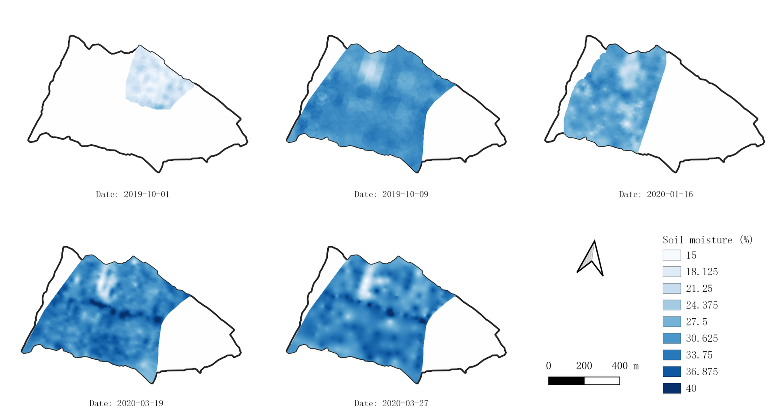

Figure 6: field scale

Outlook

Soil moisture monitoring at the field-scale will be strengthened by using remote sensing and Cosmic-ray soil moisture probes. Also, the identified soil moisture spatial pattern will be further applied in the hydrological modelling of the catchment. Future study will focus on the spatial-temporal changes of the soil moisture within the catchment with hydrological modelling process.

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