CURRENT PROBLEMS IN HYDROLOGY

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70th Anniversary of the establishment of the Institute of Hydrology SAS

Book of Extended Abstracts and Posters

Edited by
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Pavla Pekárová, Patrik Sleziak, Lucia Toková, Lenka Botyanszká
(Editors)

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from the conference

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27–29 September, 2023

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Institute of Hydrology of the Slovak Academy of Sciences

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Dear colleagues,

Seventy years represents a period in a person's life that only a few people remember. Even in the existence of a scientific organization, it is a jubilee that should be celebrated. That is why we started organizing this conference a year ago. Its purpose is not only to recall the most significant results of our institute, but also to show what we are currently dealing with, who our collaborators are in Slovakia and in the world, and what the research directions of our organization will be.

Three types of abstracts are included in this collection:

1. *Extended abstracts of presented contributions;*
2. *short abstracts;*
3. *and abstracts with posters from poster sessions.*

On behalf of the organizers of the conference
Pavla Pekárová

Milí kolegovia,

Sedemdesiat rokov predstavuje v živote človeka obdobie, ktoré si pamätá už len málokto. Aj v existencii vedeckej organizácie je to jubileum, ktoré sa patrí pripomenúť a osláviť. Preto sme už pred rokom začali s organizovaním tejto konferencie. Jej účelom je nielen pripomenúť si najvýznamnejšie výsledky nášho pracoviska, ale aj ukázať, čím sa v súčasnosti zaoberáme, kto sú naši spolupracovníci na Slovensku i vo svete a aké budú najnovšie smery výskumu našej organizácie.

V tomto zborníku sú zaradené tri typy abstraktov, ktoré nám boli zaslané do uzávierky tohto zborníka:

1. *Rozšírené abstrakty prenášaných príspevkov;*
2. *krátke abstrakty;*
3. *a abstrakty s postermi z posterových prezentácií.*

Za organizačný výbor konferencie
Pavla Pekárová

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I. Extended Abstracts

PREDICTING THE SATURATED HYDRAULIC CONDUCTIVITY OF AGRICULTURAL SOIL BY PEDOTRANSFER FUNCTIONS OF DIFFERENT PRINCIPLE

Kamila Báťková [1], Svatopluk Matula [1], Markéta Miháliková [1], Eva Hrúzová [1], David Kwesi Abebrese [1], Recep Serdar Kara [1], Cansu Almaz [1]

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ABSTRACT

Saturated hydraulic conductivity Ks refers to the ease with which the pores of saturated soil/rock transmit water. Ks is considered as one of the key parameters in soil hydrology and water transport modelling. Ks determines the water flow behaviour, infiltration rate, runoff generation and deep drainage. Agricultural soil is subjected to the cultivation and fertilisation of its surface layer, which leads to the changes in its hydrophysical properties. Relatively high Ks variability of agricultural soil is caused not only by soil treatment, but also by the plant growth and root development, activity of soil fauna and cracks creation due to soil shrinking, which contribute to the formation of the preferential pathways. Preferential pathways allow faster infiltration and undesirable leaching of herbicides or pesticides into deeper soil layers and/or to the groundwater.

There are various methods for Ks determination in the field and in the laboratory; however none of these methods can be referred to as benchmark or reference method. Suitability of each available method needs to be carefully considered and evaluated. For large or heterogeneous areas, unreasonably high number of replicates would have to be carried out in order to account for the spatial variability of Ks. In 1987, Bouma and van Lannen introduced an alternative approach of Ks determination by means of pedotransfer functions (PTF). The concept of PTF is based on easily available and easily measured soil data (predictors) which are translated into the desired hydraulic parameter (Ks). Soil texture, particle size distribution, dry bulk density and eventually, the organic matter/organic carbon content, are the most common predictors for the Ks estimation. The development of the PTF is going on for more than 30 years. The first types of PTF were tabular values of Ks attributed to the particular soil texture class and linear/nonlinear regression equations. A more recent approach utilises Neural Network analysis, relating the predictors to the Ks value by an iterative calibration procedure. The current technical progress of high-performance computing together with collection of measured hydraulic data into large databases has enabled the development of data-driven methods such as machine learning (ML) in which various types of ML algorithms are utilised (K-Nearest Neighbours, Support Vector Regression, Random Forest and Boosted Regression Trees).

The purpose of this study is to evaluate functionality of three publicly available types of PTF based on different estimation principles and different levels of predictors. In total, ten models of PTF have been applied to the 56 data sets containing essential information of measured Ks value and necessary predictors. The ability of the PTF to reflect the variability of Ks of an agricultural field with relatively homogeneous particle size distribution has been evaluated by means of the correlation coefficient, coefficient of determination, mean error and root mean square error (RMSE). The tested PTF were ranked according to the RMSE values; the best ranking (1) was attributed to the PTF with the smallest RMSE. All statistical evaluation was carried out for log-transformed Ks data.

The experimental field is managed within an experimental research at the Crop Research Institute in Praha Ruzyně. The soil has been classified as Haplic Luvisol (IUSSS Working Group, 2015) and the basic soil properties are displayed in Table 1. The following models of the PTF were selected for testing: two ML-algorithms with three levels of predictors from the ML-based PTF App of Araya and Ghezzehei (2019); two

hierarchical models based on the neural network (NN) analysis incorporated into modelling program Rosetta (Schaap et. al. 2001); and the continuous PTF of Wösten et al. (1998) applied in their original form and also with the newly derived regression parameters specific for the silty clay loam texture of the soil under investigation. The parameters were derived based on the Czech database of Soil Hydraulic properties HYPRES CZ (Miháliková et al., 2013). Applied PTF models, utilised predictors, resulting RMSE values and ranking of each PTF model are summarised in Table 2.

Table 1. Measured Ks values and basic soil properties of the experimental site in Praha-Ruzyně

	OM (%)	**C_{ox} (%)**	**Dry bulk density ($g\ cm^{-3}$)**	**Clay (%)**	**Silt (%)**	**Sand (%)**	**Particle density ($g\ cm^{-3}$)**	**Ks ($cm\ day^{-1}$)**
Min	1.241	0.720	1.13	22.0	54.2	8.0	2.60	**10.2**
Max	3.362	1.950	1.62	33.5	65.5	19.0	2.64	**1261.2**
Average	2.339	1.357	1.35	30.2	57.2	12.6	2.62	**336.8**
St.dev.	0.476	0.276	0.12	3.3	3.3	2.7	0.02	**271.4**

Table 2. Applied PTF, corresponding predictors and functional PTF evaluation

PTF model	**Method**	**Predictors**	**Reference**	**RMSE**	**Ranking**
BRT 3-0	Boosted regression trees	% sand, % silt, % clay	Araya and Ghezzehei (2019)	1.385	7
BRT 3-1	Boosted regression trees	% sand, % silt, % clay, BD ($g\ cm^{-3}$)	Araya and Ghezzehei (2019)	1.587	9
BRT 3-2	Boosted regression trees	% sand, % silt, % clay, BD ($g\ cm^{-3}$), C_{ox} (%)	Araya and Ghezzehei (2019)	1.314	5
RF 3-0	Random Forest	% sand, % silt, % clay	Araya and Ghezzehei (2019)	1.238	3
RF 3-1	Random Forest	% sand, % silt, % clay, BD ($g\ cm^{-3}$)	Araya and Ghezzehei (2019)	1.682	10
RF 3-2	Random Forest	% sand, % silt, % clay, BD ($g\ cm^{-3}$), C_{ox} (%)	Araya and Ghezzehei (2019)	1.456	8
Rosetta-SSC	Neural network	% sand, % silt, % clay	Schaap et al. (2001)	1.348	6
Rosetta-SSC+BD	Neural network	% sand, % silt, % clay, BD ($g\ cm^{-3}$)	Schaap et al. (2001)	1.235	2
Wösten-original p.	Non-linear regression analysis	% silt, % clay, OM (%), BD ($g\ cm^{-3}$), topsoil	Wösten et al. (1998)	1.273	4
Wösten - own p.	Non-linear regression analysis	% silt, % clay, OM (%), BD ($g\ cm^{-3}$), topsoil	Wösten et al. (1998)	0.521	**1**

**Note: BD = dry bulk density, Cox = organic carbon content, OM = organic matter content, topsoil is a qualitative variable with a value 1 for topsoil, and 0 for subsoil*

The results showed a high Ks variability within the agricultural field; the measured data ranged from 10 to 1261 cm/day. The soil reflected the temporal variability caused by tillage operations, which is difficult to describe by the predictors (Figure 1) The best and the only estimates with acceptable accuracy comparable to other published studies were provided by the continuous PTF in a form by Wösten et al. (1998) for which own regression parameters were derived. The involvement of the data from the HYPRES CZ database into the background database of the ML-based PTF might lead to the improvement of their estimates. More details from this study and PTF application on the soils in the Czech Republic can be found in the papers published in Soil and Water Research, 18, 2023 (1): 25-32 and Plant, Soil and Environment, 68, 2022(7): 338-346.

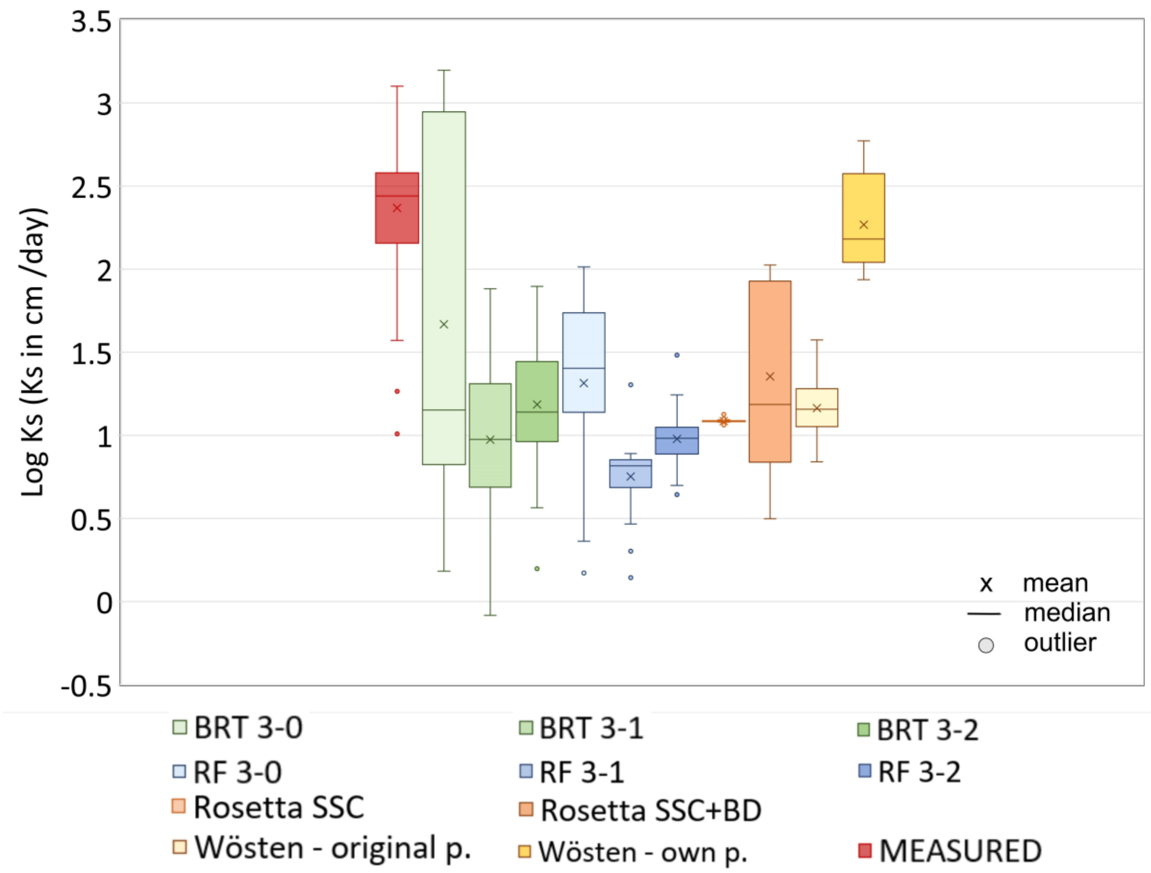

Figure 1. Graphical comparison of the measured and estimated Ks values

Keywords: soil hydraulic properties, estimation accuracy, machine learning, artificial neural network, non-linear regression

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HYDROLOGICAL RESEARCH IN THE JALOVECKÝ CREEK CATCHMENT

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ENLARGED ABSTRACT

Hydrological research in the Jalovecký Creek catchment (the Western Tatra Mountains, area 22.2 km^2, mean elevation 1500 m a.s.l.) started at the end of the 1980'. It means that it lasts about a half of the existence its parent organization, Institute of Hydrology of the Slovak Academy of Sciences (IHSAS). The overall mission of the research is to increase the knowledge on hydrological cycle in the highest part of the Western Carpathians which is regional water tower of northern Slovakia and southern Poland.
Hydrological research catchments remain worldwide an important tool in obtaining hydrological knowledge. It is documented by a number of operating catchments that were recently reviewed in several inventories published online or in thematic issues of journals:
(https://publicaciones.unirioja.es/ojs/index.php/cig/issue/view/206;
https://onlinelibrary.wiley.com/doi/toc/10.1002/(ISSN)1099-1085.research-catchments;
https://experimental-hydrology.net/wiki/index.php?title=Category:Experimental_Catchments)

Despite a long tradition in former Czechoslovakia, systematic hydrological catchment research is currently conducted in Slovakia only in the Jalovecký Creek catchment. Its main themes include monitoring of basic hydrological and meteorological variables and research of the water balance, snow accumulation and melt and runoff formation in the mountain environment. The objectives of our presentation are to summarize the main results obtained in the last decade (i. e. since the 60 years' anniversary of the IHSAS) and assess the main research themes for the future. The summary is based on approximately 70, mostly journal publications. Much of the work was also presented in three chapters of Halmová and Kováčová (2018).
Catchment monitoring provided the data series that are already more than thirty years long. It was therefore meaningful to examine if and which data series exhibited sings of trends or abrupt changes in the period 1989-2018 (Holko et al., 2020a, 2020b). Sgnificant trends or abrupt changes were not found. However, several time series (the flashiness index, number of flow reversals, annual and seasonal discharge maxima, runoff coefficients) indicated that hydrological cycle became more dynamic in the last years of the study period and more precipitation run off since 2014. Temporal evolution and maximum of the snow water equivelent (SWE) did not exhibit substantial changes either, but the diel cycles in the streamflow during the snowmelt period disappeared in the month of June since 2010 (Holko et al., 2021). The highest peak discharge (22.5 m^3.s^{-1}) observed since the beginning of measurement at catchment outlet (1987) occured in 2014 (Danko, 2014). The extended monitoring of summer rainfall in summer seasons 2013-2015 (June to September) revealed that the altitude explained only about 60% of precipitation variability even for seasonal totals (Holko et al., 2015). The rainfall-elevation relationships seemed to be less scattered in the drier years. The extended rainfall data confirmed that it rained more and more often in the mountains, but the differences in the number of rainy days were not big in the drier years.
Snow accumulation and melt research utilized the long-term data to investigate the relationships between the SWE in the forest and open area (Danko et al., 2014) and derive the equations to estimate the SWE from measured snow depth for mountain areas of Slovakia (Holko et al., 2022). We have tested several new methods of the snow and snowmelt characteristics measurements including GPS, liquid water content of the snowpack, ground thermometers, registering snow lysimeters and passive capillary samplers (Danko et al., 2016; 2017; Krajčí et al., 2016; Penna et al., 2014). We have also contributed to international comparison of the snow bulk density and water equivalent measurements (López-Moreno et al., 2020) and preparation of

the European Snow Booklet (Haberkorn, 2019). A new method of the snow line estimation from the satellite images was proposed (Krajčí et al., 2014a). Its application in the Upper Váh River catchment in winters 2001-2013 (Krajčí et al., 2014b) showed that the snow line elevation during the significant increase of spring discharges is usually around 1500 m a.s.l. which means that approcimately only 14% of the catchment remains covered by the snow at that time. The spatially distributed SWE simulation for winters 2002-2014 (Danko et al., 2015) provided among other also the information about the snowmelt water outflow (between 291 mm and 677 mm in particular winters) and snow sublimation (41 mm - 60 mm).
The runoff formation research included various activities related to processes affecting the pathways and timing of water movement in the catchment from precipitation or snowmelt to the streams. An important part of this research that was not studied so intensively in the catchment before, was related to soil water in mouintain soils. These soils are typical for their high stoniness. It was shown that the rock fragments can substantially decrease the soil water storage (Hlaváčiková et al., 2018) and the shape and orientation of the fragments influence modelled soil hydraulic conductivity (Hlaváčiková et al., 2016a). It was shown that the spatial variability in the soil moisture at a small plot scale can be greater than its seasonal variability (Hlaváčiková et al., 2016b). The soil moisture measurements at different depths were used to identify the preferential flow that occured approximately in one half of the rainfall events (Hlaváčiková et al., 2017). Compared to the open area site covered with grass, the forested site had more macropores. The number of macropores decreased with soil depth at all study sites and the contribution of macropores to the water infiltration ranged between approximately 60% and almost 100% (Hlaváčiková et al., 2019). The importance of studying the soil water regime is highlighted by finding that the simulated soil water outflow hydrographs were similar to (measured) catchment runoff hydrographs in approxiamtely one half of the selected rainfall events (Mujtaba et al., 2020).
A novel setup of the electrical resistivity tomography was proposed and used to visualize water infiltration into the soil (Kostka and Holko, 2016, 2017), The measurements documented shallow infiltration of the water into the soil and lateral movement of the infiltrated water along the slope. A number of irrigation experiments with a small rainfall simulator indicated that the overland flow is the studied part of the catchment was mostly quite small, i. e. below 10% (Holko et al., 2018). The pre-event water contribution to peak flow during the rainfall-runoff events calculated by the isotopic hydrograph separation was between 70%-80% for most analyzed events. Because of the uncertainty in the determination in the event water singal it was proposed to use a range within which the pre-event water contribution could exist instead of one single value (Holko et al., 2018a). The snowmelt runoff events in one microcatchment of the Jalovecký Creek catchment were also mostly contributed by the pre-event water. Greater contribution of the snowmelt water was calculated only for the highest discharges (Holko et al., 2018b). Dissolved silica and diatomes were applied/investigated as the tracers as well (Holko et al., 2014; Pfister et al., 2015). Chemical and isotopic composition of the stream water from the mountains to the foothill part of the catchment and of the groundwater in three springs were analysed in Holko et al. (2015).
Hydrological modelling of several rainfall-runoff events of different type (a few smaller, consecutive events, a flash flood event and two large events caused by frontal precipitation) indicated that possibly saturated soil (and contributing to catchment runoff by the overland flow) occured mostly along the stream network and expanded in the upper part of the catchment with wider valleys and smaller slopes. The length over which the potentially saturated areas were connected varied between 45 m and more than 6000 m (Sleziak et al., 2023a). While the spatial variability in precipitation may be very important to explore the contributing areas (and difficult to measure in mountains), the comparison of measured and radar based precipitation showed that the radar product available currently in Slovakia does not provide suitable information about the spatial variability of precipitation in our mountain catchments (Sleziak et al., 2023b).
An important change became visible in the catchment approximately since 2012. It is the change in the forest structure. Wind calamities, bark beatles and dry weather resulted in natural dieback, dissintegration and subsequent regeneration of the spruce forest that was at many stands more than 100 years old (Celer, 2015). Our unpublished data show that the change affected approximately one quarter of the original forest. This gradual change has an impact on many naural processes. The information about precipitation interception and snow cover has been studied (e.g. Bartík et al., 2019; Jančo et al., 2020). Further evaluation of the effects of this change on the hydrological cycle will be an important part of our future work. Alhough

these effects may not be clearly detected at the catchment scale; we can use the experience from the evaluation of the windfall effects in the High Tatra Mountains in 2004. Flashines index and flow duration curves may be helpful (Holko and Škoda, 2016), but the values of more detailed measurements of the overland flow at different stands (Holko et al., 2021), quantification of the differences in leaf area index (Danko et al., 2018) and other approaches will be explored as well.

Keywords: hydrological research catchments, water balance, snow cover, runoff formation, future research

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HYDROLOGICKÝ PREDPOVEDNÝ SYSTÉM SHMU

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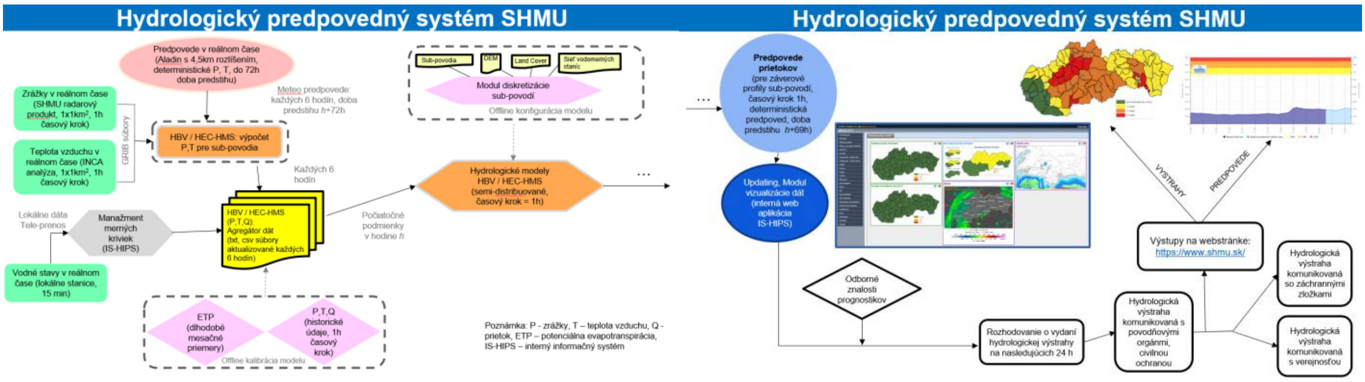
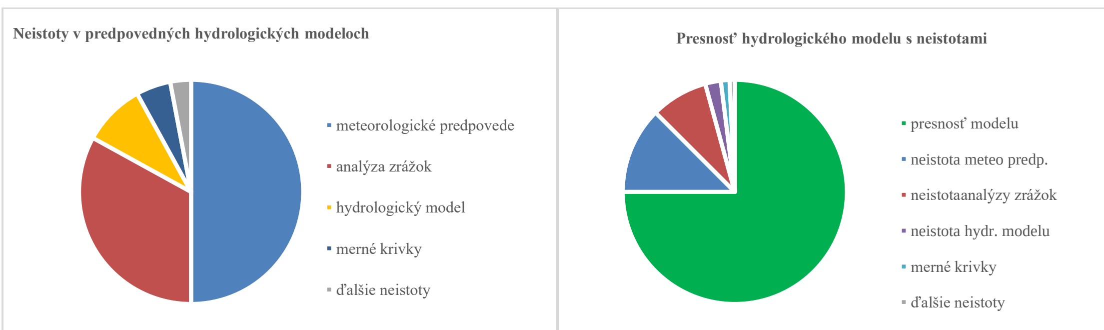
ABSTRAKT

Hydrologická informačná a predpovedná služba (HIPS) bola v minulosti a je aj v súčasnosti dôležitou zložkou Slovenského hydrometeorologického ústavu. Jej rozvoj bol spojený s povodňami v roku 1958 a 1960. Založením služby sa položil základ pre vznik komplexnej operatívnej hydrometeorologickej informácie pokrývajúcej celé územie Slovenskej republiky. HIPS je veľmi dynamická zložka hydrológie so špecifickými metódami práce, s odbornými nárokmi na pracovníkov a značnými požiadavkami na technickú vybavenosť a podporu. K významným zmenám v ostatných desaťročiach prispelo využitie technického pokroku, nových možností v technike merania, diaľkového prenosu informácií, dostupnosti výpočtovej techniky, programovej vybavenosti, modelovaní hydrologických procesov, medzinárodnej výmeny údajov a skúseností. V príspevku sa zameriame na súčasný stav a vízie hydrologického predpovedného systému na Slovenskom hydrometeorologickom ústave.



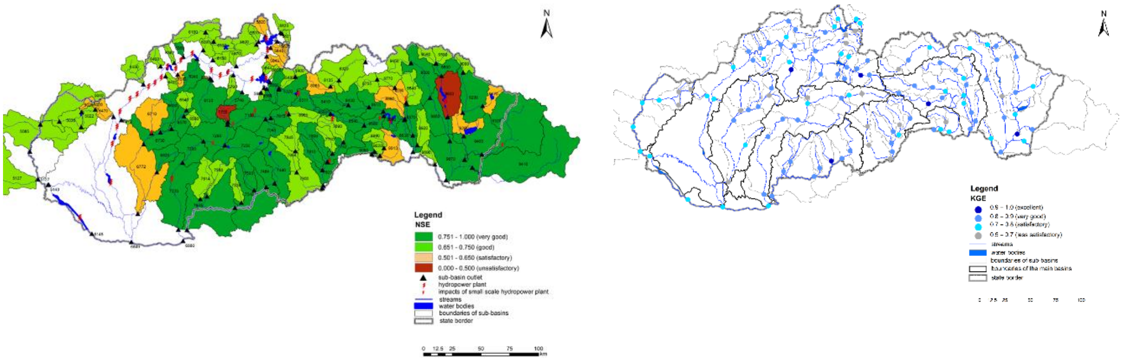
Obr. 1 Schéma toku dát v hydrologickom predpovednom systéme

Hydrologické modelovanie je základným pilierom hydroprognóznej služby. Poznať fyzikálnu podstatu zrážkovo-odtokových procesov je predpoklad dobrého základu predpovedného systému. Avšak každý predpovedný systém obsahuje rôzne druhy neistoty. Na obrázku 2 je ilustrovaná miera neistoty hydrologického predpovedného modelovania. Významným zdrojom neistoty sú zrážky, jednak spadnuté, ako aj predpovedané. Ďalšou neistotou je samotný hydrologický model, jeho štruktúra, počiatočné stavy modelu pred predpoveďou a kalibrácia modelu.



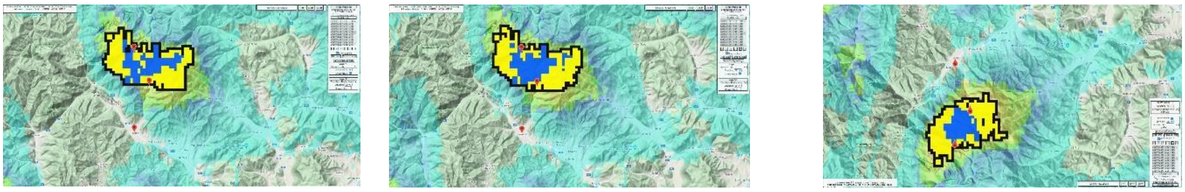
Obr. 2 Ukážka zastúpenia jednotlivých druhov neistôt v hydrologických modeloch SHMU

Priestorová informácia o spadnutých zrážkach je k dispozícii z radarového odhadu zrážok (prostredníctvom produktu qPrec, ktorý Odbor Dištančných meraní SHMÚ stále vyvíja) a informácia o predpovedaných zrážkach je z modelu ALADIN/SHMU (produkt poskytovaný Odborom Numerické predpovedné modely a metódy). Dnes sú hydrologickými modelmi predpovedané prietoky pre 138 predpovedných profilov s priemernou plochou povodia 400 km^2 dvoma zrážkovo-odtokovými modelmi (HBV a HEC-HMS). Modely sú na oddelení HIPS kalibrované, verifikované, je hodnotená ich úspešnosť/výkonnosť *(Obr. 3) a* znižovaná neistota jednotlivých vstupov (zrážok a prietokov).



Obr. 3 Výkonnosť modelu HBV vyjadrená štatistickou metrikou NSE (vľavo) a KGE (vpravo)

Zo skúseností v operatívnej službe vyplýva, že aj relatívne jednoduché hydrologické modely môžu poskytovať spoľahlivé výstupy, čo potvrdzujú aj viaceré výsledky v zahraničí. Napriek tomu je potrebné na oddelení testovať aj sofistikované distribuované modely, ktoré majú pri dnešnej dostupnosti priestorových dát a zlepšujúcej sa výkonnosti výpočtovej techniky určite budúcnosť. Stálou výzvou pre hydrologické modelovanie ostáva tiež predpovedanie rýchlych povodňových udalostí, prívalových povodní. So zvyšujúcim sa nárastom výskytu búrkových situácií s mimoriadne nepriaznivým dopadom je pochopiteľné, že Povodňová služba potrebuje predpovedný systém obohatiť aj o systém na predpovedanie prívalových povodní. Pre potreby HIPS bol vyvinutý nástroj, ktorým je možné sledovať odhady zrážok a ich intenzitu (modré plochy – 30 mm/15 min, žlté plochy– 15 mm/15 min). Prekrývanie kritických plôch pri ďalších radarových meraniach už môže spôsobiť nepriaznivú odtokovú situáciu (*Obr. 4*).



Obr.4 Zobrazenie oblastí s vysokou intenzitou zrážok 28.6.2020 o 11:05, 11:10, 11:15 v povodí v oblasti Muránskej planiny.

So zohľadnením ďalších faktorov, ako napr. nasýtenie povodia predchádzajúcimi zrážkami, citlivosť územia po predchádzajúcich epizódach, fyzicko-geografické podmienky, výskyt bleskov (Linet), osídlenie a pod. je vydávaná výstraha 2. a 3. stupňa na prívalové povodne.

Dôležitou aktivitou je školenie prijímateľov hydrologických predpovedí a výstrah. Pravidelné stretnutia sú pre HIPS dôležité a inšpirujúce pre zrozumiteľnejšie zobrazenia hydrologických produktov. V blízkej budúcnosti sa chce oddelenie zamerať na poskytovanie pravdepodobnostných predpovedí a predpovedí dopadov vo vzťahu k rizikovým oblastiam.

Kľúčové slová: predpovedný systém, predpovede

A STUDY OF THE WATER BALANCE IN TREE SELECTED SUB-BASINS OF THE CENTRAL RIFT VALLEY, ETHIOPIA INFLUENCED BY CLIMATIC CHANGE

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ENLARGED ABSTRACT

Introduction

Sub-Saharan Africa is a region sensitive to and highly affected by climate change. This study is focused on the Central Rift Valley Basin (CRVB), Ethiopia and explores the impacts of climate change on the major components of the water balance. The study basin (CRVB) is a vast closed area and thus it is divided into smaller sub-basins with known outlets (sub-basins: Ketar, Meki, and Shalla). The major components of the water balance are surface runoff (Q), water yield (WY) and evapotranspiration (ET). Projected climate data from the climate emission scenarios were used for the analyses. Representative Concentration Pathway (RCP) data from the MIROC-RCA4 ensemble driving climate models were downscaled, bias corrected and applied for the impact analyses. Climate scenario analyses for near term (2031-2060) and for long-term (2070-2099) periods were used to assess the conditions of the water balance components. The endo hydrogenic CRVB (divided into three sub-basins), and their respective hydroclimatic impacts were simulated with a calibrated Arc-SWAT (ArcGIS extension program used for basin modeling) models separately. SWAT (Soil Water Assessment Tool) is widely used model for analyzing the water balances of a basin using long-term meteorological and spatial data of a location. It is a physically-based deterministic, continuous, basin-scale simulation model (USDA). The future impacts simulated on the annual average basis are varying in the maximum ranges from -65.2% to +85.8% in Q, from -42.2% to +23.9% in WY and from -4.1% to +17.3% in ET compared to the baseline data outputs in the individual sub-basin. Water management options according to the water balance sensitivities to the climate impacts were proposed for each of the sub-basin. SWAT based studies aimed at a balanced water resources management in combination with agricultural practices within the CRVB are recommended for future applications.

Material and methods

Study location

The CRVB is in East Africa region and is in the upper head of the Central Rift Valley (CRV) in Ethiopia. The subbasins Ketar, Meki and Shalla are presented on Fig. 1. The subbasins, main lakes and major streams are displayed on Fig. 2.

Model SWAT-2012, requires a digital elevation model (DEM), land cover and land use information, soils, and basic climate data. SWAT subdivides a watershed into individual hydrologic response units (HRU) and treats the HRU as a homogeneous block of land use, management techniques, and soil properties and then quantifies the relative impact of vegetation, management, soil, land use and climate changes within each HRU (Arnold et al., 2011).

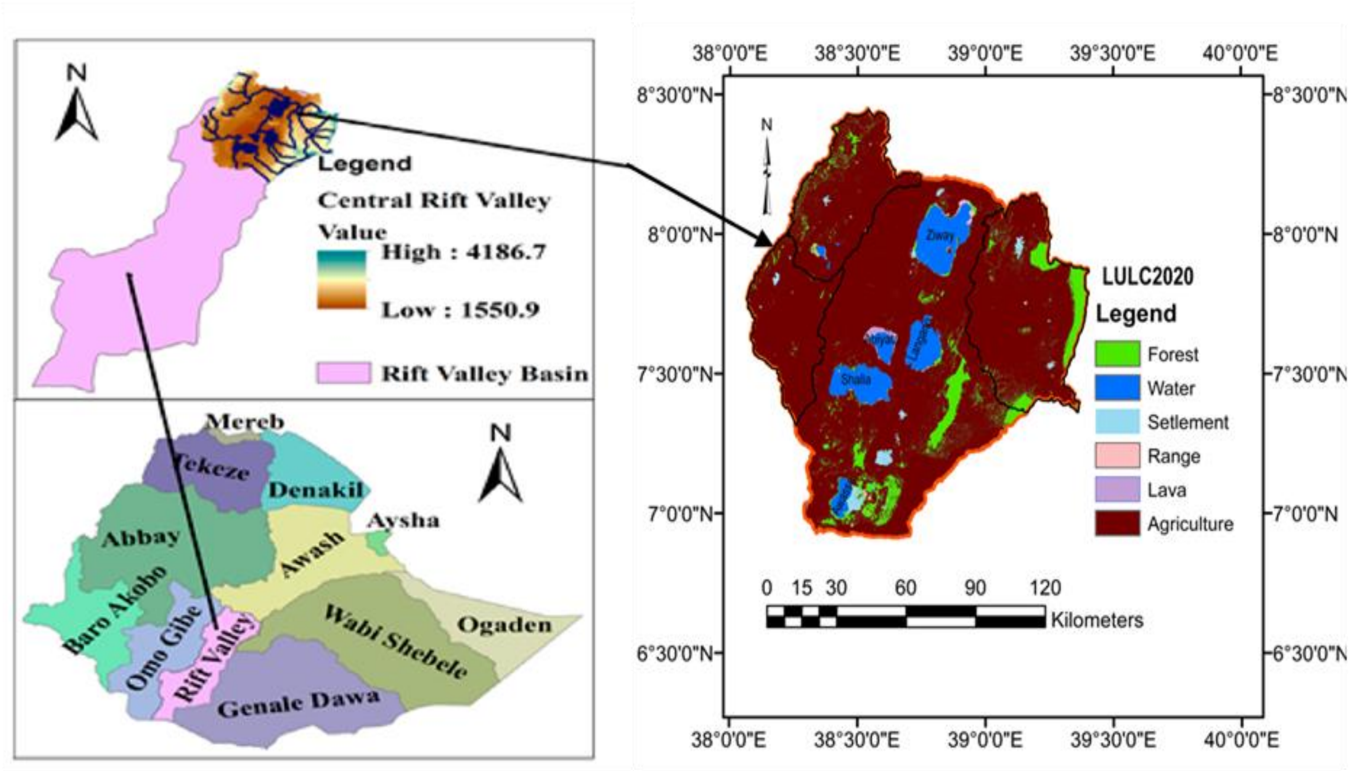

Fig.1. Major river basins in Ethiopia (left bottom), location of CRV in the rift valley basin (left - up) adapted from Gadissa et al. (2019) and the detail LULC of the year 2020 of CRV sub-basins (right)

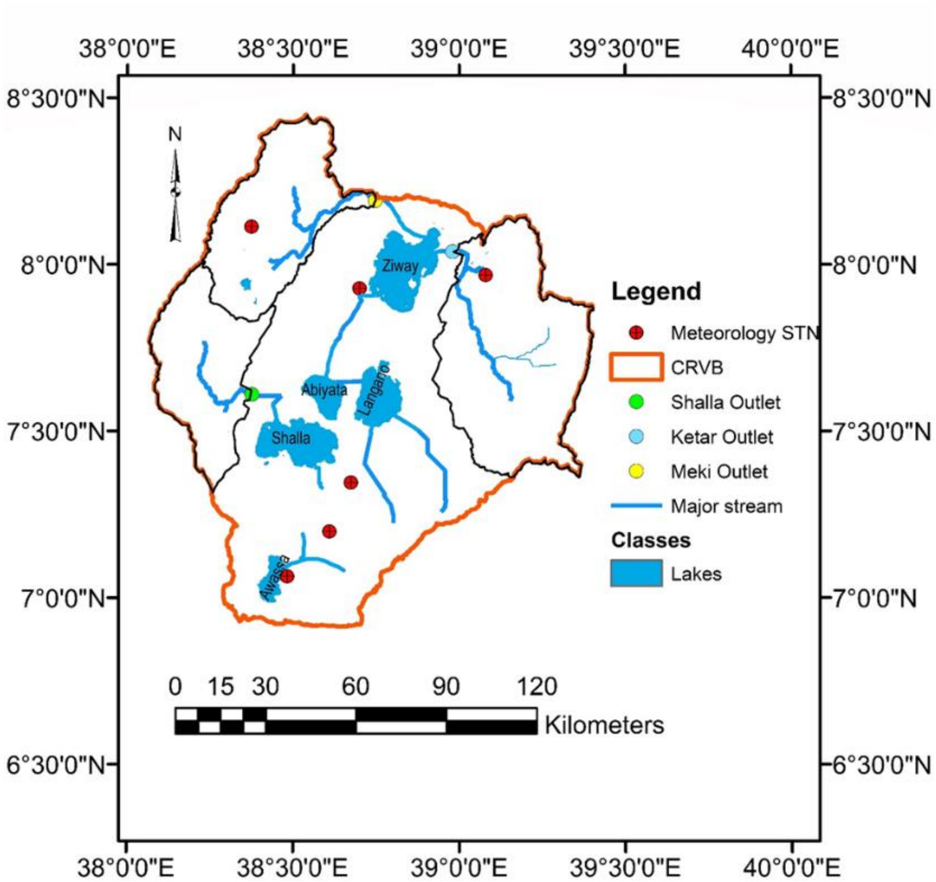

Fig. 2. Sub-basins of CRVB, stream networks and their outlets where the impacts of LULC changes were analysed (Truneh et al., 2023) The sub-basins boundaries are indicated in black line.

Data source

Basic climate data such as the daily observed precipitation, maximum and minimum temperature, wind speed, sunshine hour, and relative humidity data from six stations in CRV region were collected from Ethiopian resources (Ministries, Meteorological Agency, etc.). Similarly, data of land cover and land use, soil data maps, and other data. The major land use and land cover (LULC) of the sub-basins were re-classified into Agriculture, Forest, Rangeland, Water, and Settlements based on their hydrologic response similarities. Fig. 3 indicates the re-classified LULC maps of the CRVB for each time step in the past.

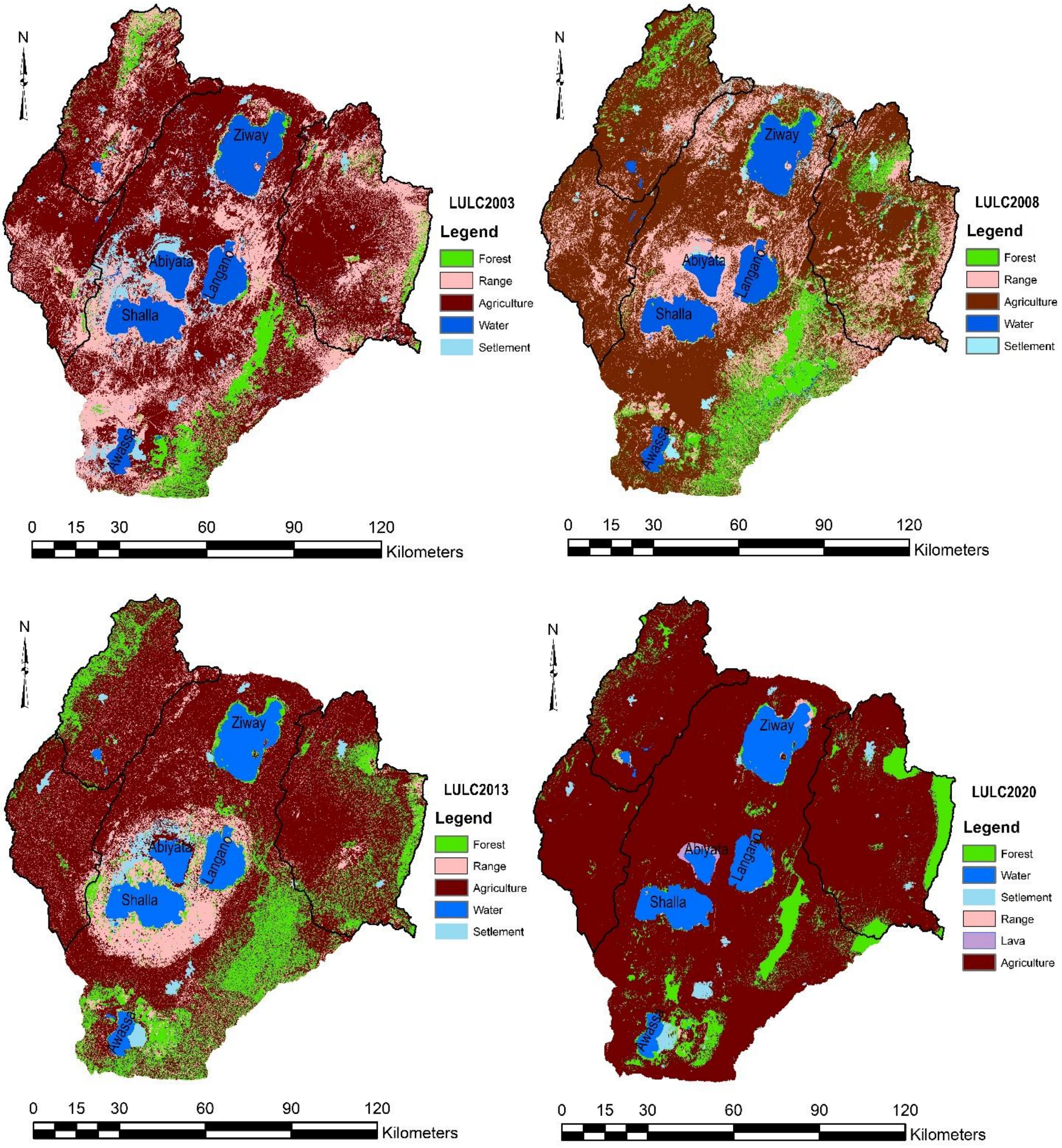

Fig. 3. Map of the past re-classified LULC maps of CRV sub-basins for each time steps.

SWAT model setup, calibration, validation, and performance evaluation

The SWAT is a versatile model of watershed, and it can simulate many processes from rainfall-runoff processes to many other important parameters. Operations of the model involve soil characteristics, hydrology, weather, land management, plant growth, pesticides, and nutrients in its sub-components. It can also be applied on wide scale watershed with high efficiency of computation and is very appropriate in analysing the impacts of land use changes.

The SWAT model was properly calibrated and validated for the sub-basins of the CRVB. The model accuracy and performances were evaluated and checked prior to using it for simulation in the sites. In this work, the SWAT model was calibrated, validated and its performances were evaluated against coefficient of determination (R^2), Nash-Sutcliffe efficiency (NSE) and Percentage of bias (PBIAS) using the monitored stream flows from the outlets of the Ketar, Meki and Jidu river gauging stations. The ArcSWAT 2012, an Arc GIS extension program was used for watershed modelling. For a particular site, Arc-SWAT contains many hydrological parameters that need to be calibrated. However, not all the parameters may be contributing significantly to the model output, and it is therefore necessary to identify the input parameters that are significant for the site in streamflow simulations. In addition, the heterogeneity of the sites makes it difficult for all SWAT parameters to be monitored simultaneously. Calibration and validation also help to identify the parameters to use for the specific area in a balanced way.

The model was calibrated and validated using monthly monitored stream flows from the outlets of the Ketar, Meki and Jidu (Shalla) Rivers. The outlet locations were set at the flow gauging stations. Calibration and validation of the SWAT model were performed with the use of SWAT-CUP, a calibration uncertainty program for SWAT with the SUFI-2 algorithm. The models were set to run for the baseline periods from 1984 to 2010 for each of the sub-basins (Ketar, Meki, & Shalla).

Before applying for analysis, the models' performances were conducted. Three main statistical parameters were used to evaluate the performances of the model: the Coefficient of Determination (R^2), the Nash-Sutcliffe Efficiency *(NSE*), and the Percentage of Bias (*PBIAS*).

Data Downscalling

Climate data from CMIP6 with the MIROC ensemble driving climate models were obtained for future climate impact analyses. To obtain realistic outputs, the predicted climate data values were downscaled, were bias corrected and were adjusted from the GCMs. The Representative Concentration Pathway (RCP) data variables from the Coordinated Regional Downscaling Experiment (CORDEX) for Africa, AFR- 44, were downscaled for the analyses. Historical data and data of RCP2.6, RCP4.5 and RCP8.5 were downscaled by RCA4 methods. The downscaled data sets were daily precipitation, daily maximum near-surface air temperature, daily minimum near-surface air temperature, duration of daily sunshine, near-surface relative humidity, and near-surface wind speed for future periods from 2006 to 2100. The variables were extracted and adjusted for SWAT use and to the SWAT input data standard units.

Bias Correction

The data for precipitation and temperature were bias corrected via linear scaling methods with CMhyd software, which is a SWAT community tool, before they were applied in SWAT. The need for bias correction is mainly due to onshore and offshore trade wind disturbances. The historical data from the model and the observed locational data set from six stations in the study region were applied to the software (data ranges from 1990 to 2006).

Climate Scenario Analysis Setting and Simulation

The climate scenarios (CSc) were set for the analysis of the impacts of the climate change in the near term (2031-2060) and in the long term (2070-2099) periods for each of the RCPs.

Results and discussion

Model parameters sensitivity

The differences in the sensitivity of the hydrological parameters in the sub-basins indicate that the sub-basins are heterogeneous, although they refer to a single closed lakes region. The differences are mainly due to land use, soil, hydrogeologic and due to anthropogenic variations.

Calibration and validation

The calibration results indicate good agreement between the simulated and observed monthly discharges in the sub-basins. The results for simulated and observed monthly discharges in the sub-basins were evaluated against R^2, NSE and PBIAS during calibration and validation for all three sub-basins (Ketar, Meki and Shalla).

Climate scenarios

The impacts of climate change on the major water balance components such as runoff (Q), Water yield (WY) and ET were analyzed for each sub-basin. The Q, WY and ET were identified as the most sensitive elements of the water balance components in the CRVB. The annual, seasonal and monthly variations of the components due to climate change were discussed in detail for each sub-basin and additional analysis and detailed results were also presented. The simulated monthly distributions of runoff, water yield WY and evapotranspiration ET for all three sub-basins linked with different is shown in the Fig. 4.

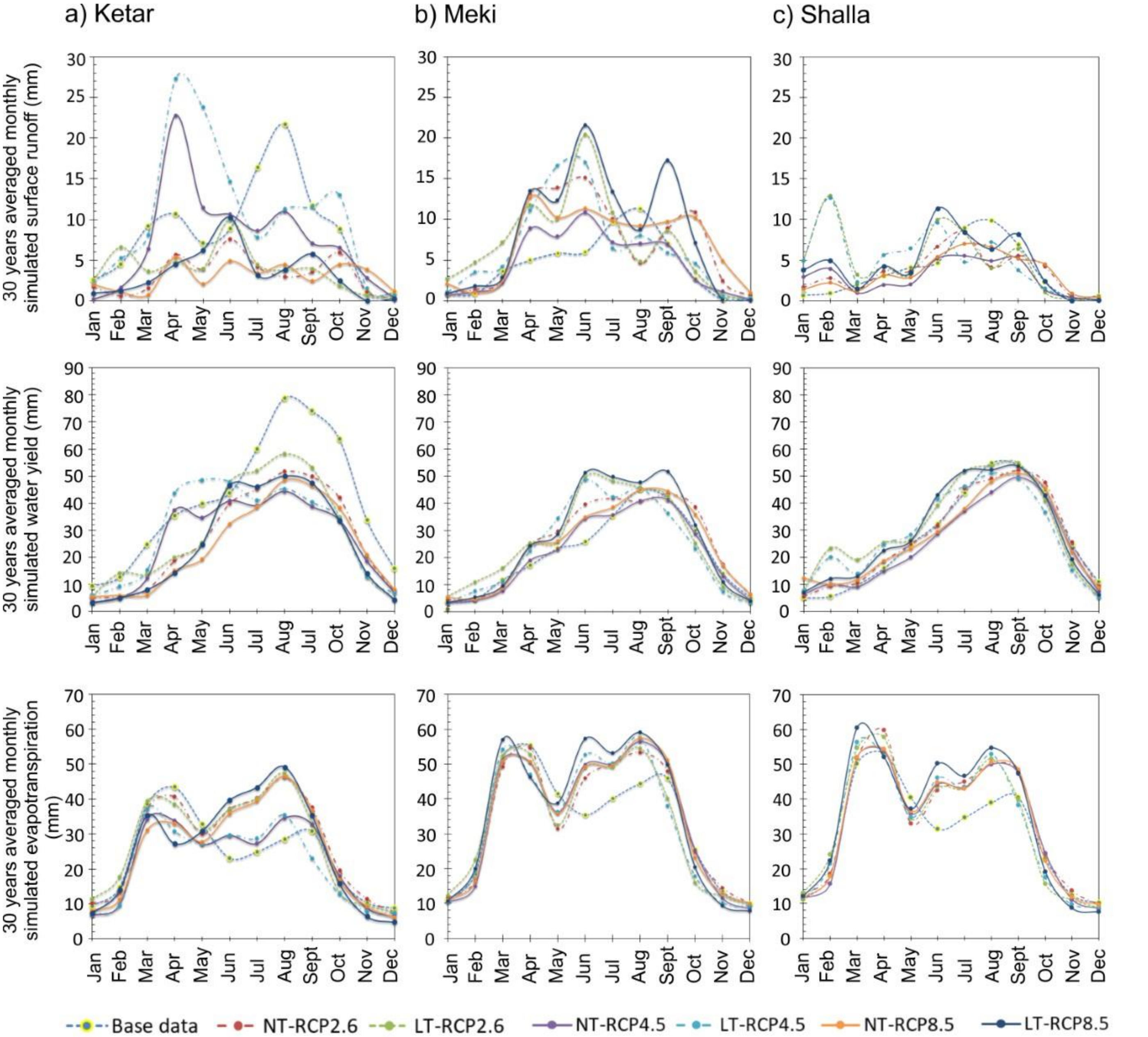

Fig. 4. The simulated monthly distributions of Q, WY, and ET in the Ketar, Meki and Shalla sub-basins for the applied climate scenarios.

Discussion for Water Management Options

From the projected analyses of the impacts of climate change in the model, the major water balance components such as surface runoff and water yield are mainly expected to decrease, and evapotranspiration were projected to increase in the sub-basins. This will have an impact on the increasing demands of agricultural water in the sub-basins. Seasonal shifts in the patterns of the projected water balance distributions were also observed. Therefore, water management strategies that help mitigating the impacts should be searched and applied. Their applications might help to face the food security challenge caused by the water shortage that would occur due to climate changes.

Conclusions

This study investigated the impacts of future climate change on the major components of the water balance in the Central Rift Valley Basin in Ethiopia from the seasonal and the spatial point of views. The evaluations are based on the magnitude of water yield, evapotranspiration and surface runoff components changed in relation to the baseline data outputs. Regional Climate Models (RCM) data in CORDEX - Africa were applied for the investigation. RCP data from the MIROC-RCA4 ensemble driving climate models were downscaled, bias corrected and used for the analyses. The methodology followed a calibrated Arc-SWAT modelling approaches to search for basin wide climate impacts on water resources and to indicate possible agricultural water management and adaptation strategies. The findings are solely based on model simulation outputs within the scope of its evaluations and error limitations.

Accordingly, the study identified a general decrease in water yield and surface runoff and a seasonal increase in evapotranspiration in Ketar and Shalla sub-basins in both near term (2031 - 2060) and long-term (2070 - 2099) periods in comparison to the baseline periods (1984 - 2010). However, all the three water balance components projected were showing an increment in the Meki sub-basin for all the periods. The sub-basins were also found to be heterogeneous, and they showed variabilities in terms of their hydroclimatic reactions to the impacts of climate change even though they are in one endo hydrogenic region. In the sub-basins, some similarities were also found in the ways in which the pattern of the water balance components will be changed. However, the magnitudes of the impacts varied from sub-basin to sub-basin, between the RCPs and between near term and long-term periods due to the projected climate changes. These indicate that each of the sub-basin has a unique water balance environment.

The study also indicated huge impacts of regional climate forcings (RCM) on surface components of the regional water cycle. These RCMs are a derivative of the Global Circulation Models (GCM).

The management interventions to the climate impacts should therefore be according to the sub-basins water balance sensitivities while keeping the equilibrium in the closed CRVB water requirements. Finally, an investigated integrated watershed, agricultural water use, and farm management in Water-Agriculture-Land and Climate nexus approaches following each sub-basin climate responses and other alternative resource management options for the closed CRVB must be fetched and applied to cope up with the hydroclimatic impacts.

The calibrated SWAT model has proved to be a useful tool for analyzing and identifying the temporal and spatial conditions of the water resources at a basin level under different climate change conditions in CRVB. Therefore, further studies dealing with climate based water resource management in combination with farming practices using SWAT model would bring additional importance.

Keywords: Arc-SWAT, Climate change; Climate scenario; Water balance sensitivity; Water management

INFLUENCE OF LOCAL FACTORS ON MICROCLIMATIC VARIABILITY WITHIN A UNIVERSITY CAMPUS: A COMPARATIVE ANALYSIS OF METEOROLOGICAL TRENDS IN PRAGUE-SUCHDOL

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ABSTRACT

Urbanization has a significant impact on microclimates, profoundly altering energy balance and radiation budgets. This study explores the effects of urban development on meteorological elements, with a particular focus on the urban heat island (UHI) effect. The UHI phenomenon stems from alterations in the urban energy budget, reductions in evapotranspiration, geometric factors, and the release of waste heat from various sources, including automobiles and industry.
The aim of this study is to compare meteorological data collected in the month of June from 2013 to 2020 at two meteorological stations located in the campus of Czech University of Life Sciences in Prague 6-Suchdol. These stations correspond to differing urban development settings: i) the official University meteorological station, referred to as 'CZU,' which is situated within a protected plot surrounded by buildings, thereby primarily reflecting urban conditions. Data are publicly available on http://meteostanice.agrobiologie.cz/. ii) The Experimental terrain station of soil moisture dynamics, referred to as the 'DWR', operated by the Dept. of Water Resources, which is located at an open plot on the campus border, surrounded mostly by fields, making it rather representative for rural conditions. However, neither of the stations meets the standard meteorological site criteria. Direct distance between the two stations is 465 m and their altitude is 286 and 280 m a.s.l., respectively. The study focuses on key meteorological variables listed in Tab. 1, collected at 10-15 min intervals and statistically evaluated through factorial ANOVA.

Table 1. Overview of processed data

Observed element	**Compared interval**	**Unit**	**Instrument**	**Height (m)**
Air Temperature	hourly average	°C	thermometer	2
Air Temperature Diurnal Differences	daily min-max diff.	°C	thermometer	2
Air Temperature Extremes	daily maximum	°C	thermometer	2
Air Humidity	hourly average	%	relative humidity sensor	2
Air Humidity Diurnal Differences	daily min-max diff.	%	relative humidity sensor	2
Air Pressure	hourly average	hPa	barometric pressure sensor	2
Daily Totals of Precipitation	daily total	mm/d	rain gauge	1
Global Radiation	10 min average	$kJ/m^2/10$ min	pyranometer	2
Wind Speed	hourly average	m/s	anemometer	10
Wind Direction	hourly average	compass direction	anemometer	10

Results revealed notable distinctions in microclimatic conditions between the two stations (see Tab. 2). CZU consistently recorded higher average air temperatures, while DWR exhibited lower temperatures. Diurnal temperature variations were significantly higher at DWR, suggesting an increased influence of heat

accumulation and radiation at CZU. Notably, June 2019 saw a dramatic rise in air temperature, exceeding long-term average by 4.9°C throughout the Czech Republic. Temperature extremes showed variations between years, in 2019 the highest temperature (on 30 June 2019 t_{max} was 37.3°C) while in 2013 the lowest temperature were observed (on 3 June 2013 t_{min} was 11.2°C). Several factors, including anomalous anticyclones and soil moisture-temperature feedback, contributed to extreme temperature events. Air humidity was notably higher at CZU, while DWR displayed greater diurnal variations, possibly due to limited ventilation in the urban canyon. The highest air humidity levels were observed in 2013 and lowest in 2019, contrasting with temperature trends. Daily precipitation sums exhibited low correlation but were generally higher at CZU, partially attributed to undercatch at DWR caused by wind. The highest precipitation values occurred in 2013, and the lowest in 2014. Global radiation levels varied at both stations, with DWR recording higher in overall during the observed period (not statistically significantly). Always higher values were observed in the morning at DWR and always higher in the afternoon at CZU station, likely due to reflection from surrounding buildings at CZU. Wind speed was significantly higher at DWR, with differences accentuated since 2016. Wind direction at CZU has also changed since 2016, which can be attributed to ongoing campus development.

Table 2. Summary of statistical analysis (ANOVA)

Meteorological variables	**CZU**	**DWR**	**Factor**		
			Year	**Station**	**AM/PM*Station**
Air Temperature		🡅*	$p<0.05$	$p<0.05$	
Air Temperature Diurnal Differences		🡅*	$p<0.05$	$p<0.05$	
Air Temperature Extremes		🡅	$p<0.05$	$p>0.05$	
Air Humidity	🡅*		$p<0.05$	$p<0.05$	
Air Humidity Diurnal Differences		🡅*	$p<0.05$	$p<0.05$	
Daily Totals of Precipitation	🡅		$p<0.05$	$p>0.05$	
Global Radiation		🡅	$p<0.05$	$p>0.05$	
Global Radiation “am”		🡅	$p<0.05$	$p>0.05$	$p<0.05$
Global Radiation “pm”	🡅		$p<0.05$	$p>0.05$	$p<0.05$
Wind Speed		🡅*	$p<0.05$	$p<0.05$	
Wind Direction			$p<0.05$	$p<0.05$	

** significant at $p<0.05$*

In conclusion, this study illustrates that CZU, representing an urban microclimate, exhibited higher air temperatures, lower humidity, and increased diurnal temperature and humidity variations compared to the rural conditions at DWR. Precipitation sums were generally higher at CZU, and global radiation varied between the stations. These findings emphasize the need for continued research to comprehensively understand and quantify the effects of urban development on meteorological variables, providing valuable insights for urban planning and climate adaptation strategies.

Keywords: Urbanization, Microclimate, Urban Heat Island, Meteorological Variables, Climate Adaptation.

Acknowledgements: This study was supported by the Czech University of Life Sciences Prague, Faculty of Agrobiology, Food and Natural Resources, project No. SV22-15-21380. Authors dedicate it to the memory of dear dr. František Doležal.

CURRENT PROBLEMS OF PERSONNEL PROVISION FOR THE SOLUTION OF PROFESSIONAL ACTIVITIES FOR THE NEEDS OF SHMI HYDROLOGY

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ABSTRACT

SHMI conceptually and long-term monitors the quantity and quality of waters and their regime in Slovakia. SHMI is authorized by law to perform the state hydrological service, to manage the state hydrological network. Through the state hydrological network SHMI ensures continuous monitoring of the quantity, quality and regime of waters. Hydrological monitoring is the basis for evaluating the current state of water resources, forecasting not only floods, but also the future development of the whole water regime, including drought. Hydrological monitoring is also the basis for estimating the negative impacts of climate change on the state of water resources, for setting measures to reduce the consequences of drought.
It performs its activities on the basis of systematic observation, collection, processing and evaluation of data in its observation networks and in cooperation with relevant national and international organizations and institutions. SHMI analyzes, evaluates, interprets, archives, archives and performs other activities related to the assessment of water status for various purposes. And so it creates a technical and professional background for the performance of state administration in the areas of its own competence. It provides information on the subject of its activity to the public and other subjects, under the conditions set by the relevant legal regulations, including the fulfilment of international obligations.
With the entry of the Slovak Republic into the EU and acceptance of the resulting obligations, the approach to the management of water resources at the national level also began to change. This has opened up possibilities for new approaches to water monitoring and assessment, and throughout hydrology. Hydrology deals with water in all its states and water-related processes. The subject of its investigation is the hydrosphere. Hydrology is the natural science basis of water management. Hydrology also includes a technical-scientific discipline - engineering hydrology, which developed from hydrology for the needs of planning, designing and building water management structures.
The structure and content of hydrological tasks at the institute changed with changes in requirements both at the national level and at the international level. New requirements were added to the basic activities of the institute, which they ensured, especially in connection with the fulfilment of EC requirements in the field of water.
Are sufficient resources, both financial and professional, allocated all for these tasks?

Keywords: hydrology, water monitoring, the state hydrological service,

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II. Short Abstracts of presentations

IMPACT OF BIOCHAR PARTICLE SIZE AND FEEDSTOCK TYPE ON HYDRO-PHYSICAL PROPERTIES OF SANDY SOIL

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ABSTRACT

Biochar, as an organic amendment, could positively change soil properties, especially soil with low organic matter and/or poor structure. Biochar application in sandy soil with low organic matter could be an effective tool for improving hydro-physical parameters of the soil economically and ecologically as well. The effect on bulk density, particle density, porosity, saturated hydraulic conductivity and available water content for plants of two biochar types applied at three different particle sizes in a sandy soil was examined. The results confirmed previous studies, showing decreased bulk density, particle density and saturated hydraulic conductivity and partially increased available water content for plants and porosity. Both biochar type and particle size affected the studied soil hydro-physical parameters. After analysis and comparison of two different types of biochar and three particle sizes, the most effective treatment for sandy soil was proved by the biochar produced from willow with the smallest particle size (< 125 μm).

Keywords: feedstock, biochar, sandy soil, soil hydro-physical parameters

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CHANGES IN CRACK WIDTH ON THE SURFACE OF HEAVY SOILS DURING DROUGHT, DETERMINED BY PRECISE MEASUREMENT AND CALCULATION

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ABSTRACT

In heavy soils, changes in humidity incur soil volume changes. In the horizontal plane, these are manifested by cracks formation and in the vertical plane by the movement of the soil surface. Cracks have a significant impact on hydrodynamics of the soil profile. The work is based on the hypothesis that soil volume changes depend on both the content of clay particles in soil and soil volumetric moisture. The aim of the work is to measure and analyze the changes in the width of the cracks and their reaction to the changes in volumetric soil moisture. One of the objectives of the work was to design a simple tool for accurate measurement of the crack width on the soil surface and to propose a calculation procedure for calculating their width. For the study of crack width, a soil profile in an area on the East Slovakia Lowland was selected. The profile was examined under conditions of extreme drought, at the turn of July and August 2022. Crack width varied between 1.0 cm and 3.3 cm. The model was evaluated as satisfactory for estimating the change in crack width on the soil surface.

Keywords: heavy soil, crack width, volume changes, volumetric soil moisture

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FLOW RESISTANCE AT LOWLAND AND MOUNTAINOUS RIVERS

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ABSTRACT

This study initially examines the various sources of flow resistance in sand-bed (lowland) and gravel-bed (mountainous) rivers along with the limitations of traditional estimation methods. The nondimensional hydraulic geometry approach, relating dimensionless flow discharge (q*) to the Darcy-Weisbach friction factor (f), has demonstrated good performance for both river types, covering shallow to moderately deep flows. However, accuracy in estimating f is affected by simplifications like assuming uniform and deep flow, neglecting bed load transport and vegetation effects, which require further evaluation. To address these issues, the proposed method is evaluated using data from four sand-bed rivers in Slovakia (with vegetation), and three gravel-bed rivers in Iran (dominated by cobbles and boulders). Bedforms prove to be significant resistance sources in all studied rivers. The approach yields separate predictors for each river type, showing a satisfactory agreement between observed and calculated values within a maximum deviation of ±20% error bands. These predictors are further validated using field data and established equations from rivers with similar physiographic characteristics. Results indicate the method performs well in predicting flow resistance in sand-bed rivers, slightly overestimating overall (+40%). It effectively captures riverbed features and vegetation influence under small-scale roughness conditions. However, the predictor's validity for gravel-bed rivers is somewhat limited due to high variability in water-surface profiles, making it challenging to accurately capture flow dynamics under large-scale roughness conditions. Addressing complex characteristics of gravel-bed riverbeds, including boulders and local energy extraction, is crucial for improving the estimation of water-surface profile variations and flow resistance using the hydraulic geometry approach.

Keywords: Flow resistance; Hydraulic geometry; Gravel-bed river; Sand-bed river; Field data; River engineering

MONTHLY STREAM TEMPERATURES ALONG THE DANUBE RIVER: STATISTICAL ANALYSIS AND PREDICTIVE MODELLING WITH INCREMENTAL CLIMATE CHANGE SCENARIOS

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ABSTRACT

The aim of the study is to analyse changes and predict the course of mean monthly water temperatures of the Danube River at various locations for the future. The first part of the study involves conducting a statistical analysis of the annual and monthly average air temperatures, water temperatures, and discharges along the Danube River. The study examines long-term trends, changes in the trends, and multiannual variability in the time series. The second part of the study focuses on simulating the average monthly water temperatures using Seasonal Autoregressive Integrated Moving Average (SARIMA) models and nonlinear regression models (NonL), based on two RCP based incremental mean monthly air temperature scenarios. To assess the impact of future climate on stream temperatures, the historical long-term average of the monthly water temperature (1990–2020) was compared with scenarios S1 (2041–2070) and S2 (2071–2100). The simulation results from the two stochastic models, the SARIMA and NonL, showed that in scenario S1, the Danube River's average monthly water temperature is projected to increase by 0.81/0.82°C (Passau), 0.55/0.71°C (Bratislava), and 0.68/0.56°C (Reni). In scenario S2, the models predict higher increases: 2.83/2.50°C (Passau), 2.06/2.46°C (Bratislava), and 2.52/1.90°C (Reni). Overall, the SARIMA model proved to be more stable and effective in simulating the increase in monthly water temperatures in the Danube River.

Keywords: SARIMA models, nonlinear regression models, water temperature changes, climate change, incremental scenarios

Acknowledgements: This work was supported by the MVTS project WATSIM, APVV No. 20-0374, No. APVV 19-0340 and VEGA No. 2/0015/23.

EFFECTS OF THE APPLICATION OF BIOCHAR ON THE SOIL EROSION OF PLOTS OF SLOPING AGRICULTURAL AND WITH SILT LOAM SOIL

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ABSTRACT
The application of biochar is considered to be a beneficial strategy for improving soil ecosystem services. The objectives of this study are to evaluate the differences in the soil erosion of silt loam soil with or without the application of biochar and to compare the impact of the application of biochar on soil erosion for different agricultural practices, namely, bare soil, silage corn, and sown peas. Specifically, the physically-based EROSION 3D model was used to estimate the soil erosion of small plots of sloping agricultural land. In considering various combinations of agricultural practices and rainfalls with different durations and intensities, several scenarios were used to assess the impact of the application of biochar on soil erosion.
The results of this study demonstrate that the highest mean values of mean soil erosion in the case study area were simulated without using any biochar on bare soil. The values of the mean soil erosion were reduced with the use of biochar. The effect of the application of biochar was shown for all types of agricultural practices; above all, it reduced soil erosion that occurred above high values (over 30 t ha^{-1}). Although the application and reapplication of biochar showed promise in reducing soil erosion, further research is needed to gain a deeper understanding of its total effects.

Keywords: application of biochar, soil erosion, EROSION 3D model, rainfall

EVALUATION OF PRECIPITATION MEASUREMENTS USING A STANDARD RAIN GAUGE IN RELATION TO DATA FROM A PRECISION LYSIMETER

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ABSTRACT

The construction of modern lysimeters with a precise weighing system made it possible to achieve an unprecedented accuracy of precipitation measurement. This study compares two methods of measuring precipitation in the conditions of the humid continental climate of the Eastern Slovakian Lowland (Slovakia): measurement using a standard tipping-bucket rain gauge vs. precision weighable lysimeter. Data from the lysimeter were used as a reference measurement. The comparison period lasted four years (2019–2022). Only liquid rainfall was compared. The rain gauge was found to underestimate precipitation compared to the lysimeter. Cumulative precipitation for the entire monitored period captured by the rain gauge was 2.8% lower compared to lysimeter measurements. When comparing hourly and daily totals of precipitation and precipitation events, a very high degree of agreement was detected ($r^2 > 0.99$; *RMSE* from 0.22 to 0.51 mm h^{-1}). A comparison based on precipitation intensity showed a decreasing trend in measurement accuracy with increasing precipitation intensity. This tendency has an exponential course. With increasing intensity of precipitation, increasing intensity of wind was also recorded. In order to correct measurement errors, simple correction method was proposed, which helped to partially eliminate the inaccuracies of the rain gauge measurement.

Keywords: tipping-bucket rain gauge, precision weighable lysimeter, precipitation measurement, rainfall intensity

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INVERSE TASK OF POLLUTION SPREADING - LOCALIZATION OF SOURCE IN EXTENSIVE OPEN CHANNEL NETWORK STRUCTURE

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ABSTRACT

This paper is focused on the problem of the pollutant source localisation in streams in other words the solution of the inverse problem of pollution spreading with in an extensive open channel network structure, i.e. in a complex system of rivers, channels and creeks in natural catchments or sewer systems in urban catchments. The design of the overall localisation procedure is based on the requirement that the entire localization system be operative and fast enough to enable quick operative interventions and help prevent the spread of pollution. The proposed model, as well as, the overall localisation procedure was calibrated and tested on a real sewer system, which represents in this case an extensive open channel network structure with free surface flow.

The first part of the localisation procedure was the generation of pollutograms (concentration time courses) from each possible pollution entry points for each open channel network node in the downstream direction using the assumed pollution entry pollutogram (intensity function) and pollution transport model. All simulated pollutograms were stored in database form for further evaluation. It is important to mention, that the pollutograms were generated for instantaneous pollution entry and the generated pollutograms in the database are transformed into the unit form.

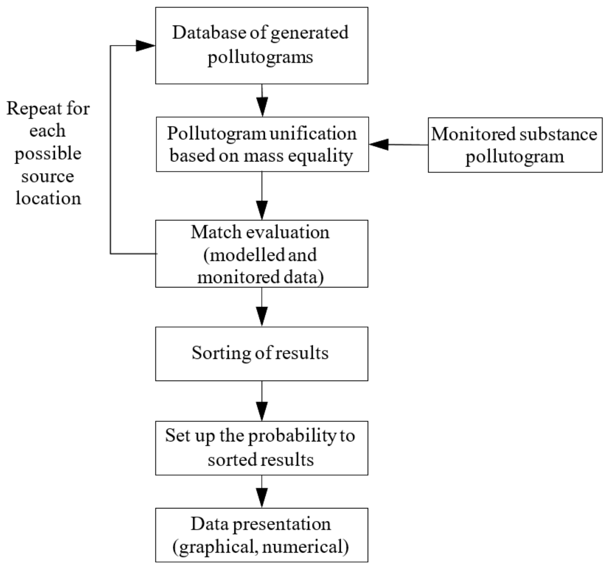

Figure 1. Flowchart of the evaluation / localization procedure

The next step in the evaluation procedure is the comparison (match evaluation) of the monitored (real) and modelled pollutograms. The basic scheme of this procedure is shown on Figure 1. As mentioned above, the pollution shape comparison is possible only if both pollutograms are on the same (unit) basis, e.g. the mass of both pollutogram should be the same. The shape comparison is then realized with standard statistical methods, like Root Mean Square Error (RMSE) or Normalised Root Mean Square Error (NRMSE).

We regard the obtained results as successful and promising. However, it is necessary to remember, that the localisation precision highly depends on the precision of the transport model used. A correct and accurate model requires careful calibration; in the case of the proposed method, it is not only a large-scale spatial calibration, but also a calibration for multiple hydraulic conditions (flow rates) on the network. Such extensive calibration procedures can be highly cost and time demanding. On the other hand, such calibration is necessary in all modelling tasks, including inverse tasks.

The proposed source localisation tool has its advantages, as well as disadvantages. One of the advantages of the proposed procedure is its applicability in real conditions and possibility to obtain results in real time. The main disadvantage of the proposed source localisation method, we regard the fact, that to reduce the ill - posed problem of the inverse task, it is necessary to assume the shape of the entry pollutogram. It is necessary to emphasize, that it is not necessary to know the complete parameters of the source intensity function, it is sufficient to estimate the duration and shape of the intensity function (i.e. the relative variation of the concentration values in time). This brings us to the conclusion, that such an approach would be appropriate for short-term pollution spills in the channel network, e.g. short leakage events in sewer networks.

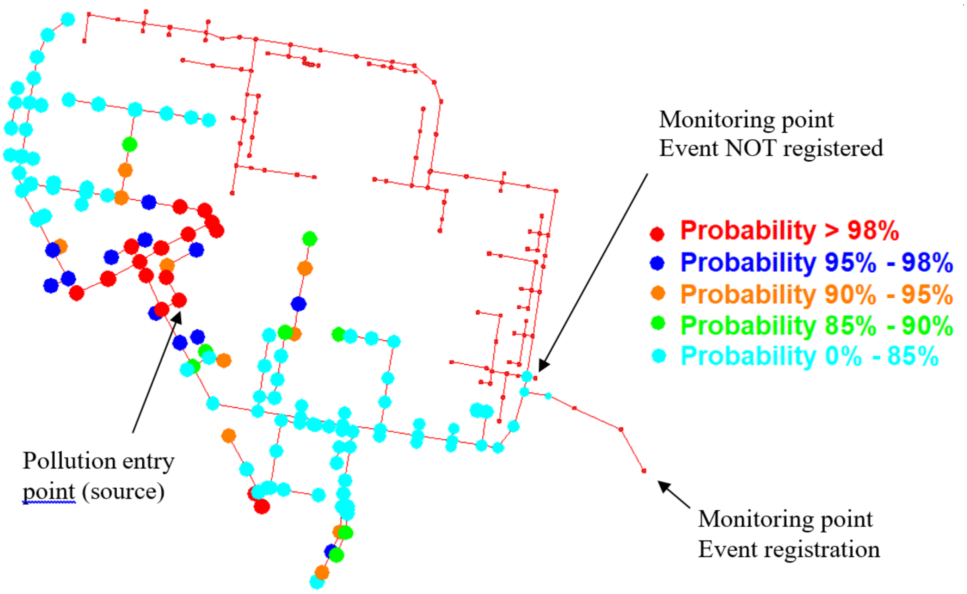

Figure 2. Results of the localisation procedure

As it is demonstrated on the Figure 2, the proposed localisation tool selected manholes with the highest pollution source occurrence probability (red circles) on a relatively short section of the street. If we assume the buildings (and their house connections) as possible pollution source points, the range of possible pollution sources will be limited to 3-4 blockhouses.

Keywords: pollution, sources, localisation, open channel, network, inverse task

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THE TESTING OF A MULTIVARIATE PROBABILISTIC FRAMEWORK FOR RESERVOIR SAFETY EVALUATION AND FLOOD RISKS ASSESSMENT IN SLOVAKIA: A STUDY ON THE PARNÁ AND BELÁ RIVERS

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ABSTRACT

Intense floods represent a challenge to risk management. While they are multivariate in their nature, they are often studied in practice from univariate perspectives. Classical frequency analyses, which establish a relation between the peak flow or volume and the frequency of exceedance, may lead to improper risk estimations and mitigations. Therefore, it is necessary to study floods as multivariate stochastic events having mutually correlated characteristics, such as peak flood flow, corresponding volume and duration. The joint distribution properties of these characteristics play an important role in the assessment of flood risk and reservoir safety evaluation. In addition, the study of flood hydrographs is useful because of the inherent dependencies among their practice-relevant characteristics present on-site and in the regional records.
This study aims to provide risk analysts with a consistent multivariate probabilistic framework using a copula-based approach. The framework respects and describes the dependence structures among the flood peaks, volumes, and durations of observed and synthetic control flood hydrographs. The seasonality of flood generation is respected by separate analyses of floods in the summer and winter seasons. A control flood hydrograph is understood as a theoretical/synthetic discharge hydrograph, which is determined by the flood peak with the chosen probability of exceedance, the corresponding volume, and the time duration with the corresponding probability. The framework comprises five steps: 1. Separation of the observed hydrographs, 2. Analysis of the flood characteristics and their dependence, 3. Modelling the marginal distributions, 4. A copula-based approach for modelling joint distributions of the flood peaks, volumes and durations, 5. Construction of synthetic flood hydrographs. The flood risk assessment and reservoir safety evaluation are described by hydrograph analyses and the conditional joint probabilities of the exceedance of the flood volume and duration conditioned on flood peak. The proposed multivariate probabilistic framework was tested and demonstrated based on data from two contrasting catchments in Slovakia. Based on the findings, the study affirms that the trivariate copula-based approach is a practical option for assessing flood risks and for reservoir safety.

Keywords: Copula-based approach; Flood risk; Flood seasonality; Trivariate analysis; Synthetic hydrographs

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III. Abstracts and Posters, poster sessions

30 ROKOV SLOVENSKÉHO NÁRODNÉHO VÝBORU PRE MEDZIVLÁDNY HYDROLOGICKÝ PROGRAM UNESCO

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ABSTRAKT

Slovenský národný výbor pre hydrológiu je nástupcom Československého výboru pre hydrológiu, ktorý bol ustanovený na základe uznesenia Predsedníctva vlády ČSSR č.96 z 3. apríla 1975 o účasti Československa na Medzinárodnej hydrologickej dekáde UNESCO a zabezpečení Medzinárodného programu (ďalej MHP) UNESCO a ktorý ukončil svoju činnosť zánikom ČSFR.
Uznesenie Vlády SR z 12. apríla 1994 číslo 338 poverilo plnením týchto úloh Slovenský výbor pre hydrológiu. Ostatná úprava legislatívneho rámca bola urobená Uznesením vlády SR č. 279 zo 7. júla 2016 k Štatútu Slovenskej komisie pre UNESCO.
Slovenský výbor pre MHP UNESCO je orgánom Slovenskej komisie pre UNESCO. SVH za svoju činnosť zodpovedá Ministerstvu zahraničných vecí SR (ďalej MZV SR), Slovenskej komisii pre UNESCO (ďalej SK UNESCO) a Predsedníctvu Slovenskej akadémie vied (ďalej PSAV). V oblasti zahraničných stykov a medzinárodnej spolupráce SVH postupuje v plnom súlade so zásadami zahraničnej politiky Slovenskej republiky.
Na základe vlastného štatútu plní výbor aj úlohu Národného komitétu Medzinárodnej asociácie hydrologických vied (ďalej IAHS) v rámci Medzinárodnej únie pre geofyziku a geodéziu (IUGG) a Medzinárodnej rady pre vedu (ISC).
Výbor má v súčasnosti 5 členov a spolu s Plénom SNV 13 členov.
Predsedami výboru boli Ing. Ľudovít Molnár, CSc. (v rokoch 1993-1998) a RNDr. Pavol Miklánek, CSc. (od roku 1998 doteraz). Národným reprezentantom pre IAHS a podpredsedom výboru je prof. Ing. Ján Szolgay, PhD. (od roku 1993 doteraz).
Hlavné projekty v súčasnosti:

- Regionálna spolupráca podunajských krajín v hydrológii;
- Low Flow and Drought in the Danube River Basin;
- ERB – European Reference Basins

Hlavné domáce aktivity:

- Konferencie mladých hydrológov (v roku 2023 sa bude konať 35. konferencia);
- Posterový deň (v roku 2023 sa bude konať 30. Posterový deň s medzinárodnou účasťou „Transport vody, chemikálií a energie v systéme pôda-rastlina-atmosféra“;
- Vydávanie série monografií Publikácie SVH (doteraz bolo vydaných 12 zväzkov);
- Udeľovanie Cien Ľuda Molnára (doteraz bolo udelených 8 cien).

Kľúčové slová: Slovenský výbor pre hydrológiu, Medzivládny hydrologický program, UNESCO

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Slovenský výbor pre Medzivládny hydrologický program

30 ROKOV SLOVENSKÉHO NÁRODNÉHO VÝBORU PRE MEDZIVLÁDNY HYDROLOGICKÝ PROGRAM UNESCO

Pavol Miklánek, Dana Halmová
Ústav hydrológie SAV, v.v.i., Bratislava, Slovensko

70
1953-2023

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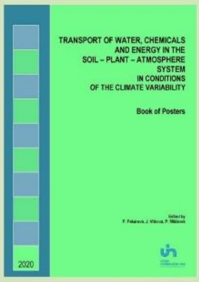
Zasadnutie Medzivládnej rady IHP UNESCO


Zborník KMO 2021



Zborník Posterového dňa 2020


Konferencia mladých hydrológov 2013

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Regionálna spolupráca podunajských krajín v hydrológii

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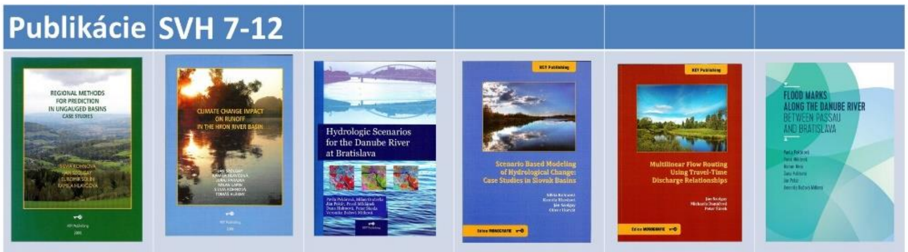

Mean annual runoff in the Danube River Basin, 1960–1990, Authors: Kostka, Z. and Holko, L. in Petrovič et al. (2006).

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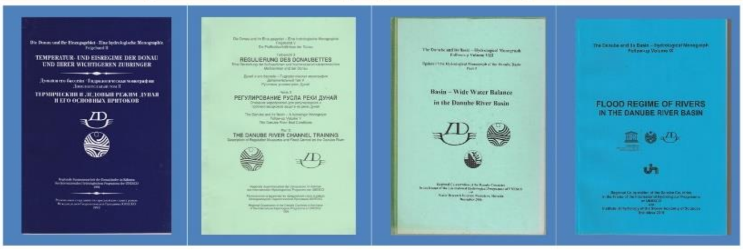
- Udeľovanie Cien Ľuda Molnára (doteraz bolo udelených 8 cien)


Cena Ľuda Molnára udelená v roku 2015 Ing. Josefovi Hladnému, CSc.

Následné diely Monografie Dunaja spracované a vydané na Slovensku



PROBLEMS OF THE WATER-GAUGING STATIONS' NETWORK

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ABSTRACT

Department of Surface Water Quantity at the Slovak Hydrometeorological Institute (SHMÚ), based on Act no. 201/2009 Coll. and Act no. 364/2004 Coll, operates the State Hydrological Network for monitoring surface water quantity, thereby ensuring the operation and continuous monitoring of quantitative indicators of surface water in Slovakia. The construction of the first water-gauging stations on the territory of today's Slovakia began back in the 19th century. Significant increases in the number of stations occurred mainly after the First World War, and subsequently also after floods in the 1960s, along with the construction of large waterworks, when there was a greater need to understand the hydrological regime of flows. In 2023, SHMÚ will operate 417 objects of the State Hydrological Network for monitoring surface water quantity with automatic instrumentation, in which the water level, water temperature, and in the vast majority, flow rates, air temperature, amount of precipitation, ice phenomena, and suspended load are monitored in 16 of them.

The quality of the measured data is influenced by several factors and their interaction, and the fact that the monitoring is carried out in the field in natural conditions must be taken into account. In the long term, age of water-gauging station, changing weather conditions, effects of water on construction objects, instrumentation, and stability of the subsoil or unmaintained riparian vegetation is a big challenge for the serviceable life and proper functionality of monitoring objects. Last but not least, the problem of maintaining water measuring stations in a satisfactory condition during flood situations is problematic, this significantly change the longitudinal and transverse shape of the riverbed resulting in regular damage to objects or their parts, which is financially expensive to repair or replace, especially in cases where work with an external supplier is required. The preparation of the reconstruction of damaged objects is protracted, the administrative load is very large, and in some cases, it takes several years, leading not only in further damage to the object but also outdated financial coverage of the project, and thus its non-implementation. One of the solutions to the problem of ensuring better and simpler maintenance and repairs at water-gauging stations could be, in addition to minimizing administrative tasks, to ensure and deepen the cooperation of SHMÚ and other departmental organizations, so that employees of SHMÚ can properly monitor and evaluate hydrological parameters at water-gauging stations.

Not only nature, but also people with some of their activities intentionally or unintentionally make it difficult or impossible to monitor flows. With various artificial dams, unannounced withdrawals or discharges, they artificially change the nature and regime of the flow, which is subsequently reflected in the demanding evaluation and balancing of the water regime of the flow. In worse cases, it is vandalism and theft at the stations, when water meter booths, staff gauge, instrumentation are damaged or stolen, causing the monitoring facility to become inoperable. The resulting damages and their solutions are not only a great financial load, but also a time load for SHMÚ.

Despite several problems, the preservation of a long-term series of observations of the water level, water temperature, flows, precipitation, etc., is the priority of hydrological service workers who regularly look for solutions to unexpected situations in the field. Their effort is to record every case of change in the discharge measurement cross section in order to repair damaged objects, to look for a place to move existing water-gauging stations and build new water-gauging stations, or to arrange an administrative agenda related to personnel and financial security of their operation.

Keywords: water-gauging stations, reconstruction, restoration, floods, vandalism, theft

PROBLÉMY SIETE VODOMERNÝCH STANÍC

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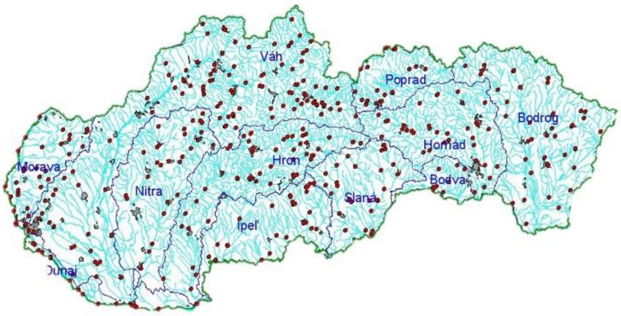
S budovaním prvých vodomerných staníc na území dnešného Slovenska sa začalo už v 19. storočí. K výrazným nárastom počtu staníc došlo najmä po 1. svetovej vojne, a následne aj po povodniach v 60-tych rokoch 20. storočia spolu s výstavbou veľkých vodných diel, kedy vznikla silnejšia potreba poznania hydrologického režimu tokov. V roku 2023 SHMÚ prevádzkuje 417 objektov Štátnej hydrologickej siete monitorovania kvantity povrchových vôd s automatickým prístrojovým vybavením, v ktorých sa monitoruje výška vodnej hladiny, teplota vody, vo veľkej väčšine aj prietoky, teplota vzduchu, množstvo zrážok, ľadové úkazy a v 16 z nich aj plaveninový režim.



Na kvalitu nameraných údajov vplýva viacero faktorov a ich vzájomné pôsobenie, pričom treba brať do úvahy najmä fakt, že monitoring sa vykonáva v teréne, v prírodných podmienkach. Z dlhodobého hľadiska majú vplyv na životnosť a správnu funkčnosť monitorovacích objektov najmä:

- vek vodomerných staníc
- poveternostné podmienky
- povodne
- chemické zloženie vody
- účinky vody na stavebné časti staníc
- vodné živočíchy
- postupné narúšanie stability podložia
- neudržiavané brehové porasty

Príprava rekonštrukcie poškodených objektov je zdĺhavá, administratívne zaťaženie veľmi veľké a, v niektorých prípadoch trvá aj niekoľko rokov, čo má za následok nielen ďalšie poškodzovanie objektu, ale už aj neaktuálne finančné krytie projektu, a tým jeho neuskutočnenie. Jedným z riešení problému so zabezpečením lepšej a jednoduchšej údržby a opráv na vodomerných staniciach by mohlo byť okrem minimalizácie administratívnych úkonov, zabezpečiť či prehĺbiť spoluprácu SHMÚ a iných rezortných organizácií.

Nie len príroda ale aj ľudia niektorými svojimi aktivitami úmyselne alebo neúmyselne sťažujú či znemožňujú monitoring tokov. Rôznymi umelými prehrádzkami, nenahlásenými odbermi alebo vypúšťaniami, umelo menia charakter a režim toku, čo sa následne prejaví na náročnom vyhodnocovaní a bilancovaní vodného režimu toku.

V horších prípadoch ide o vandalizmus a krádeže na staniciach, kedy sú poškodené vodomerné búdy, vodočetné laty, poškodená alebo ukradnutá prístrojová technika, čím dochádza k znefunkčneniu monitorovacieho objektu. Vzniknuté škody a ich riešenia sú nielen veľkou finančnou, ale aj časovou záťažou pre SHMÚ.

Aj napriek viacerým problémom je zachovanie dlhodobého radu pozorovania výšky vodnej hladiny, teploty vody, prietokov, zrážok atď. prioritou pracovníkov hydrologickej služby, ktorí pravidelne hľadajú riešenia na nečakané situácie v teréne. Ich snahou je každý prípad zmeny vo vodomernom profile zaznamenať, poškodené objekty opraviť, vyhľadávať miesto pre presun existujúcich a vybudovanie nových vodomerných staníc či vybaviť administratívnu agendu súvisiacu s personálnym a finančným zabezpečením ich prevádzky.

UNCERTAINTY OF PRECIPITATION INPUT DATA IN THE HYDROLOGICAL FORECASTING SYSTEM OF SHMU

Hana Hlaváčiková [1], Eva Kopáčiková, Kateřina Hrušková, Danica Lešková

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ABSTRACT

A well-configured, verified hydrological operational forecasting system is an invaluable tool for hydrological forecasting and warning service. Department of Hydrological Forecasts and Warnings of the Slovak Hydrometeorological Institute (SHMU) recently performed the comprehensive evaluation of its hydrological forecasts based on the new radar precipitation estimate (product known as qPrec) and resulting from the HBV rainfall runoff model. It was shown that in the Slovak physical-geographical conditions, the precipitation data (measured and predicted) and the configuration of the hydrological model are the most significant sources of hydrological forecasts´ uncertainties.

Two precipitation data sets enter the hydrological models in operational service as forcing data, which affect results of the forecasting system in a different way. Measured one, as radar precipitation estimate, influences primarily the initial states of the model before the forecasts, and the offline model calibration. Another one, forecasted precipitation, affects directly the value of forecasted flows following up on their initial states, and with its uncertainty they can provide very different results compared to real flows. Meteorological precipitation forecasts come from the deterministic ALADIN/SHMU model with 4.5 km resolution, generated 4 times per day with hourly time-step and 69 hours lead time. Gridded precipitation products are post-processed into the areal precipitation for sub-catchments, the hydrological units, needed as input data for the hydrological models.

For evaluation of the precipitation entering the hydrological forecasting system, the precipitation maps and two kind of proportion maps are generated every month. Then for particular catchments qPrec and forecasted precipitation related to measured ones are quantified. From these results, it can be determined in which catchments rainfall inputs are under- or overestimated and to what extent. For example in the upper Hron river basin, radar product (qPrec) was underestimated in all sub-catchments during the year 2022 in the range of 0 – 60 % compared to measured data (interpolated from rain-gauge measurements). Contrary, forecasted precipitation by the ALADIN/SHMU model were mostly overestimated in the range of 0 – 90 % compared to measured data. In these analyses, the water availability of a given month must also be taken into account. Under- or overestimation of the qPrec and the forecasted precipitation may not have any significant effect on the predicted dry month flows. However, during the wet periods (caused by regional or convective rainfall), over- or underestimated precipitation entering the hydrological models have a significant impact on the hydrological forecast itself. The precipitation analysis carried out on a regular basis can help to understand the hydrological model performance in both simulation and forecast modes. We would like to focus on how to implement these findings into the hydrological forecasting process in future.

Keywords: radar precipitation estimate, hydrological model, sub-catchments

UNCERTAINTY OF PRECIPITATION INPUT DATA IN THE HYDROLOGICAL FORECASTING SYSTEM OF SHMU

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A well-configured, verified hydrological operational forecasting system is an invaluable tool for hydrological forecasting and warning services. However, precipitation data and hydrological models are the considerable sources of hydrological forecasts´ uncertainties. In this work, examples of analyses of precipitation data, measured and forecasted as well, entering the hydrological models used for hydrological forecasts, are presented.

In August 2016, a new system of 4 radars for the territory of Slovakia was put into operation. Recalibration and validation of the hydrological models based on precipitation from the radar product (called qPrec) was carried out for the period 08/2016 - 12/2020.

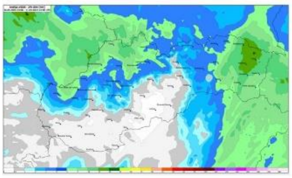


Fig. 1: radar + rain-gauges, merged product qPrec (Méri et al. (2021))

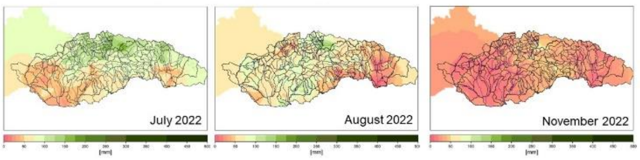
Fig. 2: Network of automatic rain-gauges

What is for precipitation analyses available?

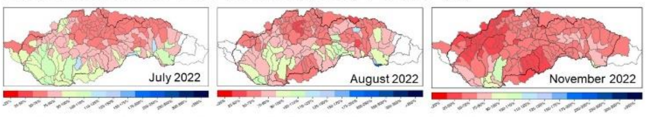
Monthly precipitation totals, in form of maps:

- precipitation maps (denoted as „climate"), spatial interpolation of 568 rain-gauge stations in a GIS environment
- proportion maps: combined radar product (qPrec) with respect to „climate"
- proportion maps: ALADIN/SHMU, 0:00 UTC model run, forecasted precipitation for the first day with respect to „climate"

Precipitation maps: monthly totals (mm)

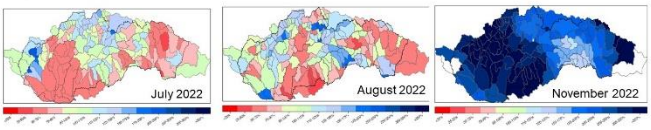


Proportion maps: radar product (qPrec) / climate (%)



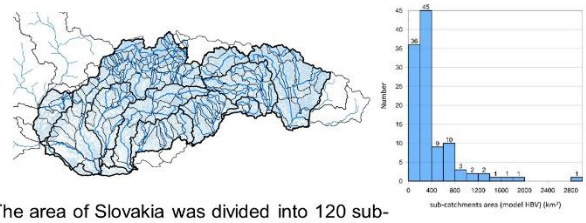
In many catchments qPrec product is significantly underestimated

Proportion maps: ALADIN/SHMU (0:00 UTC) precipitation forecast for the first day / climate (%)

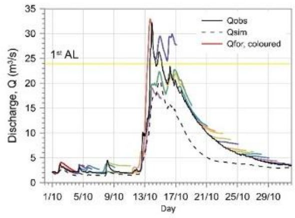


red colour underestimated blue colour overestimated

The HBV hydrological rainfall-runoff model was recalibrated with the new radar precipitation estimate (qPrec)



The area of Slovakia was divided into 120 sub-catchments with mean area of 400 km^2



Simulated and forecasted flows

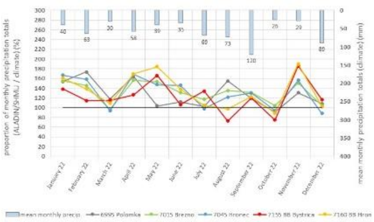
Qobs – observed discharge,
Qsim – simulated discharge with measured radar (precipitation estimate) and INCA input (measured temperature),
Qfor – forecasted discharge with ALADIN/SHMU input,
AL – flood alert level

Two precipitation inputs in the hydrological models are:

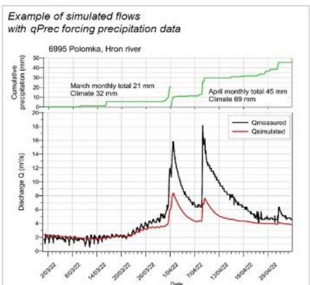
- **Measured precipitation**
  radar-merged product (qPrec) – it influences model *calibration*, and *initial states* before the forecast
- **Forecasted precipitation**
  deterministic ALADIN/SHMU model

Trying to answer the questions:
In which catchments combined radar product is under /overestimated?
In which catchments ALADIN/SHMU precipitation forecast is under/ overestimated? When and how much?
How much does this affect the modelled flows? Can we improve precipitation input and achieve better hydrological forecasts?

Analyses for particular catchments



Analyses for particular catchments



CONCLUSIONS AND FUTURE OUTLOOK

By regularly analysing precipitation data for hydrological forecasting purposes, it is possible to identify, for example systematic errors, but also the areas where they do not provide satisfactory results. The findings can serve as a basis for improving precipitation data quality (both measured and predicted) and are a challenge for their further processing to improve the quality of hydrological forecasts.

Literature: Méri, L. et al. (2021): Improved Radar Composites and Enhanced Value of Meteorological Radar Data Using Different Quality Indices, Sustainability, 13, 5285

Acknowledgement: *This work was supported by the Slovak Research and Development Agency under the Contract no. APVV-19-0340.*

VERIFICATION OF CALCULATED ACTUAL EVAPOTRANSPIRATION USING LYSIMETER MEASUREMENT

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ABSTRACT

Actual evapotranspiration is an important component of the equation describing the water balance in the soil – groundwater – plant cover – atmosphere (PPVRAT) system. Its values can be obtained by direct measurement or calculation. The calculation of actual evapotranspiration is based on a numerical simulation using the mathematical model HYDRUS. This model of soil water regime enables to quantify individual members of the balance equation. Actual evapotranspiration totals are expressed through water consumption by plant roots and surface flow. The reliability of model outputs must always be verified by measured data. In this case, a lysimeter was used, which is a part of the lysimeter station located in Petrovce nad Laborcom. It is a weighing lysimeter with groundwater level control that allows to express the actual evapotranspiration totals by quantifying the water flows at the top and bottom boundary of the lysimeter. In addition, data from a nearby weather station was used to calculate the reference evapotranspiration. The obtained hourly courses of evapotranspiration and meteorological elements were further analysed and compared.

Keywords: evapotranspiration, numerical simulations, lysimetric measurements, soil water regime

Acknowledgement: This study was supported by the grant from the Slovak Academy of Sciences (project VEGA No. 2/0044/20). The authors thank the agency for its research support.

Overenia vypočítanej aktuálnej evapotranspirácie lyzimetrickými meraniami

Verification of calculated actual evapotranspiration using lysimeter measurement

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Actual evapotranspiration is an important component of the equation describing the water balance in the soil - groundwater - plant cover - atmosphere (PPVRAT) system. Its values can be obtained by direct measurement or calculation. The calculation of actual evapotranspiration is based on a numerical simulation using the mathematical model HYDRUS. This model of soil water regime enables to quantify individual members of the balance equation. Actual evapotranspiration totals are expressed through water consumption by plant roots and surface flow. The reliability of model outputs must always be verified by measured data. In this case, a lysimeter was used, which is a part of the lysimeter station located in Petrovce nad Laborcom. It is a weighing lysimeter with groundwater level control that allows to express the actual evapotranspiration totals by quantifying the water flows at the top and bottom boundary of the lysimeter. In addition, data from a nearby weather station was used to calculate the reference evapotranspiration. The obtained hourly courses of evapotranspiration and meteorological elements were further analysed and compared.

Lyzimetrická stanica v Petrovciach nad Laborcom - **N** 48° 47,540´; **E** 21° 53,175´; 117 m n. m.

Stanica bola vybudovaná v roku 2014. Pozostáva z 5 vážiteľných lyzimetrov uložených v dvoch samostatných plastových kontajneroch. Každý lyzimeter je tvorený oceľovým valcom s plochou 1 m^2 a výškou 2,5 m. Vo valcoch sú pôdne monolity odobrané z rôznych lokalít Východoslovenskej nížiny (VSN) tak, aby čo najlepšie reprezentovali typické pôdne druhy na VSN. Každý lyzimeter je vybavený regulovateľným systémom hladiny podzemnej vody (HPV) napojeným na blízky vrt, ktorý slúži ako zdroj vody. Súčasťou lyzimetrického celku je aj meteorologická stanica poskytujúca údaje o meteorologických prvkoch. Všetky monolity sú postavené na váhach s presnosťou ± 0,01 kg. Rastlinný kryt vo valcoch tvorí tráva zastrihávaná na výšku 12 cm.

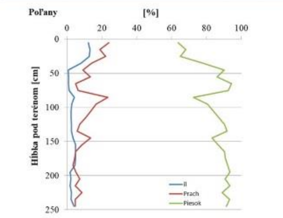
Pri bilancovaní vody v pôde je podstatnou zložkou na strane odtoku evapotranspirácia. **Na evapotranspirácii sa podieľajú** dva čiastkové procesy. Prvým z nich je **transpirácia**, ktorá sa uskutočňuje cez prieduchy rastlín a je dôležitým produkčným faktorom. Druhým je **evaporácia**, t.j. výpar z voľnej plochy. Veľkosť evapotranspirácie závisí predovšetkým od meteorologických podmienok a vlhkosti pôdy. Vlhkosť pôdy ovplyvňuje to, či je dostatok vody na výpar a či bude dosiahnutý jeho potenciál. Ak tomu tak nie je, vzniká evapotranspiračný deficit. **Veľkosť evapotranspirácie** možno získať buď **priamo meraním alebo výpočtom**. Jedným zo spôsobov **merania výparu** je meranie pomocou vodnej bilancie na lyzimetri. Lyzimeter umožňuje kvantifikovať toky na hornom a dolnom okraji bilancovanej zóny pôdy. Spolu s meraním presnej hmotnosti pôdy je možné bilančne vyjadriť veľkosť evapotranspirácie. **Výpočtové metódy** sú založené na numerickej simulácii vodného režimu pôd pomocou matematických modelov.

Príspevok je zameraný na verifikáciu použitého modelu HYDRUS-1D pomocou lyzimetra.

Analyzované boli hodinové úhrny ET_a vypočítané modelom s meranými hodnotami na lyzimetri za 148 dňové obdobie (27. 05. 2017 až 21. 10. 2017).

Verifikácia modelu bola vykonaná metódami matematickej štatistiky. Vlhkostné podmienky v lyzimetri boli udržiavané tak, aby bol dosiahnutý evapotranspiračný potenciál. To zároveň umožnilo overiť aj spoľahlivosť rôznych prístupov výpočtu ET_{ref}.

Pôdny profil monolitu v skúmanom lyzimetri, odobranom pri obci Poľany na juhovýchode VSN, zobrazený na obrázku vpravo je ľahší hlinitopiesočnatý až piesočnatý prechádzajúci vo vrchnej časti do pieskovitej hliny.



Zrnitostné zloženie pôdy v skúmanom lyzimetri po výške pôdneho profilu.

Spracovanie lyzimetrických meraní

Lyzimeter je nástroj, ktorý umožňuje kvantifikovať jednotlivé zložky vodného režimu pôd.

Ak poznáme hodnoty jednotlivých členov bilančnej rovnice potom je možné vyjadriť aj hodnoty ET_a pomocou upravenej bilančnej rovnice do tvaru:

$$\Delta W = P_{lys} - ET_a \pm BF \qquad (1)$$

Každá zmena hmotnosti o 1 kg predstavuje zmenu vlhkosti pôdy ΔW o 1 mm, vzhľadom k ploche lyzimetra 1 m^2. Závlaha nebola aplikovaná a HPV bola nastavená na konštantnú úroveň -1 m pod terénom. V rovnici boli použité zrážky získané z lyzimetra (P_{lys}) a toky na dolnom okraji lyzimetra BF (bottom fluxes). BF majú kladnú hodnotu ak voda prúdi do lyzimetra a naopak záporné hodnoty reprezentujú výtok z lyzimetra.

Popis použitého modelu

Matematický model HYDRUS-1D vo verzii 4 bol použitý pre výpočet analyzovaných členov bilančnej rovnice v hodnotenom časovom období. HYDRUS-1D je jednorozmerný model na simuláciu toku vody, prenosu tepla a pohybu rozpustných látok podieľajúcich sa v následných reakciách prvého rádu vo variabilne saturovaných pôdach. Je založený na riešení Richardsovej rovnice pre variabilne nasýtené prúdenie a na advekčno-disperznom type rovníc pre prenos tepla a rozpustných látok. Rovnica prúdenia ráta s poklesom pre zohľadnenie príjmu vody koreňmi rastlín.

Úhrny modelovanej aktuálnej evapotranspirácie (ET_a) boli získané súčtom množstva vody odčerpanej z pôdy koreňmi rastlín (transpirácia) a vody z povrchového toku na rozhraní medzi povrchom pôdy, rastlinným krytom a atmosférou (evaporácia).

Výpočet referenčnej evapotranspirácie (ET_{ref}) v modeli HYDRUS-1D vychádzal z Penman-Monteithovej kombinačnej rovnice (2) podľa FAO, 1990:

$$ET_{ref} = \frac{0{,}408\,\Delta\,(R_n - G) + \gamma \frac{C_n}{T_{hr}+273} u_2\,(e_s - e_a)}{\Delta + \gamma\,(1 + C_d\, u_2)} \qquad (2)$$

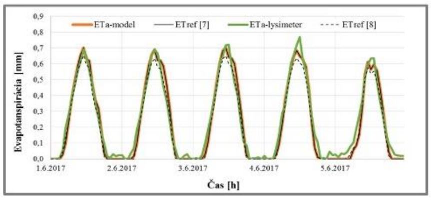
kde R_n je radiačná bilancia povrchu plodiny [MJ m^{-2} h^{-1}], G je tok tepla v pôde [MJ m^{-2} h^{-1}], T_{hr} je priemerná hodinová teplota vzduchu vo výške od 1,5 do 2,5 m [°C], u_2 je priemerná hodinová rýchlosť vetra vo výške 2 m [m.s^{-1}], e_s je tlak nasýtenej vodnej pary do 2,5 m [kPa], e_a je priemerný aktuálny tlak vodnej pary vo výške od 1,5 do 2,5 m [kPa], Δ je derivácia tlaku nasýtenej vodnej pary pri teplote vzduchu T_{hr} [kPa °C^{-1}], γ je psychrometrická konštanta [kPa °C^{-1}], C_n a C_d sú konštanty, ktoré sa menia podľa referenčného typu. V modeli sú hodnoty konštánt C_n = 900 a C_d = 0,34. Pre porovnanie bol zvolený aj novší prístup výpočtu ET_{ref} podľa rovnice (2) s hodnotami konštánt C_n = 37 a C_d = 0,24 (denné hodiny), 0,96 (nočné hodiny) podľa Allen a kol. 2005.

Na ďalšom obrázku sú spoločne znázornené hodinové priebehy ET_a vypočítanej modelom a bilančne pomocou lyzimetra s priebehmi ET_{ref} podľa rôznych metodík [7] podľa FAO, 1990 a [8] podľa Allen a kol., 2005. Pre lepší náhľad je na obrázku zobrazených prvých 5 júnových dní z celého analyzovaného obdobia (27. 05. 2017 až 21. 10. 2017). Tu je jasne viditeľná zhoda modelovaných a lyzimetrom zmeraných úhrnov ET_a. Vlhkostné podmienky v lyzimetri boli udržiavané tak, aby bol dosiahnutý maximálny možný výpar pomocou konštantnej hladiny podzemnej vody nastavenej na -1 m pod terénom. Pre evapotranspiračný deficit ΔET daný rozdielom medzi ET_{ref} a ET_a teda platilo $\Delta ET \approx 0$. To zároveň umožnilo overiť presnosť rôznych metód výpočtu. Z obrázka je rovnako zrejmá aj vysoká miera zhody medzi ET_a a ET_{ref}.

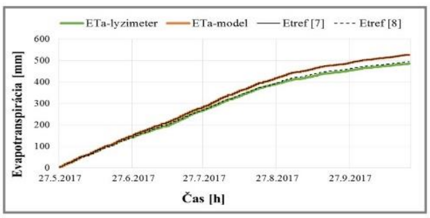
Hodnoty odchýlok a koeficienta determinácie medzi meranými, modelovanými a vypočítanými hodnotami evapotranspirácie.

Evapotranspirácia	ΔMAX	ΔMIN	SE	R^2
ET_a (lyzimeter) – ET_a (model)	0,2532	-0,3727	0,0538	0,9302
ET_{ref} [8] – ET_{ref} [7]	0,0567	-0,0929	0,0147	0,9948
ET_a (lyzimeter) – ET_{ref} [7]	0,2532	-0,3727	0,0538	0,9302
ET_a (lyzimeter) – ET_{ref} [8]	0,2307	-0,3054	0,0468	0,9388
ET_a (model) – ET_{ref} [7]	0	-0,0075	0,0004	1
ET_a (model) – ET_{ref} [8]	0,0929	-0,0567	0,0136	0,9948

ET_{ref} - výpočet podľa FAO, 1990 [7], výpočet podľa Allen a kol., 2005 [8]



Porovnanie priebehov modelovanej a meranej ET_a s priebehmi vypočítanej ET_{ref} počas piatich dní zo začiatku júna 2017.



Priebeh kumulatívnych hodnôt evapotranspirácie v hodnotenom období (27.5.2017 – 21.10.2017).

Výsledky lineárnej regresie preukazujú vysokú mieru závislosti medzi meranými a vypočítanými hodnotami evapotranspirácie (na obrázkoch vľavo). Hodinové úhrny ET_a vypočítané modelom veľmi dobre korelujú s meranými hodnotami na lyzimetri (vpravo obrázok ***a***). Poukazuje na to vysoká hodnota koeficienta determinácie R^2 = 0,9302. Odchýlky sa pohybujú v rozmedzí hodnôt -0,3727 (MIN) až 0,2532 (MAX). Štandardná odchýlka je nízka (SE = 0,0538) čo znamená, že hodnoty sa od seba odlišujú minimálne. Vzájomne sú korelované aj hodnoty ET_{ref} vypočítané dvoma rozdielnymi metodikami. Rozdiely v úhrnoch ET_{ref} vypočítaných podľa staršej metodiky [7] a novšej metodiky [8] sú veľmi malé (obrázok ***b***).

Odchýlky spolu s hodnotou koeficienta determinácie sú uvedené v tabuľke. Výpočet ET_{ref} podľa rôznych metodík vo vzťahu k meranej ET_a vykazuje určité rozdiely (obrázky ***c***, ***d***). V prípade staršej metodiky výpočet viac nadhodnocuje meranie a hodnota koeficienta determinácie je o niečo nižšia R^2 = 0,9302 v porovnaní s novšou metodikou, kde R^2 = 0,9388. Tak ako koeficienty determinácie aj hodnoty odchýlok uvedených v tabuľke ukazujú v prospech novšej metodiky pre výpočet ET_{ref} voči lyzimetricky meranej ET_a. Ak porovnávame tieto dva prístupy výpočtu ET_{ref} s modelovanou ET_a, potom je situácia opačná. Úhrny modelovanej ET_a sú takmer totožné s ET_{ref} počítanou staršou metodikou (obrázok ***e***). Je to ale skôr dôsledok toho, že v modeli je implementovaný tento starší výpočet ET_{ref}, ktorý je v simulácii zohľadnený. V tomto prípade s modelom veľmi dobre koreluje aj novší výpočet, čo potvrdzuje vysoká hodnota R^2 = 0,9948 a veľmi malé odchýlky (obrázok ***f*** a tabuľka).

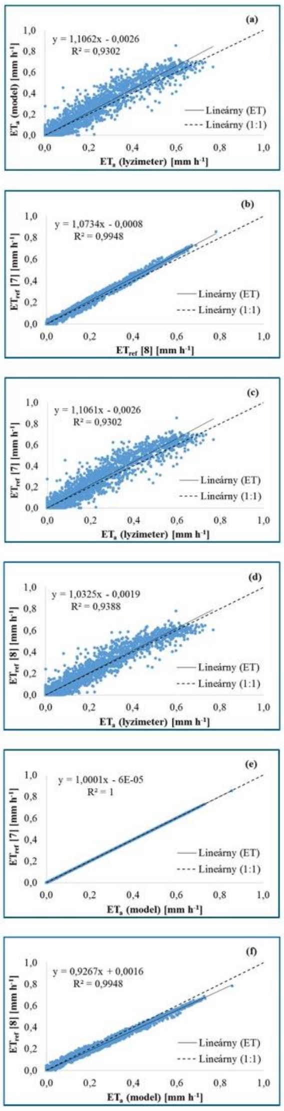
Rozdiely medzi meranými a vypočítanými hodnotami evapotranspirácie sú za celé analyzované obdobie znázornené na predchádzajúcom obrázku. Z kumulatívnych priebehov vychádza celkový rozdiel medzi modelovanou a meranou ET_a 42,02 mm. V prípade ET_{ref} je rozdiel vyplývajúci z rôznych metodík výpočtu 33,21 mm. Ak porovnávame meranú ET_a s ET_{ref} tak menší rozdiel je pri novšej metodike (Allen a kol. 2005) (8,97 mm) oproti staršej (FAO, 1990) (42,18 mm). Kumulatívny rozdiel medzi modelovanou ET_a a ET_{ref} podľa rôznych metodík je nižší pri staršej metodike (0,16 mm) a vyšší pri novšej metodike (33,05 mm). V priebehu analyzovaného obdobia sa priemerné hodinové úhrny evapotranspirácie za jednotlivé mesiace postupne znižovali. Najvyššie hodnoty boli v mesiacoch máj až august, od kedy postupne klesali k najnižším hodnotám v jesenných mesiacoch september a október. Priemerné hodinové úhrny meranej a modelovanej ET_a v jednotlivých mesiacoch sú nasledovné: Máj (0,20 / 0,21 mm), Jún (0,19 / 0,20 mm), Júl (0,17 / 0,19 mm), August (0,16 / 0,17 mm), September (0,08 / 0,09 mm) a Október (0,05 / 0,06 mm).

ZÁVER

Verifikácia modelu HYDRUS-1D bola uskutočnená na hodinových úhrnoch ET_a za obdobie od 27.5.2017 do 21.10.2017. V tomto období boli k dispozícii aj merané hodnoty získané na základe vodnej bilancie pomocou váženého lyzimetra. Podmienky pre simuláciu boli v modeli nastavené tak, aby zodpovedali skutočným podmienkam v lyzimetri. Pre dosiahnutie maximálnych hodnôt výparu (kde $\Delta ET = ET_{ref} - ET_a \approx 0$) bola hladina podzemnej vody nastavená na -1 m pod terénom. Týmto bolo možné overiť aj presnosť dvoch rôznych metodík výpočtu ET_{ref} voči meranej a modelovanej ET_a. Lineárnou regresiou bola preukázaná vysoká zhoda medzi meranými a modelovanými hodnotami ET_a (R^2 = 0,9302; SE = 0,0538). V prípade ET_{ref} sa ako vhodnejšia ukázala novšia metodika výpočtu vo vzťahu k meranej ET_a (R^2 = 0,9388, SE = 0,0468), kde bol sumárny rozdiel iba 9 mm (2 %). V kumulatívnom vyjadrení ET_a je rozdiel medzi modelom a meraním 42 mm (9 %) za celé hodnotené obdobie.

Výsledky verifikácie ukázali, že model HYDRUS-1D je vhodný pre použitie v podmienkach simulujúcich existujúci pôdny profil v skúmanom lyzimetri. S použitím všetkých dostupných dát z blízkej meteorologickej stanice, hydrofyzikálnych charakteristík pôdneho profilu a fenologických charakteristík porastu dokáže spoľahlivo odhadnúť veľkosť výparu.

Táto práca bola podporovaná grantovou agentúrou VEGA 2/0044/20.



Vyjadrenie lineárnych závislostí medzi meranými, modelovanými a vypočítanými hodnotami evapotranspirácie.

THE SOIL WATER CONTENT IN THE DANUBE FLOODPLAIN FOREST IN 1995 - 2020

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ABSTRACT

The need to measure soil moisture in floodplain forests of the Danube results from the assumed damage to floodplain forests in the area affected by the construction of the Danube hydroelectric dam and from the objective of monitoring the water requirements of the floodplain forest under the conditions of the natural and later also affected water regime of the inundation area. The importance of soil moisture monitoring lies in the possibility of assessing water reserves in the aeration zone available for consumption by vegetation of the area of interest, with the possibility of their effective regulation by planned flooding of the Danube branches.
Soil moisture in forest ecosystems was monitored between 1995 and 2020. The measurement sites followed other monitoring subtasks with which they were shared. Measurements were made in permanent observation wells rigidly fitted with metal pipes extending below the groundwater level, normally more than 4 m. The basic set of observation objects consisted of 24 boreholes. The number of observation objects monitored varied from year to year, depending mainly on available funding. Generally speaking, observations were made 1x a month outside the growing season and at 14-day intervals during the growing season (in some years only during the growing season from March to early December).
To measure soil moisture, a neutron probe of the Neutron Probe System IH-II type produced by the English company DIDCOT INSTRUMENTS was used.
The water content of the soil layers (0-30 cm, 0-80 cm and 0-150 cm) is an important indicator of the actually available amount of water for vegetation. The first layer characterizes the depth of the root system of the herbaceous undergrowth, the second layer of shrubbery and the entire layer to a depth of 150 cm is assumed to be a decisive layer for supplying water to the forest tree cover. It can be estimated from the soil moisture percentage and compared to soil water content thresholds (FC—field capacity, PDA—point of decreased availability, and WP—wilting point) to assess the sufficiency or insufficiency of water reserves in the soil for vegetation.
Based on twenty-five years of observations directly provided by the Institute of Hydrology SAS (1996-2020), the water content in the soil was evaluated, which made it possible to evaluate its changes during this period.

Keywords: floodplain forest, soil moisture, Danube

Acknowledgements: This work was supported by the project APVV No. 20-0374 "Regional detection, attribution and projection of impacts of climate variability and climate change on runoff regimes in Slovakia".

OBSAH VODY V PÔDE V DUNAJSKOM LUŽNOM LESE V ROKOCH 1995 - 2020

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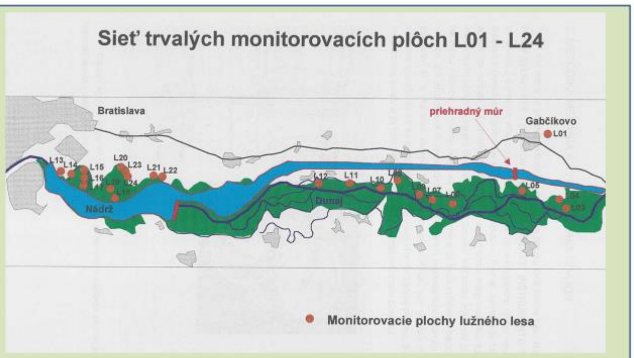
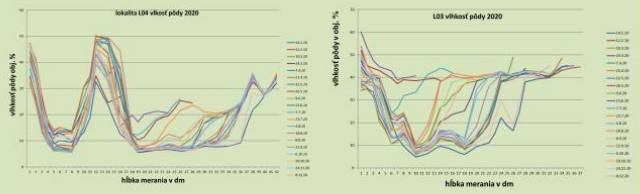
Potreba merania pôdnej vlhkosti v lužných lesoch Dunaja vyplýva z predpokladaného poškodenia lužných lesov v oblasti ovplyvnenej výstavbou vodného diela na Dunaji a z cieľa monitorovania požiadaviek lužného lesa na vodu v podmienkach prírodného a neskôr aj ovplyvneného vodného režimu inundačného územia. Význam monitorovania pôdnej vlhkosti spočíva v možnosti posúdenia zásob vody v nenasýtenej zóne, ktoré sú k dispozícii na konzumáciu vegetáciou záujmovej oblasti, s možnosťou ich účinnej regulácie plánovaným zaplavením ramien Dunaja.

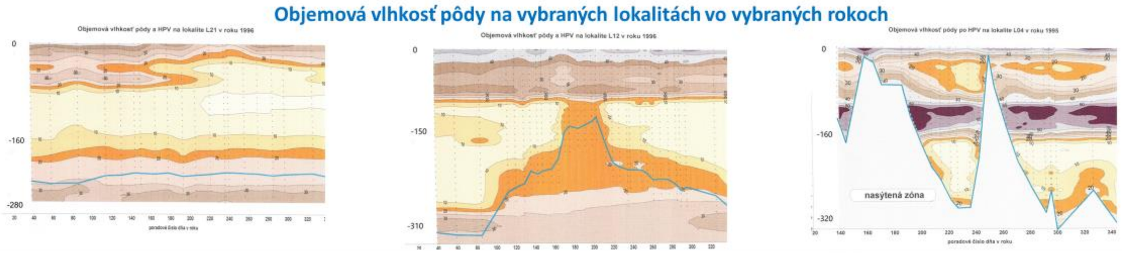
Vlhkosť pôdy v lesných ekosystémoch bola monitorovaná v rokoch 1995 až 2020. Lokality merania nadväzovali na iné čiastkové úlohy monitoringu, s ktorými boli spoločné. Merania boli vykonávané v permanentných pozorovacích vrtoch pevne osadených kovovými rúrkami siahajúcimi pod hladinu podzemnej vody, zvyčajne viac ako 4 m. Základný súbor pozorovacích objektov pozostával z 24 vrtov. Počet monitorovaných pozorovacích objektov sa z roka na rok menil, najmä v závislosti od dostupných finančných prostriedkov. Vo všeobecnosti sa pozorovania vykonávali 1x mesačne mimo vegetačného obdobia a v 14-dňových intervaloch počas vegetačného obdobia (v niektorých rokoch iba počas vegetačného obdobia od marca do začiatku decembra).
Na meranie pôdnej vlhkosti sa používala neutrónová sonda typu Neutron Probe System IH-II z produkcie anglickej firmy DIDCOT INSTRUMENTS. Na základe dvadsiatich piatich rokov pozorovaní priamo vykonávaných Ústavom hydrológie SAV (1996-2020) bol vyhodnotený obsah vody v pôde, čo umožnilo vyhodnotiť jeho zmeny v tomto období.





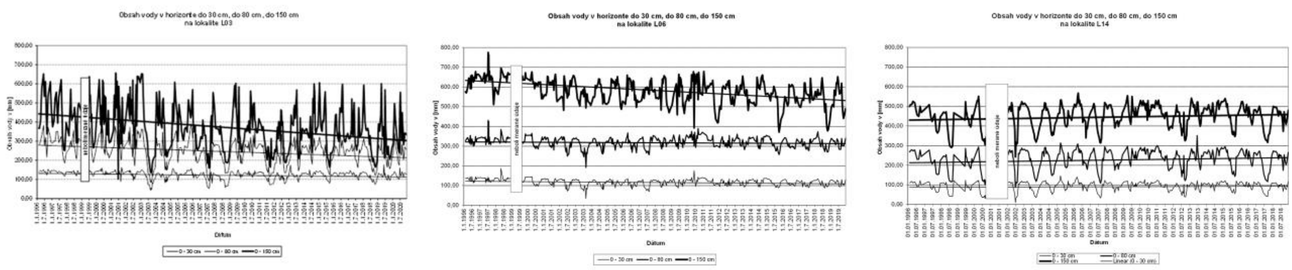
Priebehy objemovej vlhkosti pôdy na lokalitách L03 a L04 počas roka 2020

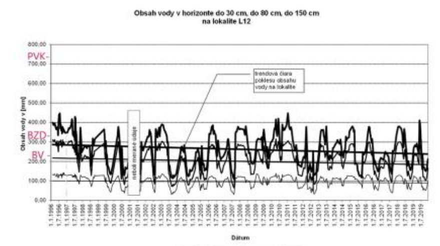
Objemová vlhkosť pôdy na vybraných lokalitách vo vybraných rokoch



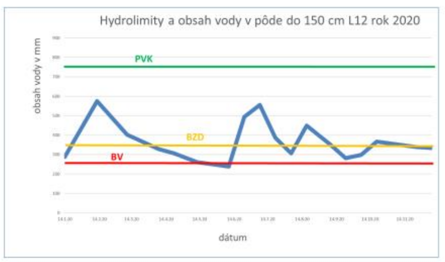
Obsah vody v pôde na vybraných lokalitách za celé obdobie 1996 - 2020

Obsah vody v pôdnych vrstvách (0-30 cm, 0-80 cm a 0-150 cm) je dôležitým ukazovateľom skutočne dostupného množstva vody pre vegetáciu. Prvá vrstva charakterizuje hĺbku koreňového systému bylinného podrastu, druhá vrstva kríkov a celá vrstva do hĺbky 150 cm sa považuje za rozhodujúcu vrstvu pre prívod vody do lesného stromového porastu. Dá sa odhadnúť z percenta pôdnej vlhkosti a porovnať s prahovými hodnotami obsahu vody v pôde (PVK – poľná vodná kapacita, BZD – bod zníženej dostupnosti a BV – bod vädnutia) na posúdenie dostatočnosti alebo nedostatočnosti zásob vody v pôde pre vegetáciu.





Porovnanie obsahu vody v pôde s hydrolimitmi na lokalite L12 za celé obdobie a za rok 2020



This work was supported by the project APVV No. 20-0374 "Regional detection, attribution and projection of impacts of climate variability and climate change on runoff regimes in Slovakia".

DYNAMICS OF POTENTIALLY SATURATED AREAS DURING RAINFALL-RUNOFF EVENTS

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ABSTRACT

The water content in the soil is an important component of the water balance either at the scale of the soil profile or at the scale of the river basin. It plays a key role in controlling the hydrological interactions among soil, climate, hydrologic response, solute transport, and ecosystem dynamics. Estimation of the spatial and temporal variability of soil moisture at a hillslope scale is important for understanding hillslope runoff generation processes. During different rainfall-runoff events and periods, different parts of the catchment may contribute differently to the stream. For example, during dry periods only a small part of a catchment can be connected to the stream, but the connected area can expand during rainfall or snowmelt events. Knowledge of which areas are connected and contribute to streamflow is important because it helps to shape our understanding of how catchments work.

In this study, we used a spatially distributed hydrological model Mike SHE in a pristine mountain catchment (the Jalovecký Creek catchment) in Slovakia to address the following research questions: a) How does the model perform in hourly runoff simulations? b) What is temporal and spatial variability of soil moisture during various rainfall-runoff events (several smaller, consecutive events, a flash flood event, large events caused by frontal precipitation)? c) What is the potential hydrological connectivity during the events?

The Jalovecký Creek catchment (area 22.2 km^2, elevations 820-2178 m a.s.l., mean elevation 1500 m, mean slope 30°) is representative for the highest part of the Carpathian Mountains and hydrological monitoring and research are conducted there since 1986. Hydrological response of the catchment is fast (runoff peaks appear at the catchment outlet on average within 2.5 hours after rainfall maxima). Soil cover in the catchment is represented by cambisol, podzol and lithosol. All soils have high stoniness that is often 40–50% and more. Soil moisture is regularly measured in the catchment since 1993, but more data are only available since 2013. Evaluation of the long-term data series indicated that hydrological cycle in the catchment became more dynamic approximately since 2014. It was manifested in greater annual runoff coefficients, increasing flashiness index and flow reversals and the fact that the majority of highest observed seasonal and annual discharges occurred since 2014.

A spatially distributed hydrological model Mike SHE was used to provide runoff and soil moisture simulations in the soil root zone during the rainfall-runoff events. The required data to run the model consist of hydro-meteorological data (precipitation and air temperature measured at stations) as well as spatially distributed data to describe topography, land use and soil parameters. Catchment precipitation and air temperature were interpolated using the altitude gradients of 6.75%/100 and -0.9°C/100 m for precipitation and air temperature, respectively. Model set-up and parameterisation were carried out for a 25 m grid. Parameterization of the soil layers was based on the field data. Model parameters were calibrated by the Shuffled Complex Evolution (SCE) method using the measured discharge data from the catchment outlet. The root mean square error (RMSE) was used as the optimization function. Model performance was evaluated by the Nash-Sutcliffe (NSE) and correlation coefficients (r). We applied an omnidirectional approach using the integral connectivity scale (ICS) method to measure the presence of hydrological connectivity. The ICS was calculated for the selected rainfall-runoff events. Then we analyzed the ICS evolution in time to estimate how long were the potentially saturated pixels in the catchment interconnected. The ICS was calculated for the threshold soil moisture of 44%.

The results show that according to NSE, the model acceptably represented the large runoff events caused by long rains in 2017 and 2018 (NSE 0.86 and 0.95, respectively). However, weaker model performance was found in case of consecutive smaller runoff events in 2014. These results suggest that for the future it would be useful to pay more attention to runoff events caused by short intensive rainfalls. The results also indicate that great part of the catchment contributed to runoff formation during the large runoff events in 2017 and 2018. Potentially saturated areas with soil moisture 44% and more during these events were 100% (event in 2017) or increased from 6.5% of catchment area to 68.6% (event in 2018). ISCmax (i.e., average distance over which were individual pixels connected) varied for the events between 45 and 6327 m. Time from the event beginning until ISCmax during smaller runoff events varied from 3 to 23 hours and during the large events it was quite consistent (26-27 hours). While in 2017, the entire catchment was already saturated at the beginning of the event (duration of ICSmax = 118 h), in 2018, after 23 hours, almost two-thirds of the catchment were saturated (duration of ICSmax = 42 h).
The results also suggest that runoff from the saturated areas was controlled by the rainfall amount. Rainfall of 100 mm and more resulted in the large areal extent (half of the catchment or more) of saturated areas. These areas expanded from the vicinity of stream network during smaller events to the flatter parts of the mountain valleys during larger events. Denser in situ soil moisture measurements are necessary to confirm these results.

Keywords: mountain catchment, hourly runoff simulation, saturated area, integrated connectivity scale

Acknowledgements:This study was supported by the grants from the Slovak Research and Development Agency (project APVV No. 19-0340) and the Slovak Academy of Sciences (project VEGA No. 2/0019/23).

DYNAMIKA POTENCIÁLNE NASÝTENÝCH OBLASTÍ POČAS ZRÁŽKOVO-ODTOKOVÝCH UDALOSTÍ

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1 MOTIVÁCIA

Obsah vody v pôde zohráva kľúčovú úlohu pri riadení hydrologických interakcií medzi pôdou, klímou, hydrologickou odozvou, transportom rozpustených látok a dynamikou ekosystémov. Odhad priestorovej a časovej variability pôdnej vlhkosti v mierke svahov je dôležitý pre pochopenie procesov tvorby odtoku na svahu. Počas rôznych zrážkovo-odtokových udalostí a období môžu rôzne časti povodia prispievať k odtoku rôzne. Napríklad počas suchých období môže byť hydrologicky prepojená len malá časť povodia, ale prepojená oblasť sa môže rozširovať počas zrážok alebo topenia snehu. Poznanie toho, ktoré oblasti sú prepojené a prispievajú k odtoku je dôležité, pretože pomáha formovať naše chápanie o fungovaní povodí.

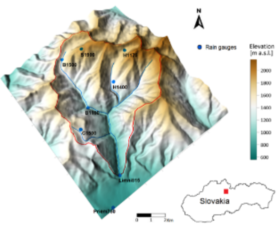
V tejto štúdii sme použili priestorovo distribuovaný hydrologický model Mike SHE v horskom povodí Jaloveckého potoka na Slovensku na riešenie nasledujúcich výskumných otázok:

a) Aký výkonný je model v hodinových simuláciách odtoku? b) Aká je časová a priestorová variabilita pôdnej vlhkosti pri rôznych zrážkovo-odtokových udalostiach (niekoľko menších, po sebe nasledujúcich udalostí, prívalová povodeň, veľké udalosti spôsobené frontálnymi zrážkami)? c) Aká je potenciálna hydrologická konektivita počas udalostí?

2 SKÚMANÉ ÚZEMIE A ÚDAJE

Povodie Jaloveckého potoka

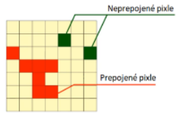
- Reprezentatívne pre **hydrologický cyklus najvyššej časti Západných Karpát**,
- **Merania od roku 1987** (vlhkosť pôdy od 1993, viac údajov od 2013),
- Plocha: 22 km^2,
- Priemerná nadmorská výška: 1500 m n.m.,
- Priemerný sklon: 30°,
- Lesnatosť: smrek 44%, kosodrevina 31%, vysokohorské lúky a skaly 25%,
- Pôdy: kambizem, podzol, litozem. Všetky pôdy majú vysokú kamenitosť, ktorá je často 40–50 % a viac.



3 METÓDY

Distribuovaný z-o model Mike SHE, ICS metóda

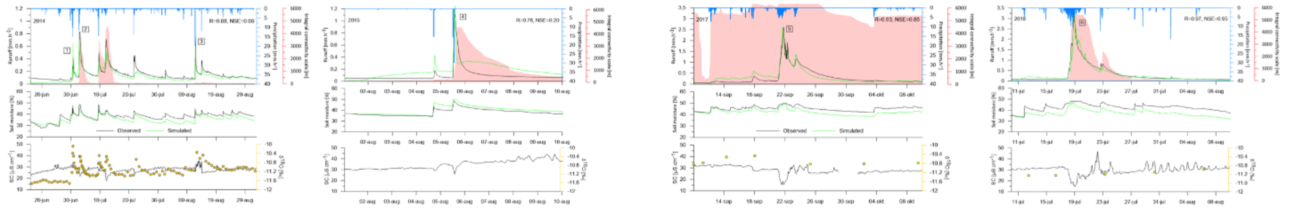
- Priestorovo **distribuované hydrologické modelovanie** (Mike SHE, Mike by DHI, 2011), hydrometrické údaje a výsledky hodnotení založené na izotopoch.
- Vstupy do modelu: **hodinové údaje** (zrážky, teplota vzduchu) počas vybraných letných z-o udalostí v rokoch 2014, 2015, 2017 a 2018; **geopriestorové údaje**: DEM, využitie územia, pôdy.
- Kalibrácia: metóda Shuffled Complex Evolution (Duan et al., 1993) na **meraný prietok** v záverečnom profile povodia.
- Simulácie **odtoku** a **vlhkosti pôdy v koreňovej zóne** (25 m grid).
- **Integral connectivity scale (ICS),** priemerná vzdialenosť cez ktorú sú pixle prepojené. Počítané viasmerovým prístupom pre hodnotu **vlhkosti pôdy 44% a viac.**



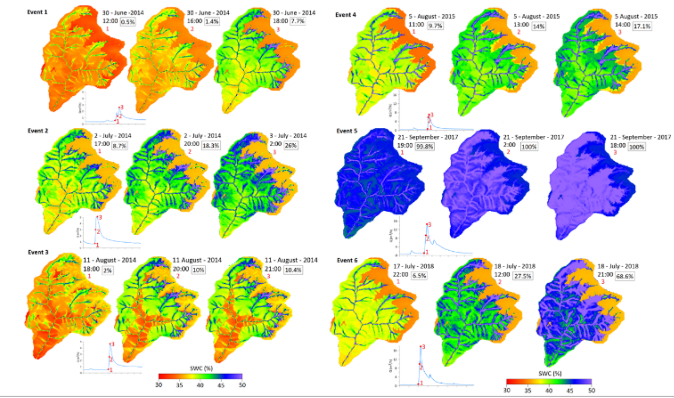
4 VÝSLEDKY

Porovnanie meraného a simulovaného odtoku a vlhkosti pôdy

- Podľa NSE **model prijateľne reprezentoval veľké odtokové udalosti** spôsobené dlhými dažďami v rokoch 2017 a 2018 (NSE 0,86, resp. 0,95). Slabšia výkonnosť modelu sa zistila v prípade po sebe nasledujúcich menších odtokových udalostí v roku 2014.
- Simulovaná pôdna vlhkosť v koreňovej zóne dobre reprodukovala meranú variabilitu pôdnej vlhkosti.
- **ISCmax** (t.j. **priemerná vzdialenosť cez ktorú boli jednotlivé pixle prepojené**) sa menila pre udalosti medzi 45 a 6327 m. Čas od začiatku udalosti do ISCmax počas menších odtokových udalostí sa pohyboval od 3 do 23 hodín, počas veľkých udalostí bol celkom konzistentný (26-27 hodín). Kým v roku 2017 bolo celé povodie nasýtené už na začiatku udalosti (trvanie ICSmax = 118 h), v roku 2018 po 23 hodinách boli nasýtené takmer dve tretiny povodia (trvanie ICSmax = 42 h).



Priestorové rozdelenie vlhkosti pôdy a konektivita počas z-o udalostí



- **Plochy**, ktoré by mohli byť podľa našich terénnych a laboratórnych údajov pravdepodobne **nasýtené**, reprezentované bunkami s **pôdnou vlhkosťou 44% a vyššou**, počas menších odtokových udalostí v roku 2014 postupne narástli z 0,5% plochy povodia na 26%. Najvlhkejšie oblasti sa nachádzali v horných, pomerne rovinatejších častiach dolín.
- Plocha potenciálne nasýtených oblastí pri odtokovej udalosti spôsobenej krátkym prívalovým dažďom v roku 2015 bola približne 17% plochy povodia. Najvyššia pôdna vlhkosť bola simulovaná vo vysokých častiach povodia, čo pravdepodobne nemohlo spôsobiť prudký nárast prietoku v záverečnom profile povodia.
- Potenciálne nasýtené oblasti s pôdnou vlhkosťou 44% a viac počas veľkých zrážkovo- odtokových udalostí spôsobených dlhými dažďami v rokoch 2017 a 2018 boli 100 % (udalosť v roku 2017) alebo vzrástli zo 6,5% plochy povodia na 68,6% (udalosť v roku 2018).
- Odtok z nasýtených oblastí bol riadený množstvom zrážok. **Zrážky 100 mm a viac** mali za následok veľký **plošný rozsah** (polovica povodia alebo viac) **nasýtených oblastí**. Na potvrdenie týchto zistení sú potrebné hustejšie merania pôdnej vlhkosti.

5 ZÁVERY

Výsledky ukázali, že potenciálne nasýtené oblasti nachádzajúce sa pozdĺž riečnej siete počas menších udalostí sa pri väčších udalostiach rozširovali do rovinatejších častí horských dolín. Kvantifikácia rozsahu a trvania hydrologicky prepojených častí povodia počas udalostí poskytla nové údaje, ktoré sú užitočné pri úvahách o tvorbe odtoku v horských povodiach.

Poďakovanie:

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AKTUÁLNE PROBLÉMY HYDROLÓGIE
Smolenice, Slovensko, September 27 – 29, 2023

COMPARISON OF METEOROLOGICAL DROUGHT OVER TWO NORMAL PERIODS

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ABSTRACT

The frequency of extreme meteorological events, such as drought, has risen in the last years. This is, among other things, due to climatic changes occurring in the atmosphere. These extremes have been monitored also on the East Slovakian Lowland. Dry periods are defined as periods of water scarcity in its various forms. In order to quantify changes in the climate at a particular location, it is useful to compare the climatic characteristics monitored over two normal periods. The basic assumption of this work is that Earth's climate has been warming and therefore the drought incidence has been increasing. The aim of this work is to quantify differences in the climate at a particular location over two consecutive normal periods. The two normal periods (NP) are years 1961–1990 (NP1) and 1991–2020 (NP2). Compared atmospheric elements were monitored at the meteorological station of SHMÚ (Slovak Hydrometeorological Institute) in Milhostov, which is in the central part of the East Slovakian Lowland. Normal periods were analysed in terms of precipitation, temperature, potential evapotranspiration, and selected drought indices. The analysis has shown that the normal period of 1991–2020 (NP2) is both annually and monthly drier than the period of 1961–1990 (NP1), with the significant increase in temperatures and potential evapotranspiration.

Keywords: drought index, normal period, meteorological elements

Acknowledgement: This study was supported by the grant from the Slovak Academy of Sciences (project VEGA No. 2/0044/20). The authors thank the agency for its research support.

HARMONIZATION OF THE UNIFORM PROCESSING OF *T*-YEAR VALUES OF MINIMUM DAILY DISCHARGES IN THE DANUBE RIVER REGION

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ABSTRACT

The consistent determination of minimum daily flows in rivers within the Danube River basin faces challenges due to the use of varied methodologies across different Danube states. To date, we have not succeeded in developing and implementing a standardized methodology that would be applicable across all Danube countries. This discrepancy arises from differences in selecting the minimum annual flow period (calendar year, hydrological year, water year) and variations in the distribution functions used to calculate *T*-year values of minimum daily flows. Consequently, comparing design flows between different countries is not feasible. The presented study proposes a method for the uniform processing of *T*-year values of minimum daily flows at ten selected stations within the Danube basin, where long-term daily flow observations are available. We assessed the homogeneity of the selected time series data, verifying the assumption that anthropogenic activities or technological inconsistencies in data measurement and processing did not significantly influence flow levels above the water gauge profile throughout the entire observed period.

To establish a standardized unified methodology, we selected streams with daily flow data available since at least 1921 for analysis and statistical processing. Specifically, we chose five stations located on significant tributaries of the Danube (Lech: Landsberg (1901–2019), Moravia: Moravský sv. Ján (1901–2019), Váh: Liptovský Mikuláš (1921–2019), Tisza: Senta (1921–2019), Sava: Litija (1895–2019). On the Danube itself, stations were selected: Hofkirchen (1901–2019), Achleiten (1901–2019), Bratislava (1876–2019), Orsova (1840–2005) and Reni (1921–2019).

In this study, time series of 1-, 3-, 7-, 30-, and 90-day minimum flows for the calendar year were compiled and evaluated from average daily flows. Log-Pearson Type III (LP3) distribution was employed when assessing *T*-year minimum flows. The variability of hydrometeorological conditions in different parts of the Danube basin is inevitably reflected in specific discharges at individual stations. For instance, *100*-year 1-day minimum specific discharges on the Danube at the Achleiten station, downstream from the confluence with the Inn River, reach their highest level at 4.75 $l.s^{-1}km^{-2}$, while they maintain a similar level up to Bratislava. However, on the middle and lower reaches, they decrease to as low as 1.77 $l.s^{-1}km^{-2}$ at the Reni station. Variability is also evident in the tributaries of the Danube, where the 100-year specific discharge is below 0.5 $l.s^{-1}km^{-2}$ for the Morava and Tisza rivers, but exceeds 5 $l.s^{-1}km^{-2}$ for the Lech and Sava rivers.

The assessment of minimum flows and the basic characteristics of low flows serve as essential foundations for the design, construction, and operation of water management facilities and structures on rivers, aiming at the economic management of water resources. Hence, it is imperative to focus on these matters.

Keywords: Methodology, Harmonization, Low Flows Characteristics, *T*-year minimum daily discharge

Acknowledgements: This work was supported by VEGA No. 2/0015/23.

HARMONIZÁCIA STANOVENIA *N*-ROČNÝCH MINIMÁLNYCH PRIETOKOV NA PRÍKLADE VÁHU V L: MIKULÁŠI

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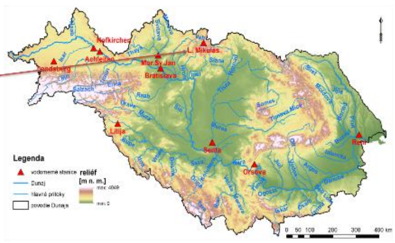
Abstrakt

Hydrológom sa dodnes nepodarilo jednotnou metodikou vyhodnotiť minimálne prietoky vo všetkých Podunajských štátoch. Vzhľadom na rôzne spôsoby výberu období radov minimálnych ročných prietokov (kalendárny rok, hydrologický rok, vodohospodársky rok), ako aj použitie rôznych distribučných funkcií výpočtu *N*-ročných minimálnych prietokov sa výsledky nepodarilo porovnať. Cieľom tejto štúdie je spracovanie podkladov k návrhu jednotnej metodiky spracovania *N*-ročných minimálnych prietokov na tokoch s čo najdlhšími radmi pozorovaní v povodí rieky Dunaj jedným typom teoretickej distribučnej funkcie. Testovaná bola homogenita vybraných časových radov údajov (tj. overoval sa predpoklad, že za celé pozorované obdobie nedošlo na toku nad vodomerným profilom k výraznejšiemu ovplyvneniu odtoku antropogénnou činnosťou, alebo technologickou nehomogenitou pri meraní a spracovaní údajov). Na tomto postri sú prezentované výstupy štatistických analýz minimálnych prietokov z rieky Váh v stanici L. Mikuláš.

Analyzované vodomerné profily na prítokoch a na Dunaji:

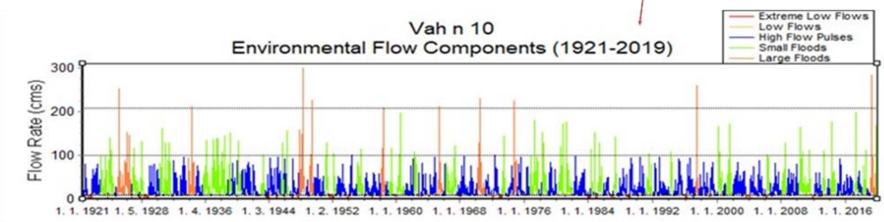
- Lech: Landsberg (1901–2019)
- Morava: Moravský sv. Ján (1901–2019, okrem rokov 1917–1919)
- **Váh: Liptovský Mikuláš (1921–2019)**
- Tisza: Senta (1921–2019)
- Sava: Litija (1895–2019).
- na Dunaji: Hofkirchen (1901–2019), Achleiten (1901–2019), Bratislava (1876–2019), Orsova (1840–2005) a Reni (1921–2019)

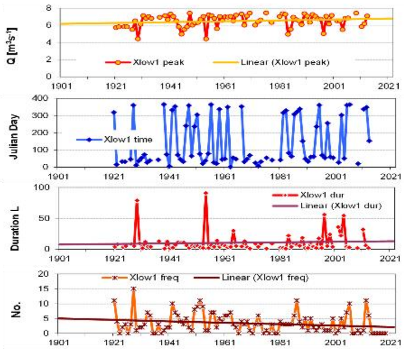


Obr. 1. Schéma povodia Dunaja s vybranými vodomernými stanicami v povodí.

Metódy

Pre vytvorenie jednotnej metodiky boli pri analýze a štatistickom spracovaní vybrané toky, kde sú k dispozícii denné prietoky minimálne od roku 1921.

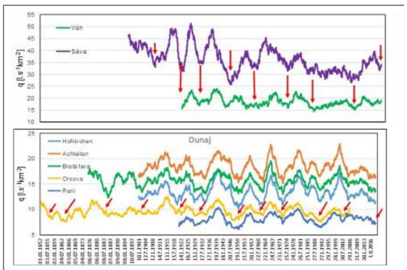




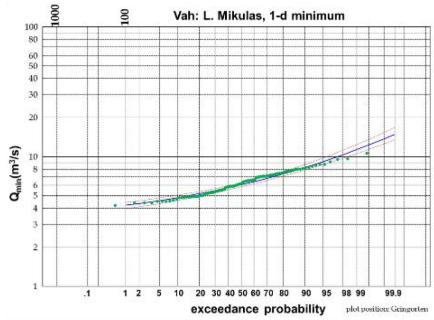
Obr. Vyhodnotenie vybraných charakteristík minimálnych prietokov (zhora) :

- priemer extrémne nízkych prietokov vĺn v roku (Q),
- deň výskytu (Julian Day),
- priemerná doba trvania vĺn v dňoch (Duration L),
- počet období nízkych prietokov v roku (No.)

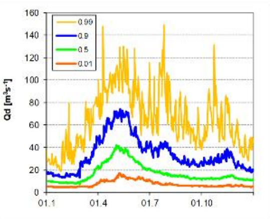
môžeme prezentovať zmeny extrémne nízkych prietokových udalostí rieky Váh vo vybranom profile L. Mikuláš.



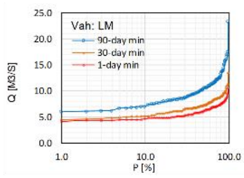
Z priemerných denných prietokov vybraných riek v povodí Dunaja i zo staníc na Dunaji sme vypočítali rady 4-ročných kĺzavých priemerných denných špecifických odtokov. Viacročné málovodné a vodné obdobia sa viac-menej pravidelne cyklicky striedajú po celej dĺžke Dunaja v tých istých obdobiach.



Obr. Teoretická LP3 čiara nedostúpenia 1-denných minimálnych prietokov (modrá čiara) 97,5 a 2,5 horný a dolný limit (červené čiary), a empirické hodnoty (zelené body), Váh: L. Mikuláš.



Z dlhodobých percentilov denných prietokov Váhu v L. Mikuláši vyplýva, že minimálne prietoky Váhu sa vyskytujú v zimnom období.



Obr. Teoretické LP3 čiary nedostúpenia/podkročenia radu 1-dňových minimálnych ročných prietokov Qmin (vľavo), empirické čiary nedostúpenia pre 1-, 30- a 90-dňové rady minimálnych prietokov vo vodomernej stanici L. Mikuláš na Váhu.

Tabuľka. N-ročné 1-dňové minimálne špecifické odtoky vo vodomerných staniciach na Dunaji (Dunaj: Hofkirchen, Dunaj: Achleiten, Dunaj: Bratislava, Dunaj: Orsova, Dunaj: Reni) a vodomerných staniciach na vybraných prítokoch (Lech-Landsberg, Morava-Moravský sv. Ján, Váh-Liptovský Mikuláš, Tisza-Senta, Sava-Litija)

Dunaj: Hofkirchen				Lech: Landsberg			
	q	q(5)	q(95)		q	q(5)	q(95)
0,1	4,75	4,95	4,54	0,1	8,13	8,57	7,66
0,05	4,36	4,56	4,13	0,05	7,29	7,73	6,80
0,02	3,94	4,15	3,69	0,02	6,42	6,88	5,91
0,01	3,67	3,90	3,42	0,01	5,89	6,35	5,37
Dunaj: Achleiten				**Morava: Moravský sv. Ján**			
	q	q(5)	q(95)		q	q(5)	q(95)
0,1	6,17	6,40	5,92	0,1	0,57	0,62	0,52
0,05	5,66	5,91	5,39	0,05	0,49	0,53	0,43
0,02	5,11	5,37	4,81	0,02	0,40	0,45	0,35
0,01	4,75	5,02	4,44	0,01	0,35	0,40	0,30
Dunaj: Bratislava				**Váh: Liptovský Mikuláš**			
	q	q(5)	q(95)		q	q(5)	q(95)
0,1	5,43	5,59	5,26	0,1	4,36	4,55	4,14
0,05	5,11	5,28	4,92	0,05	4,14	4,34	3,92
0,02	4,76	4,94	4,55	0,02	3,93	4,14	3,70
0,01	4,54	4,73	4,32	0,01	3,81	4,02	3,58
Dunaj: Orsova				**Tisza: Senta**			
	q	q(5)	q(95)		q	q(5)	q(95)
0,1	2,87	2,98	2,75	0,1	0,75	0,81	0,68
0,05	2,63	2,75	2,50	0,05	0,65	0,72	0,58
0,02	2,38	2,50	2,24	0,02	0,56	0,62	0,49
0,01	2,22	2,34	2,08	0,01	0,51	0,57	0,44
Dunaj: Reni				**Sava: Litija**			
	q	q(5)	q(95)		q	q(5)	q(95)
0,1	2,40	2,55	2,24	0,1	7,10	7,43	6,73
0,05	2,16	2,31	1,99	0,05	6,37	6,71	5,98
0,02	1,91	2,07	1,74	0,02	5,60	5,96	5,19
0,01	1,77	1,92	1,59	0,01	5,11	5,48	4,69

Závery

Vyhodnocovanie minimálnych prietokov a základných charakteristík malej vodnosti je jedným zo základných podkladov na návrh, výstavbu a prevádzku vodohospodárskych zariadení a objektov na tokoch za účelom ekonomického nakladania s vodnými zdrojmi, preto je potrebné týmto otázkam venovať pozornosť. Z analýzy vyplýva, že po celej dĺžke toku Dunaja dochádza k striedaniu sa vodných a málovodných období. Na Dunaji sa minimálne prietoky vyskytujú v rovnakých obdobiach. Naproti tomu vo významných prítokoch Dunaja Tisza a Sáva sa suchá vyskytujú s časovým posunom – mohli by sme povedať, že keď prevládajú na Tisze suché roky, na Sáve prevláda obdobie s vyššími prietokmi.

Táto práca bola podporená projektmi VEGA 2/0015/23 a APVV-20-0374.

ESTIMATION OF WATER TEMPERATURE CHANGES IN THE IPEĽ RIVER SUB-BASINS BASED ON FUTURE SCENARIOS

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ABSTRACT

Water temperature in rivers is not only a physical characteristic, but also an important environmental factor and indicator of water quality and aquatic habitat (Grbić et al., 2013; Lešková and Skoda, 2003). The assessment of changes in this variable is essential in order to be able to take measures for the management of impacts and the implementation of preventive measures. Therefore, this study focuses on the simulation of water temperatures in the Ipeľ Basin. Regression models were used to predict water temperatures. The results of this analysis indicate that the temperatures of the Ipeľ River are slowly increasing due to climate change. The Cran R programming language (R Core Team, 2013) was chosen for statistics and graphing because it provides a comprehensive set of analytical tools.

To predict water temperature and its changes in two gauge profiles of the Ipeľ River, statistical approaches were used. Two types of non-linear multiple regression models were used to predict the monthly water temperature in the Ipeľ River at the Slovenské Ďarmoty and Kalinovo stations using the air temperature from the Bzovík station, where in the first case the model worked with annual data and in the second case with monthly step data. The air temperature was used to model the monthly mean water temperature. In the second phase, in order to predict the impact on water temperature, a climate change scenario derived from EURO-CORDEX simulations was used. According to the models, monthly mean water temperature in Ipeľ will increase under scenarios S1 to S4. For the model working with the whole annual data series, the largest increase in water temperature at the station Slovenské Ďarmoty is 4.01 °C in the month of April for S4. Conversely, models working with monthly data predict the largest increase in S4 at the Slovenské Ďarmoty station in the month of June at 2.1 °C. According to the models for the whole year, the absolute smallest increase may occur in summer, while the largest increase is expected in the months of February, March and April at both stations. For both stations, the monthly models show smaller monthly increases in water temperature. Overall, in modelling the monthly water temperature variations in the Ipeľ River, the month-by-month model has shown greater stability and efficiency. It appears to be a useful tool for prediction of water temperatures in rivers without measurements, but for modelling future development it has some limitations which make this model less useful.

Keywords: prediction of water temperature, change in water temperature, Ipeľ climatic scenarios

Acknowledgement: This work was supported by the projects VEGA No. 2/0015/23 "Comprehensive analysis of the quantity and quality of water regime development in streams and their mutual dependence in selected Slovak basins" APVV No. 20-0374 "Regional detection, attribution and projection of impacts of climate variability and climate change on runoff regimes in Slovakia".

ODHAD ZMIEN TEPLOTY VODY V RIEKE IPEĽ NA ZÁKLADE SCENAROVÝCH ZMIEN TEPLOTY VZDUCHU

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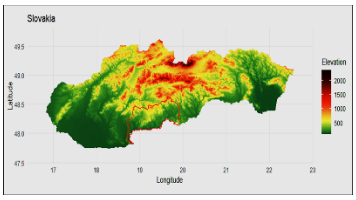
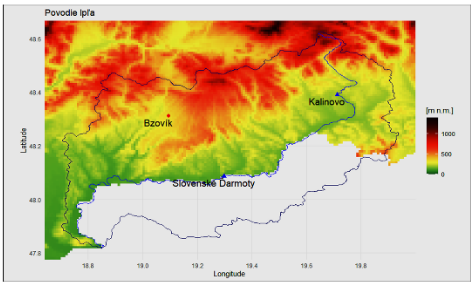
Abstrakt: Teplota vody - jej kolísanie - má významný vplyv na vodné ekosystémy, z čoho vyplýva potreba jej presného monitorovania a predpovedania. Teplota vody v riekach nie je len fyzikálnou vlastnosťou, ale aj dôležitým environmentálnym faktorom a indikátorom kvality vody a vodných biotopov. Zmeny teploty vody v rieke preto môžu významne zmeniť hydroekologické a socioekonomické podmienky rieky a jej povodia. Priame merania teploty vody sú často obmedzené na merné profily a súčasne dostupnosť dlhších časových radov meraní je obmedzená. Pre optimalizované hospodárenie s vodou je nevyhnutné odhadnúť, ako sa bude teplota vody v rieke vyvíjať v budúcnosti, najmä pri zohľadnení očakávanej klimatickej zmeny a kolísaní klímy. V predloženej práci bol dvoma multiregresnými modelmi simulovaný očakávaný vývoj teploty vody v rieke Ipeľ v dvoch staniciach - Kalinovo a Slovenské Ďarmoty - podľa štyroch scenárov S1 až S4 očakávaného vývoja teploty vzduchu.



Obr. 1. Lokalizácia povodia Ipľa v rámci Slovenska.



Obr. 2. Detail povodia Ipľa, modré trojuholníky indikujú vodomerné stanice Slovenské Ďarmoty a Kalinovo. Červený kruh označuje klimatickú stanicu Bzovík. Použité dáta za obdobie rokov 1977 – 2020.

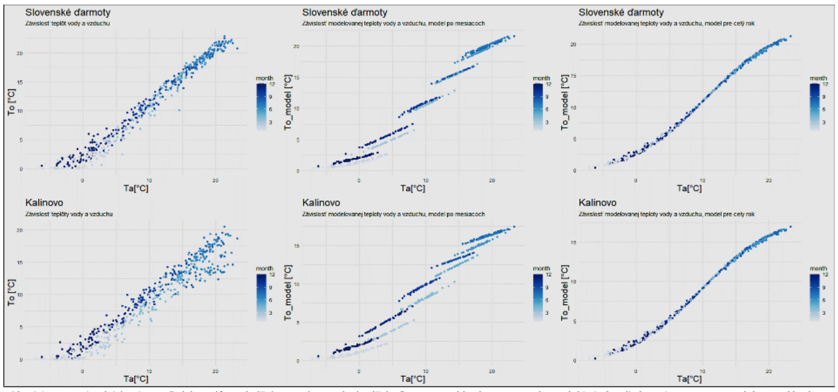
Metódy

Nelineárne viacnásobné regresné modely sú štatistické modely používané na analýzu vzťahu medzi dvoma alebo viacerými nezávislými premennými a závislou premennou. Viacnásobné regresné modely možno použiť na testovanie hypotéz, vytváranie predpovedí a identifikáciu významných prediktorov výslednej premennej. V tomto prípade je použitá verzia modelu (štvorparametrová nelineárna funkcia teploty vzduchu), ktorá bola pôvodne navrhnutá na odhad týždenných teplôt toku počas ročného cyklu Mohsenim a kol. (1998). Podľa tejto metódy možno vzťah medzi teplotami vody a vzduchu opísať spojitou funkciou v tvare písmena S. Jej parametre majú fyzikálny význam:

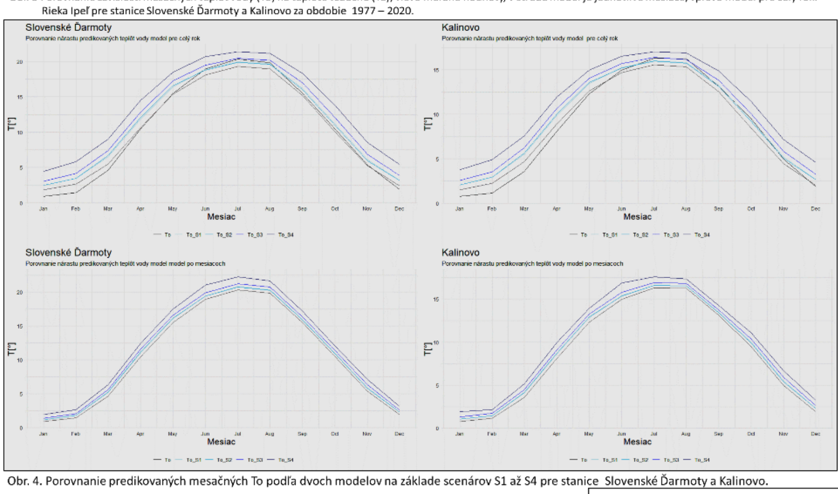
$$To=\mu+((\alpha-\mu))/(1+e^{(\gamma(\beta-Ta))}),$$

kde:
To - predstavuje priemerné mesačné teploty vody;
Ta - predstavuje priemerné mesačné teploty vzduchu;
μ - dolná asymptota závislej premennej;
α - horná asymptota závislej premennej;
β - inflexný bod rastu závislej premennej;
γ - sklon krivky v inflexnom bode.

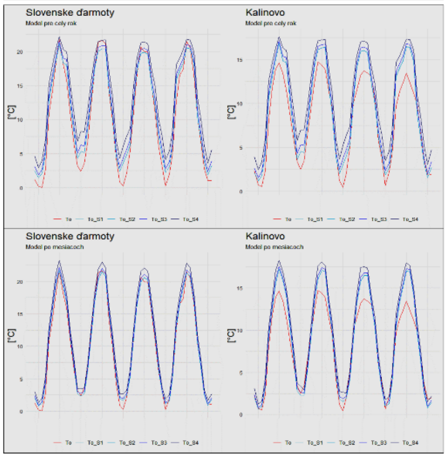
Parametre modelu sa zvyčajne odhadujú metódou najmenších štvorcov, ktorá minimalizuje charakteristiky rozdielov medzi pozorovanými a predpovedanými hodnotami závislej premennej.



Obr. 3 Porovnanie závislosti mesačných teplôt vody (To) na teplote vzduchu (Ta); vľavo merané hodnoty, v strede model je jednotlivé mesiace, vpravo model pre celý rok. Rieka Ipeľ pre stanice Slovenské Ďarmoty a Kalinovo za obdobie 1977 – 2020.



Obr. 4. Porovnanie predikovaných mesačných To podľa dvoch modelov na základe scenárov S1 až S4 pre stanice Slovenské Ďarmoty a Kalinovo.



Obr. 5. Porovnanie meraných a modelovaných mesačných To.

Výsledky

V tejto štúdii sa použili štatistické prístupy na predpovedanie teploty vody a jej zmien v dvoch vodomerných profiloch rieky Ipeľ. V tejto štúdii sme použili dva spôsoby tvorby modelu na predpovedanie mesačnej teploty vody v Ipli v staniciach Slovenské Ďarmoty a Kalinovo, pričom sme použili teplotu vzduchu zo stanice Bzovík pričom v prvom prípade model pracoval z ročnými dátami a v druhom v mesačnom kroku. Testovali sme viacere nelineárne modely viacnásobnej regresie. Modelovanie priemernej mesačnej teploty vody sa uskutočnilo na základe scenárov zmeny teploty vzduchu odvodeného zo simulácií EURO-CORDEX. Podľa modelov sa v rámci scenárov S1 až S4 predpokladá zvýšenie priemernej mesačnej teploty vody v Ipli. U modelu pracujúceho z celým ročným radom udajov je najväčšie zvýšenie teploty vody v stanici Slovenské Ďarmoty pri S4 o 4,01 °C v mesiaci apríl. Naopak modely pracujúce z mesačnými udajmi predpokladajú najväčší nárast pri S4 v stanici Slovenske Ďarmoty v mesiaci jún o 2,1 °C.

Tab. Zmena priemernej teploty vody podľa S1 až S4, pre obe stanice a typy modelov.

		Slovenské Ďarmoty pre celý rok				Kalinovo model pre celý rok				Slovenské Ďarmoty model po mesiacoch				Kalinovo model po mesiacoch			
month	To	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4
1	0.776	1.548	1.548	2.136	3.534	1.284	1.284	1.793	2.992	0.251	0.251	0.487	1.045	0.272	0.272	0.525	1.116
2	1.152	2.017	2.017	2.729	4.375	1.762	1.762	2.373	3.771	0.354	0.354	0.647	1.224	0.31	0.31	0.558	1.021
3	3.594	1.866	2.039	2.75	4.35	1.91	2.055	2.649	3.969	0.536	0.625	0.977	1.699	0.486	0.567	0.889	1.55
4	8.088	1.385	1.584	2.376	4.012	1.786	1.945	2.571	3.848	0.59	0.691	1.1	1.992	0.538	0.631	1.011	1.864
5	12.325	0.951	1.12	1.77	3.019	1.122	1.249	1.736	2.659	0.593	0.694	1.101	1.987	0.509	0.598	0.925	1.615
6	14.954	-0.059	-0.124	0.557	1.734	0.298	0.25	0.743	1.581	0.516	0.469	0.991	2.101	0.432	0.392	0.849	1.809
7	16.288	-0.388	-0.441	0.115	1.052	-0.266	-0.304	0.091	0.746	0.474	0.43	0.91	1.926	0.32	0.29	0.613	1.294
8	16.25	-0.206	-0.263	0.327	1.329	-0.449	-0.49	-0.069	0.637	0.471	0.429	0.889	1.815	0.31	0.282	0.576	1.096
9	13.144	0.723	0.547	1.483	2.853	0.13	-0.002	0.702	1.718	0.483	0.395	0.992	1.685	0.33	0.27	0.594	1.105
10	9.483	0.692	0.493	1.59	3.352	-0.153	-0.313	0.562	1.948	0.515	0.425	0.905	1.604	0.494	0.406	0.879	1.605
11	4.951	0.741	0.577	1.503	3.134	0.239	0.101	0.877	2.227	0.508	0.417	0.919	1.701	0.52	0.426	0.936	1.725
12	1.895	1.242	1.242	1.92	3.5	0.774	0.774	1.357	2.703	0.368	0.368	0.658	1.208	0.408	0.408	0.729	1.367

Závery

Podľa modelov pre celý rok sa absolútne najnižší nárast môže vyskytnúť v lete, zatiaľ čo najvyšší nárast sa predpokladá v mesiacoch február, marec a apríl v oboch staniciach. Modely po mesiacoch vykazujú menšie mesačné nárasty teploty vody pre obe stanice. Celkovo model po mesiacoch preukázal väčšiu stabilitu a účinnosť pri modelovaní mesačných výkyvov teploty vody v Ipli. Zdá sa, že je vhodným nástrojom na predpovedanie rastu mesačných teplôt vody v reakcii na zvyšovanie teploty. Zvýšenie teploty vody, napr. počas extrémnych a dlhotrvajúcich vĺn horúčav a sucha, môže spôsobiť nežiadúce chemické a biochemické reakcie, pre ktoré sa zvyčajne nenavrhujú priame opatrenia na jej zníženie.

This work was supported by the projects VEGA No. 2/0015/23 "Comprehensive analysis of the quantity and quality of water regime development in streams and their mutual dependence in selected Slovak basins" APVV No. 20-0374 "Regional detection, attribution and projection of impacts of climate variability and climate change on runoff regimes in Slovakia".

CURRENT PROBLEMS IN HYDROLOGY, Smolenice, Slovakia, September 27 – 29, 2023

MODIFICATION OF THE HARGREAVES–SAMANI MODEL COEFFICIENTS FOR SELECTED CLIMATOLOGICAL STATIONS OF SLOVAKIA

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ABSTRACT

Evapotranspiration is an essential component of the hydrological cycle, significantly impacting other hydrological and meteorological variables. It affects the volume of water storage and runoff by reducing precipitation water volume. However, we still don’t have any uniform and generally recognized methodology for the estimation of evapotranspiration. One of the ways how to estimate this value is through the calculation of the reference evapotranspiration. Reference evapotranspiration is also important variable for many engineering tasks related to agriculture and the design of irrigation. For estimation of reference evapotranspiration, the Penman-Monteith method was recommended by The Food and Agriculture Organization (Allen et al., 1998) of the United Nations and many research studies. Unfortunately, this method is very input-demanding, so there is no ability to use it in locations with a sparse network of stations or where all the required measurements are unavailable. For these reasons, many researchers tried to find a less demanding method with results in sufficient accuracy in local conditions. One of the methods for calculating reference evapotranspiration, requiring simple air temperature inputs, is the Hargreaves method; however, it yields insufficient results using the original coefficients in different climatic regions than they were originally designed for (Haslinger & Bartsch, 2016).
This research aimed to optimization of Hargreaves method coefficients by Curve Fitting Analyses for the local condition of 36 meteorological stations, using remote sensing-based data and machine learning models for gap filling of radiation datasets based on meteorological measurements. This study evaluated four remote sensing-based models using a mean BIAS and Pearson correlation coefficient. MERRA2 dataset, with mean BIAS -1.7% and Pearson correlation coefficient 0.91 (Fig.2). The main advantage of this dataset algorithm is that inputs originate from satellite measurements, not only from the models. Lower accuracy provides Fluxcom-cruncep dataset (mean BIAS 5.6% and mean Pear. C.C. 0.93) and Fluxcom-CRES (mean BIAS -8.6 % and Pears. C.C. 039). The Era 5 and Era 5 Land datasets correlate well with FAO radiation (0.85 for Era 5 and 0.86 for Era 5 Land) but very low accuracy in mean BIAS (54,6% for ERA5 and 52.6% for Era 5 Land). According to the comparison of remote sensing-based radiation datasets accuracy, we used the Merra2 dataset of net radiation, which values were optimized by the Random Forest Regressor machine learning model. This modified value was used for gap filling of the radiation dataset based on measured data. We used the Curve Fitting Analysis for the calibration of the Hargreaves method coefficient. The proposed Hargreaves equation with modified coefficients brings improvements in the mean BIAS from 133% in the original method to 0.8% in our modified form.

Keywords: evapotranspiration, Hargreaves method, remote sensing, machine learning, Slovakia

Modification of the Hargreaves–Samani Model coefficients for selected climatological stations of Slovakia

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Introduction

FAO56 Penman-Monteith method is mainly recommended for the calculation of reference evapotranspiration by many authors and authorities (Allen et al., 1998; Djaman et al., 2019; Jensen & Allen, 2016). One of the most discussed problems of Penman-Monteith method is the number of requested climatic variables, which makes its application questionable under limited data availability. The Hargreaves method can calculate reference evapotranspiration, requiring only minimum, maximum, and mean temperature and geographical data. Calibration of constants in the Hargreaves equation was used in much research for improving Hargreaves model accuracy for local conditions. Sivaprakasam Subburayan (2011) proposed exponent value 0.653 for the hot and humid locations in Tamilnadu State in India. Niranjan & Nandagiri (2021) estimated individual values of the Hargreaves equation coefficient for different climatic zones in India, significantly improving this model's accuracy. This study aimed to determine the optimal values of coefficients and exponent in the Hargreaves equation to improve the accuracy of the Hargreaves model for the local condition of climatological stations of Slovakia.

Material and Methods

$$ET_0 = \mathbf{0.0023}(T_{mean} + \mathbf{17.8})(T_{max} - T_{min})^{0.5} R_a \rightarrow ET_0 = \mathbf{a}*(T_{mean} + \mathbf{b})(T_{max} - T_{min})^{c} R_a$$

We approximated the new values of coefficients in the original Hargreaves method by Curve Fitting Analyses to improve Hargreaves method accuracy in local conditions. Curve Fitting analyses provide powerful tools for analyzing and understanding complex relationships within the data, model fitting and making predictions. This part of the analysis was divided into two steps; in the first step, we estimated the optimal values of two coefficients in Hargreaves method (0.0023 and 17.8) separately for each measurement station. For the calculation of reference evapotranspiration by the FAO Penman-Monteith method, the values of net solar radiation are necessarily.

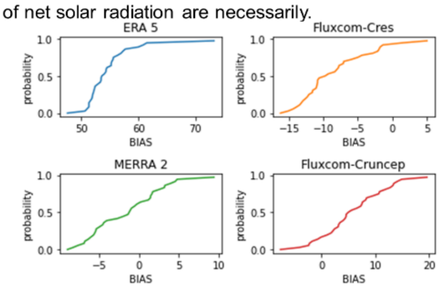

Fig.2 Cumulative distribution function of Pearson correlation coefficient and mean BIAS of radiation results from different machine learning models

Solar net radiation on the earth's surface is calculated from the station characteristics, location, radiation inputs, and meteorological inputs. The radiation estimation is based on the value of actual sunshine duration on the day. The radiation dataset from the measured data was calculated according to FAO 56 method, using this data and other meteorological inputs provided by Slovak Hydrometeorological Institute. An improved global gridded dataset was used for filling this gap in the next step. The comparative results indicate that the Merra2 Dataset gave better predictions than other datasets and provide a lower variance of mean BIAS across the stations (fig.2). This dataset was selected for gap filling of measured data because of the more consistent ability to predict radiation with good accuracy in different conditions. To improve Merra2 radiation accuracy in local conditions, the three machine learning models were used- Random Forest Regressor, Support Vector Machines and Multiple Linear Regression using the same input features to predict radiation values. This model was also used in other climatological research providing good performance for the estimation of solar net radiation components using measured data (Fan et al., 2019; Salcedo-Sanz et al., 2018; Wu et al., 2021; Wu & Liu, 2012).

Area of research and input data

The 36 automatic meteorological stations were selected for the analyses, where the length of the actual sunshine duration dataset was more than 60% days between 2000-2020. This subset of the stations contains stations with altitudes from 100 to 2005 m.a.s.l (Fig.1), with a median altitude of 222 m.a.s.l. The stations are situated in different morphological and climatical conditions. The measured meteorological variables were accessed from the database of the Slovak Hydrometeorological Institute. Remote sensing-based datasets were acquired from open sources and processed in Python programming language.

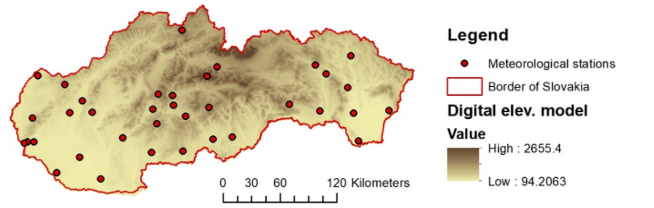

Fig.1: Localization of the subsetting meteorological stations

Results and Conclusion

The resulting values of coefficients did not show any correlation with altitude or other characteristics of stations, inclusive of the geographical location. In connection with this part of the analysis, the two stations with altitude higher than 1000 m.a.s.l was removed from the dataset as outlayers to increase the accuracy. The new proposed "a" coefficient value was determinate to 0.00065, and the mean value for the "b" coefficient value was 36.5. The results are valid for the Slovak stations with altitudes lower than 1000 m.a.s.l. In the second step of Curve Fitting Analyses, we used the mean values of a and b coefficients to estimate the exponent in the Hargreaves equation, with an original value of 0.5. The exponent values through the stations showed a similar value as the proposed initial value; the stational values ranged from 0.46 to 0.52, with a mean value of 0.485. Using the new, modified equation of the Hargreaves method, the Mean BIAS for the stations was reduced from the 133% in the original approach to 0.8% in our modified Hargreaves method (Fig.3), with mean value of Pearson correlation coefficient 0.93.

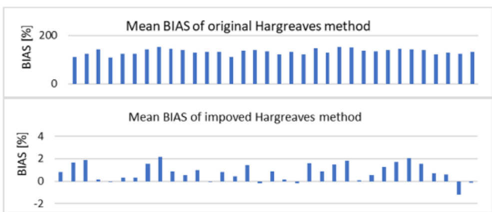

Fig.3: Results of mean BIAS for the stations from Original and our improved Hargreaves method

Analyses of long-term seasonal daily mean values showed the consistently good performance of the modified Hargreaves method for each month of the year (Fig.6). In the majority of the stations, the most significant deviations between the Penman-Monteoth FAO65 and modified Hargreaves method were detected from May to July and in December. Seasonal distribution of the mean values of mean, maximum and minimum Modified Hargreaves deviation values shown minimum deviation peak value in March, and peaks of maximum and median deviation values in May (fig.4). This result could be described by maximum precipitation totals in the summer months on this region, which affects the accuracy of the Modified Hargreaves estimates.

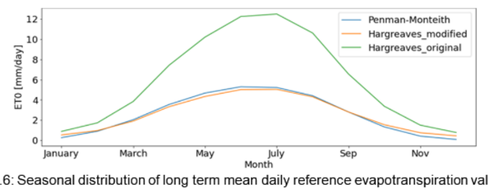

Fig.6: Seasonal distribution of long term mean daily reference evapotranspiration values

COMPARING THE IMPACT OF MICROPLASTICS ON SOIL PROPERTIES AND PLANT PERFORMANCE

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ABSTRACT

A continuously growing volume of microplastics is infiltrating the environment, exerting an influence on soil attributes and the development of plants. The primary objective of this research was to assess the impact of incorporating three distinct types of microplastics (high-density polyethylene, HDPE, polyvinyl chloride PVC, and polystyrene, PS) into sandy soil, constituting 5% of the soil's weight, on various soil characteristics (bulk density, water sorptivity, hydraulic conductivity, and soil water repellency) as well as on the attributes of radish plants (maximum PSII photochemical efficiency) (*Raphanus sativus* L.). The results demonstrated that the introduction of microplastics led to a reduction in soil bulk density, water sorptivity, and hydraulic conductivity while augmenting the degree of soil water repellency (evaluated through contact angle measurements). The research did not establish a significant impact of microplastic contamination on the maximum photochemical efficiency of PSII in sandy soil. Although the photosynthetic efficiency values fluctuated over time, they eventually stabilized for all examined soil samples by the conclusion of the experiment.

Keywords: microplastics, sandy soil, plant growth, bulk density, water sorptivity, hydraulic conductivity, soil water repellency.

Acknowledgement: The study was supported by the Slovak Scientific Grant Agency (VEGA) grant number 2/0020/20.

Comparing the impact of microplastics on soil properties and plant performance

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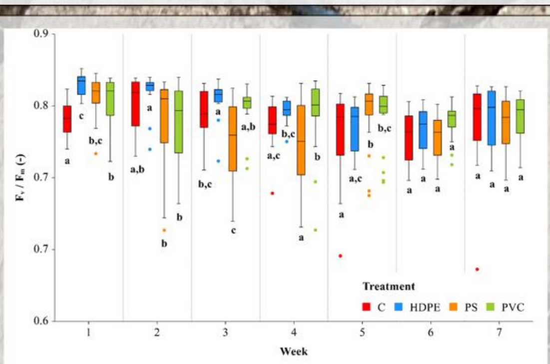
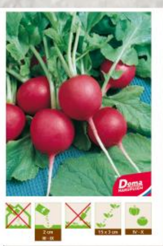


Fig. 1: The measured values of maximum quantum yield of PSII, Fv/Fm (–), of radish plants during the growing period for the individual treatments of the experiment. The whiskers show minima and maxima and coloured points represent outliers. Box plots denoted with different letters are significantly different on significance level 0.05.

Fig. 2: Growing plant, microplastic material, fluorescence measurement.



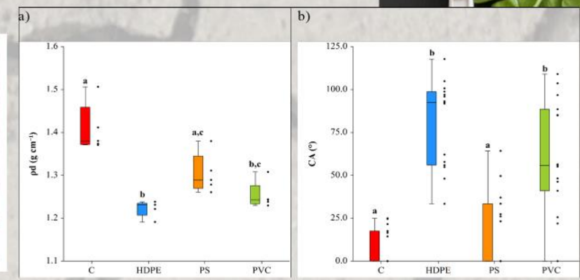


Fig. 3: Measured values of a) bulk density, ρ_d (g cm^{-1}), and b) contact angle, CA (°), for the experiment treatments; the whiskers show minima and maxima, and points represent individual measurements. Box plots denoted with different letters are significantly different on significance level 0.05.

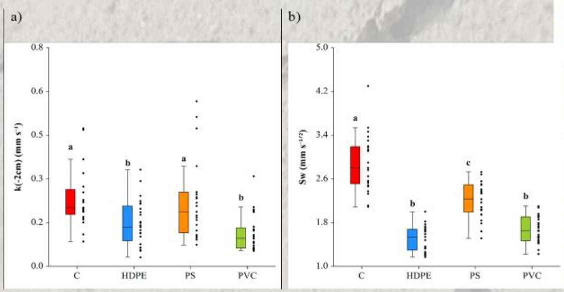


Fig. 4: Values of a) hydraulic conductivity, k(–2 cm) (mm s–1), and b) water sorptivity, Sw(–2 cm) (mm s–1/2), measured in pots after the growing period. The whiskers show minima and maxima and points represent individual measurements. Box plots denoted with different letters are significantly different on significance level 0.05.

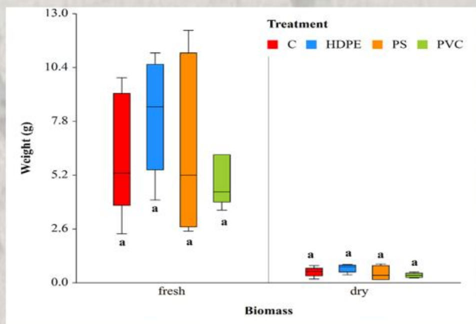


Fig. 5: The fresh and dry weight of the radish plants biomass from all experimental treatments. The whiskers show minima and maxima and points represent individual measurements. Box plots denoted with different letters are significantly different on significance level 0.05.

Acknowledgement

The study was supported by the Slovak Scientific Grant Agency (VEGA) grant number 2/0020/20.

IMPACT OF DURATION OF LAND ABANDONMENT ON SANDY SOIL PROPERTIES

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ABSTRACT

Sandy soils are less fertile and, therefore, often abandoned in the Central European region. Land abandonment can cause the recovery of ecosystems by the replacement of crop species by vegetation that disperses from surrounding habitats and will be subsequently established (secondary succession). The objective of this study was to find the impact of secondary succession during more than 30 years of lasting abandonment of agricultural fields with acidic sandy soil on soil properties. The impact of abandonment was characterised by the changes in soil organic carbon content, pH, water and ethanol sorptivity, hydraulic conductivity, water drop penetration time and repellency index. The results showed a decrease in pH and significant increase in soil water repellency. The pH(H_2O) and pH(KCl) decreased monotonously and ethanol sorptivity did not change significantly during abandonment. Water sorptivity and hydraulic conductivity showed a decrease between 1 and 10 years followed by a slight increase between 10 and 30 years of abandonment. On the other hand, soil organic carbon content, water drop penetration time and repellency index showed an increase between 1 and 10 years followed by a slight decrease between 10 and 30 years of abandonment. In the context of climate change to prevent soil water repellency and its consequences in sandy soils, an adequately high soil water content should be maintained, and mixed forest afforestation should be preferred to pine afforestation.

Keywords: land abandonment, water repellency, sandy soil

Acknowledgement: The study was supported by the Slovak Scientific Grant Agency (VEGA) grant number 2/0020/20.

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Impact of duration of land abandonment on sandy soil properties

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Purpose

The main aim of this study was to determine the effect of secondary succession during 30-year-lasting abandonment of agricultural fields at Studienka (south-west Slovakia) on soil properties (organic carbon content, pH, water and ethanol sorptivity, hydraulic conductivity, water drop penetration time and repellency index). Our experimental sites were 1-, 10- and 30-years abandoned agricultural fields. We hypothesized that with an increase in duration of agricultural field abandonment, pH, water sorptivity and hydraulic conductivity would decrease, soil organic carbon content and water repellency characteristics (water drop penetration time and repellency index) would increase, and the ethanol sorptivity would not change.

Material and methods

Study sites

The experimental sites were selected to include three different stages of secondary succession in relatively the same site conditions in Studienka village (Slovakia):

- Study site 1 (Figure 1) – is arable land with flat relief, covered by synanthropic vegetation, which replaced the harvested crops. More detailed information about the vegetation is in Toková et al. (2022).
- Study site 2 (Figure 2) – is about 10-year-abandoned arable land with flat relief. More detailed information about the vegetation is in Toková et al. (2022).
- Study site 3 (Figure 3) – is about 30-year-abandoned arable land with scattered Scots pine (Pinus sylvestris) trees with flat relief. More detailed information about the vegetation is in Toková et al. (2022).

Figure 1. Study site 1.

Figure 2. Study site 2.

Figure 3. Study site 3.

Field methods

- Volumetric water content, *w* (%vol.) – directly measured using soil moisture meter HH2 with soil moisture sensor SM200 (Delta-T Devices Ltd., Cambridge, UK).
- Sorptivity, *S* (both for etanol, S_e and water S_w) – was calculated based on Philip equation as a relationship of cumulative infiltration, *I* vs time, *t* measured with minidisk infiltrometer (Figure 4) (Decagon, 2012): $S(-2\text{ cm}) = I/t^{1/2}$
- Repellency index, *RI* – was estimated from the combination of all the ethanol and water sorptivities: $RI = 1.95\ S_e/S_w$
- Water drop penetration time, *WDPT* - involves placing a 50 ± 5 µL water drop from a standard medicine dropper or pipette on the soil surface and recording the time of its complete penetration.
- Hydraulic conductivity, *k*(-2 cm) was estimated according Zhang (1997) from the equation where *C2* is a slop of cumulative infiltration curve and *A* is a dimensionless coefficient: $k(-2\text{ cm}) = C2/A$

Figure 4. Field measurements with minidisk infiltrometer.

Laboratory methods

The basic physical and chemical properties were analyzed on disturbed soil samples in ISO certificated laboratory (VÚPOP, Bratislava) (Table 1).

Statistical treatment

The statistical analysis to find differences between the characteristics estimated in different sites was performed with Statgraphics Centurion XV.I. software (Statpoint Technologies, Inc. Warrenton, VA, USA). We used one-way ANOVA test at *p<0,05*.

Table 1. Basic physical and chemical properties of the experimental sites.

Attribute	Study site 1	Study site 2	Study site 3
Sand content (%)	91.936	95.377	94.503
Silt content (%)	2.407	1.568	1.525
Clay content (%)	5.657	3.055	3.972
$CaCO_3$ (%)	<0.05	<0.05	<0.05
SOC (%)	0.66	1.30	1.12
pH(H_2O)	6.11	5.90	5.21
pH(KCl)	5.63	5.07	4.12

Table 2. Statistical characteristics of soil properties.

Attribute	Study site 1	Study site 2	Study site 3	Number of replicates (n)
w (% vol.)	0.83^a	0^b	0.06^b	33
k (mm s^{-1})	0.104^a	0.001^b	0.002^b	8
S_w (mm $s^{-1/2}$)	1.487^a	0.011^b	0.020^b	8
S_e (mm $s^{-1/2}$)	2.584^a	2.094^a	1.750^a	3
WDPT (s)	3.2^a	2625^c	1083^b	33
RI (–)	3.583^a	416.3^c	182.6^b	24

Results and conclusions

- We observed an increasing in sand content and decreasing in small particles (silt and clay) during 30-years-lasting abandonment (Table 1).
- We observed an decreasing in pH (Table 1) and increasing in *SOC* between Study site 1 and 2 and decreasing trend between Study site 2 and 3 (Table 1).
- The volumetric water content, *w* were minimal at all study sites (Table 2).
- The hydraulic conductivity, *k*(-2 cm), showed a decrease between 1 and 10 years of abandonment and slightly increase between 10 and 30 years of abandonment of agricultural fields (Table 2).
- The water sorptivity, S_w, showed a same trend as *k* (Table 2).
- The ethanol sorptivity, S_e, did not changed significantly (Table 2).
- The repellency characteristics, (*WDPT* and *RI*) showed an increase between 1 and 10 years followed by decrease between 10 and 30 years of abandonment of agricultural fields (Table 2).

Acnowledgement

This study was supported by Scientific Grant Agency VEGA 2/0020/20.

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CURRENT PROBLEMS IN HYDROLOGY, Smolenice, Slovakia, September 27 – 29, 2023

EFFECT OF BIOCHAR APPLICATION ON SATURATED HYDRAULIC CONDUCTIVITY CHANGES IN DIFFERENT SOIL TYPES

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ABSTRACT

Saturated hydraulic conductivity is one of the basic hydrophysical parameters of soil. In our work, we investigated how biochar applied to different soil types affects this important soil characteristic. We used biochar produced from paper fibre sludge mixed grain husks at 550 °C, which was crushed into three size fractions <125 µm, 125 µm - 2 mm and >2 mm. Our results showed a positive effect of different biochar fraction used in different studied soils. Significant decrease of saturated hydraulic conductivity was measured when the smallest biochar size fractions (<125 µm) was used in sandy soil. In contrast, the largest increase of saturated hydraulic conductivity was measured when the largest biochar fraction (>2 mm) was used in the silt loam and silty clay soils. For all three soils was choosen the best biochar fraction size which had a statistically significant positive effect on the saturated hydraulic conductivity of that soil.

Keywords: biochar, saturated hydraulic conductivity, sandy soil, silt loam soil, silty clay soil

Acknowledgements: This work was supported by the Scientific Grant Agency of the Ministry of Education of the Slovak Republic and the Slovak Academy of Sciences, Grant No. 2/01557/21, and by the Slovak Research and Development Agency under Contract No. APVV-21-0089.

VPLYV APLIKÁCIE BIOUHLIA NA ZMENY NASÝTENEJ HYDRAULICKEJ VODIVOSTI V RÔZNYCH PÔDACH

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ABSTRACT: EFFECT OF BIOCHAR APPLICATION ON SATURATED HYDRAULIC CONDUCTIVITY CHANGES IN DIFFERENT SOIL TYPES
Saturated hydraulic conductivity is one of the basic hydrophysical parameters of soil. In our work, we investigated how biochar applied to different soil types affects this important soil characteristic. We used biochar produced from paper fibre sludge mixed grain husks at 550 °C, which was crushed into three size fractions <125 µm, 125 µm - 2 mm and >2 mm. Our results showed a positive effect of different biochar fraction used in different studied soils. Significant decrease of saturated hydraulic conductivity was measured when the smallest biochar size fractions (<125 µm) was used in sandy soil. In contrast, the largest increase of saturated hydraulic conductivity was measured when the largest biochar fraction (>2 mm) was used in the silt loam and silty clay soils. For all three soils was choosen the best biochar fraction size which had a statistically significant positive effect on the saturated hydraulic conductivity of that soil.

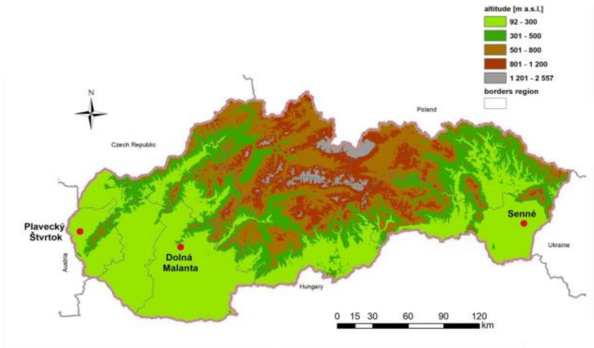
Key words: biochar, saturated hydraulic conductivity, sandy soil, silt loam soil, silty clay soil

MATERIÁL A METÓDY

Pôdy – tri skúmané pôdy odobraté z rôznych miest (obr. 1.): piesočnatá – Záhorská nížina (oblasť ***Plavecký Štvrtok***); prachovito hlinitá – Nitrianska pahorkatina (oblasť ***Dolná Malanta***); prachovito ílovitá – Východoslovenská nížina (oblasť ***Senné***);
- zrnitostný rozbor hustomernou metódou skúmaných pôd (Tab. 1.);

Biouhlie – vyrobené z kalov z papierových vlákien zmiešaných s obilnými šupkami, pyrolýzou pri teplote 550 °C;
- tri veľkostné frakcie biouhlia: <125 µm, 125 µm – 2 mm, >2 mm;
- vlastnosti použitého biouhlia (Tab. 2.);

Nasýtená hydraulická vodivosť pôdy (K) bola meraná metódou zariadenia s premenlivým hydraulickým sklonom (obr. 2.).



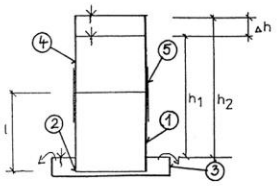
Obr. 1. Zobrazenie odberných miest troch skúmaných pôd

Tabuľka 1. Zrnitostný rozbor skúmaných pôd

	Piesok (%)	Prach (%)	Íl (%)
Piesočnatá	91	7,5	1,5
Prachovito hlinitá	15,2	59,9	24,9
Prachovito ílovitá	11,1	42,9	46

Tabuľka 2. Základný chemický rozbor použitého biouhlia

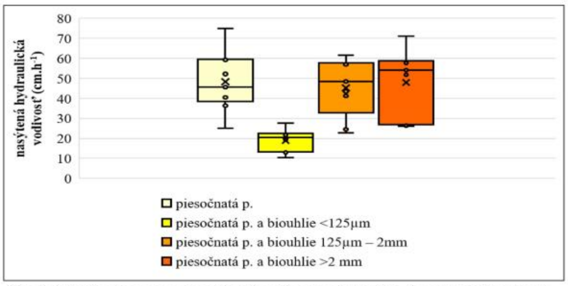
pH (–)	C (g.kg⁻¹)	N (g.kg⁻¹)	P (g.kg⁻¹)	K (g.kg⁻¹)
8,8	531	14	6,2	15



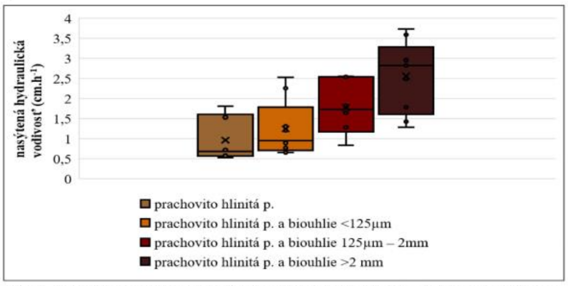
Obr. 2. Zjednodušené zariadenie na meranie nasýtenej hydraulickej vodivosti pôdy s premenlivým hydraulickým sklonom (1 - odberný valček so vzorkou pôdy, 2 - filtračný papier a drôtené sitko, 3 - Petriho miska, 4 - nadstavec, 5 - tesnenie).

VÝSLEDKY A DISKUSIA

Namerané priemerné hodnoty K sa pohybovali v rozmedzí od 18,958 do 48,363 cm.h^{-1} pre piesočnatú pôdu (obr. 3.), od 0,966 do 2,563 cm.h^{-1} pre prachovito hlinitú pôdu (obr. 4.) a od 0,083 do 0,966 cm.h^{-1} pre prachovito ílovitú pôdu (obr. 5.). Naše merania ukázali pokles K po aplikácii biouhlia <125µm v piesočnatej pôde (obr. 3.) a nárast K po aplikácii biouhlia v prachovito hlinitej a prachovito ílovitej pôde (obr. 4. a obr. 5.). Tiež sme zistili, že s nárastom veľkostnej frakcie aplikovaného biouhlia došlo k postupnému nárastu K vo všetkých troch pôdach. Pri piesočnatej pôde to bol negatívny jav, pretože hodnota K nebola štatisticky rozdielna pri variantoch s biouhlím 125µm – 2mm a >2 mm oproti variantu bez biouhlia. Naopak, štatisticky významný pokles K v tejto pôde (*$p<0.05$*) bol pozorovaný v prípade aplikovaného biouhlia s najmenšou veľkostnou frakciou (<125 µm).



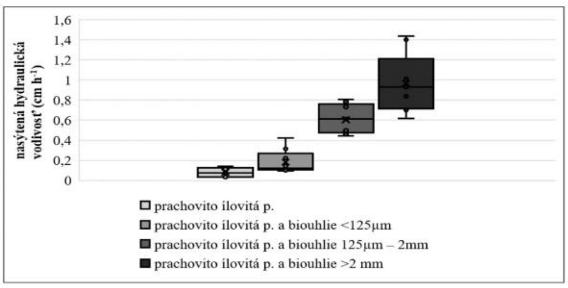
Obr. 3. Grafické znázornenie vplyvu biouhlia na K v piesočnatej pôde. Rozsah hodnôt: minimum, 1. kvartil, medián, 3. kvartil, maximum, „o“ znázorňuje jednotlivé merania a „x“ znázorňuje priemer.



Obr. 4. Grafické znázornenie vplyvu biouhlia na K v prachovito hlinitej pôde. Rozsah hodnôt: minimum, 1. kvartil, medián, 3. kvartil, maximum, „o“ znázorňuje jednotlivé merania a „x“ znázorňuje priemer.

ZÁVER

Naše výsledky ukazujú, že veľkosť častíc biouhlia aplikovaného do pôdy jednoznačne ovplyvňuje K. V rôznych pôdnych druhoch má pozitívny vplyv iná veľkostná frakcia biouhlia. Bolo preukázané, že v piesočnatej pôde účinne spomaľuje odtok biouhlie s najmenšou veľkosťou frakcie (<125 µm) o 60%. V prachovito hlinitej pôde sa zvýšila nasýtená hydraulická vodivosť s najväčšou veľkosťou frakcie (>2 mm) o 65%. Podobne aj v prípade prachovito ílovitej pôdy bolo najvýraznejšie zvýšenie nasýtenej hydraulickej vodivosti pri použití biouhlia s najväčšou veľkosťou frakcie (>2 mm). Pri tejto pôde došlo k viac ako 10 násobnému zvýšeniu K. Na záver môžeme konštatovať, že aplikácia biouhlia do pôdy mení jej K. Zároveň z našej analýzy vyplýva, že k dosiahnutiu zmeny K pre rôzne druhy pôd je vhodnejšia iná frakcia biouhlia.



Obr. 5. Grafické znázornenie vplyvu biouhlia na K v prachovito ílovitej pôde. Rozsah hodnôt: minimum, 1. kvartil, medián, 3. kvartil, maximum, „o“ znázorňuje jednotlivé merania a „x“ znázorňuje priemer.

POĎAKOVANIE

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OPTIMIZING TEMPERATURE-DEPENDENT REFERENCE EVAPOTRANSPIRATION PREDICTION WITH MACHINE LEARNING

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ABSTRACT

The authors of this study investigated the use of machine learning (ML) and feature engineering (FE) techniques for accurate determination of the FAO reference evapotranspiration (ETo) with minimal measurement of climate variables. A number of ML methods were tested in order to assess how sophisticated an ML algorithm would need to be for this task. The main focus was on feature engineering, where raw variables are converted into inputs more suitable for ML algorithms, leading to improved results. The authors confirm that the ability of ML to perform such tasks depends not only on the choice of the appropriate algorithm, but also on this often ignored step. The results of computational experiments are presented, accompanied by a comparison of the proposed method with standard empirical ETo equations. Machine learning methods, mainly due to the transformation of raw variables using FE, provided better results than traditional empirical methods and sophisticated ML algorithms without FE. In addition, the authors tested the applicability of the developed models in the wider field to assess the possibility of their generalisability. The potential of this approach to provide improved predictions, reduced input requirements and increased efficiency holds interesting promise for optimising water management strategies, irrigation planning and decision making in the agricultural sector.

Keywords: reference evapotranspiration, input data reduction, machine learning, feature engineering

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CHALLENGING HYDROLOGY AND CHALLENGES TO HYDROLOGY IN SLOVAKIA

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ABSTRACT

Although a large amount of research has been undertaken to investigate the primary sources of natural drivers and societal pressures of hydrological phenomena globally, regionally and locally, there is still an urgent need to achieve a comprehensive understanding of the impacts of the changing climate, current and future land use and management practices on runoff processes in general and those of extremes in particular. It is recognized that understanding the interactions of drivers and hydrological processes on local and regional scales is also an essential prerequisite for addressing practical socio-hydrological and water resources management problems. The rich spatial and temporal heterogeneity of climatic drivers and regional and local control conditions in Slovakia makes it challenging to arrive at generalized descriptions of the genesis of particular hydrological regimes and events. The same applies to specific regional and local hazards and risk factors and the design of generally applicable mitigation schemes. In this respect, the regional understanding and modelling of catchment hydrological processes are becoming increasingly essential for addressing science and practical water resources management questions. Chances offered by new sources of data, based on the latest developments in radar meteorology, experiments on hillslopes, and tracer studies in catchments have given hydrologists opportunities to compare different models of the same type (e.g., distributed) or different types of models (e.g., distributed vs lumped, process-based vs conceptual) on a regional basis. The confrontation of catchment experiments with results from catchment modelling has become more critical in recent years. Against this background, this contribution reviews recent and present research on the emerging topics of scientific hydrology connected to global water challenges and societal development priorities in Slovakia. It calls for new programmes of catchment experiments leading to better process understanding and representations, confrontation of hydrological catchment models with new types of data and process representation for distinct purposes, regionalization and generalizations of hydrological regimes on various temporal and spatial scales using increased process knowledge and the application of models and ensembles for improved characterization and predictions of changes in hydrological processes and climate change impacts on the water cycle.

Keywords: global water challenges, climate change, sociohydrology, challenges to hydrology, Slovakia

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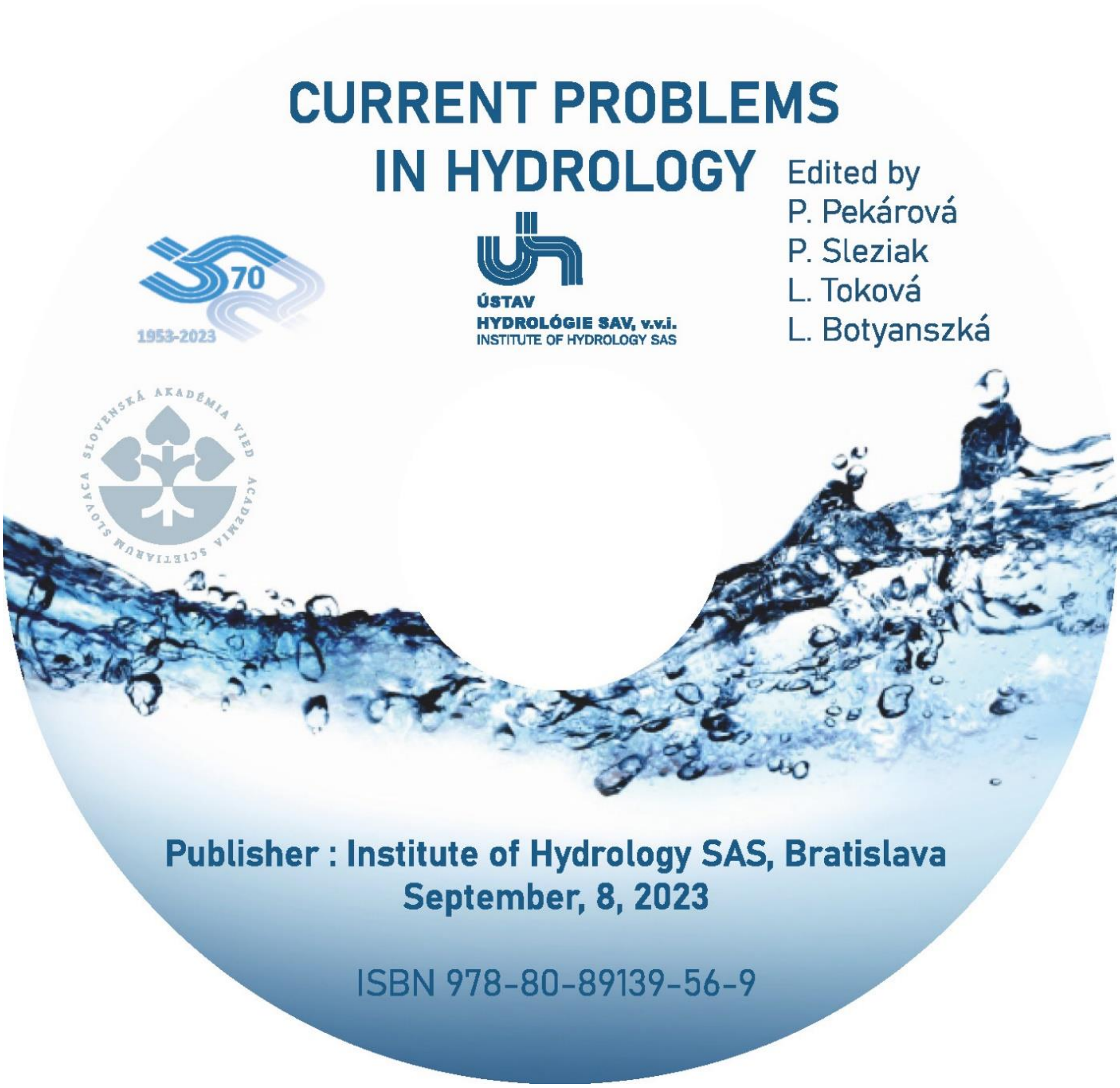
Conference program

	WEDNESDAY 27. SEP
12:00 – 13:30	**Lunch**
12:00 – 13:30	**Registration, preparation of posters**
12:30 – 13:30	**Meeting of the SNV IHP UNESCO committee (Art salon)**
14:00 – 14:45	**Opening Ceremony**
14:45 – 15:30	**Keynote Speakers**
	Ing. Yvetta Velísková, PhD. **(Ústav hydrológie SAV, v. v. i. - história a súčastnosť**
	prof. Ján Szolgay, PhD. **(Výzvy hydrológie a pre slovenskú hydrológiu)**
15:30 – 16:30	**Coffee Break, Poster Session, (Pekárová)**
15:30 – 16:30	**30th Anniversary Plenary session of the SNV IHP UNESCO (Art salon)**
16:30 – 18:00	**Presentations 1. (chairmans: Hlavčová, Šurda)**
16:30 – 16:45	**Hodnotenie a financovanie ekosystémových služieb pôdy a krajiny**
	Ing. Martin Kováč a kol.
16:45 – 17:00	**Hydrologický výskum v povodí Jaloveckého potoka**
	Ladislav Holko, Michal Danko, Patrik Sleziak, Martin Jančo, Michal Chrenek*
17:00 – 17:15	**Flow resistance at lowland and montainous rivers**
	Saeid Okhravi, Mahdi Alemi, Hossein Afzalimehr, Radoslav Schügerl, Yvetta Velísková*
17:15 – 17:30	**Evaluation of precipitation measurements using a standard rain gauge in relation to data from a precision lysimeter**
	Andrej Tall, Branislav Kandra, Dana Pavelková, Sascha Reth, Milan Gomboš*
17:30 – 17:45	**Changes of drought indicates in relation with the geographic altitude of the crop site**
	*Ákos Tarnawa, Katalin M. Kassai, Zoltán Kende, Márton Jolánkai**
17:45 – 18:00	**The testing of a multivariate probabilistic framework for reservoir safety evaluation and flood risks assessment in Slovakia: A study on the Parná and Belá Rivers**
	Výleta, R., Rončák, P., Liová, A., Valent, P., Bacigál, T., Gribovszki, Z., Šurda, P., Vitková, J., Hlavčová, K.
18:30 – 21:30	**Welcome Reception**
	THURSDAY 28 SEP
08:00 – 09:00	**breakfast, preparation of posters**
09:00 – 10:20	**Presentations 2. (chairmans:** *Zeleňákova, Vitková* **)**
09:00 – 09:15	**Comparison and analysis of agricultural drought occurrence and predicting future drought in two cases at eastern Slovakia and northern Serbia**
	Martina Zeleňáková, Tatiana Soľáková, Helena Hlavatá, Dorota Simonová*
09:15 – 09:30	**Inverse task of pollution spreading - localization of source in extensive open channel network structure**
	Velísková Y., Sokáč M., Barati Moghaddam M.*
09:30 – 9:45	**A Study of the Water Balance in Tree Selected Sub-basins of the Central Rift Valley, Ethiopia influenced by Climatic Change**
	*Lemma Adane Truneh, Svatopluk Matula *, Kamila Báťková*
09:45 – 10:00	**Change in crack width on the surface heavy soils during drought, determined by precise measurement and calculation**
	*Milan Gomboš, Andrej Tall, Branislav Kandra, Anca Constantin, Dana Pavelková**
10:00 –10:15	**Poster Session**

10:15 – 10:30	**Coffee Break,**
10:30 – 12:00	**Presentations 3. (chairmans:** *Poórová, Miklánek*)
09:45 – 10:00	**Metóda operatívnej detekcie prívalových povodní využitím meteorologických radarov ako podklad pre vydávanie hydrologických výstrah**
	Michaela Bírová, Ladislav Méri, Peter Smrtník, Valéria Wendlová*
11:00 – 11:15	**Hydrologický predpovedný systém SHMU**
	Danica Lešková, Hana Hlaváčiková
11:15 – 11:30	**Novinky v Európskom povodňovom varovnom systéme EFAS**
	Martin Halaj, Michaela Mikuličková, Hana Hlaváčiková*
11:30 – 11:45	**Problémy pri výbere nového referenčného obdobia (Chellenges in selecting the new reference period)**
	Lotta Blaškovičová, Katarína Jeneiová, Katarína Kotríková, Ľubica Lovásová, Katarína Melová, Soňa Liová*
11:45 – 12:00	**Uncertainty of precipitation input data in the hydrological forecasting system of SHMU**
	Hlaváčiková, H., Kopáčiková, E., Hrušková, K., Lešková, D.
12:00 – 13:00	**Lunch**
13:30 – 16:00	**Excursions (Molpír Museum, Hlbočiansky Waterfall, Cave Driny, Castle tour)**
16:00 – 16:30	**Coffee Break**
16:30 – 17:30	**Presentations 4. (chairmans:** *Matula, Gomboš* **)**
16:30 – 16:45	**Vplyv vlastností krajiny na toky vody a energie v ekosystémoch Slovenska**
	Viliam Novák
16:45 – 17:00	**Monthly stream temperatures along the Danube River: Statistical analysis and predictive modelling with incremental climate change scenarios**
	*Pekárová, P., Bajtek, Z., Pekár, J., Výleta, R., Bonacci, O., Miklánek, P. *, Belz, J.U., Gorbachova, L.*
17:00 – 17:15	**Effects of the application of biochar on the soil erosion of plots of sloping agricultural and with silt loam soil**
	*Rončák, P. *, Németová, Z., Vitková, J., Danáčová, M., Toková, L., Aydin, E., Valent, P., Honek, D., Igaz, D.*
17:15 – 17:30	**Estimation of runoff in the Danube river sub-basins**
	*Pekárová, P. *, Halmová, D., Sabová, Z., Pekár, J., Miklánek, P., Bačová Mitková, V., Prohaska, S., Kohnová, S., Garaj, M.*
18:00 – 21:00	**Social evening**
	FRIDAY 29 SEP
08:30 – 09:30	**breakfast, check-out**
09:30 – 10:30	**Presentations 5. (chairmans:** *Lešková, Danko* **)**
09:30 – 09:45	**Using Feature Engineering and Machine Learning in FAO Reference Evapotranspiration Estimation**
	*Barbora Považanová, Milan Čistý, Zbynek Bajtek**
09:45 – 10:00	**Impact of biochar particle size and feedstock type on hydro-physical properties of sandy soil**
	*Botková, N. *, Vitková, J., Šurda, P., Massas, I., Zafeiriou, I., Gaduš, J., Rodrigues, F.C., Borges, P.F.S.*
10:00 – 10:15	**Dynamics of potentially saturated areas during rainfall-runoff events**
	Patrik Sleziak, Michal Danko, Martin Jančo, Juraj Parajka, Ladislav Holko*
10:30 – 11:00	**Closing Ceremony**
11:30 – 12:30	**Lunch**



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