Innovative monitoring techniques and modelling approaches for analysing hydrological processes in small basins

Darmstadt / Germany, September 11 - 14, 2018

Book of Abstracts
**PROGRAM ERB2018**

**Tuesday, Sept. 11, 2018**
ERB Steering Committee meeting (by invitation)

**Wednesday, Sept. 12, 2018**

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**Thursday, Sept. 13, 2018**

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**Friday, Sept. 14, 2018**
Field trip
ORAL PRESENTATIONS

Wednesday, Sept. 12, 2018

09:30 – 10:30  Session 1  New monitoring techniques for analysing hydrological and biogeochemical processes, I  (Hubert Holzmann)

1. Berta Singla, Jérôme Latron, Kazuki Nanko, Delphis F. Levia, Antonio J. Molina, Carles Cayuela, Mireia Oromí, Francesc Gallart and Pilar Llorens: Relationship between throughfall drop size and isotopic composition: Preliminary insights from an ongoing experiment in Mediterranean conditions (Vallcebre, North-Eastern Spain)
2. Barbara Glaser, Marta Antonelli, Luisa Hopp, Julian Klaus: Surface saturation within a headwater catchment – observation and simulation of spatio-temporal variabilities
3. João R.C.B. Abrantes, João L.M.P. de Lima: Detecting the movement of very shallow surface flows by means of thermal tracers: results from laboratory to field tests
4. Daniele Penna, Ilja van Meerveld: How does spatial variability in the isotopic composition of different water compartments affect mixing model results for small catchments? A global analysis

11:15 – 12:30  Session 2  New monitoring techniques for analysing hydrological and biogeochemical processes, II  (Janusz Siwek)

2. Monika Nausch, Sandra Jahn, Petra Kahle, Günther Nausch, Thomas Leipe, Bernd Lennartz: Phosphorus losses from small catchments and across spatial scales
4. Paul D. Wagner, Georg Hörmann, Britta Schmalz, Nicola Fohrer: Characterisation of the water and nutrient balance in the small rural lowland catchment of the Kielstau
5. Edvinas Stonevicius, Dalia Grendaite, Jurate Karosiene, KsenijaSavadova, Jurate Kasperoviciene: Sentinel 2 data for retrieval of chlorophyll-α concentration in small lakes

14:00 – 15:00  Session 3  New monitoring techniques for analysing water balance components  (Ladislav Holko)

1. Johannes Deelstra, Synneve Rivedal: Is subsurface drainage needed
2. Leonie Kiewiet, Ilja van Meerveld, Jan Seibert, Manfred Stähli: Spatial variability in shallow groundwater chemistry and its potential influence on isotope hydrograph separation results
3. Giulia Zuecco, Daniele Penna, Luisa Pianezzola, Ilja van Meerveld, Chiara Marchina, Anam Amin, Ylenia Gelmini, Marco Borga: Do different tracers help to identify runoff components in a small forested catchment?
4. Gerald Krebs, Johannes Leimgruber, David Camhy, Robert Schatzl, Dirk Muschalla: Hydro-meteorological trends in a small research basin

16:15 – 17:30  Session 4  Assessment of water balance components (Péter Kalicz, Miroslav Tesař)

1. Tetiana Zabolotnia, Liudmyla Gorbachova, Borys Khrystiuk: The main tendencies of input parameters for hydrological modeling on small mountain catchments (Ukraine)
2. Babar Mujtaba, Hana Hlaváčková, Ladislav Holko, João L.M.P. de Lima: The role of stony soils in hillslope and catchment runoff formation
3. Julian Klaus, C. Rhett Jackson: How far does interflow travel down slope: a comparison study across seventeen hillslopes
4. Eva Olmo Gil, Martin Trappe, Benno Kuegel, Ulrich Kaul: Influence of karst tributaries and their seasonal variability on the water quality of the Altmühl River in South Franconia (Germany)
5. Noemí Lana-Renault, Estela Nadal-Romero, José Ángel Llorente, Makki. Khorchani, David Regués, Purificación Ruiz-Flaño, José Arnáez: Differences in streamflow after farmland abandonment – a comparative study in four small mountain catchments
Thursday, Sept. 13, 2018

09:00 – 10:00  Session 5  Measuring erosion and associated transport processes  (Christophe Hissler)

1. Abelardo A.A. Montenegro, Iug Lopes, Ailton Alves, João Pedroso de Lima, Hélio Araújo, João Gabriel de Souza, Thayná Almeida, Hugo G.L. Montenegro: Spatio temporal soil moisture dynamics under different soil cover conditions in a semiarid representative basin in Brazil
2. Peter Fiener, Florian Wilken, Karl Auerswald: Eight year monitoring of surface runoff and sediment delivery from 14 small watersheds under soil conservation – what can we learn from the Scheyern data-set?
3. Angela Rebscher, Britta Schmalz: How to generate input for small-scale modeling - Example of soil erosion
4. Janine Köhn, Frido Reinstorf, Andrea Heilmann, Hardy Pundt, Martin Scheinert: Erosion mitigation investigations and knowledge transfer from the small catchment Schäferbach to other regions of the Harz Mountains in the project “BebeR”

11:00 – 12:00  Session 6  New modelling approaches for analysing (eco-) hydrological processes  (João Pedroso de Lima)

1. Matthias Kopp, Markus Disse: Measuring and modeling of snow cover in subalpine regions of the Bavarian Alps – The Dreisäulerbach catchment
2. Václav Šípek, Miroslav Tesař: Seasonal variability of soil hydraulic properties in soil water content modelling
3. Roel Dijksma, Bart Middelburg, Kas Lange: Modelling complex flow patterns in an area with abandoned coal mines in the Netherlands

13:15 – 14:15  Session 7  New modelling approaches for analysing (eco-) hydrological processes and extreme events  (Johannes Deelstra)

1. Andreas Bauwe, Petra Kahle, Bernd Lennartz: Predicting stream flow, flow components, nitrate losses and crop yields in a small artificially drained catchment employing the SWAT model
2. Maite Meaurio, Ane Zabaleta, Jesus Angel Uriarte, Garikoitz Bengoa, Raghavan Srinivasan, Iñaki Antiguedad: Streamflow and suspended sediment hourly simulation using SWAT: strengths and weaknesses in a small forested catchment
3. Amrei David, Britta Schmalz: Modeling approaches for floods in different spatio-temporal scales – Do smaller catchments need smarter models?
4. Janusz Siwek, Joanna P. Siwek, Miroslaw Żelazny, Wojciech Szymański: The hysteresis patterns of phosphates and potassium concentration as the indicator of flowpaths during high flow events (Carpathian Foothills, Poland)
14:45 – 15:30  Session 8  Adaptation of water management to climate change  (Jérôme Latron)

1. Marcus Beylich, Janine Köhn, Frido Reinstorf: Precipitation-runoff modeling and simulation of current climate projections in the catchment area of the Schäferbach / Harz Mountains

2. Henning Meesenburg, Johannes Sutmoeller, Birte Scheler: Increasing drought stress caused by climate change and forest growth at Lange Bramke, Harz Mountains, Germany

3. Christian Peters, Thomas Hirschhäuser, Matthias Reimers: A modelling approach for future water management in a lowland area under special consideration of large-scale subsidences
POSTER PRESENTATIONS

A) New monitoring techniques for analysing hydrological and biogeochemical processes

1. Britta Schmalz, Stephan Dietrich, Ulrich Looser, Henning Meesenburg, Konrad Miegel, Frido Reinstorf: Small hydrological research basins in Germany
2. Leonie Kiewiet, Manfred Stähli, Ilja van Meerveld, Jana von Freyberg, Andrea Rücker, Rick Assendelft, Jan Seibert, James Kirchner: 50-years of hydrological research in the pre-alpine Alptal catchment
3. Marion Kruse, Britta Schmalz: Assessing the impact of land use on stream water quality in the German low mountain range basin Gersprenz
4. Josef Fürst, Karsten Schulz, Hans-Peter Nachtebel, Hubert Holzmann: A forested (hydrological) experimental research watershed to study transport processes in the system of soil, water, plants and atmosphere: Test site Rosalia
5. Nataliia Osadcha, L. Holko, V. Osadchyi, M. Lytvyn: Runoff components in a small agricultural catchment in Ukraine studied by water chemistry, stable isotopes and hydrograph separation
6. Joanna P. Siwek, Joanna Pociask-Karteczka, Janusz Siwek, Miroslaw Żelazny: Monitoring of hydrological processes in high mountain environment – the Tatra Mountains (Carpathians, Europe)
7. Christophe Hissler, Ladislav Holko, Laurent Gourdol, Jean François Iffly, Laurent Pfister: Towards more pertinent tracers for studying hydrological processes at catchment scale: a comparative study between experimental sites in Luxembourg and Slovakia
8. Stefan Koch, Andreas Bauwe, Petra Kahle, Bernd Lennartz: Assessing phosphorus transport pathways from the field to the catchment scale
10. Mariola Kędra: Analysing air and water temperatures by wavelet and EMD methods
11. Giulia Zuecco, Michael Rinderer, Daniele Penna, Marco Borga, Ilja van Meerveld: Application of graph theory to describe subsurface connectivity: results for four headwater catchments and sensitivity analysis
12. Rick S. Assendelft, Ilja van Meerveld, Jan Seibert: Spatiotemporal variation in the flowing stream network in a mountainous headwater catchment
13. Jean François Iffly, Olivier Faber, Viola Huck, Jérôme Juilleret, Cyrille Tailliez, Christophe Hissler, Laurent Pfister: Technological progress and innovation in environmental monitoring
14. Xiuming Sun, Naicheng Wu, Claas Faber, Nicola Fohrer: Sampling frequency affects the assessment of water quality using diatom-based indices in a German lowland river

B) Assessment of water balance components

15. Karolina Mostowik, Marta Kisiel, Janusz Siwek, Bartłomiej Rzonca: Runoff trends in a changing climate in small catchments in the Eastern Carpathians (Bieszczady Mountains, Poland)
16. Péter Csáki, Kornél Czimber, Géza Király, Péter Kalicz, Zoltán Gribovszki: Downscaling of the CREMAP actual evapotranspiration map using MODIS NDVI data
17. Péter Kalicz, Péter Csáki, Katalin Zagyvai-Kiss, Santiago Navarro Palacios, Zoltán Gribovszki: Automation efforts of interception measurements in the Hidegvíz Valley,
Hungary - Interception measurements in the Hidegvíz Valley, Hungary – Comparing traditional and novel sampling methods

18. Adam Beran, Eva Melíšová, Roman Kožín, Petra Fialová: Derivation of regression equations for calculation of evaporation from a free water surface and identification of trends in measured variables in Hlasivo station

19. Gianina Neculau, Florentina Iuliana Stan: The effect of evapotranspiration on the water reserve of Romanian lakes (Case Study)

20. Michal Danko, Ladislav Holko: Overland flow in a mountain microcatchment during rainfall simulator experiments

21. Johannes Deelstra: Flow processes and subsurface drainage systems

22. Carles Cayuela, J. Latron, J. Geris, P. Llorens: Uncertainty in the isotope-based hydrograph separation due to spatiotemporal variations of the input signal in a partially forested catchment

C) Measuring erosion and associated transport processes

23. Martin Neumann, Jakub Stašek, Adéla Roudnická, Tomáš Dostál, David Zumr, Josef Krása, Luděk Strouhal, Petr Kavka, Tomáš Laburda: Field measurement of surface runoff and soil loss on agricultural land using rainfall simulator


25. Jakub Stašek, Josef Krása, Tomáš Dostál, Václav David, David Zumr, Petr Kavka, Markéta Báčová, Adam Tejkl: Monitoring of soil erosion by water in multiple scales

26. Dominik Scholand, Britta Schmalz: Spatial and temporal variability of suspended sediment in low mountain range Gersprenz basin

27. Joaquim Farguell, X. Úbeda, E. Pacheco: Dissolved sediment transport and ion characteristics of runoff and groundwater at a low Mediterranean mountain catchment: the Vernegà river, Gavarres Massif, NE Spain.

D) New modelling approaches for analysing (eco-)hydrological processes

28. Michael Kissel, Angela Rebscher, Anna Bach, Britta Schmalz: Hydrological modelling of the Fischbach catchment using two sources of precipitation data

29. Florentina Stan, Vinicius Carmello, Gianina Neculau, J.L. Sant’Anna Neto: Validation of the Cropwat Model at a Romanian experimental station and in other different climatic regions (Brazil, India and USA)

30. Jana Votrubová, Veronika Mikešová, Michal Dohnal, Miroslav Tesař: Modeling soil water regime under varying climatic, soil profile, and vegetation conditions

31. Michal Dohnal, Tomáš Vogel, Jaromír Dušek, Jana Votrubová: Coupled water flow and heat transport modeling under winter season conditions at a small mountainous catchment of Central Europe

32. P. V. Femeena, I. Chaubey, A. Aubeneau, S. McMillan, P. D. Wagner, N. Fohrer: Predicting nutrient uptake in streams using an enhanced physically-based solute transport model
ORAL PRESENTATIONS
Relationship between throughfall drop size and isotopic composition: Preliminary insights from an ongoing experiment in Mediterranean conditions (Vallcebre, North-Eastern Spain)

Berta Singla 1,2, Jérôme Latron 1, Kazuki Nanko 3, Delphis F. Levia 4, Antonio J. Molina 1, Carles Cayuela 1, Mireia Oromí 5, Francesc Gallart 1 and Pilar Llorens 1*

1 Surface Hydrology and Erosion group, Institute of Environmental Assessment and Water Research (IDAEA), Spanish National Research Council (CSIC). Barcelona, Spain
2 University of Lleida. Lleida, Spain
3 Department of Disaster Prevention, Meteorology and Hydrology, Forestry and Forest Products Research Institute. Tsukuba, Japan
4 Departments of Geography and Plant & Soil Sciences, University of Delaware, Newark, DE, USA
5 Scientific and Technical Services. University of Lleida. Lleida, Spain
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Abstract

Even though throughfall is the dominant input of water to forests, many questions remain about the temporal fine-scale mechanisms controlling the redistribution of rainfall by forest canopies. Hydrologists must therefore combine different methods in novel way to achieve breakthroughs in our understanding of rainfall partitioning and its interactions with pre-event water storage on tree surfaces. Here, we apply a combination of isotopes (oxygen and hydrogen) and laser disdrometers to quantify the isotopic composition of free, splash, and release throughfall at the sub-event timescale. For individual events, isotopic differences between throughfall and open rainfall may indeed vary in magnitude and direction as a result of evaporation, exchange or selection processes.

Our working hypothesis is that relating the sub-event timescale throughfall measurements with that of drop size distribution and of isotopic variations will provide an unprecedented understanding of the throughfall generation process. Such an understanding would be required to fully and accurately track the transfer of moisture from the canopy to the forest floor.

This work performed in a Scots pine forest under Mediterranean conditions is based on the continuous (5min data) measurement of open rainfall and throughfall amounts (by means of tipping-buckets) and of drop size distributions (laser disdrometers) at the same two locations. In addition, rainfall and throughfall passing through the laser disdrometers and the tipping buckets are finally collected sequentially by means of automatic samplers.

This presentation will show preliminary findings on the relationship between throughfall drop size and isotopic composition for several rainfall events of different magnitudes and intensities, helping to reveal how water moves through flowpaths and storage reservoirs in the canopy.

Key words: Rainfall, Throughfall, Drop size distribution, Isotopic composition, Scots pine
Surface saturation within a headwater catchment – observation and simulation of spatio-temporal variabilities

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$^2$ University of Bayreuth, Department of Hydrology, Bayreuth, Germany
$^3$ Wageningen University & Research, Hydrology and Quantitative Water Management Group, Wageningen, The Netherlands

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Abstract

Surface saturated areas can strongly influence runoff generation and related water quality. Many field and modelling studies have identified various types of surface saturation (e.g. generated by saturation excess / infiltration excess, active vs. contributing areas) and heterogeneous spatial and temporal occurrences. Yet, in the past, surface saturation patterns were often considered as having static patterns over time (e.g. mapping from vegetation patterns, predictions based on topographic indices) or as behaving uniformly over a catchment and investigations of spatio-temporal variabilities of surface saturation generation within a catchment are lacking.

In this study we combined a comprehensive 2-year surface saturation mapping campaign with hydrologic modelling to analyze the generation of surface saturation (i.e. where and when it occurs, which are the water sources) across the forested Weierbach headwater catchment (45 ha) in western Luxembourg. For simulating the spatio-temporal evolution of surface saturated areas in the catchment we used the integrated surface subsurface hydrologic model HydroGeoSphere, which allows to simultaneously consider surface saturation generation with water contributions from above (e.g. precipitation) and below (e.g. groundwater exfiltration) the ground surface. The field campaign consisted of mapping surface saturation in nine distinct riparian areas along the Weierbach stream with thermal infrared imagery once every second week. Both field mapping and simulation were performed over two hydrological years (November 2015 – November 2017).

The infrared images provided a detailed picture of similarities and differences of surface saturation patterns and their extension-contraction dynamics within the catchment and helped to discern different generation processes (e.g. groundwater exfiltration vs. ponding water). This information was used to validate how well the hydrological model could simulate the spatio-temporal variabilities within the catchment. The spatially distributed validation allowed to identify areas with matching and mismatching simulated and observed saturation patterns. Both were very useful for better understanding the hydrologic processes underlying the surface saturation generation. For areas with matching saturation patterns the model provided detailed information on the origin of the surface saturation, whereas for areas with mismatching saturation patterns the model helped to understand which processes were not responsible for the development of surface saturation.

Key words: surface saturation generation, thermal infrared images, integrated surface-subsurface modelling, spatial validation
Detecting the movement of very shallow surface flows by means of thermal tracers: results from laboratory to field tests

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Abstract

Shallow surface flows can occur in natural and urbanized basins (e.g. hillslopes, drainage systems) and the accurate detection of their movement has been of great concern to the hydro-environmental research community, in order to better understand and model the dynamics of sediment and pollutant transport.

Recent developments have been made in sensing technology (e.g. acoustic, ultrasonic, microwave), resulting in a wide spectrum of powerful and versatile tools for high accuracy flow velocity measurement. However, such tools may have some limitations when operating outside their ideal measurement conditions. Particularly for very shallow surface flows, the characterization of the velocity fields is complicated, mostly because of their small depth (i.e. from millimetres to a few centimetres). For a long time, tracer techniques (e.g. dyes, salts, particles) have been used in estimating these velocities. A more recent approach uses thermal tracers (e.g. water hotter or colder than the flow, ice cubes, cold oil droplets) that can be detected by an infrared sensor (e.g. infrared video camera).

This study presents results of several thermal tracer applications to detect the movement of very shallow surface flows and estimate their velocity. Experiments were conducted both in laboratory and in field, in natural (e.g. bare soil, vegetated soil with grass, soil covered by tree leaves) and urbanized (e.g. smooth acrylic, asphalt pavements, concreted sidewalks) surfaces and considered very shallow flows from 1 mm to 5 cm depth. Hand-held infrared video cameras were used to detect the thermal tracer in the flow. This more recent thermal tracer technique was compared to more traditional and well established dye and salt tracer techniques, using optical video cameras and electric conductivity sensors.

The different tracer techniques yielded very similar results. One advantage of the thermal tracer was the higher visibility of the movement of the tracer in the thermal videos compared with the real image videos. Thermal tracer also measures flow velocities in a cleaner way, leaving less residue in the water or the soil. In very shallow flows, velocity estimation using tracers contains a large amount of uncertainty and caution must be taken in these measurements, especially in the field studies, where these variables greatly vary in space and time.

Key words: Tracers, Infrared thermography, Flow velocity, Laboratory and field experiments
How does spatial variability in the isotopic composition of different water compartments affect mixing model results for small catchments? A global analysis

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Abstract

Most isotope-based studies on catchment hydrology focus on the temporal variability of the isotopic composition of surface or subsurface water. Usually, samples are collected at only a few locations, and it is assumed that they are representative for that hydrological compartment. We reviewed more than 150 papers published in international peer-reviewed journals between 1970 and 2017 that used stable isotopes of hydrogen and oxygen to infer hydrological processes in small catchments (up to 10 km²). The aim of our literature review was to answer the following questions: i) How many water samples do researchers typically collect in small catchments? ii) How large is the observed spatial variability in isotopic composition when the same compartment is sampled at multiple locations? iii) Does the spatial variability influence the results of mixing models and affect our understanding of hydrological processes?

We found that the two most frequently sampled hydrological compartments were streamflow and precipitation, followed by soil water and shallow groundwater. The studies that characterized a hydrological compartment at more than five locations all revealed a large spatial variability, even over short distances. However, this spatial variability was overall less marked than the temporal variability in isotopic composition, especially for throughfall and streamflow, followed by shallow groundwater and soil water. We used the median observed spatial variability in isotopic composition to determine for which compartment spatial variability in isotopic composition has the largest effect on mixing model results. We found that the spatial variability in isotopic composition of shallow groundwater significantly affect the computed runoff fractions but not their temporal dynamics. These results highlight the need to consider the spatial variability in the isotopic composition of surface and subsurface water in isotope-based studies on runoff processes, even in small catchment studies.

Key words: stable isotopes; spatial variability; hydrological compartments; small catchments; mixing models
Identification of rainfall-runoff processes formation with high-frequency monitoring of water chemistry

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Abstract

Small river basins, where the forest is the main land use, represent the natural land use in the climatic conditions typical for Slovenia. Hydrological conditions are reflected in the properties of individual precipitation events, such as, for example, the intensity and/or duration of precipitation. In order to improve our understanding about the impact of hydrological conditions on the variability of water chemistry and water dissolved nutrient forms, a large number of different data needs to be obtained. Moreover, the existing data does not provide sufficient spatial and temporal resolution (e.g., low-frequency measurements, low number of measurement locations), therefore majority of the input parameters still has to be measured.

For this purpose, a measurement network was established inside the Gradaščica River experimental catchment in central Slovenia. The installed measurement equipment includes water level sensors, rain gauges, disdrometer, and multiparameter sonde for the monitoring of water chemistry. With monitoring and analysis of the measured data we want to explore a) the impact of the characteristics of precipitation events on the dynamics of nutrient mobilization from the forested area, b) how the temporal variability of water chemistry contributes to the identification of processes of rainfall-runoff formation, and c) if the role of the watershed changes seasonally in terms that part of the year the basin represents source of nutrients and part of the year their sink.

Acknowledgements: The authors acknowledge the project (Modelling hydrologic response of nonhomogeneous catchments, J2-7322) was financially supported by the Slovenian Research Agency.

Key words: high-frequency monitoring, rainfall-runoff formation, biogeochemical processes
Phosphorus losses from small catchments and across spatial scales

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Abstract

Phosphorus (P) is a major contributor to eutrophication of rivers, lakes and coastal ecosystems such as the Baltic Sea. Most of the P is coming from diffusive sources of agricultural origin. The German catchment to the Baltic Sea is dominated by agriculture and the majority of arable land is artificially drained. Tile-drainage systems may constitute a significant source of P to aquatic ecosystems. The objective of this study was to detect the P loads and their composition from a tile-drain outlet (4.5 ha) and how P fractions vary along the flow path towards the Baltic Sea (ditch, brook, river). The investigations were conducted in the Zarnow catchment (16 km²) a sub-catchment of the Warnow river basin (3028 km²). Water samples were collected during three discharge seasons (1th November - 30th April) in 2013/2014, and 2015/2016 and 2016/2017. All periods covered relative dry and mild winters. Total phosphorus (TP) concentrations in tile-drain water ranged from 15.5 ± 3.9 µg l-1 in 2013/2014 to 34.6 ± 46.9 µg l-1 in 2015/2016; they increased along the flow path, especially in the brook. Thus, the contribution of tile-drain water to the P concentrations in the brook and the river Warnow seems to be low and other sources such as the groundwater might be more important to the overall riverine P load to the Baltic Sea. Tile-drain water was dominated by dissolved P (>70%) with an increase of particulate P along the flow path. In the river Warnow, dissolved inorganic P was converted into particulate organic P by the spring bloom in March and April. Clay minerals and Fe(hydr)oxides were the main carrier of particle bound P. In order to fully understand the transport pathways of P in agricultural used lowland catchments, edge of field investigations alone seems to be insufficient as processes along the flow path may modify the P signal that is eventually released into the Baltic Sea.

Key words: Phosphorus Losses, Lowland Catchment, Tile Drainage, Baltic Sea
Quantification and comparison of C,N,P – Fluxes from small basins with different land uses

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Abstract
For the identification of governing hydrological processes or the assessment of the impact of land use on the export of solutes in small basins, high-resolution, high-quality measurements are favorable. However continuous monitoring at multiple sites is laborous and expensive.

Therefore, often a time discrete monitoring in varying temporal resolution is practiced. Fluxes of solutes are then calculated with load estimation techniques of various complexity.

In our study, we have monitored three small basins (0.9ha, 17ha, 21ha) under different land uses (agriculture, pasture, forest). All basins were monitored by a weekly sampling and continuous discharge measurements in the first two years. In the third year, the sampling was carried out at bi-weekly intervals. Additionally, for all three basins, storm events have been sampled at a high-temporal resolution by the means of automatic samplers.

We have calculated fluxes for DOC, Nitrate-Nitrogen and Total-phosphorus for three small basins with different land uses with different load estimation and prediction techniques. In the load prediction techniques continuous discharge measurements serve as a predictor for solute fluxes. The discharge-solute relationship was established by various methods like interpolation, linear or regression models. The comparison of the results for the different solutes and load calculation procedures revealed that no single method brings equally good results in all basins. The results also differ as well when only the results from the time discrete sampling have been used or combined from time discrete and event sampling.

We draw the conclusion that no general procedure for flux estimation should be applied to calculate loads of solutes from small basins. Instead, several methods need to be tested. This also gives insights into governing processes in the basin and useful information in how an existing monitoring scheme can be improved to gain higher information.

Key words: sampling strategy, solute fluxes, load prediction procedures
Characterisation of the water and nutrient balance in the small rural lowland catchment of the Kielstau

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Abstract

Kielstau is a small rural catchment in the north of Schleswig-Holstein with a size of about 50 km². Hydrological data are available since 1985. Additionally, water quality and field campaign measurements have been taking place since 2005 by the Department of Hydrology and Water Resources Management of the University of Kiel. Since 2010 the Kielstau catchment is recognized as a UNESCO demonstration site for ecohydrology. The aim of this study is the characterisation of the water and nutrient balance in the lowland catchment Kielstau as well as the detection of seasonal and long-term trends. To this end, water quality measurements with high temporal resolution are analysed over a period of ten years (2007 to 2016). In addition to descriptive statistics, the statistical analysis covers trend analysis as well as auto- and cross-correlation tests. Our results indicate the great effect of groundwater and vegetation on runoff processes in the catchment. In the study period, a significant decrease of 0.12 mg/l NO₃-N and 0.006 mg/l NH₄-N per year was detected. For PO₄-P no significant trend was found. This is a result of great social relevance, especially in light of the overall nitrate pollution of water bodies in Germany and Schleswig-Holstein. Moreover, the results underline the importance of long-term measurements for process understanding and sustainable river basin management.

Key words: nitrogen, phosphorus, data series, Northern Germany
Sentinel 2 data for retrieval of chlorophyll-α concentration in small lakes

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Abstract

In situ measurements are limited in space and time and are expensive. Copernicus Earth observation programme data is available at no charge, cover large domains and are frequent, therefore has a high potential to become important tool in analysis of lake processes.

Multispectral instruments on board European Space Agency satellites Sentinel-2 (2015) measure Earth surface reflectance. High spatial resolution (most bands 10-20 m.) of instruments provides opportunity to estimate spatial patterns of water quality parameters for small lakes. Satellites revisit time over the same point is at least 5 days. High frequency of data allows analyzing short-term changes and long-term trends of lake water quality.

In this study, the suitability of the Sentinel-2 Multispectral Imager (MSI) sensor data is being tested for observation of cyanobacteria blooms in lakes and retrieving the chlorophyll-α concentration - an indicator of phytoplankton biomass. The analysis was carried out for four Lithuanian lakes with surface area from 75 to 426 ha. Two of selected lakes are eutrophic - suffering from recurrent blooms of toxic cyanobacteria and two oligo-mesotrophic, non-blooming lakes. The in situ chlorophyll-α concentration data and six satellite images were used in this study. Based on availability of in-situ and satellite data the 2015 July to September period was selected for analysis.

Fig. 1. False Colour Red-Green-Blue (R – band B8A [885 nm], G – B4 [665 nm], B – B3 [560 nm]) composite of the lakes studied on the 4th August 2015, from left to right - eutrophic lakes: Jieznas, Širvys, oligo-mesotrophic lakes: Guostus, Šventas. Land vegetation is visible in red and phytoplankton in blue.

Nineteen chlorophyll-α concentration retrieval algorithms combining different methods for atmospheric correction, different bands and empirical coefficients were tested. The performance of the best algorithm was good (R²=0.81). The determination coefficient of half of tested algorithms was higher than 0.60 and only two algorithms performed poorly R²<0.40.

The first attempts to map water quality parameters in Lithuanian lakes using the data received from the Sentinel 2 Multispectral Imager sensor seem to show promising results. However, more research has to be done to develop reliable methods for chlorophyll-α concentration retrieval from satellite data.

Key words: lake, chlorophyll-α, remote sensing, Sentinel-2
Is subsurface drainage needed

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Abstract

In 2013 a experimental drainage field was established near Askvoll, located in Western Norway, having soil types representing many agricultural areas along the west coast. The climate in Western Norway is characterized by wet conditions in autumn, winter and spring. The normal long term annual precipitation for the location is 2250 mm but during the measurement period exceeding 3000 mm/year. Soils are most susceptible to compaction under wet conditions, influencing agricultural practices. A monitoring system was initiated with the objectives 1) to study the effect of subsurface drainage design on yield, nitrogen loss, nitrogen use efficiency and trafficability of ley production along the western coast of Norway 2) increase understanding of the hydrological and nitrogen flow paths and 3) provide drainage design criteria under present and future condition with climate change. The experiment consists of 2 x 2 alternatives having drain spacings of 6 and 12 m respectively and different harvesting frequency and fertiliser application. Runoff and nitrogen loss is measured using a combination of tipping bucket and volume proportional water sampling. In addition are continuous measurements carried out of soil moisture and -temperature as well as groundwater level. In addition are manual groundwater observations carried out. Also continuous groundwater measurements were carried out under zero subsurface drainage. Measurement so far have shown that large variations in runoff and nutrient loss occur, both within and between the different alternatives which partly might be due to the large variety in soil type within the experimental field, as observed also at many locations along the west coast. Both the water balance, being the difference between precipitation and evapotranspiration plus drainage runoff and the nitrogen balance, being the difference between nitrogen added as fertiliser and removed through harvest and drainage, indicated that a significant amount of both water and hence nitrogen is passing the subsurface drainage system as natural drainage to the groundwater. The presence of natural drainage is also confirmed by groundwater observations under zero drainage. A question can be raised whether subsurface drainage is necessary. The main challenges for farmers under the prevailing weather conditions along the west coast is to be able to carry out farming practices without risk of soil compaction. In this case subsurface drainage can be seen as supplemental drainage to guarantee the trafficability without which agriculture would not have been possible to practice.

Key words: subsurface drainage, climate change, farming practices, trafficability, hydrology, nitrogen flow path
Spatial variability in shallow groundwater chemistry and its potential influence on isotope hydrograph separation results

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Abstract

End Member Mixing Analyses use changes in streamwater chemistry and isotopic composition to estimate the relative contributions of different types of water to streamflow during an event. While it is recognized that catchment groundwater storages are rarely well mixed and that not all parts of the catchment are continuously hydrologically connected to the stream, often only one (or a few) groundwater samples are used to characterize the groundwater component. Similarly, for isotope based hydrograph analyses the pre-event streamflow sample is assumed to represent a mixture of all pre-event water. However, it may reflect only a certain part of the groundwater storage if groundwater has a different chemical signature in different parts of the catchment and not all parts are connected to the stream during baseflow conditions. Therefore, it is important to understand the spatial and temporal variations in groundwater chemistry in order to better understand which parts of the catchment contribute to streamflow during baseflow and rainfall events.

We combined the results from nine baseflow and four stormflow sampling campaigns in a 20-ha steep mountainous catchment in the Swiss pre-Alps events to identify stream water sources. During the nine baseflow sampling campaigns, shallow groundwater was sampled from 34 to 47 wells and at seven stream locations. The samples were analyzed for major and trace ions and stable water isotopes (δ2H and δ18O). The results show that the spatial variability in shallow groundwater chemistry is large. The Electrical Conductivity (EC) ranged from 68 – 610 μS/cm during the campaign with the highest antecedent moisture conditions and from 194 – 780 μS/cm during the driest campaign. The spatial variability in the isotopic composition of the groundwater was smallest in early summer and autumn (standard deviation: δ2H 2.3 ‰ and 3.4 ‰, respectively) and largest during the dry conditions in late August (standard deviation: δ2H 9.5 ‰). Manganese and iron concentrations were highest at sites that had persistent high groundwater levels, while concentrations of lead and zinc were highest at sites that were predominantly dry. Baseflow streamwater samples most closely resembled the groundwater in the lower part of the catchment. During the stormflow campaigns, streamwater and groundwater samples were taken at regular intervals (two and five locations respectively). Not only streamwater chemistry, but also the groundwater composition changed remarkably during the events. These results highlight the high spatial and temporal variability in groundwater chemistry, which needs to be taken into account when analysing streamflow sources.

Key words: shallow groundwater, hydrograph separation, end-member mixing analyses, spatial variability, pre-event water component
Do different tracers help to identify runoff components in a small forested catchment?

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Abstract

Identification of the spatial and temporal variability of tracer (i.e. chemical and isotopic) signatures of different water sources is crucial for assessing the main sources of stream runoff and improving our understanding of runoff generation mechanisms. In this study, we used hydrometric and tracer data (stable isotopes of water, major ions and electrical conductivity) from the 2-ha forested Ressi catchment in the Italian pre-Alps to i) study the spatial and temporal variability in the tracer signature of different water sources, ii) assess the sensitivity of the results of the two-component hydrograph separation to the choice of the tracer, and iii) determine the controls on event water contributions to runoff.

Streamflow, rainfall, shallow groundwater levels (six locations), and soil moisture (four locations) were measured continuously. Samples for tracer analysis were collected from rain and stream water, shallow groundwater and soil water in the riparian zone for 18 rainfall-runoff events between September 2015 and November 2017. All samples were analyzed for electrical conductivity using a portable field meter, isotopic composition by laser absorption spectroscopy and major ions concentrations by ion chromatography.

Results show that riparian shallow groundwater sustains runoff during baseflow conditions and riparian soil water and shallow groundwater are the main contributors to stream runoff during rainfall-runoff events. There was a high temporal variability in isotopic and chemical signature of stream water and shallow groundwater. Most concentrations in stream water decreased during rainfall-runoff events, except for nitrate, potassium and chloride concentrations that increased in stream water at the very beginning of rainfall-runoff events, likely due to a rapid flushing of deposited solutes from the dry parts of the stream channel and the riparian area. The tracer signature of groundwater in the riparian zone was quite stable in time compared to the hillslope sites and one site at the bottom of the hillslope which were affected by mixing of event water. Two-component hydrograph separation results showed that average event water contributions increased when rainfall intensities and streamflow peak flows increased. The average event water contribution was underestimated when ions were used instead of stable isotopes in the two-component hydrograph separation. These differences were related to the different ion concentrations of soil water and groundwater and their spatial and temporal variability during rainfall-runoff events. Overall, these results highlight how the use of different tracers and accounting for the spatial and temporal variability of these tracers can help improve our understanding of runoff processes.

Key words: end-member mixing analysis; hydrograph separation; groundwater; stable isotopes of water; ions; forested catchment.
Hydro-meteorological trends in a small research basin

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Abstract

Hydrological research basins (HRB) are characterized by a dense monitoring network and help to answer different questions depending on their size. The HRB Pöllau (58.3 km²) was instrumented in 1978 by the Graz University of Technology and is located in the eastern alpine foothills in Austria. A number of reasons supported the selection of the Saifenbach basin in Pöllau to conduct in-detail studies of hydrological processes: (i) the confining arched mountain ridge allows a clear delineation of the catchment, (ii) the loamy soils are characterized by low storage capacities, minimizing the influence of subsurface flow on catchment hydrology, and (iii) the climate of the catchment with heavy storm events in the summer and relatively dry winters is representative for the eastern alpine foothills.

Monitoring started with the first operating rain gauge in 1979. In 1980 the meteorological observation network comprised seven stations that are still in operation. Over the years, the monitoring network was continuously updated and currently, precipitation is monitored with five tipping gauges and three scales. Additionally, a number of meteorological parameters (such as wind speed and direction, air and soil temperature, radiation and evaporation) are observed at the “Heiling station”, centrally located in the catchment. Discharge in the drainage network is currently monitored at two locations (both operated since 1980). Since the start of the HRB, discharge has also been monitored at five additional stations in the network for limited periods between 1980 and 2009.

The identification of hydrological and climatological trends was conducted by applying statistical methods to the available data. Prior to the analysis, the data was validated with respect to data gaps, the sensor and climate specific plausibility, and the data variability. Furthermore, an inter-stational validation was performed for the rainfall observations.

The results show an increasing trend for the annual precipitation sums since 1980. While this observation is confirmed by the literature, the declining development of the mean annual air temperature for the Pöllau HRB is contrary to similar studies and climate predictions. A general increase of 1.5 °C has been reported for Austria since the 1970’s. Analysis of the discharge measurements at the catchment outlet show a significant peak in annual mean flow around the year 2000. This increase is also confirmed by corresponding rainfall observations. However, while long-term precipitation values show an increasing trend, catchment discharge declines till today, indicating increasing losses through evapotranspiration.

Key words: rural basin, long-term observations, rainfall, runoff, air temperature
The main tendencies of input parameters for hydrological modeling on small mountain catchments (Ukraine)

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Abstract

Runoff, evaporation, precipitation are not only elements of water balance, but also important input parameters for hydrological modeling. In this work, we present the long-term tendencies of the main elements of the water balance of small river catchment. It will allow to define the possible changes these parameters and is analyzing the reasons for such changes. The water balance calculations for six mountain catchments within Rika River Basin (right tributary of the Tysa River) were carried out.

The database includes time series of the annual layer of runoff (Y) and annual precipitation (P) over the period 1957-2015. Evaporation (E) and runoff coefficient (k) was calculated (E = P – Y; k = Y/P). Furthermore, the time series of average annual air temperature (T), humidity deficit (∆E) and wind speed (W) from weather station Nyzhni Studenyi are used to detect empirical relation between evaporation, runoff and precipitation.

During the study, we used the classic methods of hydrological balance calculation and the basic statistical methods of time series processing.

For catchments of small rivers the values of the main components of the water balance were determined and their correlation were investigated. The precipitation is characterized by fluctuations and do not have significant changes to increase or decrease. Long-term average amount of precipitation ranges from 1049 mm to 1271 mm and layer of runoff – from 731 to 797 mm at different gauges. Long-term average evaporation is 312-498 mm and characterized by increasing tendency. The average annual air temperature increased by about 1.7 °C for almost 60 years. So, we found out that despite the fact that the precipitation is stable, there is a decreasing of the layer of runoff and runoff coefficient. The reason for this is to increase the humidity deficit and evaporation (although wind speed is decreasing) due to increase air temperature. The correlation between water runoff and precipitation is close (0.8), evaporation and air temperature – medium (0.5) and evaporation and precipitation – not very close (0.1).

The influence of the forest on the runoff was also considered. It has been found that the study basins have different afforestation: from 12% (Pylypets River – Podobovets village) to 93,3% (Lopushna River – Lopushne (verhn.) village). However, the results of the study are the same for all 6 small basins, i.e. the tendency of runoff is not significantly dependent on the degree of afforestation of the catchment.

Key words: water balance, small catchments, evaporation, runoff
The role of stony soils in hillslope and catchment runoff formation

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Abstract

Soils containing rock fragments, generally termed as stony soils, are commonly found in hilly and forest regions of the world. Water flow along the stony soil profile is difficult to calculate or measure due to heterogeneity of rock fragments distribution and quantity. Correct estimation of hydraulic characteristics (i.e. hydraulic conductivity and soil water content) is essential to evaluate the water flow (hydrological response) in these stony soils. We have studied the response of stony soils on rainfall events with different intensities from the point of view of hillslope runoff formation and possible links with catchment runoff response. Three research plots were used where soil moisture was measured at several depths, with known stoniness, located in the Jalovecký creek catchment (the Western Tatra Mountains, Slovakia).

The work was composed of two sequential parts. First, soil hydraulic parameters, namely the saturated hydraulic conductivity ($K_s$) and parameters of van Genuchten soil water retention functions $\theta_s$, $\theta_r$, $\alpha$, $n$ were obtained by inverse modelling with the Hydrus-1D single porosity model simulating water flow in soils with and without rock fragments. Parameters for nine rainfall events with small intensities (<2.5 mm/10 min) and six rainfall events with large intensities (>3.5 mm/10 min) were evaluated separately.

Inverse modelling indicated that mean saturated soil water content ($\theta_s$) and $K_s$, which were found as the most sensitive model parameters, decreased with increasing rock fragments content for both small and large rainfall events at the open area experimental site. Similar response was seen only for $K_s$ at other two experimental sites which are located in the forest.

In the second part of the work the hydraulic parameters obtained by inverse modelling were used as input parameters in the Hydrus-2D model to simulate the hillslope discharge. Also, the soil parameters estimated on the base of the REV concept, i.e. corrected for measured stoniness, were used as well. Modelled hillslope responses for rainfall events were compared with the measured catchment runoff response.

Key words: Stony soil, Soil water content, Hydraulic conductivity, Numerical simulations.
How far does interflow travel down slope: a comparison study across seventeen hillslopes

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Abstract

Hillslopes and headwater catchments exert critical controls on the quality and quantity of downstream waters. To understand and model dominant hillslope and headwater processes we need to estimate the relative importance of different runoff generation mechanisms that result from landscape characteristics such as pedology, lithology, topography, climate, and floral and faunal influences. However, our current observational techniques and protocols for quantifying hillslope processes are limited in the sense that they observe system states (e.g. piezometric and soil moisture levels) rather than fluxes, flow directions, or the processes themselves. This limits our ability to identify the key processes. In this work we analyze published data from studies of seventeen different hillslopes from a range of landscapes to better understand the relative role of interflow, i.e. shallow lateral subsurface flow moving over a layer impeding percolation, in streamflow generation. For each slope, we calculated downslope interflow travel distances, i.e. the potential distance a water parcel can travel down slope in a perched groundwater body above an impeding layer until it percolates through the impeding layer. We interpret this a measure of hydrological connectivity in the landscape. The downslope travel distances from the seventeen hillslopes ranged from around one meter to over 1000 meters. Fourteen of the seventeen landscapes produced downslope travel distances of less than 50 m, eleven produced travel distances less than 26 m, and ten produced travel distances of 16 m or less. The vector analysis of downslope travel distances also revealed that these travel distances are commonly much shorter than hillslope lengths with the exception of three landscapes. For the remaining fourteen cases we show that most water perched above a shallow impeding layer percolates through the impeding layer before it can reach the valley or the stream channel. Thus, interflow usually contributes directly to valley water or streamflow only from the lower portions of the hillslope in most landscapes. A critical finding of our analysis is that a continuously perched saturated zone with downslope flow does not imply continuous connectivity to the stream. Such a continuous connectivity is the exception rather than the rule in most landscapes. Future hillslope and headwater processes and modeling studies will need to account for this.

Key words: Interflow, Subsurface stormflow, Hillslope hydrology, Connectivity, Comparative Hydrology
Influence of karst tributaries and their seasonal variability on the water quality of the Altmühl River in South Franconia (Germany)

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Abstract

The Altmühl River with a catchment of 3258 Km² and a length of 220 Km, located in Bavaria region is a northern tributary stream of the Danube River. The river acquires its nutrient load from the drains of several sewage treatment plants and from agriculturally used catchment area situated in the Northern part of the South Franconian Alb. Within the karstic area the river shows a low incline caused by landscape and river development during Tertiary and Quaternary times. Additionally the regulation of the Altmühl by water mills and weirs caused a further reduction of the stream velocity being one of the slowest rivers in southern Germany.

Official water quality maps of the Bavarian Water Management designate the Altmühl River as moderate to critical polluted for organic matter and polytroph concerning nutrient pollution. Especially during spring and summer months a dramatic increase of water temperature is produced by the intense solar radiation, which causes often the process of eutrophication. A different supply of water and chemical load to the Altmühl River with a possible water purification is observed at several karst springs and minor tributaries from the deep and the shallow karst region. The influence of the springs on the water quality of the Altmühl is depending on its catchment characteristics and their different rainfall-discharge behaviour.

Scope of the hydrological study was to evaluate the influence of the karstic input to the water quality of the Altmühl River in an area of 416.3 km² (river length: 46.2 km) under different climatic and hydrological conditions and to show how is the behaviour of the Altmühl within two scenarios, with flood-water on the one hand and in base-flow conditions on the other. Main focus was whether the karst of the South Franconian Alb exhibits an ability to improve the water quality of the Altmühl River, and if yes, at which time the influence of the deep and the shallow karst is most effective and at which time the agriculture use and/or the sewage treatment plants have more influence on the water quality of the river. The DWA - Water Quality Model used in the Bavarian Environment Agency was applied. Along the forty kilometre range discharge measurements, sampling of water referring to physical parameter (e.g. temperature, pH, conductivity), chemical load (e.g. chloride, ammonium, nitrate, phosphate) and selected chemical survey of the Altmühl River itself and its karst springs and minor tributaries were accomplished.

Key words: karst spring, karst hydrology, discharge modeling, Altmühl River, South Franconia, nitrate, phosphate, DWA - Water Quality Model.
Differences in streamflow after farmland abandonment –a comparative study in four small mountain catchments

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Abstract

Vegetation expansion following farmland abandonment is a complex process that depends on multiple natural and human-induced factors, resulting in differences in the evolution of land cover on former cultivated fields, with various environmental implications. To assess the hydrogeomorphological consequences of farmland abandonment we monitored three small headwater catchments in northern Spain, representative of different post land abandonment scenarios: natural revegetation (Arnás), afforestation (Araguás, afforestation) and abandoned terraced fields (Munilla), and one small catchment, representing an undisturbed forested environment (San Salvador). This study analyses the streamflow response of the three abandoned scenarios and compares them to that of the natural forested area.

Both the revegetated and afforested catchments were able to generate runoff over the entire year, with the highest floods recorded in winter and spring and a lower response during dry summer conditions. In the natural forest and the terraced catchments, the high flood period was concentrated in late winter and spring, with little or no response during summer and autumn. As a result, the revegetated and afforested catchments recorded more than twice the number of floods per year than the other two catchments. The streamflow responses of the catchments differed significantly, showing the influence of not only vegetation cover but of the properties of soil remaining after previous agricultural activities. In the revegetated and afforested catchments peakflows were always greater, response times faster and recession limbs shorter. Interestingly, the response under afforested trees differed greatly from that of a catchment covered by natural forest, with the latter characterized by gentler hydrographs. The hydrological response in the catchment dominated by abandoned terraces was the lowest, with long response times and recessions, associated with the thick soils of the terraced fields. Stormflow was unusually greater in the revegetated and afforested catchments; however, under very wet conditions, stormflow in the natural forest area could be large and similar to that of the revegetated and afforested catchments. The terraced catchment showed always low to moderate stormflows.

Differences in vegetation cover but also soil properties may explain the differences in the hydrographs characteristics, suggesting contrasting dominant runoff generation processes in each catchment. These results demonstrated the large variability of post land abandonment scenarios and associated hydrological implications, and highlighted the need to consider these differences to reduce future uncertainties in forecasting water resources and soil conservation.

Key words: farmland abandonment scenarios; streamflow; headwater catchment; Mediterranean mountain
Spatio Temporal Soil Moisture Dynamics Under Different Soil Cover Conditions
In A Semiarid Representative Basin In Brazil

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Abstract

Long term hydrological studies in small basins are essential for investigating the role of distinct water cycle components on water resources conservation, and to assess the impact of the natural ecosystems on improving water security, especially in semiarid environments. In Brazil, the cooperative hydrological Network REHISA (“Rede de Hidrologia do Semiárido”) comprises hydrologists from several universities of Brazil, focusing on field measurements, monitoring and modeling activities in well instrumented experimental rural catchments located at different regions and biomes. Water scarcity is common aspect among the catchments, as well as risks of soil and water degradation. The objective of this work is to present long term assessments of near surface soil moisture spatio-temporal distribution, spatial distribution of carbon stocks in soil, and to evaluate the impact of soil conservation techniques in reducing runoff and sediment losses, using small scale runoff plots in a representative catchment of the Pernambuco State, Brazil. The study catchment is located in Alto Ipanema River Basin (AIRB) (with an area of 150 km2), which is located at the semiarid region of the São Francisco River (area of 641,000 km2). Soil and water monitoring was performed in experimental plots with different soil cover conditions (Bare Soil Plots; Plots with Natural Cover – Caatinga Biome Vegetation; Plots with mulch cover – Coconut straw at 4 t ha-1), where CS616 Campbell Scientific probes were installed for high resolution soil moisture assessment. In addition, Regular soil moisture monitoring campaigns were conducted at 32 different locations, using a capacitance probe (Diviner – 2000®), with arboreal and shrub Caatinga vegetation and pasture, predominantly Brachiaria decumbens. Calibration functions were developed and updated. Temporal stability was evaluated through the mean relative difference technique. Points located at the middle of a slope under pasture and bushes were the most stable, properly representing the catchment mean distribution of soil moisture. Mulch cover runs close to the Caatinga natural vegetation cover, but still with higher runoff and sediment losses, and presenting lower soil moisture temporal mean value. The Caatinga deciduous vegetation was highly effective in terms of soil and water conservation at the small basin both for the dry and the wet season, resulting in a positive Nexus between vegetation and water availability at the region.

Key words: Semiarid; Caatinga Biome; soil and water conservation; mulch; REHISA
Eight year monitoring of surface runoff and sediment delivery from 14 small watersheds under soil conservation – what can we learn from the Scheyern data-set?

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Abstract

The effects of soil conservation on arable land on surface runoff and associated matter fluxes is traditionally analysed based on plot experiments which allow to compare individual arable management treatments. The major advantage of plot experiments is that these can be replicated and statistically evaluated. However, plot experiments ignore the complexity of landscapes and cannot address hydrological and sedimentological connectivity, which is essential if more holistic soil and water conservation measures, including features such as grass filters, small retention ponds etc., should be evaluated. The aims of this study are (i) to analyse 8 years of surface runoff and sediment delivery from 14 small watersheds under soil conservation, including an analysis of magnitude and frequency of events and importance of extremes, to (ii) analyse and discuss uncertainties in long-term and event data, and to (iii) discuss lessons learned from this long-term monitoring exercise. In general, the long-term data show that the effect of in-field soil conservation and linear and point conservation features along the thalwegs cannot be simply summed, as the effectivity of linear and point measures increased with decreasing water and sediment influx. The data underline the importance of extreme events for long-term mean surface runoff and sediment delivery. The dominance of single surface runoff events significantly increased with decreasing long-term mean runoff. Interestingly, this relation between extremes and mean was less clear for sediment delivery. Here, specific field/soil conditions seemed to be more important. The data also underline the requirements of long-term measurements if mean surface runoff and sediment delivery should be determined. Due to the event nature of the observed processes the 8 yr annual means still show relative 95-% confidence intervals of up to ±200% for both surface runoff and sediment delivery. Overall, it is a huge investment in time and resources to produce continuous long-term data from multiple small watersheds, but this substantially improves our knowledge of processes which cannot be measured on the plot scale and are averaged out in larger watersheds. Therefore, such data are especially important for model development and testing. However, it is important to note, especially if data should be used for modelling, that such monitoring at the outlets of the small watersheds must include a detailed (daily) monitoring of agricultural management. The importance of the latter is best illustrated by the largest individual erosion event measured in all watersheds within the entire 8 years, which occurred in case of a moderate convective rainfall reaching a watershed few days after potato harvest on the draining field.

Keywords: long-term monitoring, surface runoff, sediment delivery, uncertainties
How to generate input for small-scale modeling - Example of soil erosion

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Abstract

Soil erosion through precipitation and surface runoff from agricultural areas is a main cause of soil degradation in Europe. Modeling approaches are needed to estimate the magnitude of erosion processes and evaluate appropriate protection measures. In physically-based approaches, used for small scales, a general difference exists between continuous and event-based modeling. While the latter is driven by high spatial and temporal resolution and an emphasis on good estimation of initial conditions, the main challenge for continuous models is the parametrization of the enormous amount of input data.

At the Chair of Engineering Hydrology and Water Management (ihwb) of Technische Universität Darmstadt (Germany) a systematical analysis was conducted with the example of the Water Erosion Prediction Project (WEPP) model. Eight years of measurement of discharge and sediment yield from several small watersheds in the German low mountain range area (Fiener and Auerswald 2007) were analyzed and compared with calibrated and uncalibrated modeling results in WEPP. Overparametrization proved to be more severe than in other hydrological tasks. On one hand this is a consequence of the much bigger amount of input data, including more detailed representation of land use, hydraulic input for routing of surface runoff and additional soil parameters for the erosion module. Yet on the other hand calibration events for sediment yield and even runoff are rarely available, because of the very small catchment scales. Therefore a calibration – validation approach is often not applicable.

Without calibration yearly average was modeled accurately, yet the modeled and measured hydrograph and sedigraph fit poorly. Due to the combination of several modules (climate, land cover, hydrology, hydraulics, erosion) model structure and interactions of modules is extremely complex, which can lead to unexpected outcome. Uncertainty analysis showed that all parameter groups influenced the modeled discharge and sediment yield drastically. An emphasis was given on input parameters that would not be the subject of calibration in classic hydrological modeling i.e. the generation of climate input and the representation of topography. None the less these input parameters proved very important for the quality of results. Hence, measurement uncertainty has to be accounted for. Unfortunate estimation or generation of input can result in misleading modeling results even though still appearing reasonable. Additionally, high resolution input did not necessarily produce better outcome – again due to the complex model structure. Using broad bands of possible input within reasonable uncertainty proved to give the most reliable results for uncalibrated models.

Key words: soil erosion, parametrization, uncertainty analysis, physically-based model
Erosion mitigation investigations and knowledge transfer from the small catchment Schäferbach to other regions of the Harz Mountains in the project “BebeR”

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Abstract
The effects of climate change are being investigated intensively. Changes in the erosion characteristics of soils in the future are very probable and will have economic, social and ecological consequences. Soil erosion and its consequences play a major role in the foothills of the Harz Mountains (Middle Germany). Currently, measures to reduce erosion related to the actual knowledge have already been published in advisory guides. Nevertheless, in connection to the German National Adaptation Strategy for Climate Change (DAS) the effects of climate change projections on the erosion characteristics needs to be available to be able to find mitigation strategies especially in mountainous regions. This is the aim of the BebeR project “Mitigation of soil erosion in mountainous regions at the example of the district Mansfeld-Südharz (Saxony-Anhalt)” which is funded by the German Ministry of Environment (BMUB). The project will demonstrate a planning and assessment process to implement measures of soil erosion reduction in rural mountainous areas by involvement of different groups of actors (communities, population, agriculture, nature conservation). The Schäferbach catchment, which is affected by extensive erosion, is a good example to develop and demonstrate model tools for projecting effects of mitigation measures in this region. In order to estimate the erosion risk of an area, a simple tool kit was developed which can be used by planners to check different measures that could be taken. In a decision support process these knowledge is needed to discuss and to identify effective measures. This tool kit contains a two-step process with calculation of surface water runoff generated and in case of runoff an erosion calculation. The runoff calculation is done using the model SMINF (based on GREEN&AMPT) and the erosion calculation with an adapted Universal Soil Loss Equation (ABAG). The last one was integrated into a Geographic Information System (GIS) and is named ABAGis. Both models can be transferred and applied from the Schäferbach to other mountainous catchments. The results show threshold values for erosive precipitation and the sensitivity of the area to land use changes and soil tillage. For the district of Mansfeld-Südharz, an interactive web based map system was developed and will be implemented during the project duration. From that, the data needed to use SMINF and ABAGis as well as erosion and vulnerability maps will be available for planners. The project is carried out by a cooperation between the Universities of Applied Sciences in Wernigerode and in Magdeburg.

Key words: soil erosion, modelling, vulnerability maps
Measuring and modeling of snow cover in subalpine regions of the Bavarian Alps – The Dreisäulerbach catchment

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Abstract

The forecast quality of hydrological simulations for the snow ablation period in subalpine regions relies heavily on the accuracy of the underlying modeling methods for snow-hydrological processes. The changing topography, exposition and vegetation cover of subalpine regions result in a strong heterogeneity of characteristic values of the snow cover, i.e. the snow height and the snow water equivalent. A special characteristic of subalpine regions is the multiple occurrence of snow accumulation and snow ablation periods within one winter season. Altogether, the correct modeling of the snow cover development in subalpine regions poses a serious challenge for hydrological simulations.

Nowadays it is widely accepted that newly developed hydrological modeling methods can and should be verified by using experimental setups. According to this methodology the Chair of Hydrology and River Basin Management of the Technical University of Munich sustains the experimental Dreisäulerbach catchment in the Ammergauer Alps in order to monitor snow parameters and their influencing factors in subalpine regions. On the one hand high resolution meteorological data, recorded in this catchment, is used as input drivers for ensuing spatially distributed, hydrological simulations, carried out with WaSiM. On the other hand the evolution of the snow cover in time and its spatial distribution, with a special focus on different types of landuse, is being monitored by a variety of instruments. A newly developed snow lysimeter provides exact values of snow melting and accumulation processes. The collected measurement data is used in order to verify more sophisticated modeling methods applying the energy balance method for snow cover simulation.

The introduction of the energy balance method poses a significant improvement for the simulation of snow ablation processes in spatially distributed, hydrological models like WaSiM. Nevertheless, there is still room for improvement like considering the effect of interception processes caused by canopies on the radiation balance of the snow cover.

Within the scope of this presentation we want to show comparisons between observations from and simulations of the experimental catchment and depict the impact of the enhanced modeling methods for the energy balance of the snow cover on the simulation quality.

Key words: snow hydrology, snow cover measurement, experimental catchment, snow cover modeling, canopy effects, canopy radiation balance
Influence of seasonal variability of soil hydraulic properties in soil water content modelling

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Abstract

Soil moisture plays a key role in the hydrological cycle as it controls the flux of water between soil, vegetation, and atmosphere. This study is focused on a year-round estimation of soil moisture in a forested mountain area using the bucket-model approach. For this purpose two soil moisture models are utilised. The procedure is based on splitting the whole year into several complement periods. Model parameters are allowed to vary between these periods and also from year to year in the calibration procedure. Consequently, average course of model parameters respecting their seasonal changes is proposed.

The process of splitting is strongly supported by the experimental data and it enables us to vary saturated hydraulic conductivity and pore-size characterisation. First, the use of the two different parameter sets (representing dormant and vegetation season) significantly enhances the simulation of two utilized models (Teuling and Troch model and Soil Water Balance Model-Green–Ampt (SWBM-GA)) in the six-year period from 2009 to 2014. For these two models, the overall Nash-Sutcliffe coefficient increased from 0.64 to 0.79 and from 0.55 to 0.80, respectively. Further enhancement of the model efficiency was achieved by allowing the variances between particular vegetation seasons as the variability of the parameter sets between particular years was more pronounced in the vegetation seasons. The soil hydraulic parameters in the cold periods exhibited approximately similar values during all inspected years.

Acknowledgements: The research was supported by the Czech Science Foundation (GA CR 16-05665S).

Key words: Soil moisture, seasonal variability, soil hydraulic parameters, saturated hydraulic conductivity, pore-size distribution, hydrological modelling
Modelling complex flow patterns in an area with abandoned coal mines in the Netherlands

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Abstract
In the south part of the Netherlands, Upper-Carboniferous coal was mined for decades in deep mine systems. A dry working environment was required, therefore large quantities of water were pumped from the system. After closure of the mines in 1974, the pumps were shut down, causing a water level rise up to 600 m in the mines. The overlying aquifers react slowly, with an expected new hydrostatic equilibrium around the year 2060. Given the land subsidence, caused by the former mining activity, the new groundwater levels will come closer to surface level. The question is now whether these higher water levels will cause water problems at a regional or sub-regional scale.

The regional groundwater model IBRAHYM, based on the MODFLOW modelling concept, was extended in order to be able to include the mine water levels. Also all the significant faults in the study area were implemented in IBRAHYM. Steady state modelling revealed that a significant part of the modelled area will face groundwater levels within 2 m from surface level. Part of that area is urbanized over the last decades. Therefore it is possible or even likely (given the modelling uncertainties) that these urbanized areas will face water problems in future, unless additional drainage is installed in the most vulnerable areas.

Key words: regional modelling, groundwater level rise, MODFLOW
Groundwater controls nitrate pollution in an agricultural catchment

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Abstract

The Kocinka catchment (surface area ca. 250 km², length 40 km) in Southern Poland was the subject of an interdisciplinary study aimed at the identification and characterization of sources, pathways and fate of nitrate pollution and at forecasting nitrate levels in groundwater and surface water under various climatic and socio-economic scenarios. Application of a suite of environmental tracers contributed to the understanding of nitrate pollution origin, groundwater flow structure and of the extent of groundwater – surface water interactions. Computer models were applied to evaluate nitrate leaching from soils (NLES4) and to simulate groundwater flow and nitrate transport to the surface catchment (MODFLOW, MT3D). At the whole catchment scale agriculture is the dominant source of nitrate pollution. Nitrate levels in the Kocinka and its tributaries are controlled by groundwater discharging through springs and river beds from the large underlying karstic-fissured aquifer. The nitrate removal potential is very limited in both the subsurface and surface environments, therefore the abatement of this pollution relies on the reduction of nitrogen leaching from soils. Additionally, groundwater nitrate transport is associated with large lag times (45 years on the average), which has consequences for effectiveness of measures undertaken to reduce nitrate loads from the catchment. Results of the presented study provide an example of the integrated approach to assessment and monitoring of pollution in groundwater dominated catchments.

Key words: groundwater, nitrate, modelling, tracers
Predicting stream flow, flow components, nitrate losses and crop yields in a small artificially drained catchment employing the SWAT model

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Abstract

We have been investigating hydrological and solute, mainly nitrate, transport processes at different spatial scales for more than 15 years at the experimental field site in Dummerstorf, northeastern Germany. In recent years, we used the comprehensive data set of the 180 ha agricultural used tile-drained catchment as a basis for simulation studies. The widely applied eco-hydrological semi-distributed model Soil and Water Assessment Tool (SWAT) was employed to predict hydrology including flow components, nitrate losses and crop yields. Tile flow was modelled using the DRAINMOD approach. The performance of SWAT to predict stream flow and flow components for small catchments was tested by comparing the Green and Ampt and curve number infiltration methods. In addition, measured precipitation data at a resolution of 0.1 mm were taken to investigate the influence of different precipitation time steps (5-, 15-, 30-, and 60-minutes) as SWAT model input. Results indicated reasonable model performance for both the curve number and the Green and Ampt infiltration methods at a monthly time scale. Discharge was mainly divided into tile flow and groundwater flow under both infiltration models. The only important difference with respect to flow components was related to surface runoff with negligible surface runoff using the Green and Ampt method and about 5% surface runoff using the curve number method. When using different precipitation time steps, model outputs were almost identical, showing that simulations responded nearly independently of the chosen precipitation time step. However, a scenario analysis revealed that the precipitation time step becomes important when saturated hydraulic conductivities are low. We conclude that there is no need in using precipitation time steps < 1 h for lowland catchments dominated by soils with low surface runoff. In addition to stream flow, nitrate losses and crop yields were simulated. Overall, the study results provide a good basis for scenario analyses such as nutrient mitigation strategies or climate change analyses.

Keywords: Soil and Water Assessment Tool, catchment modeling, tile drainage flow, artificial drainage
Streamflow and suspended sediment hourly simulation using SWAT: strengths and weaknesses in a small forested catchment

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Abstract

One of the handicaps in small catchments is the need for sub-daily time step hydrological modelling in order to properly simulate quick hydrological response at such small spatial scale. This paper aims to evaluate the sub-daily simulation results in a small forested catchment in a continuous modelling approach and to assess the simulation performance for different types of storm events. To that purpose hourly simulation of discharge and suspended sediment concentration was carried out using SWAT2012 in the small headwater Aixola catchment (central part of the Basque Country, Bay of Biscay).

Aixola River drains a 4.6 Km² headwater catchment in the Aixola water reservoir. The main bedrock in the basin is Upper Cretaceous Calcareous Flysch with alternating marl and sandy limestone layers, considered as impervious material for practical purposes, however, there are deep loamy soils in the catchment (between 1 m to 13 m) that show an important water regulation function. In the gauging station, located at the outlet of the catchment, precipitation, air temperature, streamflow and turbidity are measured every 10 minutes. Turbidity is used to estimate continuous suspended sediment flux (Zabaleta et al., 2007). Since 2011 electrical conductivity of water is measured every 20 minutes and its value is used to separate baseflow from surface runoff (Meaurio et al., 2015).

Continuous hourly streamflow (m³ s⁻¹) and sediment load (kg) obtained from data measured at the gauging station were used to calibrate (from 2010 to 2014) and validate (from 2005 to 2009) the SWAT. After an automatic sensitivity analysis of model parameters and a manual calibration step, a reasonable data range for each parameter was obtained and finally calibrated using the SUFI2 algorithm included in SWAT CUP. Subsequently, results were evaluated for the validation period. While satisfactory simulations were obtained for discharge, the total exported sediment load was well simulated but the peaks were underestimated.

Once the results for the 5-year period of validation were evaluated, results for single storm events were assessed. Ten storm events with different characteristics of precipitation, antecedent conditions, discharge and suspended sediment concentration were selected for the evaluation. Results show different performance of the model depending on the surface runoff/baseflow ratio and the antecedent conditions. It was possible to conclude that when baseflow was the most significant component of streamflow, related to wetter antecedent conditions of the catchment, discharge and sediment simulation results were better.

Key words: Basque Country, hourly long-term modelling, event-based evaluation, antecedent conditions, streamflow and sediments.
References:


Modeling approaches for floods in different spatio-temporal scales – Do smaller catchments need smarter models?

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Abstract

Over the past decade, the focus of flood risk assessment and management has been on floods along the major rivers. The methods and modelling approaches to identify the potential floodplains along the large river basins are getting gradually standardized. As part of the second round of the European Flood Risk Assessment (EU Floods Directive), the picture of the procedure for identifying flooded areas and the subsequent risk management has become clearer. Due to some hazardous events in small river basins and flooded urban areas by heavy convective rainfall events, interest also increases for the consideration of flood risk and management in small catchment areas. The awareness of floods in small (about 10 - 200 km²) and urban catchment areas is getting greater. This is also reflected in the establishment of the European Flood Protection System (EFAS) and the development of national early warning systems for flash floods. But in addition to the development of early warning systems, the (small catchments') flood risks and risk management has to be better understood and communicated to the local authorities. Apart of the short warning times, the interaction between high (convective) precipitation, surface flow and channel flow in small watersheds is much faster than in the slow-responding large river basins. The flooding is not only caused by rivers passing over their banks (fluvial flooding), but also by flooded surface area (pluvial flooding) and reached sewer capacity (urban flooding). This presentation deals with the topic, to what extent the different flood characteristics in small catchments make an adaptation of hydrological and hydrodynamic model approaches necessary. In addition to a short theoretical classification of modelling techniques, applications and results of various hydrological (HEC-HMS, OpenLISEM) and hydraulic models (HEC-RAS, FloodArea) in a typical central German low mountain range are going to be shown. The aim of these different model applications is to show that hydrological-hydraulic processes are strongly linked, especially in small catchment areas. The project area, the "Fischbach"-catchment area (about 37 km²), has recently been well monitored through our Department monitoring campaign and there are long-term observation time series of the Hessian Agency for Nature Conservation, Environment and Geology (HLNUG) and German Weather Service (DWD) available. In this presentation different hydrological and hydraulic modelling approaches are shown.

Key words: small catchments, floods, hydrological-hydrodynamic models
The hysteresis patterns of phosphates and potassium concentration as the indicator of flowpaths during high flow events (Carpathian Foothills, Poland)

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Abstract

The phosphorus and potassium are ones of the most important biogenic compounds and their presence in stream water during high flow events is strictly controlled by the processes of flushing out with overland and throughflow.

The research of phosphates and potassium changes in stream water during high flow events were conducted in the four catchments (0.29 - 22.24 km²) of different land use: woodland, agricultural, and mixed-use. All these catchments are located in the Carpathian Foothills in southern Poland. The elevation of the area ranges from 217 to 362 m a.s.l. The purpose of the study was to determine the role of land use, seasonality, and hydrometeorological conditions on the relationship between stream water potassium and phosphates concentration vs discharge during different types of floods—short- and long-duration rainfall floods as well as snowmelt floods on frozen and thawed soils.

The research has shown that the direction of hysteresis loops depends on water circulation patterns, which are determined by the different influx times of particular runoff components (overland flow, throughflow). The stream recharge mechanism during a flood event is affected both by the factor initiating the event (precipitation, snowmelt) as well as by land use in the given catchment. Anticlockwise hysteresis concentration–discharge relationship was identified in the forested catchment during short and long rainfall floods. Under the same conditions, the clockwise direction was observed in the agricultural catchment. In the mixed-use catchment, the direction of hysteresis loops was various, driven by the share of water flowing from each part of the catchment.

Key words: phosphate, potassium, hysteresis loop, flow paths
Precipitation-runoff modeling and simulation of current climate projections in the catchment area of the Schäferbach/Harz Mountains

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Abstract

The Bode catchment area is an important area for fresh water supply, energy supply, tourism and flood protection in the Harz Mountains in central Germany. A part of this region is the small catchment area of the Schäferbach, which is investigated as a hydrological study area since the year 1968. As part of a study about scale-related effects of climate change in the Bode catchment, a water balance model was created for the catchment area of the Schäferbach. With a total area of 1,44 km², this catchment characterizes the smallest scale level in the study, which pursues the goal of determining to what extent extreme runoff events in catchments of different scales can be expected in course of the predicted climate change. Based on a daily simulation time step, the study made use of a well-established approach. A model ensemble of four RCP8.5 scenarios was used to simulate the future development of 20-year return period flood peaks and to examine the future influence of snowmelt on winter floods in the catchment area. The results show up to the year 2100 an increasing frequency of winter floods in early parts of a year, while the 20-year return period flood peaks significantly decreases. The cause analysis shows that the results are caused by a reduction of snowfall and snowmelt due to temperature increases accompanied by the simultaneous increase of the precipitation amount in the winter half-year. In the summer half-year an opposite behaviour was found. The results point to a future increase in HQ20 peaks as a result of increasing heavy precipitation events in the summer months. Overall, it was determined that changes in both, precipitation and temperatures, will have a strong influence on the hydrological behaviour of the small catchment area of the Schäferbach in the future.

Key words: climate change, extreme floods, winter floods, snow melt, small catchments
Increasing drought stress caused by climate change and forest growth at Lange Bramke, Harz Mountains, Germany

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Abstract

Effects of climate change and forest development on the hydrological regime and drought stress were analyzed for the catchment of Lange Bramke, Harz Mountains, Germany. Forest stands at Lange Bramke were clear-cut in 1948 and the complete catchment was reforested thereafter. Hydrological observations at Lange Bramke started immediately after the clear cut resulting in a 70 year-long time series. Water budget components and drought stress indicators were simulated using the hydrological model WaSiM-ETH, which was linked to a statistical forest growth model. Climate projections based on the climate scenario RCP8.5 served for the analysis of possible climate change effects on the discharge regime and on the drought stress risk of the Norway spruce stands within the catchment. Observed runoff relative to observed precipitation decreased within the first four decades after reforestation, while evapotranspiration increased due to the increasing water demand of the growing forest stands. Climate scenarios project a rising temperature and corresponding prolongation of the growing season until the year 2070, which will probably increase the evaporative demand of the atmosphere and the water consumption of the forest stands. As a consequence, soil water availability will decrease and drought stress risk for the trees will increase. Under the climate change scenario RCP8.5 the future vulnerability of Norway spruce, which is rated as drought sensitive, will increase and the suitability of the site conditions for Norway spruce cultivation will become questionable.

Key words: hydrological regime, drought stress, climate change, Lange Bramke
A modelling approach for future water management in a lowland area under special consideration of large-scale subsidences

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Abstract

The Miele catchment is located in the north-western part of Germany, draining an area of approximately 400 km² into the North Sea. Water levels in the catchment are maintained below sea level. This is only possible because of the tide. A tide gate closes during high tide and opens during low tide.

The catchment is subject to several transformations, which will make future water management more difficult than today:

- Sea level rise will substantially shorten the time slot for drainage of the area to the North Sea during low tide via the tide gate.
- Precipitation in the catchment will increase due to climate change, especially in winter time, which is the main flooding season.
- Two large moor areas are located in the catchment. These areas consolidate and subside due to intensive drainage in the past. The settlement rate is up to several cm per year. In the future, those areas will be located so low, that natural drainage is hardly possible. This means that inundations will last for many days per year, which has strong implications on future land use.

A hydrodynamic model was built to calculate the effects of the given transformations and to investigate, how several measures could reduce flood hazard in the future to the present level.

The following steps were carried out:

- Calibration of the hydrodynamic model for the present state
- Development of a method to estimate future subsidence and its consideration in the model
- Simulation of floods for future conditions
- Calculation of future flood levels for each of the given transformations
- Investigation of measures to reduce flood hazard

The main result of the study was, that the large-scale subsidences in the area influence future flood hazard much stronger than the effect of sea level rise or increasing precipitation induced by climate change.

Currently, the results are intensively discussed by the stakeholders to develop a sustainable water and land use management concept for the future.

Key words: Hydrodynamic modelling, lowlands, moor, subsidence, climate change
POSTER PRESENTATIONS
Small hydrological research basins in Germany

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Abstract

Small research basins are hotspots of hydrological research. They are extensively equipped to measure different hydrological parameters with high temporal and spatial resolution. The resulting data are the basis for the identification of regional basin characteristics and hydrological processes, statistical analyses, model development and parameter identification. Altogether these comprehensive research activities address a wide range of objectives and goals, such as analyses of initial landscape genesis, water and nutrient balance, or current climate projections on runoff patterns.

The German IHP/HWRP working group "FRIEND/ERB" supports such research activities in small hydrological basins in Germany and contributes to UNESCO's International Hydrological Program (IHP) as well as the Hydrology and Water Resources Program (HWRP) of WMO. Its focus is on catchments smaller than 50 km² with continuous data acquisition of time series longer than 5 years. They are operated by universities, environmental authorities and other research institutions.

This presentation illuminates the German research in selected small hydrological research basins ranging in size from 0.06 km² to 50 km². It summarizes the objectives, measured variables and chosen methodical aspects. Continuous measurements at the respective gauges will in future be more and more supplemented by spatially and temporally higher resolution measurement campaigns. The advancement of sensor and IT technologies promotes a continuous increase in data volumes, allowing for more precise and specific analyses and predictions as well as the possibility of a better understanding of the prevailing hydrological processes including their spatio-temporal variability. But often this requires the development of new evaluation methods. The use of models supports these goals. Scenarios allow the evaluation of different land use and management strategies and of possible impacts caused by climate change.

The evaluation of the German IHP/HWRP working group "FRIEND/ERB" emphasises an increasing need for high resolution measurements and long time series as well as regular updates of all research activities in small hydrological basins. Only their continuation will also in future provide valuable contributions to research, teaching and the management of environmental problems. Their integration into a research network increases the efficiency of the activities and provides opportunities for joint evaluations.

Key words: small basins, need, research activities, Germany
50-years of hydrological research in the pre-alpine Alptal catchment

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Abstract

The Alptal research catchments are located approximately 40 km southeast from Zürich in the Swiss pre-alpine region. The area has a temperate climate and is characterised by frequent precipitation events and a mean annual precipitation of 2300 mm y⁻¹, of which half falls during the snow-free season (June-October). The catchments are steep; the elevation of the catchments ranges from 1000 to 1656 m a.s.l.. The geology is dominated by Tertiary Flysch and the soils are low permeability gleysols, resulting in a water table close to the soil surface for most of the year. Streams respond quickly to precipitation (i.e. within minutes to an hour) but generally return to baseflow conditions within 1-2 days.

Research in the Alptal began in 1963 and focused on the effects of forestry on streamflow and water quality. The Alptal area was selected as a research catchment because many areas in Switzerland that are underlain by Flysch were reforested after the 1900s because logging and degradation of the forests were considered to be partially responsible for the large floods in 1834, 1839, 1860 and 1868. Initially, streamflow was measured in eleven sub-catchments but after a destructive flood in June 1974, continuous streamflow and climate measurements focused on three of them: Vogelbach, Lümpenenbach and Erlenbach. The Erlenbach catchment is well known for its infrastructure to measure sediment transport, is part of the National River Monitoring and Survey program (NADUF), and investigations on the influence of acid rain on forests and runoff. More recently the Erlenbach measurement station has been developed into a modern and comprehensive field laboratory with high frequency stream water quality and isotope measurements, yielding unprecedented high frequency data to unravel stream water sources. The influence of snowmelt on streamflow is studied with snowmelt lysimeters at different locations in forested and open sites. Several other studies have focused on runoff generation, investigated streamflow sources during baseflow and stormflow, the expansion and contraction of the flowing stream network and the spatial variation in groundwater levels and groundwater chemistry. In 2018, 50-years of hydrological research in the Alptal is celebrated with an international scientific workshop to discuss past and future work in the Alptal and to identify open research questions. This poster presents highlights from current and past research in this unique research catchment.

Key words: long-term research catchment, Alptal, pre-alpine, water quality, streamflow, snow hydrology, groundwater
Assessing the impact of land use on stream water quality in the German low mountain range basin Gersprenz

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Abstract

The Gersprenz basin is ca. 485 km² large and it is located in the federal state of Hesse, Germany. It is part of the river basin district Rhine. River Gersprenz originates in the low mountain range area Odenwald in the southern part of the basin and discharges into the river Main at Stockstadt / Main (topography changes from ca. 600 m asl to 100 m asl from south to north). Several larger and smaller tributary streams, e.g. Semme, Lache, Fischbach and Wembach, flow into river Gersprenz, which is ca. 62 km long. Nearly 50% of the basin is used for agriculture, incl. grassland, vineyards and orchards. Forest areas cover ca. 36% and several larger and smaller settlements (ca. 13%) are distributed in the basin. 17 wastewater treatment plants are located in the basin.

The state of Hesse monitors water level and discharge data at both Gersprenz gauges Harreshausen (since 1955) and Wersau (since 2006). For assessing water quality, there are further hydrochemical and biological measuring points operated by the state of Hesse. Additionally, periodic, random water sampling is carried out usually on a monthly basis.

Since 2016, ihwb measures relevant parameters, which complement the official data of Hesse and literature data. The measurement concept is two-parted, which contains a continuous monitoring at few selected locations and a short-term monitoring with less temporal resolution but higher spatial resolution. Continuous measurements are conducted at relevant points in the basin. Therefore, ihwb installed sensors for measuring water level, water temperature and electrical conductivity at the gauges Harreshausen, Wersau and Groß-Bieberau.

To obtain additional spatial information, a weekly measuring campaign at 12 measuring points in the tributary stream Fischbach is conducted. Here, water depth and flow velocity (since October 2016) as well as electrical conductivity (since February 2017) are measured.

In this study, the first data series are analysed to study the spatial and temporal variability in the water courses and the influence of land use in the basin. The results show that electrical conductivity is in relationship with rainfall events and streamflow. Furthermore, land use, such as agriculture, urban areas and waste water treatment plants, change water quality.

Key words: land use, field sampling, electrical conductivity
A forested (hydrological) experimental research watershed to study transport processes in the system of soil, water, plants and atmosphere:

Test site Rosalia

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Abstract

The BOKU university forest Rosalia with an area of 950 ha has been used for research and education since 1875. In 2013 – upon an initiative of a group of researchers in various disciplines – it was decided to extend the so far mainly forestry oriented activities by implementing a hydrological experimental research watershed. The overall objective is to collect data that support the study of transport processes in the system of soil, water, plants and atmosphere. More specifically, emphasis is on bridging the gap between point related measurements and effective values and parameters for watersheds.

The Rosalia Mountains (German: Rosaliengebirge) belong to the eastern foothills of the Alps on the state border between Lower Austria and Burgenland in Austria. The terrain height ranges from 320 to 725 masl, and is characterised by very steep slopes. Crystalline rocks are dominating, but coarse grain gneiss, some sericitic schist, phyllite and dolomite are also encountered. Mean annual precipitation is approximately 700-800 mm.

The main elements of the currently implemented hydrological experimental research watershed are:

1. Monitoring of hydrometeorological data in a densified network of stations: river discharge, water and air temperature, relative humidity and electrical conductivity of water are monitored at 4 gages. The locations were selected to cover nested sub-watersheds of 9, 27, 120 and 220 ha, respectively. Precipitation is measured by 5 rain gauges at different altitudes.

2. At four locations, soil profiles were installed where soil moisture and temperature are measured in four depths.

3. Water quality (nitrogen) is monitored by a spectrometer probe in one location.

All time series measurements are taken at a 10 min sampling interval, and data acquisition is based on an UHF telemetry network (Adcon).

Monitoring of time series is complemented by terrestrial surveys of soil properties during field courses of students and geophysical explorations. Topographic information is available from various DEM, including a 1 x 1m resolution LIDAR.

The operation of the sites is planned for a period of at least 10 years and uses only internal resources of the university.

Key words: hydrometry, experimental research watershed
Runoff components in a small agricultural catchment in Ukraine studied by water chemistry, stable isotopes and hydrograph separation

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Abstract

Water quality is a serious issue in many agricultural catchments of Ukraine. Rivers and water reservoirs which are the main sources of water supply in Ukraine often suffer from the deteriorated water quality, e.g. increased concentrations of nutrients, organic substances, hazard elements. Regional climatic changes resulted in a significant redistribution of the water supply components in rivers which also affected the water quality.

Understanding of runoff formation and sources of pollutants is important to develop methodologies helping to improve the water quality. For that purpose we have established a research program in the small test catchment of the Boguslavka river, situated in the forest-steppe zone of Ukraine. Catchment area is 11.0 km², about 35% of which is cultivated, 25% is covered by a forest while the rest is occupied by two settlements. The catchment is included in the national observational network and has been monitored since 1950 within the framework of the extended water balance and meteorological observations programme.

Hydrograph separations by the two parameters recursive digital filter, water chemistry and stable isotopes of oxygen and hydrogen are intended to be the main approaches to elucidate the pathways of the pollutants to the river. The manual graphic filters hydrograph separation was used to compare results.

Monthly samples of precipitation and river water have been collected in the catchment since spring 2017 and analysed for major ions (HCO₃⁻, SO₄²⁻, Cl⁻, Ca²⁺, Mg²⁺, Na⁺, K⁺), dissolved nutrients (NH₄⁺, NO₂⁻, NO₃⁻), organics as CODMn, and stable environmental isotopes of oxygen and deuterium. Environmental isotopes are considered to be typically conservative whereas water chemical components could be affected by geochemical interactions with soils.

More frequent sampling has been done during the snowmelt periods and selected rainfall-runoff events. The poster will present results from two years 2017 and 2018. The most significant changes were observed during the spring high flows. Among the studied ions only SO₄²⁻ showed a conservative behavior that allows to used it a chemical tracer. A significant positive correlation was found between the SO₄²⁻ and stable water isotopes as well as water mineralization and stable water isotopes. Temporal variability of other ions in river water points out at the interaction with the soil layer, especially in case of nutrients. Input of atmospheric precipitation shifts the equilibrium that was formed in the soil solution and stimulates the leaching of nitrogen and phosphorus compounds into the river water.

Key words: hydrograph components, water quality, tracers
Monitoring of hydrological processes in high mountain environment – the Tatra Mountains (Carpathians, Europe)

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Abstract

High mountain areas are of great environmentally and economically importance. They provide a wide range of ecosystem services. Anthropopressure as well as climate change have been influencing some high mountain regions significantly. There is a need of monitoring hydrological cycle in high mountain environment with respect of quantity and quality of surface water and groundwater. The Tatra Mountains are an example where hydrological monitoring network has developed in recent several years. The Tatra Mountains (2,655 m a.s.l.) are the highest mountain range in the Carpathian Mountains. Large part of the Tatra Mountains has been protected as national park both in Poland and Slovakia yet strong human activity (i.e. tourism, fresh water intake, sport resorts, electricity generation) influences locally hydrology of the region yet.

To recognize spatial diversity of physical and chemical composition of water three sampling series were conducted in August-September 2007, 2008, and 2009. As many as 1018 springs and 487 streams were sampled. Each of research series was lasting 3-4 days and large number of persons such as hydrologists, geographers of other specializations and students was involved. Thanks to that, all samples were taken during almost the same weather conditions in a whole region. Up to 23 streams and 5 springs were chosen for detailed monitoring and it’s worth to mention that water samples from there were collected biweekly in 2007-2009 to determine seasonal changes in physical and chemical composition of fresh water.

A project started in 2013 in the Bystra catchment has been dedicated to assess the impact of downhill ski run on the water quality and quantity. Stream (8 streams) and karst spring water (3 springs) has been sampled biweekly. Specific electrical conductivity and temperature of water, and water level in streams and springs have been measured every 10 minutes (project K/KDU/000435). There has been a new a project started in 2015 focused on the impact of deforestation by strong foehn winds and tree infested by bark beetle on water chemistry in the Kościeliski catchment (project K/KDU/000405). The research has been based on monthly sampling of stream water (7 streams) and spring water (9 springs). The water level in streams has been controlled to assess the river runoff.

Hydrological monitoring network in the Tatra Mountains is a fundamental tool to recognize hydrological conditions there and it allows to assess the impact of human activity to quantity and quality of water.

Key words: hydrological monitoring network, anthropopressure
Towards more pertinent tracers for studying hydrological processes at catchment scale: a comparative study between experimental sites in Luxembourg and Slovakia

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Abstract

Catchment hydrological functions of water collection, storage and release trigger geochemical signatures in stream water that largely mirror those found in critical zone compartments. These signatures are largely controlled by the different bio-geo-physico-chemical processes that occur within the regolith-plant interface. Although water-rock interactions within the regolith are well understood, the significance of the regolith’s mineral and geochemical compositions for hydrological processes conceptualisation remains unclear. Until now, investigations of the critical zone’s regolith and hydrological processes research have largely remained uncoupled – eventually leading to a widespread use of non-conservative tracers with multiple origins and thereby violating some of the most fundamental assumptions of classical approaches in tracer hydrology. Ultimately, this has stymied our capability for identifying water pools and flow paths.

Here we study the mixing of water in the subsurface through a unique portfolio of complementary groups of tracers (O-H stable isotopes and trace elements) which enables us to investigate regolith evolution processes and solutes transport within the critical zone. We report on the potential for a new approach – combining O-H stable isotopes with trace elements – to strengthen water end-members characterization and identify flowpaths from plot to catchment scale. We present a comparative hydro-geochemical dataset acquired in contrasted geological settings, encompassing nested stream networks located on sedimentary and magmatic bedrock geologies in Luxembourg and Slovakia, respectively.

Key words: trace elements, O-H stable isotopes, multi-variate analysis, catchment scale
Assessing phosphorus transport pathways from the field to the catchment scale

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Abstract

Phosphorus (P) losses from agricultural fields and watersheds are an important water quality issue because of the critical role P plays in eutrophication processes. The enrichment of P in the surface water tends to an increased growth rate of algae blooms and inferential consumption of oxygen. The reduction of nonpoint sources of P should therefore be a major challenge for future agriculture. A clear understanding of leaching and transport processes of P in agricultural landscapes is crucial for P-reduction strategies.

Long-term monitoring data from the State Department of Environment, Nature Conservation, and Geology Mecklenburg and Western-Pomerania and a hierarchical monitoring scheme from the pedon to the catchment scale was used to identify P fluxes in agricultural landscapes that originate from various diffuse sources. Attention was given to P losses and P dynamics with flow measurements and automatic sampling stations. The hierarchical monitoring program is amended with in-situ micro-lysimeter and dye tracer experiments on the pedon scale.

Results indicate the importance of rainfall and flow events on the release of P from agricultural fields. Long-term data showed that the dissolved reactive P followed a baseflow component whilst the total P is preferably transported by a fast flow component. A consistent increase of total P concentrations with increasing drainage areas indicates the presence of re-suspension of river bed and stream bank sediments along the river continuum. The spatial pattern of dissolved reactive P concentrations varies among years which indicates the influence of groundwater flow. The in-situ lysimeter and dye tracer experiments gave evidence for the potential transport of dissolved reactive P and total P through the soil profile following rainfall events. The experimental results revealed the importance of multiple diffuse sources to the overall P loss (tile-drainage, groundwater, sediment re-dissolution); P mitigation and management strategies should be designed accordingly.

Key words: catchment hydrology, phosphorus transport, Tile drainage, Baltic Sea
Application of infrared thermography to estimate velocity fields in riverine areas: Fieldwork

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Abstract

Thermography is based on the detection of infrared radiation that is transformed into proportional electrical signals and defines a thermal image. Thermography is a very fast and efficient real-time test methodology, applying to various temporal and spatial scales with different domains and areas of intervention. Thermography plays a relevant role in researching and supporting the development of new techniques used in the study of hydrological and hydraulic phenomena involving detection of water presence and its movements. It presents potential to be used as an instrument to support water management in ecosystems, especially in riverine areas, using thermal, liquid or solid tracers.

The overall objective of the experimental study to be conducted in the field involved the measurement of shallow flow velocity fields, with and without the presence of riparian vegetation, to visualize and identify preferential flow paths. As auxiliary tools of analysis to measure flow velocities, a drone attached with a thermographic camera, was used. The effectiveness application of a group of thermal tracers was evaluated, according each riverine environment and depending on its characteristics. Thermal images treated with appropriate software, where flow velocity maps was constructed and all relevant parameters analysed.

Results of the 2018 measurement campaign are presented, which demonstrate a greater efficiency of the liquid tracers compared to the solid tracers due the intersection and retention of the solids in the riparian vegetation present in the analysed areas. Furthermore, the application of liquid and thermal tracers shows promising results for the velocity field characterization in the riverine zones, due the quick and ease treatment of the thermographic images and the possibility comparing the data obtained with colourful tracers. Also, the floating tracers used have more potential to be applied in areas without vegetation.

In future applications the monitoring of floodplains as well as the influence they manifest on these ecosystems may be the subject of analysis.

Key words: Infrared thermography, drones, tracers, shallow flow velocity, riparian vegetation.
Analysing air and water temperatures by wavelet and EMD methods

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Abstract

New and/or innovative methods of analysis can facilitate better understanding of hydrological processes and their interactions. As hydrological processes are non-linear, non-linear methods of analysis seem to be a promising alternative to the widely used linear methods.

Surface air temperature and water temperature in rivers and lakes are key environmental variables determining conditions of life and survival for organisms on the Earth. River water temperature largely follows changes in local air temperature due to heat exchange at the air-water interface; hence, changing climatic conditions with global warming are expected to introduce changes in water temperature dynamics and distribution. In particular, identifying trends in air and water temperature and accurate assessment of their magnitude can be crucial for proper management of water resources.

The aim of the study was to analyse air and water temperature (trends and frequency contents) using two different methods of signal decomposition: the wavelet transform and the Hilbert-Huang empirical mode decomposition (EMD) methods. The methods used are intended for the analysis of non-linear and non-stationary processes. Daily air and water temperature series (1984–2009) taken at 6:00 Coordinated Universal Time in the same locality (Lesko, the Polish Carpathians) were provided by the Institute of Meteorology and Water Management–National Research Institute. The obtained results indicate important differences both in the magnitude of identified trends and in the frequency content of temperature signals studied.

Key words: air temperature, water temperature, wavelet analysis, EMD method
Application of graph theory to describe subsurface connectivity: results for four headwater catchments and sensitivity analysis

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Abstract

Hillslope-stream connectivity significantly affects the amount and quality of stream water during rainfall and snowmelt events. Despite the wide interest in the concept of hydrologic connectivity, it still remains difficult to quantify. Graph theory, which considers linear connections among shallow groundwater measurement sites and the stream, is one approach to quantify subsurface hillslope-stream connectivity. While the method has been used to describe connectivity between sediment source areas and the stream network, it has been rarely used to determine subsurface hydrologic connectivity and it remains unclear how sensitive the results are to the monitoring network. We, therefore, quantified subsurface connectivity based on shallow groundwater data from four small (<14 ha) headwater catchments in the Italian Dolomites and the Swiss pre-Alps, determined the relation between rainfall, antecedent wetness conditions and subsurface connectivity and assessed the sensitivity of these results to changes in the groundwater monitoring network. We found a threshold relation between maximum subsurface connectivity and stormflow volume. Subsurface connectivity increased during rainfall events but maximum connectivity occurred later than peak streamflow, resulting in anti-clockwise hysteretic relations between the two. Maximum subsurface connectivity was related to the sum of total rainfall plus antecedent rainfall for the Dolomitic catchments, but these relations were less clear for the Swiss pre-alpine catchments. Indices of antecedent wetness conditions alone could not predict subsurface connectivity in these wet study catchments. For the pre-alpine catchments, the fractions of time that the groundwater monitoring sites were connected to the stream were significantly correlated to upslope site characteristics, such as the Topographic Wetness Index. For the Dolomitic catchments, the fractions of time that the monitoring sites were connected to the stream were correlated to the topographic characteristics of the upslope contributing area for the catchment with the small riparian zone, and with the distance to the nearest stream for the catchment with the large riparian zone. Small changes in the structure of the monitoring network did not have a large effect on the relations between connectivity and the characteristics of the rainfall-runoff events, which suggests that the graph-theory approach is a robust method to quantify subsurface hydrologic connectivity.

Key words: hydrologic connectivity; subsurface runoff; headwater catchments; groundwater; graph theory; hysteresis.
Spatiotemporal variation in the flowing stream network in a mountainous headwater catchment

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Abstract
Temporary streams are abundant and account for at least 50% of the total stream length and discharge globally. Temporary streams alternate between wet and dry states, causing expansion and contraction, connection and disconnection of the flowing stream network. Knowledge about this is important as these dynamics can significantly affect downstream (perennial) streamflow amounts and water quality. However, temporary streams are understudied and largely unmonitored, especially in headwater catchments. Conventional methods to study streamflow are often not suitable for monitoring temporary streams because of the high spatial variability in the occurrence of flow, high costs associated with each gauging station, and high sediment loads in temporary streams. We therefore designed a low cost system to monitor the presence of water and occurrence of flow in temporary streams in mountainous headwater catchments. The newly developed system consists of an Arduino microcontroller, a data logger and four sensors (electric resistivity, water level switch, temperature and flow sensor), which allows collection of high spatial and temporal resolution data on the state of temporary streams (dry, standing water, flowing). The sensor system was tested during the summer-fall seasons of 2016 and 2017 in a 0.12 km² headwater catchment in the Alptal in Switzerland. Comparison of the sensor data with time lapse camera images and field mapping shows that the sensor system performs well. Preliminary analyses of the sensor data show that during baseflow conditions, streams in the upper part of the stream network alternate between standing and flowing water, depending on the duration of the period without rainfall. In the lower part of the catchment, the streams are quasi-perennial. The soils in the upper and lower part of the catchment are relatively deep and shallow groundwater flow contributes to streamflow. In the steep center part of the catchment the streams are dry during baseflow and disconnect the upper part and lower part of the stream network. Soils in this area are shallow and the bedrock is close to the surface. The stream and near stream areas contain coarse material, are heavily rooted and fractured, resulting in losing stream conditions. However, during large rainfall events water input from the upper streams is higher than the infiltration capacity, causing flow in these channels and a connection between the upper part and lower part of the catchment. Future analysis will look into the effect of these dynamics on downstream perennial discharge and water quality.

Key words: temporary streams, mountainous headwaters, low cost sensors, stream network patterns
Abstract

Over the past decades, environmental sciences have largely benefitted from the advent of field deployable monitoring and sampling instruments. Despite this technological progress, experimental hydrology remains a discipline that is severely measurement limited. With global change triggering non-stationary responses of environmental systems, water resources research is increasingly facing challenges inherent to monitoring extreme events at unprecedented spatial and temporal resolution (e.g. flashfloods, droughts). Here, we provide a historical overview of hydrological monitoring and sampling approaches that have been gradually implemented in the Sûre River basin (Luxembourg) over 50 years.

In the first half of the 20th century, all hydro-meteorological monitoring protocols relied on point measurements made by observers at fixed times of the day – transcribing various parameters on paper, sending them to central administrations for subsequent archiving, dissemination and/or analyses. In the 1950s, the first generation of recording instruments was introduced – relying on a graphite pencil and millimetric paper bands. Driven by mechanic or electric systems, they were limited to continuous measurements of one single parameter. Until the year 2000, this generation of instruments continued to be widely used for recording surface and groundwater levels, as well as multiple meteorological variables (e.g. precipitation, temperature, atmospheric pressure). Since the late 1980s and the advent of computer controlled field deployable devices, parallel measurements of multiple variables were gradually replacing the ancient generation of instruments – offering unprecedented monitoring frequencies (hourly to sub-hourly).

Similar technological advances have been made in the field of water sampling. For many decades qualitative surface and groundwater monitoring relied on labor intensive and cumbersome grab sampling protocols – followed by subsequent (delayed) laboratory analyses. The deployment of field deployable automatic samplers in the late 1970s led to a substantial increase in water sampling frequencies. A major constraint inherent to these instruments (still) lies in their limited sample capacity (typically 24 bottles) and the need for regular visits in the field for sample recovery.

In the past two decades, the development of field deployable instruments – measuring multiple parameters in parallel – has gradually offered the potential for exploring new avenues at unprecedented frequencies in hydrological processes research. Despite these recent developments in in-situ measurements, there is a pressing need for a new generation of automatic samplers with increased sampling capacities.

In the context of global change and related non-stationarity of hydrological systems, monitoring systems and protocols will increasingly have to cope with processes unfolding at high temporal frequencies.
Sampling frequency affects the assessment of water quality using diatom-based indices in a German lowland river

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Abstract

Diatoms are a group of widespread algae, which have been very well studied by the taxonomist. Due to their quick response to the environmental changes in water bodies, they have been widely investigated and suggested as one of the bio-indicators to assess the ecological status of water bodies by Water Framework Directive. To assess the water quality, different types of diatom-based indices were developed, e.g. diatom biomass, diatom density, diatom richness, Trophic Diatom Index (TDI), Trophic Index of Potamoplankton (TIP). In this study, we aimed to specify the optimal sampling frequency for water quality assessment using different bio-indices and to reveal the important environmental stressors for diatom-based indices. From 29 April 2013 to 30 April 2014, we collected daily samples from the Kielstau River in Northern Germany. The 333 valid samples were categorized into four sampling frequencies, daily, 3-day, 7-day and 10-day. We employed afterwards machine learning model random forest with 10-fold cross validation to simulate the different indices of diatoms on each sampling frequency. Our results showed that for diatom density and biomass, the daily model was better than the other sampling frequencies. In comparison, the best performance of the models for TDI and TIP were 7-day and 10-day. The variance of importance for environmental stressors of each model differed, while water temperature, silicon concentration, solar radiation, antecedent precipitation index (API) and orthophosphate concentration were the most important. We conclude that hydrological parameter (API) plays an important role in shaping diatom-based indices, future bio-monitoring protocols should take hydrological effects into consideration; for different indices, the optimal sampling frequency and the affecting environmental stressors can be different. Therefore, the proper ones must be chosen with regard to the assessment target.

Key words: diatom-based indices, sampling frequency, hydrological parameter, antecedent precipitation index (API), lowland river
Runoff trends in a changing climate in small catchments in the Eastern Carpathians (Bieszczady Mountains, Poland)

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Abstract

Small forested catchments in the Polish part of the Eastern (Flysch) Carpathians have been a valuable semi-natural research area for studying natural hydrologic conditions and changes therein over the last few decades. Water circulation in flysch mountains is characterized by a substantial role of surface runoff due to mountain topography, thin slope cover, low hydraulic conductivity, and the presence of low-porosity rocks, all of which result in low retention rates and a lack of large groundwater reservoirs. Climatic conditions determine the streamflow regime, thus changes in precipitation and temperature may affect water circulation patterns. The objectives of the study were to: (1) characterize stream runoff in the Bieszczady Mountains, and (2) identify and assess changes in streamflow and also identify potential change factors.

The studied catchments were selected in the upper San river basin (the Czarna, Solinka, Wetlina, San, and Wołosaty rivers) in the Bieszczady Mountains. In our analyses, we used the following data: daily streamflow (5 stream gauges), average daily air temperature (2 weather stations), daily rainfall (5 rainfall gauges) for the period 1986–2015. The streamflow regime of the studied rivers is characterized by the highest runoff values in the spring months (March, April) due to snowmelt, whereas the lowest runoff occurs in August and September. Streamflow and temperature quantiles and total precipitation were analyzed for trends using the nonparametric Mann-Kendall test (using a trend-free prewhitening procedure) for different time intervals: months, seasons, years. Statistically insignificant trends were found to dominate the results. The significant trends identified in the study consist of an increase in winter streamflow and a decrease in autumn (September) streamflow. There exists a strong increasing trend in air temperature (annual, summer, autumn), whereas total precipitation does not change. The observed decreasing trend in autumn streamflow is the result of an increase in air temperature, which triggers an increase in evaporation. Furthermore, the winter streamflow increase may be caused by several factors: higher rainfall/snowfall ratio, increase in the air temperature of the preceding period (autumn), decrease in frozen ground depth, increase in infiltration rates and groundwater recharge. The observed changes in recent streamflow are similar to the results of trend analyses for mountainous catchments in the temperate climate zone in Europe. Thus far, hydrologic conditions in the Eastern Carpathians seem to be relatively resistant to the globally changing climate.

Acknowledgements: This research was supported by the National Science Centre, Poland (Project 2016/23/N/ST10/01327).

Key words: streamflow changes, mountain catchments, Eastern Carpathians
Downscaling of the CREMAP actual evapotranspiration map using MODIS NDVI data

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Abstract

Evapotranspiration (ET) plays a key role in spatial and temporal distribution of water and energy between the land- or vegetation surface and the ambient atmosphere. Thus, obtaining spatially distributed ET estimates is crucial in water balance calculations for forests. The increasingly used remote sensing based techniques, such as CREMAP (which was earlier created and validated for Hungary and Nebraska), allow to obtain information about spatial variability of ET at the field and regional scales.

In Hungary, the forest management working with forest compartments (fairly homogenous forest stands) which commonly have a relative small area (approx. 5 ha). Therefore, spatial resolution of the available remote sensing based ET maps is too coarse to be used in precision forest management.

To increase the resolution, the CREMAP ET map (1000 m) was downscaled to the resolution of 250 m, considering the average size of forest compartments, with the MODIS NDVI data as a co-variable. The downscaled product was analyzed for selected forest stands in the Hidegvíz Valley Experimental Watershed.

This downscaled ET map can be usable for forest resources management and climate change impact studies on scales of the forest stands.

This research was supported by the ÚNKP-17-3-III New National Excellence Program of the Ministry of Human Capacities and by the Agroclimate.2 VKSZ\_12-1-2013-0034 project.

Key words: evapotranspiration, water balance, MODIS NDVI, forest management
Interception measurements in the Hidegvíz Valley, Hungary – Comparing traditional and novel sampling methods

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Abstract

Tree canopies play a rather important role in the hydrology of small forested basins. They intercept significant amounts of precipitation and evaporate back into the atmosphere during and after the event. This process, called interception, consumes even 35–40% of gross precipitation in the continental influenced climate of Hungary. Interception loss has large spatial and temporal variation depends on properties of forest stands (structure, tree species and age) and precipitation characteristics (rainfall height, duration, intensity and frequency). The latter will change in the next decades, according to climate change projections for Hungary. Long-term interception measurements are inevitably important in the forested catchments research.

Forest crown interception cannot be measured directly due to the complex surface of the canopy. It is measured indirectly by comparing gross precipitation to the water amount which reaches the ground by falling through or dripping from tree canopies or flows to the ground via branches and trunks of trees. The former way is called throughfall and the latter is stemflow. Both of them show high variability so the measurement is very time-consuming.

This study summarises interception measurement efforts in Hidegvíz Valley Experimental Catchment, which is located in the eastern foothills of the Alps (western part of Hungary) in Sopron Hills. In this research basin, interception was one of the first measured hydrologic elements. In the early years of the experiment, the sampling was quasi-event-based but later it is changed to weekly, biweekly. Usually, the accumulated data contain several precipitation events. Although stemflow and throughfall have been measured for several years manually, those records are not useful for analysis of interception process in finer temporal resolution.

The advent of the digital dataloggers enables us to change our research facility to new automatic types of equipment. Automation of the old collectors is also an important task. High spatial variability of throughfall and the relatively small number of sampling points required to maintain old infrastructure, thus in this way collected datasets are comparable. We analyse records of recently installed loggers and investigate the compatibility with the labour-intensive old methods.

Research has been supported by the “Agrárklíma.2” (VKSZ_12-1-2013-0034) research project. The corresponding author’s work was also supported by the János Bolyai Scholarship of the Hungarian Academy of Sciences.

Key words: interception, digital data logger, throughfall, stemflow
Derivation of regression equations for calculation of evaporation from a free water surface and identification of trends in measured variables in Hlasivo station

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Abstract

Evaporation from a free water surface is one of the important factors affecting the total water balance of a catchment. Due to the complicated direct measurements methods, evaporation is calculated from meteorological variables based formulas. Contribution evaluates data of evaporation, air temperature, relative air humidity and precipitation from Hlasivo station from seasons from May to October of 1957 to 2017.

Hlasivo station in the Czech Republic near Tábor city was built in 1957. It has sixty-one old history of evaporation measuring for purposes of TGM Water Research Institute, p.r.i. Over the years, it was started with a systematic monitoring of evaporation as a component of the hydrological balance. Hlasivo station is only the one station in the Czech Republic where evaporation measurement is not cancelled.

In the first part, statistical analyses of evaporation, air temperature, relative air humidity and precipitation are described. Significant upward trend was identified only in the evaporation values. Second part of the contribution describes the derivation of equations for calculating of evaporation based on meteorological variables regression. The evaporation was modelled with newly derived relationships and the results were compared. The best results were obtained using the formula based on the water temperature (air temperature) and wind speed.

Key words: evaporation from free water level, Hlasivo station, hydrological balance, evaporation formulas
The effect of evapotranspiration on the water reserve of Romanian lakes
(Case Study)

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Abstract
Over the last decades, hydrological research has been targeting the impact of evaporation on water reserves, present in lakes at specific moments of time. The results of these studies have shown that for reservoirs located in areas with a subtropical climate, the volume of water lost through evaporation can exceed 250 million m$^3$/year – Algeria (Remini et al., 2009), reaching values as high as 400 million m$^3$/year – Morocco (Lahlou, 2000) and even 4,100 million m$^3$/year – Turkey (Gökbulak et al., 2006). In Romania, there are very few studies following such an approach, thus underlining the importance of carrying out the present research.

Having in mind the small number of evaporation-measuring rafts, available at national level, with only 14 such instruments currently existing, it is vital to determine evaporation for those lakes that are not being monitored, as well as the impact of this parameter on a lake's water reserves.

In this context, the goals of our study are: (i) to determine the average multiannual surface evaporation, for lakes that are not measured from an evapometric point of view, but present complex functions (supplying the population with water, generating electricity, mitigating floods) and (ii) to estimate the volume of water lost through this process for every lake included in the study.

Evaporation was determined for a total of 20 lakes, by applying the modified Penman-Monteith method, using daily data on maximum and minimum air temperature, relative humidity, wind speed, duration of sunshine, which were extracted from the ROCADA database (Dumitrescu et al., 2015) for the 1961-2013 interval. The validation of evaporation data, obtained through the modified Penman-Monteith method for the 20 analysed lakes, was carried out using maps of the annual distribution of evaporation in Romania, which were in turn created based on data gathered in the 1961-2013 interval from 54 evapometric stations.

Results indicate evaporation values of more than 700 mm/year for lakes situated at altitudes of less than 200 meters, values between 600 and 650 mm/year for lakes located in hilly or plateau areas and values of less than 450 mm/year for lakes found in depressions or in the mountains.

The estimation of the volume of water, lost through evaporation, was performed using the equation elaborated by Drobot and Şerban (1999) for the year 2013, which was chosen for two reasons: it was a normal year from a hydrological standpoint, compared to the 1961-2013 reference interval, and due to the availability of the hydro-morphometrically data for the lakes. The results show the volume of water, lost due to evaporation, ranges between 1.5 and 6 million m$^3$. This represents up to 15% of the total water volume of a lake, in the case of lakes located in lowlands, and reaches 1 million m$^3$, or about 2% of a lake's volume, in the case of water bodies found in depressions and in the mountains.

Acknowledgements: This work was supported by the Ministry of Water and Forestry

Key words: evaporation, hydrological balance, water resources impact
Overland flow in a mountain microcatchment during rainfall simulator experiments

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Abstract

Overland flow does not occur frequently in undisturbed mountain catchments of humid temperate zone. The objective of our work was to quantify the overland flow following intensive rains with short duration simulated by a portable rainfall simulator Wageningen. The measurements were carried out in a mountain microcatchment of the Sokolný jarok creek, the Western Tatra Mountains, Slovakia (area 0.059 km2, mean elevation 1509 m a.s.l.). We have conducted a series of experiments with different rainfall intensities and with several short rainfalls with duration of about 14 minutes applied on the same plot. Time to the beginning of the overland flow and the amount of applied rain transformed into the overland flow (hereafter denoted as runoff coefficient) were measured. Measurements with different rain intensities provided results which were comparable with similar measurements conducted outside the mountains. Extreme rain intensity (3.8 mm.min-1 and 4.9 mm.min-1) always created overland flow which represented 1-30% of the applied rain. Overland flow was often not observed during smaller, but still extreme rain intensities (2.3 mm.min-1) and runoff coefficients were up to 10%. Repeated rains on the same plot provided surprising results. Time to the appearance of overland flow after successive rains was increasing (median 100 seconds after the first rain and about 250 seconds after the fourth rain on the same plot) and runoff coefficients were stable (about 5%). Additional experiments to confirm the results are planned for summer 2018.

Key words: rainfall simulator, overland flow, undisturbed mountain catchment
Flow processes and subsurface drainage systems

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Abstract

In Norway, and many other countries, subsurface drainage systems are a necessity to practice agriculture, both to obtain optimal growing conditions, but also to facilitate tillage operations. Drainage systems, through control of the groundwater level, have a direct influence on the soil moisture content. A rapid drawdown of the groundwater table can be obtained by decreasing the drain spacing. In Eastern Norway, under grain production, the spacings vary from 8 – 10 m. Along the west coast of Norway, under ley production, this can be 6 m. With climate change predictions indicating an increase in precipitation for Norway the question arises whether the drain spacing should be further reduced. To obtain information about the present day functioning of the drainage system, drainage runoff from three small field scale catchments was analysed. Several recession periods were selected and analysed to obtain information about the halftime, being the time needed to reduce the runoff to 50% of its maximum value at the onset of the recession period. The assumption is that the recession period could be described as an exponential decay function, as \( q_t = q_0 \times e^{-\alpha t} \), where \( q_t \) is the discharge at time \( t \), \( q_0 \) at the start and \( \alpha \) being the recession coefficient. In subsurface drainage design the recession coefficient, \( \alpha \), is a function of the saturated hydraulic conductivity of the soil (ksat), the drainable porosity (\( \mu \)) and the drain spacing (L). However several times a statistically significant better fit, based on the Akaika Information Criteria, was obtained with a two-exponential decay function describing the recession period. This might indicate the presence of dual flow process towards the drainage system. In addition, there as a considerable variability in the recession coefficients, and as such in the halftime, both when considering a one or two exponential decay function. In almost all cases the half time for the small field scale catchments was less than 24 hours, indicating a fast drawdown of the water level. The variability in half time might indicated a change in soil physical parameters over time. Further research has to be carried out as soil physical parameters are an important input to models to predict information about among others the soil moisture content, which again is important related to agricultural practices. Until now these inputs were considered constant but these results indicate a variability in these parameters.

Key words: subsurface drainage, halftime, recession period, flow processes
Uncertainty in the isotope-based hydrograph separation due to spatiotemporal variations of the input signal in a partially forested catchment

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Abstract
Water stable isotopes tracer studies often assume spatial and temporal homogeneity in the input signal. Nevertheless, even in small catchments the variability in precipitation isotopic signatures can be significant. This can increase the uncertainty in the hydrological process understanding that these tracer studies seek to gain. Moreover, in forested or partially forested catchments, the input signal can be modified by canopy interception processes. The aim of this study is to assess the spatiotemporal variations of the input signal at the catchment scale and to quantify their effect on isotope hydrograph separation (IHS) results, focusing on the uncertainties in the identification of “old water” contributions during storm events. The study considers the effects of the spatial variability related to (i) altitudinal effects and to (ii) interception processes; and the effects of the temporal variability (iii) comparing bulk and sequential sampling.

Precipitation, throughfall and discharge data were collected between May 2015 and May 2016 in a Mediterranean catchment of 0.56 km² (Vallcebre, NE Spain), partially covered by Scots pine. Rainfall was collected at an event-basis with sequential samplers and bulk collectors at two locations. The sampling design of the stand consisted of one throughfall sequential sampler and 10 throughfall bulk collectors. The isotopic sampling was combined with meteorological and hydrometric measurements (discharge at the catchment outlet, 3 rainfall tipping-buckets and 20 throughfall tipping-buckets). In total, the spatiotemporal differences in the input isotopic signal were analysed for 29 rainfall events and IHS was performed for 8 events.

Results showed the existence of an altitudinal effect on the rainfall isotopic composition. Enrichment in δD was 0.88‰ per 100m increase in elevation, with the highest differences observed during short and intense rainfall events. Differences between throughfall and rainfall were larger and more variable, ranging from 7‰ to -3‰. In IHS, significant differences in “old water” contributions were found depending the collector used for defining the input signal, however no significant differences were found for the sampling method (bulk or sequential collection).

These results confirm the importance of assessing the input isotopic variations even in small catchments to perform accurate IHS. Using sequential samplings in more than one location and taking into account the variability of the isotopic signal induced by canopies will reduce uncertainties associated with input signals and provide better insights into catchment hydrological process understanding.

Key words: Stable isotopes, Isotopic composition, Spatiotemporal variability, Hydrograph separation
Field measurement of surface runoff and soil loss on agricultural land using rainfall simulator

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Abstract

Soil erosion by water is in the last decades a frequently mentioned worldwide problem. Measurement in the field conditions is an essential tool for understanding and describing the runoff generation and related soil loss processes and for modeling and design of control measures. This contribution introduces the results of field experiments with a rainfall simulator, targeted on determination of surface runoff and soil loss and their relation to various vegetation cover types. The dataset is used for various purposes: determination of USLE C-factor values, calibration of rainfall-runoff models, revision of runoff coefficients, etc. Presented results cover two experimental seasons, further research however is expected.

The runoff and soil erosion experiments were repeatedly carried out on a set of the experimental plots located on an inclined field with various crops. Each plot of size 16 m² (8 m x 2 m) and 9 % slope was enclosed by metal plates and at the lower end directed into a collection funnel. The artificial rainfall was generated with the mobile field rainfall simulator of CTU in Prague. The rainfall intensity was set to a constant rate of 60 mm/h. Duration of each experiment was fixed to 30 minutes after the surface runoff initiation. The experiment started on the soil surface with natural initial soil moisture conditions and then was repeated after 15-minutes pause on the fully saturated soil from the previous sprinkling. The same setup was applied on a plot with the seedbed conditions, once in every experimental day. In the 2.5 minutes interval the instantaneous surface runoff and soil loss at the plot outlet were measured.

So far we tested 10 different crops during different grow stages (3 BBCH stages for each crop during vegetation season) and the bare soil (seed bed conditions). In total, 134 experiments were performed during two years. Testing different phenophases of crops allows to evaluate the vegetation protective effect on soil during the crop life-cycle. Preliminary results of runoff and soil loss for different plots and relation between the plots with vegetation and the bare soil are presented. Presented research was funded by research grants QJ1530181 and SGS 17/173/OHK1.

Key words: rainfall simulator, erosion, soil loss, runoff
Application of rice straw mulching strips to reduce runoff and soil loss: Results from laboratory soil flume experiments

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Abstract

Mulching practices have been used to improve agricultural soil fertility and reduce erosion on hillslopes (e.g. post-fire scenarios). Despite mulching high effectiveness/cost ratios, application costs can still be reduced without significantly compromise its effectiveness. One way to achieve this is to apply mulching in a strip at the bottom part of a slope rather than over the entire slope, but its implications for the effectiveness in terms of reducing runoff and soil erosion are still poorly known.

This laboratory study compared six mulching application schemes, combining three strip lengths (1/3, 2/3 and 3/3 of flume’s length) and two mulch cover percentages (50 and 70% cover). A bare soil condition (control treatment) was also studied. Rice straw was used as mulch. A total of 21 experiments (7 treatments × 3 replicate runs) were carried, each consisting of a sequence of three intermittent rainfall events, the last of which also involved application of sheet flow from the top of the soil flume.

Mulch treatments were more effective in reducing soil loss than runoff and, throughout all runs, mulching effectiveness decreased with increasing amounts of applied rainfall and inflow. In overall terms, for the same cover percentages, mulching strips covering 1/3 and 2/3 of flume’s length were less effective in reducing runoff and soil loss than mulching covering the entire flume. Nevertheless, these differences were never substantial and decreased with increasing amounts of applied rainfall and inflow. There should be noticed that application of mulching strips did not avoided generation runoff and corresponding soil loss in non-mulched parts (upslope areas).

Key words: Rice straw mulch strips, Runoff, Soil loss, Laboratory soil flume, Rainfall simulation
Monitoring of soil erosion by water in multiple scales

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Abstract

At Faculty of Civil Engineering, Czech Technical University in Prague, soil erosion models were applied since 1950 and verified by various measurements. Recently the Department of Irrigation, Drainage and Landscape Engineering focused on several scales of soil erosion monitoring. Splash erosion is monitored within project No. GA17-33751L, where several sites and soils are compared. Larger scale is provided by monitoring on 16 m² plots under natural and synthetic rainfall – this approach will be presented in the partner contribution by Ing. Neumann.

Our contribution will mainly present the third measure scale of monitoring soil erosion processes and its development, which is the monitoring of whole agricultural parcels or river basins. CTU monitoring is carried out on several locations. Within the QK1720289 project, the Býkovice basin has been monitored for a long time (M. Báčová et al. 2016) and USLE plots were also kept there in years 2009 – 2017.

Finally, three new sites (Oráčov, Lišany and Bulhary) are being monitored. Research in these new localities focuses on providing input data on existing erosion threats on agricultural fields and it is based on continuous monitoring set in place in 2018. This monitoring consists of a number sub-tasks, which are:

• field survey and on-foot monitoring of current state and evidence of erosion;
• establishing the basic hydropedological characteristics of the monitored localities;
• identification of suitable profiles for long-term erosion monitoring;
• initial RGB RPAS monitoring;
• securing and primary analysis of suitable satellite data;
• target the volume of sediment in selected reservoirs within monitored localities;
• establishing a long-term monitoring of the hydrological regime of the soil;
• repeated RGB RPAS monitoring;
• thermal RPAS monitoring of selected erosive manifestations

So far, we managed to do and process several UAV flights, estimate the extent of rill erosion, do a hydropedological survey and its link to soil properties modified by erosion processes and establish continuous monitoring of soil humidity regime. The monitored parcels are affected by a long-term erosion. There have been changes in soil horizons and soil structures. Soil chemistry is also affected by the transport of soil particles.

The research is supported by project of Ministry of Agriculture of the Czech Republic No. QK1720289, and project No. SGS 17/173/OHK1 and by project No. GA17-33751L.

Key words: soil erosion, agriculture, monitoring,
Spatial and temporal variability of suspended sediment in low mountain range
Gersprenz basin

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Abstract

The majority of solids in running waters drifts from the surface of the catchment areas in the form of suspended sediment. Due to local settling of particles in the waterways as a result of flood events, a sediment management system is required. Furthermore, the suspended sediment transport in rivers is often linked to the transport of nutrients and pollutants, which stick to the fine-grained particles. This is an important reason for sediment monitoring and estimating loads. The base of monitoring is field-measurement. Direct measurement methods for defining the concentration of suspended sediment in rivers are very time consuming (and expensive). Depending on the cross-sectional geometry, it is required to take a certain number of samples from the water to examine the solids afterwards. Analyzing individual flood events, the number of samples and thus the expenditure of time for sampling and evaluation highly increases. An alternative is an indirect (optical) measuring method, such as turbidity measurement, to get a continuous time series.

The aim of the study is to investigate the transport processes and drivers in the low mountain range Gersprenz catchment area (485 km²) including its small subbasin Fischbach (37 km²) combining direct and indirect measurement methods as well as identifying the sources and entry pathways of the suspend solids. Different empirical approaches were used to interpret the transport dynamics on various time-scales. In the analysis of temporal variability, the time-scale in particular individual events as well as seasonal differences should be considered. Our results show the evaluation of the influence of different field parameters like land use, slope, soil or hydro-meteorological factors on hysteresis loops and sediment rating curves. However, we accounted also the spatial variability of the measured values, both in the cross-section and along the watercourse, to regard the hydraulic parameters of the channel (discharge, depth, velocity, stream bed).

Key words: suspended sediment transport, hysteresis models, drivers and pathways, temporal and spatial variability
Dissolved sediment transport and ion characteristics of runoff and groundwater at a low Mediterranean mountain catchment: the Vernegà river, Gavarres Massif, NE Spain.

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Abstract

The Vernegà experimental catchment is located in the Gavarres Massif (450 m.a.s.l.) NE Spain, and it is a representative low Mediterranean mountain catchment. It drains an area of 2.5 km² and has two gauging stations: one monitoring a totally forested area (1.6 km²) and the second one monitors a mixture of forest and agriculture land use area. Discharge has been measured for 20 years, while sediment transport has been measured continuously since 2005. Groundwater was also monitored and sampled at two-week interval from 2005 at three different open-air wells, located at different heights from the river catchment. Well number 1 is at 17 m above the river channel, while well number 3 is the closest to the river channel.

The dominant sediment transport in the catchment is the dissolved load, which represents 62% of the total sediment load production and only 38% is transported in suspension. Mean dissolved sediment load production is 1.54 T/km²/year in the forested station and 7.1 T/km²/year at the outlet, while suspended load is 0.94 T/km²/year at the forested station and 4.1 T/km²/year at the outlet.

The quality of runoff waters has a pH of 7.2 and the mean electrical conductivity is 134 µS/cm at the forested catchment and 168 µS/cm at the outlet. The major cations in runoff waters of the basin are carbonates, chloride and sodium which represent 38%, 29% and 9% respectively at both monitoring sites. Other ions of importance are Ca²⁺ > SO₄²⁻ > SiO₂²⁻ > Mg²⁺ > NO₃⁻ > K⁺. Additional ions with a small content are also present in fluvial waters such Al³⁺ > Fe³⁺ > PO₄³⁻ > Zn²⁺ > Mn²⁺ > NO₂⁻.

The pH of groundwater was 7.8 and electrical conductivity was 651 µS/cm at well 1 and 445 µS/cm at well 3. Carbonates was the major ion at all three wells and it represented 50% of all dissolved content. The order of major presence ions at well 1 are HCO₃⁻ > Ca²⁺ > Cl⁻ > NO₃⁻ > Na⁺ > K⁺ > SiO₂²⁻, while at well 3 the order is as follows: HCO₃⁻ > Cl⁻ > Ca²⁺ > Na⁺ > SO₄²⁻ > Mg²⁺ > SiO₂²⁻. Thus, the content of ions changes slightly from the well number 1 to well number 3 and it seems that well 3 is more influenced by the underlying bedrock than the one on top.

The presence of phosphorus in fluvial waters of the catchment is related to the application of fertilizers in the agriculture lands. The content of phosphorus is greater in groundwater resources than in runoff waters and it is greater in the well 1, with a mean concentration of 0.9 mg/l, than at well 3, which is only 0.13 mg/l. However, its concentration has been decreasing throughout time due to land abandonment and thus, the absence of fertilizers in soil for growing crops. The same pattern is found for nitrites, being the greatest concentration in the well 1, with a 0.02 mg/l of concentration. Runoff waters also show presence of phosphates and nitrites but in lower concentrations than those on groundwater.

Key words: Dissolved sediment transport, Dissolved sediment production, water pollutants, Mediterranean catchment.
Hydrological modelling of the Fischbach catchment using two sources of precipitation data

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Abstract

Precipitation is the most important input in hydrological rainfall runoff modelling. Traditionally precipitation is recorded at rain gauges on the surface and interpolated to give a regional average. However, in more recent years an increasing amount of precipitation data from remote sensing has become available. This offers the potential for a better spatial representation of precipitation and is especially of interest for areas with no or very few rain gauges. Two main questions that arise are how the acquired data of the two sources differ and how this impacts the rainfall runoff modelling process. Currently a study is being undertaken for the Fischbach catchment in the federal state of Hesse, Germany, to address aspects of these questions. Data from several surface rain gauges as well as remote sensing data is available. The remote sensing data is acquired from the Global Precipitation Measurement (GPM) mission with a daily resolution. Precipitation data will be compared on different timescales e.g. monthly, seasonal etc.. The catchment will be modelled with a hydrological model named BlueM. A modified curve number approach is used to calculate excess precipitation for each sub catchment. Calibration is performed with BlueM.Opt and resulting parameter sets are compared. The study ends in July of 2018 and selected first results will be shown.

Key words: precipitation, remote sensing, hydrological rainfall runoff modelling
Validation of the Cropwat Model at a Romanian experimental station and in other different climatic regions (Brazil, India and USA)

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Abstract

One of the most complex atmospheric processes, evapotranspiration, is an important parameter with several applications in climatology, hydrology, environmental studies and agriculture, being conditioned by different climatic conditions (air temperature, precipitations and relative humidity), relief, soil types and water resources (water availability for crop irrigation). Taking into account that evapotranspiration measurements are difficult to carry out directly, because of the rarely available lysimeter installation, often found within experimental basins and stations, a number of applications have been developed (CERES, CRPSM, UCA, COMMOD, RIMMOD, ISOM), including the Cropwat Model. This model has already been validated in many countries, including Romania, by testing different crops (maize, peas, wheat and soybean) at the Călăraşani experimental station (in south-eastern Romania).

The paper’s aim is to estimate evapotranspiration by using the Cropwat Model (developed by FAO), for land plots covered with soybean crop, under different climatic regions: in the United State of America - Ohio State; Brazil - Rio Grande do Sul and Mato Grosso; Romania - South-East region and India - Madhya Pradesh. All five regions analyzed in this paper play an important role in the production of soybeans around the world, with the USA and Brazil ranking first and second among the world’s biggest soybean producing countries and India occupying the fifth place. At the same time, Romania has become an ever more important producer over the years at a European level.

The CropWat model estimates crop evapotranspiration by using a modified Penman-Monteith equation, where the input consists of climatology data: relative humidity, wind speed, sunshine duration, maximum and minimum air temperatures, precipitation, and also crop data: the standard crop coefficient, plant development stages, root depth, plant withering point, plant response capability, crop yields and plant height. The study was performed by using data from both dry and humid years, provided by the National Institute of Hydrology and Water Management (Romania), the National Oceanic and Atmospheric Administration for India, the Midwestern Regional Climate Centre for the USA and the National Institute of Meteorology of Brazil.

The results obtained in this study largely correspond to those presented in previous studies, carried out at experimental scale but also at a global scale, based on the satellite images. Thus, evapotranspiration in the case of soybeans crops exhibits higher values during dry years, characterized by lower rainfall values. In Brazil, soybean evapotranspiration reaches 650 mm/year, in Romania 550 mm/year, in India 600 mm/year and in the USA 500 mm/year. The highest daily values exceed 5 mm/day in all the study areas, during the period of maximum vegetation. Knowledge of evapotranspiration is essential for managing periods of atmospheric and soil dryness, when the crops need irrigation of up to 300 mm/year.
In conclusion, the Cropwat Model helped us to better know and understand the variability of soybean evapotranspiration for different climate regions and to identify the periods of the year when crops need irrigations, based on a few input data and on the experimental studies previously made.

*Key words: evapotranspiration, soybean, Cropwat, irrigation.*
Modeling soil water regime under varying climatic, soil profile, and vegetation conditions

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Abstract

Understanding the soil water regime response to unusual weather events is an essential base for evaluating the potential impact of the foreseen climate changes. Mountainous headwater catchments provide a unique opportunity for studying soil water regime. They are highly sensitive to climate stress, play a major role in initial stages of large-scale flood events, and often suffer from flash floods.

The study is based on data collected at two experimental catchments, both located in the Bohemian Forest, southern Bohemia. The catchments differ in climatic and soil conditions, as well as in vegetation cover. The Liz catchment (0.99 km²; 941 m a. s. l.) has milder climate (average temperature 6.3°C; average annual precipitation 861 mm). The soil is the oligotrophic Eutric Cambisol developed upon biotite paragneiss bedrock. The catchment is covered by spruce and beech forest. The majority of trees are 97 years old. Within the catchment, soil water regime is monitored at three sites with different vegetation (spruce tree stand, beech tree stand, mountain meadow). The Roklan catchment represents higher locations of the mountain range (0.10 km²; 1244 m a. s. l.; 4.1°C; 1725 mm). The soil type is Cryptopodzol. The region was affected by forest die-off caused by bark beetle in the late 1990s. Presently, the catchment is covered by dead trees, sparse natural regrowth dominated by spruce, and herb undergrowth.

Water regime at the experimental sites is simulated using a one-dimensional dual-continuum model of soil water flow, S1D. The model allows treating the soil profile as two semi-separate flow domains representing the soil matrix and the network of preferential pathways. Plant water uptake is described based on potential gradient approach. Daily variation of plant water storage is also accounted for.

Comparison of observed variables and model outputs for different sites and contrasting vegetation seasons serves to improve understanding and model representation of the studied headwater catchments' hydrologic function.

Key words: soil water regime, temperate climate, spruce forest, beech forest, Richard’s equation
Coupled water flow and heat transport modeling under winter season conditions at a small mountainous catchment of Central Europe

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Abstract

Year-round discharge in streams of mountainous catchments of temperate climate is strongly influenced by melting of the accumulated snowpack. Evaluation of the quantity and timing of snow melting and its partitioning onto surface runoff, subsurface runoff, and deep percolation is of major importance. Soil and water freezing (and thawing) significantly affect the spring thermal status of forest soils and co-determines the beginning and length of the growing season.

Physically-based soil freezing/thawing algorithm was implemented into S1D model for simulating the movement of water and heat in the variably saturated soil. The coupling between heat and water module allows approximation of water movement in unsaturated soils during the liquid-solid phase transition.

The model is tested by comparison with an analytical solution (neglecting water movement and energy advection) and applied for whole-year simulation of soil water regime at a small mountainous catchment Uhlířská.

The model proved to provide reliable and robust results regarding accuracy and convergence. In the case of long-term simulation, the new improved model was recognized as a useful tool for analysis of transient states during the winter season.

Key words: snow melting, soil freezing, winter season, Richard’s equation
Predicting nutrient uptake in streams using an enhanced physically-based solute transport model

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Abstract

Stream water pollution has been identified as a major issue in many parts of the world for the past several years. Industrial effluents as well as agricultural and domestic wastes have contributed to increased pollutant concentrations in streams and rivers. To study the fate and transport of such pollutants, it is necessary to employ models that simulate solute transport in streams. Existing stream solute transport models use simple first-order kinetics to evaluate nutrient uptake and ignore the actual biochemical reactions and interactions. This study aims to use knowledge from two popular models: (1) a solute transport model known as One-dimensional Transport with Inflow and Storage model (OTIS) and (2) a water quality model known as The Enhanced Stream Water Quality Model (QUAL2E). By integrating the major processes in OTIS (advection, dispersion, transient storage) with biochemical reactions in QUAL2E, we propose an improved physically-based solute transport model. The model was developed such that it is applicable to all stream types with minimal calibration requirement. Model testing was carried out with experimental data from two streams in the Kielstau catchment (Germany) and additionally using 35 sets of published tracer test data. Among the four crucial reaction parameters - ratio of Chlorophyll-a to algal biomass (α₀), fraction of algal biomass that is nitrogen (α₁), fraction of algal biomass that is phosphorus (α₂) and background algal concentration ([A] in mg/L), [A] was found to be very sensitive to nutrient uptake (13% increase in phosphorus uptake rate observed with 50 mg/L increase in concentration). The other three parameters were sensitive to nutrient uptake only at high algal concentrations. Even though we attempted manual calibration of all four parameters, default values of α₀(=10), α₁(=0.2) and α₂(=0.1) gave excellent model performance in more than 70% of test cases. Therefore, in case of data scarcity, these default estimates may be used with reasonable confidence, and background algal concentration was retained as the only single parameter that required calibration or exact field measurement. Using the field measured value of [A] in Kielstau, the model simulated phosphate breakthrough curves that closely matched the observed curves (showing insignificant differences using Kolmogorov-Smirnov test). Observed uptake rates ranged from 0.0002 m⁻¹ to 0.5 m⁻¹ considering both field and literature test data and comprised of nitrate, phosphate and ammonium uptake rates. Primarily calibrating a single parameter ([A]), the new model performed extremely well in predicting the order and magnitude of these uptake rates (R²=0.98 between measured and modelled values). Inclusion of actual biochemical reactions and parameters in the model is expected to give more confidence and opportunity for incorporating realistic data which is not feasible in existing first-order decay based models like OTIS. The proposed model is expected to act as an independent model or in a coupled version with other watershed scale models for both short-term and long-term nutrient transport simulation.
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