



An overview of hydrometeorological datasets from a small agricultural catchment (Nučice) in the Czech Republic

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Abstract: We introduce the freely-available web-based WALNUD dataset (Water in Agricultural Landscape – NUčice Database) that includes both hydrological and meteorological records at the Nučice experimental catchment (0.53 km²), which is representative of an intensively farmed landscape in the Czech Republic. The Nučice experimental catchment was established in 2011 for the observation of rainfall-runoff processes, soil erosion processes, and water balance of a cultivated landscape. The average altitude is 401 m a.s.l., the mean land slope is 3.9%, and the climate is humid continental (mean annual temperature 7.9 °C, annual precipitation 630 mm). The catchment is drained by an artificially straightened stream and consists of three fields covering over 95% of the area which are managed by two different farmers. The typical crops are winter wheat, rapeseed, and alfalfa. The installed equipment includes a standard meteorological station, several rain gauges distributed across the basin, and a flume with an H-type facing that is used to monitor stream discharge, water turbidity, and basic water quality indicators. Additionally, the groundwater level and soil water content at various depths near the stream are recorded. Recently, large-scale soil moisture monitoring efforts have been introduced with the installation of two cosmic-ray neutron sensors for soil moisture monitoring. The datasets consist of observed variables (e.g. measured precipitation, air temperature, stream discharge, and soil moisture) and are available online for public use. The cross-seasonal, open access datasets at this small-scale agricultural catchment will benefit not only hydrologists but also local farmers.

Keywords: agricultural catchment, hydrology, soil moisture, hydrological modelling

1. Data Set Name

WULNUD (Water in Agricultural Landscape-Nučice Database).

2. Site description

The Nučice experimental catchment was established in 2011 with the main aim to study water balance of cultivated fields and rainfall-runoff and soil erosion processes. The catchment is 0.531 km² and located 30 km east of Prague in an agricultural landscape in the Central Bohemian Region, Czech Republic (catchment outlet location: 49°57'49.230" N, 14°52'13.242" E) (Figure 1). The morphological management and climatic conditions are representative of farmlands of the Czech Republic. The area belongs to the moderately hilly Bohemian Massif, the catchment has an average altitude of 401 m a.s.l. and slopes ranging from 1% to 12%. The climate is humid continental with average annual precipitation of 630 mm from 1975 to 2015, mean annual potential evapotranspiration between 500 and 550 mm, and mean annual air temperature of 7.9 °C (Hanel et al., 2013). The catchment is drained by a 950 m long, narrow stream which begins as a subsurface drainage pipe in the uppermost field. The channel has a trapezoidal cross-section that is 0.6 m wide at the stream bed with an average depth of 1.5 m (Zumr et al., 2017).

The area of the catchment is almost exclusively covered by arable land. Less than 5% of the area consists of the stream, paved roads, and shrublands. The fields are tilled to the edge of the stream banks; grass strips are not present. Therefore, the surface runoff and eroded soil may enter the stream without significant transformation in a riparian zone. The catchment is divided into three parcels which have existed since 2000 (Noreika et al., 2020). The standard crop rotation is dominated by winter wheat (*Triticum aestivum* L.), rapeseed (*Brassica napus*), summer oats (*Avena sativa*), and alfalfa (*Medicago sativa*).

The soils are developed on Paleozoic conglomerate and are classified as Haplic Luvisols and Cambisols. The soil texture is considered sandy loam (9% clay, 58% silt, and 33% sand, on average; Zumr et al., 2019). Several geophysical surveys using electrical resistivity tomography (ERT) have been conducted to capture the degree of homogeneity/heterogeneity present in the plough pan and to determine the depth of the

bedrock (Jeřábek et al., 2017). Based on geophysical monitoring and a geological borehole survey conducted at a close-by location, the bedrock ranges in depth from 6 to 20 m. The soil is tilled to approximately 12 cm and below the tilled topsoil there is a compacted plough pan with low hydraulic conductivity that ranges between 10^{-8} m s^{-1} and $2.3 \cdot 10^{-7} \text{ m s}^{-1}$ (Zumr et al., 2015).

The catchment often exhibits dry conditions during the summer and the baseflow recorded at the catchment outlet declines to $0 - 0.2 \text{ L s}^{-1}$, while in winter and early spring the baseflow is around 4 L s^{-1} . The average annual runoff coefficient is 1%. The runoff coefficient is low since the ground water level is usually below the water level in the stream, some water leaves the catchment as unmonitored groundwater flow (Noreika et al., 2020; Zumr et al., 2015). Runoff has a threshold response to rainfall. Based on the measured rainfall-runoff data, we have identified a rather scattered rainfall-runoff relationship with a strong dependence of the runoff on the actual topsoil saturation. Different runoff pathways and runoff mechanisms have been observed. Once the soil moisture conditions are below a certain threshold value, the magnitude of the stormflow is not correlated to rainfall total (Zumr et al., 2015). Therefore, the shallow topsoil and its water holding capacity play a significant role in runoff generation. As the topsoil becomes saturated over a large part of the catchment, water is quickly routed via surface (especially through the compacted wheel tracks in the slope wise direction) and shallow subsurface runoff processes toward the drainage channel. Even though the channel is straight and short, it has a high retention capacity and the flood wave peaks during runoff events are attenuated. The channel serves as a trap for eroded sediment during the summer months due to dense instream vegetation (Zumr et al., 2017).

3. WULNUD (Water in Agricultural Landscape-Nučice Database)

The catchment is equipped with instrumentation for basic meteorological, hydrological, and hydropedological monitoring. Most of the variables are recorded at 5-minute intervals. As the experimental catchment does not belong to the WMO (World Meteorological Organization) nor the Czech Meteorological Institute monitoring networks, the monitoring scheme does not strictly follow WMO

standards. A detailed description of the equipment, including sensor accuracies and calibration frequencies, is listed as Appendix 1.

Discharge is monitored at two locations in the stream. Firstly, in the culvert below the upper field; a pressure probe is installed for water depth monitoring and the discharge is calculated based on the circular culvert free-flow discharge relationships, which has been re-calibrated during flood wave experiments in 2013, 2014 and 2020 (Zumr et al., 2017) when known discharge (ranging from 2 – 40 L s⁻¹) was flowing through the culvert. Secondly, at the catchment outlet there is a flume with an H-type facing with a capacity of 400 L s⁻¹ that is serially connected to a triangular overflow Thomson weir (90° V-notch) installed approximately 5 m further downstream with a capacity of 5 L s⁻¹. The water level is measured in both the flume with the H-type facing and the V-notch weir independently. This setup allows us to measure both high discharge (with the flume with H-type facing) and low discharge (with the Thomson weir), since each has the best accuracy at their respective discharge ranges. The water level is measured by pressure transducers (LMP307, BD Sensors, Czechia, accuracy = ±0.1 %) and a sonic distance sensor (SR50A, Campbell Sci., UK, accuracy = ±10 mm) in the flume with H-type facing. Stream water temperature, electrical conductivity (CS547A, Campbell Sci., accuracy = ±5%), and turbidity (VisoTurb® 700 IQ, WTW, Germany, accuracy = ±0.1 mg L⁻¹) are also recorded. The meteorological station records air temperature, relative humidity (CS215, Campbell Sci., UK, accuracy = ±0.4 °C, RH ±2%), wind speed and direction (03002, R. M. Young, accuracy = ±0.5 m s⁻¹, ±5°), and net radiation (NR Lite 2, Kipp & Zonen, accuracy = ±10 μV/W/m²). The groundwater level is monitored hourly via three 5 m deep piezometers (water level monitored with pressure transducers LMP307, BD Sensors, accuracy = ±2 mm for GWL_1, ±2.5 mm for GWL_2 & GWL_3). The soil water regime is monitored at two points by water content reflectometers (CS650, Campbell Sci., accuracy = ±1%) in the depths between 10 and 60 cm. Two cosmic-rays neutron sensors (Cosmic-Ray Neutron Detector System, StyX Neutronica, accuracy = ±6%; Bogena et al., 2013) are installed in the catchment for larger scale topsoil water content estimation (Figure 1).

Nučice catchment

Three rain gauges (Rain_1 – Rain_3; tipping buckets with 0.1 mm resolution) are distributed across the catchment (Figure 1). Rainfall observations near the catchment outlet (Rain_1) have been measured with an MR3-01s tipping bucket rain gauge (Meteoservis, Czechia) and recorded with a CR1000 datalogger (Campbel Sci., UK) at a 5-minute resolution since 2013 while the rain gauge (RAIN-O--MATIC PRO , Pronamic ApS, Denmark) in the upper field (Rain_2) began recording data at the end of 2019. The Rain_3 gauge was installed during autumn 2020 (during the datanote preparation) and its data will be regularly (every six months) added to the database with the rest of the data. All of the precipitation records in the dataset have been post-processed for quality control assurance (to exclude extreme values caused by measurement errors). The air temperature has been recorded every 10 minutes simultaneously at the same locations as precipitation intensity: near the outlet (Rain_1) since 2013 and at the Rain_2 station from 2019. The dataset contains temperature data including daily minimums, averages, and maximums at both stations. Daily net radiation, mean daily wind speed, maximal/minimal daily temperatures, and relative air humidity are also measured at Rain_1. Additionally, daily reference evapotranspiration (ET_o) is calculated based on the data recorded at location Rain_1. ET_o is calculated according to the FAO methodology (Allan et al., 1998), where ET_o is expressed in terms of the Penman-Monteith ET equation calculated for grass as a reference crop.

For the hydrological data, the stream discharge in the dataset includes the measured discharge at the catchment outlet since the end of 2013. Quality control of the runoff data (removal of extreme values caused by measurement errors) was implemented, and the runoff was saved at a 10-minute time resolution. Based on the runoff observations, one or two peak flows usually happen in the summer after intensive summer storms. In addition, the measurement errors of runoff have often occurred during the winter due to the sensor failure caused by ice cover in the flume (Figure 2). Moreover, the dataset contains temporal soil moisture records from two points: one is located near the outlet (SWC_1; at 3 depths from 10 to 40 cm) since the end of 2013, the other is close to the powerline (SWC_2; at 6 depths from 10 to 60 cm) since the end of 2019 (Figure 1). In general, the soil moisture dynamics (especially the topsoil) are behaviorally

similar to the runoff variation (Figure 2). The soil moisture in the uppermost layer has a higher degree of fluctuation when compared to the deeper layers (Figure 3). To summarize the data and provide a more comprehensive perspective of the observations for each year, we have included metadata and annual reports in the dataset. However, since more devices have been deployed at the catchment recently, the dataset will be updated every six months with the observed data also from the newly deployed devices.

4. Application

4.1 Application of the data

The hydrometeorological dataset in Nučice has been primarily used for the investigation of hydrological responses under the impacts of agricultural activities. Zumr et al. (2015) shows that based on the rainfall-runoff event analysis, the subsurface runoff dominated the storm runoff generation. The topsoil physical properties (bulk density, porosity) exhibited expected changes with topsoil consolidation during a growing season. However, the unsaturated hydraulic conductivity showed inconsistent trends in subsequent growing seasons (Zumr et al., 2019). The data have also been used to calibrate and validate a hydrological model in the Soil and Water Assessment Tool (SWAT) to conduct scenario analysis to determine the effects of crop changes on in-basin water balance (Gómez et al., 2020; Noreika et al., 2020).

4.2 Data availability

The main aim of the WALNUD (Water in the Agricultural Landscape – NUcice Database) dataset is to provide long term data of runoff dynamics and water fluxes within the soil-plant-atmosphere system in an intensively cultivated landscape of the Czech Republic.

The WALNUD dataset is available at <http://storm.fsv.cvut.cz/o-nas/vybaveni/povodi/nucice>. We have also provided guidance to the available data at <http://storm.fsv.cvut.cz/data/files/readme.txt>. Additional data from field campaigns and *ad-hoc* monitoring can be made available upon request to Tailin Li (tailin.li@fsv.cvut.cz) or David Zumr (david.zumr@fsv.cvut.cz). All the data in the dataset are shared under a Creative Commons attribution license (CC BY) and must be appropriately cited.

5. Contributors and data ownership:

Several people, including Master of Science and PhD students, have been involved in the sensor installations, maintenance, fieldwork, and experiments. Tomáš Dostál initiated the establishment of the experimental catchment. The environmental data have been collected primarily by David Zumr (2012-2020), Jakub Jeřábek (2015-2020), and Tailin Li (2019-2020). Nina Noreika analyzed and proofread data for the annual reports and the data note. The research at the Nučice experimental catchment would not be possible without the support of the local farmers Mr. Kopecký and Mr. Morávek. Czech Technical University in Prague has full ownership of the dataset.

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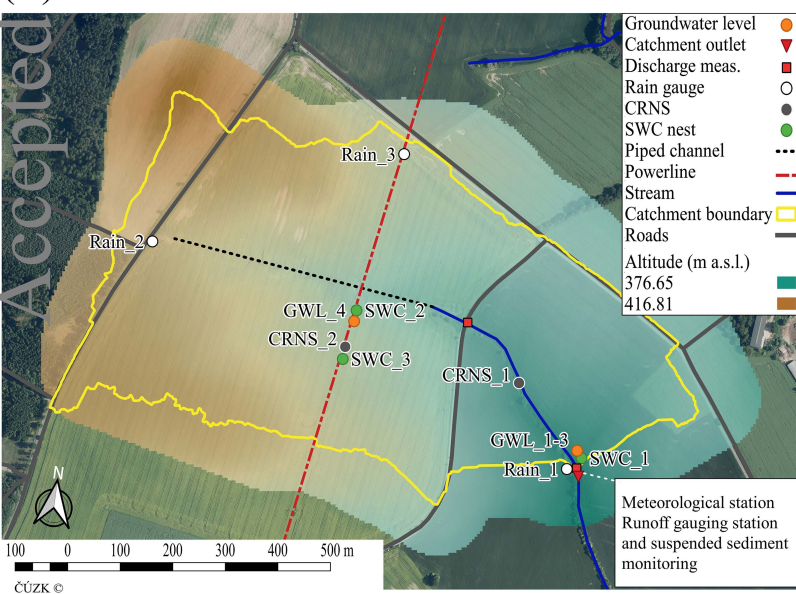
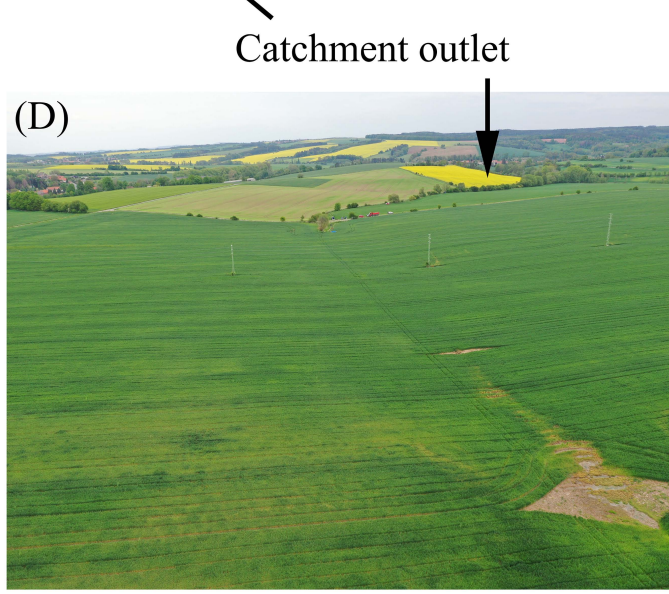
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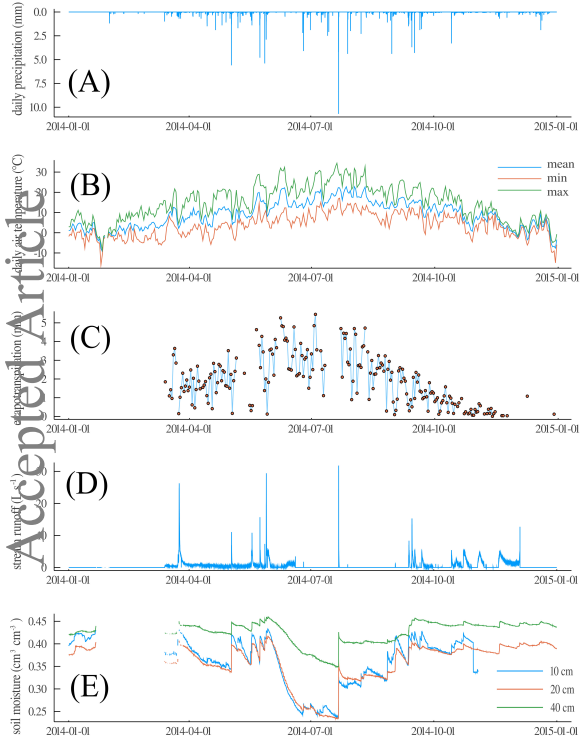
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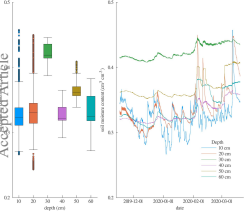
- A: Catchment location
- B: Catchment overview
- C: View from the lower part of the catchment
- D: View from the upper part of the catchment



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Appendix 1. List of sensors in the Nučice catchment

Station ID	Measured variable	Sensor	Manufacturer	Accuracy	Active monitoring period	Datalogger	Temporal resolution (min)	Calibration
Meteo	Air temperature	PT100-XM	Fiedler AMS, České Budějovice, Czech Republic	0.15 °C	2011 - 2016	LEC-3000, Libor Daneš, Roztoky, Czech Republic	10	
	Relative humidity	HS005	J. Tlusták, Praha, Czech Republic	6 % RH	2011 - 2016		10	
	Air temperature and relative humidity	HST		0.15 °C, 6 % RH	2016 - 2020		10	
	Air temperature and relative humidity	CS215	Campbell Sci., Logan, UK	0.4 °C, 2 % RH	2019 -	CR300, Campbell Sci., Logan, UK	5	
	Wind speed	W1	C.T.M. Praha, Czech Republic	0.1 m s ⁻¹	2011 - 2019	LEC-3000	10	
	Wind speed and direction	03002 Wind Sentry	R.M. YOUNG, Traverse City, MI, USA	0.5 m s ⁻¹ , 5°	2019 -	CR300	5	
Rain_1	Precipitation intensity	SR1	J. Tlusták	<9%	2011 - 2020	LEC-3000	10	once a year
	Precipitation intensity	MR3-01s	METEOSERVIS, Vodňany, Czech Republic	<5%	2014 -	CR1000, Campbell Sci., Logan, UK	5	once a year
	Net radiation	NR Lite	Kipp & Zonen, Delft, Netherlands	10 µV/W/m ²	2014 -		5	in 2017
Rain_2	Precipitation intensity	RAIN-O-MATIC PRO	Pronamic ApS, Ringkoebing, Denmark	2%	2018 -	Minikin ERI, EMS, Brno, Czech Republic	1	once a year
	Air temperature	Pt 1000 A-class	EMS, Brno, Czech Republic	0.2 °C	2019 -		1	
Rain_3	Precipitation intensity	MR3-01s	METEOSERVIS,	<5%	2020 -		5	once a year
GWL_1	Ground water level	LMP307i-451 pressure transducer	BD Sensors Buchlovice, Czech Republic	2 mm	2017 -	H40, Fiedler AMS, České Budějovice, Czech Republic	60	once a year
GWL_2	Ground water level	LMP307-451 pressure transducer		2.5 mm	2017 -	MINILOG, Fiedler AMS, České Budějovice, Czech Republic	60	once a year
GWL_3	Ground water level	LMP307-451 pressure transducer		2.5 mm	2017 -		60	once a year
GWL_4	Ground water level	LMP307-451 pressure transducer		2.5 mm	2017 -		60	once a year
Catchment outlet	Large discharge (H-flume)	H-flume, capacity up to 400 l s ⁻¹	based on HOAL, Petzenkirchen, Austria	2-5 %	2011 -			rating curve calibrated in hydraulic lab of TU Vienna, Austria; recalibrated during flood experiments in 2012, 2013 and 2020
	H-Flume water level	LMP307-451 pressure transducer	BD Sensors	2.5 mm	2011 - 2014	LEC-3000	10	4 times a year
	H-Flume water level	LMP307i pressure transducer		1 mm	2014 -	CR1000	5	4 times a year
	H-Flume water level	U-GAGE T30 ultrasonic sensor	Banner Engineering Corp., Mpls, MN, USA	2 mm	2012 - 2016	LEC-3000	10	4 times a year
	H-Flume water level	SR50A	Campbell Sci.	10 mm	2017 -	CR1000	5	4 times a year

	ultrasonic sensor							
Air temperature (SR50A temp correction)	107 termistor probe		0.4 °C	2018 -		5		
Small discharge	V-notch, 90°, capacity up to 4.5 l s ⁻¹		2%	2016 -			rating curve during flood experiments in 2012, 2013 and 2020	
V-notch water level	LMP307-151 pressure transducer	BD Sensors	1 mm	2016 - 2018	MINILOG	60	4 times a year	
V-notch water level	TSH22 pressure transducer and termistor	Fiedler AMS	0.1 %, 0.3 °C	2018 -	H7 Hydro controller, Fiedler AMS, České Budějovice, Czech Republic	10	4 times a year	
Turbidity	ViSolid 700 IQ + DIQ/ S 181	WTW, Xylem Analytics, Germany	0.1 mg l ⁻¹	2013 - 2019	CR1000	10	4 times a year	
Turbidity	S461	Chemitec, Firenze, Italy	5%	2019 -	H7 Hydro controller	10	4 times a year	
Electrical conductivity and water temperature	CS547A	Campbell Sci.	cond 5 %, temp 0.2°C	2016 - 2019	CR1000	10		
Electrical conductivity and water temperature	CS547A		cond 5 %, temp 0.2°C	2019 -		10		
Water sampling (turbidity calibration, stable isotopes)	3700 Full-Size Portable Sampler	Teledyne ISCO, Lincoln, NE, USA		2013 -			event based	
Culvert	Water level and water temperature	TSH22 pressure transducer and termistor	Fiedler AMS	0.1 %, 0.3 °C	2014 -	STELA	10	rating curve during flood experiments in 2012, 2013 and 2020
SWC_1	Soil moisture, temp, el. cond. - water content reflectometer	4 x CS650 in three depths	Campbell Sci.	1%	2015 -	CR1000	10	
SWC_2	Soil moisture, temp, el. cond. - water content reflectometer	6 x CS655 in three depths		1%	2019 -	Microlog, EMS, Brno, Czech Republic	10	
CRNS 1 & 2	thermal neutron counts, air temperature, realtive humidity, pressure	2 x STYX Neutronica detectors	STYX Neutronica, Heidelberg, Germany	water content 6% (Bogena et al., 2013)	2020-	STYX Neutronica, Heidelberg Germany	60	