Climate and surface and ground-water in the Baltic region – variability, trends, and impacts

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Book of Abstracts

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VARIABILITY OF THE HYDROMETEOROLOGICAL PARAMETERS OF THE CURONIAN LAGOON IN TWO CLIMATE NORMAL PERIODS

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The Curonian Lagoon is a shallow freshwater lagoon located southeast of the Baltic Sea. It is also the largest lagoon of the Baltic Sea, with an area of 1,584 km2 (of which 381.6 km2 belong to Lithuania). Due to its unique biodiversity, it is protected internationally and included in the Ramsar List, the Bonn Convention and the World Heritage List. However, like other bodies of water, this lagoon has not escaped climate change, which has altered its hydrological regime. The study aimed to determine the changes in the hydrometeorological parameters of the Curonian Lagoon during two climate normal periods (1961-1990 and 1991-2020) using statistical analysis methods. The daily data of air and water temperature, precipitation, wind speed, water level and ice regime observations from the Lithuanian part of this lagoon in the two climate normal periods were used. The Mann-Kendall test was applied to assess the significance of the identified changes.
The performed analysis revealed that the Curonian Lagoon experienced considerable changes during the studied climate normal periods. Due to the rising global air temperature, the air and water temperatures in the Curonian Lagoon region also increased. In the second 30-year period, the air temperature was higher by 1.3℃ and the water temperature by 0.9℃ than in the first period. Thermal expansion and glacial melt on a global scale had an impact on the rise of the water level of the Curonian Lagoon. In 1961-1990, it was 505.3 cm and in 1991-2020 – 513.1 cm. Climate change has also affected other meteorological parameters. It was found that the amount of precipitation in 1991-2020 was 7.8% higher, and the wind speed was 19.6% lower than in 1961-1990. Due to growing air and water temperatures, in the second period, the duration of the ice cover decreased by 26 days, the ice cover thinned by 7.6 cm, and its breakup began 18 days earlier than in the first period.
Rising water temperatures may have negative consequences for the abundance of stenothermic fish. The rising water level influences even greater coastal erosion of the Curonian Spit. Changes in rainfall and wind speed will likely affect the water balance of the lagoon. The altered ice regime may have a negative impact on the accumulation of suspended nutrients in the sediments.

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The influence of climate change on the dates of phenological phenomena in Lithuania

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Climate change research has been relevant on a global scale for several decades. In climatology, they are shown by various climate-related meteorological phenomena, and in phenology, they are shown by changes in living nature, that is, the reaction of plants and animals to changed conditions. In the last 30 years, warm winters have been more frequent in Lithuania. The increase in the average temperature during the winter period disrupts the seasonal rhythm of nature, the cold season of the year is shortened, and spring seasonal phenomena begin earlier. The plants that are most responsive to climate warming are those that express it in their development phases. Changes are also noticeable in insect phenology.
Phenological observations have been carried out since 1961 at the Voke Branch of Institute of Agriculture of Lithuanian Centre for Agriculture and Forestry. The program of phenological observations includes the registration of 75 dates of phenological phenomena, therefore, over a 60 years period, a large database has been accumulated that allows various scientific researches to be carried out.

The purpose of phenological research is to determine the influence of climate change on the occurrence patterns of various phenological phenomena and their interrelationships with environmental conditions.
Due to climate change, deviations of meteorological conditions from the norm have been identified in Lithuania, which have affected the seasonal rhythm of nature. It was found that the starting dates of plant phenophases in spring and summer were strongly correlated with the average air temperature of the two-month period before the occurrence of phenophases (r = -0.93). Dependence on precipitation was weaker, but a tendency was observed for phenophases to be delayed in wet spring. Both temperature and precipitation had little influence on the dates of the onset of leaf yellowing. 1961 – 2020 during the period, the dates of plant phenophases were earlier (from -0.05 to -0.43 days per year), but larger-scale earlier trends have been observed since 1981. In the last decade, the occurrence dates of spring phenological phenomena have advanced by 7 – 11 days on average.
Changes in the length of the growing season are also related to climate change. Growing season in Lithuania from 1961 to 2020 lengthened by 0.26 d. per year. Due to climate change, the growing season has become 5 – 6 days longer than the average multi-year growing season in the last two decades.
The appearance of insects (especially honey bees) in spring and their nutritional conditions are related to the timing of the phenophases of entomophilous plants. It was found that the dates of honeybee appearance on the flowers were strongly correlated with the dates of the first phenophases of plants beginning of flowering in spring (r = 0.73 – 0.80). In the last decade, climate change has advanced the dates of plant phenophases, resulting in more species of entomophilous plants flowering when the honey bees began to fly than in 1961 – 2010.

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Determination of hydrological drought by daily water level data

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Climate change is becoming more and more visible, and the consequences are getting worse. Therefore, it is critical to quickly identify the threat and respond to it. Climate change is causing hydrological droughts, which have become very noticeable in recent years. In fact, in 2022, the runoff of many rivers in Europe reached minimum values. Most commonly used indices to identify hydrological droughts use discharge as input data, but in this paper, based on the example of Lithuania, water levels were tested to speed up the process. The Standardized Water Level Index (SWLI) was calculated in the same way as the Streamflow Drought Index (SDI), but the discharge data were replaced by the water level data. The warm period of the year, namely from May to October, and 10-day accumulation period were taken for the study. All calculations were made for 30 years (1991-2020). To compare the two indices, 15 Lithuanian catchments with an area from 148 km2 to 812,000 km2 were selected. The study revealed that small rivers had more significant deviations of negative values, which could be caused by the high amount of river flora in summer. Therefore, equations of determination were applied to define the threshold value of severe drought. The SWLI showed similar results to the SDI, except for a slightly higher number of days with severe drought. The hydrological drought was most often detected in May. According to both indices, the driest years were 1992, 2006 and 2019-2020. Thus, it was confirmed, that SWLI could be used to determine severe hydrological drought in Lithuanian rivers.

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A New Tool for Climatic Information on Municipality Scale in Latvia

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Climatic data on municipality level is essential for a range of applications, from agriculture and forestry to urban planning and disaster management. In Latvia, more than 25 LEGMC (Latvian Environment, Geology and Meteorology Centre) observation stations provide climatic data, but these are widely spaced and unevenly distributed. Interpolating climatic data is therefore necessary to provide a more comprehensive understanding of climatic variables on a municipality level, especially when considering applications regarding adaptation to climate change.

This study used the universal kriging method to interpolate climatic data on a municipality level in Latvia, taking into account the influence of continentality and height above sea level. The study focused on climatic observations from 1961 to 2021, analyzing air temperature, precipitation and derived climatic indices such as summer days etc. We also processed previously bias-corrected future climate change scenarios RCP 4.5 and RCP 8.5 until 2100 (Avotniece et al 2017). The interpolated results more accurately represent the spatial distribution of these climatic variables, providing valuable insights into the effects of current and future climate on agriculture, forestry and other sectors.

The data have been published in an interactive online tool available at https://klimats.meteo.lv/pasvaldibu_apskati. This tool allows anyone interested to access the results in an interactive way, providing easy-to-use information for a wide range of applications.

We also intend to continue to improve the online tool, in the future including more climatic parameters such as prevalent wind speed and direction. This will allow for an even more comprehensive understanding of the spatial distribution of climatic variables in Latvia.

Overall, this study provides valuable insights into the distribution of climatic variables in Latvia. The interactive online tool presents accessible information for a range of users, from policymakers to the general public. The future addition of more climatic parameters will provide even more comprehensive information for a wider range of applications.

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Forecast from hindcast: Evaluation of groundwater dynamics in the Baltic region from drought indices agreement.

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Surging global increase of water demand as well as decrease in water quality put forward planning of the forthcoming water resource availability in much longer term with climate change included in this algorithm. The climate is already changing, and changes are predicted to be more accelerating in the future (IPCC, 2022). In the latest UN report the projected changes in annual mean precipitation vary substantially across the world (IPCC, 2022), while increase in global temperature is forecasted to be less spatially heterogeneous. Evaluation of future climate change impact on groundwater long term level change therefore its resources is the aim of the study.
The study is of regional scale and covers the Baltic states with 35 representative groundwater wells. The study covers three countries and wells more than 100 m deep. Regional coverage, overall long-term trends and identification of possible governing variables controlling spatial groundwater balance patterns considering climate change is the scope of this study.

Here we present our work of projected groundwater forecast for the short, middle and far future based on an ensemble of 13 EURO-CORDEX climate regional models under three Representative Concentration Pathway scenarios (RCPs) from the mildest to worst case scenario.
Future estimations of groundwater levels are based on the similarity of nowadays groundwater drought episode coincidence with surface drought indices individually estimated based on groundwater and surface water regime interaction during climate normals period.
Results show that overall increase of groundwater levels compared to recent climate normals period is expected without significant seasonal bias or spatial conformity. Gained results show that predictability of dry and wet periods during the autumn in most wells has the best results, therefore autumn can be also forecasted the best. Overall groundwater drought will be less frequent and less severe. Still, more extreme conditions are expected in the closest future period 2011-2040 with bias towards droughts and floods are expected in the period 2071-2100. There are indications that extreme conditions might occur more frequently during summer and autumn seasons. Also, wells with a trend towards dry condition are situated in the North-Eastern coast of Estonia while wells with less expected changes at all are typical in the central upland of Estonia.
Even though, the results are relevant solely to the Baltic region the used methods can be easily adopted worldwide.

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Alterations of ecological flow variables in Lithuanian rivers under climate change conditions

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Ecological flow determines the water quantity needed to sustain river functions and healthy fluvial ecosystems. This measure is important when managing rivers and aiming to meet WFD requirements of good ecological status. In Lithuania, only the definition of environmental flow is defined and this value is quantified as either an 80% or 95% probability of low flow (Q30) during the warm period. However, the ecological flow is in the first step of its determination. Existing anthropogenic pressures and changing climate are expected to bring new stresses on rivers, and new challenges for sustaining ecological flows in fluvial ecosystems. The aim of this study is to evaluate the effects brought by different climate change scenarios (RCP2.6, RCP4.5 and RCP8.5) on potential ecological flow variables (minimum, average and maximum of Q30) of Lithuanian rivers. Four low-land rivers, namely Verknė, Širvinta, Šešupė, and Bartuva were studied. All of these rivers represent different hydrological regions and feeding characteristics. The study was based on hydrological modelling performed by HBV software, assessing the temporal changes in flow regime as well as changes in ecological flow variables. The projections were made for the near future (2021-2040) and the far future (2081-2100). The results have shown that Šešupė, which is highly dependent on surface runoff (snow melt and precipitation), was the most vulnerable to climate change. It would experience the greatest decrease in discharge during the low-flow periods (30-60%). In the near future, the duration of Q30_min in Šešupė would face an increase by 4-9 days and an increase by 8-32 days in the far future. RCP8.5 scenario would have the greatest impact on flow regime patterns. The other studied rivers would experience less dramatic changes in low flow parameters in the near future. The Bartuva River as a precipitation-fed river would have an increase in minimum and average low flow

discharges. Verknė and Širvinta, both having groundwater feeding as a dominant component, in the far future will face a medium decrease in discharge (lower by 20% and 30% respectively) and a moderate increase in the duration of Q30_min by 7-16 and 6-15 days for each river respectively depending on RCP scenario. Although modelling flow regimes is a very important approach for projections of potential ecological flow variables, further studies incorporating additional parameters of river health, such as changes in water temperature, would give a better picture and deeper understanding of the behaviour of ecological indicators in the future.

Keywords: ecological flow, low flow, Lithuanian rivers, climate change, projections

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Effectiveness of water protection structures in forest drainage system: two years after construction

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Maintenance and renovation of the drainage network is carried out to ensure the functionality of the drainage system – to preserve high-quality forest stands, as well as provide safe access to forest resources. Nevertheless, the water quality of related waterbodies may be affected because of erosion during drainage network maintenance (DNM) operations. Therefore, water protection structures should be used to limit potentially negative effects by reducing the water flow velocity and minimizing the amount of eroded material and plant nutrients exiting a system.
This study was carried out in Latvia, in experimental forests of the Kalsnava Forest district in a catchment with dense drainage ditch network dominated by drained peatland forests. The effectiveness of two custom water protection structures – a peak flow control (PFC) structure and a sedimentation pond (SP) constructed during DNM was tested for two years. The catchment area of the forest drainage system is 791.3 ha.
Structures were built from August 2020 to January 2021 with sizes corresponding to related catchment size before proceeding with DNM operations upstream. pH, dissolved organic carbon, nitrate nitrogen, ammonium nitrogen, total nitrogen, phosphate phosphorus, total phosphorus and total suspended solids were measured in monthly water samples above and below the water protection structures.
Initial results when DNM was finished with six-month observation period revealed 65% mean effectiveness for the PFC (Klavina & Klavins 2021) and 68% mean effectiveness for the SP in reducing total suspended solids concentrations. Two years after the construction of the structures the mean effectiveness averaged to 61% for the PFC and 62% for the SP. Furthermore, PFC reduced dissolved organic carbon concentrations by 10% and total nitrogen by 4% on average. Looking at the study years separately, during the second year of observations mean effectiveness in detaining total suspended solids concentration was 25%, dissolved organic carbon – 26%, total nitrogen – 13% and phosphate phosphorus – 6% for the PFC; total suspended solids – 64%, total nitrogen – 1% and total phosphorus – 2% for the SP.
Both tested structures performed well during DNM detaining majority of total suspended solids from exiting the drainage system. During the second year of observations the PFC showed considerable effectiveness to detain dissolved organic carbon, total nitrogen and phosphate phosphorus. Although, concentrations of nitrogen and phosphorus compounds were generally low during all observation period. Observations are being continued to further investigate effectiveness of the structures.

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Don't forget about snow when modeling hydraulic head time series in the Baltic countries

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Analyzing the dynamics of hydraulic heads is of great importance for both environmental protection purposes as well as for characterizing the consequences of anthropogenic activities (Glazer and Likens 2012). Long-term time series of hydraulic heads are commonly used for such purposes. These historic monitoring data usually however contains various errors and missing entries (e.g., Retiķe et al. 2022). Time series modeling using impulse response functions (TS-IRF) is a convenient tool for modeling and filling head series due to short calculation times and parsimonious parametrization. These models are data-driven: the impact of drivers (such as precipitation) on the target (the head) is calibrated only for a point in space (Collenteur et al. 2019). Thorough knowledge of the relationship between the model parameters and its environmental setting is still lacking.
We employed 4 different TS-IRF model structures to simulate head time series of 735 monitoring wells across the Baltic countries. Daily precipitation, potential evaporation, and temperature data were calibrated to the measured heads. The models were calibrated over 10 years of data and validated over the most recent 5 years of data. The Nash Sutcliff Efficiency (NSE) and the Root Mean Squared Error (RMSE) were used to compare the modeling effectiveness based on the model structure. Subsequently, the correlations between the models and the environmental settings were determined. Variables of 5 groups were used to describe the setting of monitoring wells: geological, climatic, topographic, basin and land cover. Spearman rank correlation and Random Forest regression analyses were performed between these environmental variables and 1) the model fit (expressed as NSE values), 2) the parameters A, n, and a of the IRF that characterize its shape. The correlations were further described with the help of SHapely Additive exPlanations values and Partial dependence plots.
We found that accounting for snow cover periods in the modeling is of high necessity in the Baltics. Model structures best suited for modeling head series are the nonlinear snow model with Gamma function (NLS) and the linear model with a four-parameter function (L4) due to a better representation of the snow processes. While the obtained correlation coefficients were low to moderate, they offer a valuable insight. Models performed best in locations with shallow groundwater and less pronounced seasonality. The IRF parameters correlate not only to the geological and climatic characteristics, but also the topography. The obtained results will be useful for further development of the modeling methodology and to discern locations where this modeling approach is best applicable.

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The shifting of climate types and impact on seasonal temperature patterns and phenological events in Latvia

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Almost entire area of Baltics belongs to the same climate type, Dfb (according to the Köppen climate classification), which is characterized by humid continental climates with warm (sometimes hot) summers and cold winters. In the last decades whether conditions on the western part of Lithuania and Latvia more characterized by temperate maritime climates - there has been a transition (and still ongoing) to the climate type Cfb, that slightly changes seasonal patterns in air temperature regime as well in occurrence timing – phenological events in nature.
Temporal and spatial changes of temperature regime have been examined in whole territory of Latvia. We used two type of climatological data sets: gridded daily temperature from the E-OBS data set version 24.0e (Cornes et al., 2018) and direct observations from meteorological stations (data source: Latvian Environment, Geology and Meteorology Centre). We have digitized and analysed more than 47 thousand phenological records, fixed by volunteers in period 1970-2018 in Latvia for 8 taxsonomic groups.
The temperature regime has changed significantly in the last century - seasonal and regional differences can be observed in the territory of Latvia, that significantly influence seasonal events in nature, e.g., phenological events. Over the last 60 years (1961–2020), the annual mean temperature has increased by 1.2℃ across Latvia, with the largest increase during winter season. Climate warming has accelerated during the most recent climate normal by 0.5℃ compared to the previous period. More than 80% of spring phenological data series shows negative tendency as reported in most scientific publications on European phenology. In our data set, overall, autumn phenologies are occurring later over time or the trends are neutral.

The shifting of climate types slightly influences seasonality in Latvia landscape by changing temperature regime as well timing of phenological events in nature.
This study was carried out within the framework of the "Climate change and sustainable use of natural resources" institutional research grant of the University of Latvia (No. ZD2010/AZ03)

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Application of satellite and reanalysis precipitation for hydrological modeling in data-scarce Porijõgi catchment, Estonia

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The lack of adequate and reliable gauge observations has long been a major obstacle for hydrological modeling. This study focuses on a comprehensive evaluation of hydrological applicability of satellite and reanalysis-based precipitation products (IMERG, ERA5, PERSIANN-CDR, SM2RASC, and CMORPH-CRT) in Porijõgi catchment, Estonia. The evaluations were carried out in two parts: 1) evaluating the quality of satellite and reanalysis-based precipitation products relative to gauge observations, 2) comparing gauge-simulated streamflow with satellite and reanalysis-based simulations using the SWAT model. Results show reasonable variation in the detection capability of satellite and reanalysis-based precipitation products with further influence on the streamflow simulations. IMERG, ERA5, and PERSIANN-CDR show better detection capability for the monthly precipitation and demonstrated reliable performance in simulating the monthly streamflow. However, SM2RASC and CMORPH-CRT products have a common tendency to underestimate the gauged precipitation and fail to show satisfactory performance in streamflow simulation. Overall, our findings suggest that satellite and reanalysis-based precipitation products can be a priori alternative sources of precipitation data for hydrological applications in poorly gauged areas. However, along with the efforts to improve satellite and reanalysis-based precipitation products, it is important to develop more effective bias adjustment techniques at a daily scale.

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The long-term results of the Agricultural Runoff Monitoring Programme in Latvia – nitrate – nitrogen concentrations and loads

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Latvia University of Life Sciences and Technologies has been responsible for implementation of the Agricultural Runoff Monitoring Programme in Latvia since 1995 until present. Water quality and quantity monitoring activities are carried out continuously in the catchment areas with high share of agricultural land at multiple spatial scales including groundwater (20 wells), experimental plots (1 site with 16 plots), subsurface drainage fields (6 sites), small catchments (10 sites), small and medium size rivers (23 sites). The main objectives of the programme are to document and assess the current status and long-term changes in nutrient concentrations and evaluate the factors affecting water quality including natural and anthropogenic. The results obtained within the programme are periodically reported to the European Commission regarding the implementation of the Water Framework Directive (2000/60/EC) and the Nitrates Directive (91/676/EEC) in Latvia.
Water samples in the case of experimental plots, subsurface drainage fields, small catchments and rivers are collected on a monthly basis using a grab sampling approach or composite flow proportional sampling where discharge measurement structures and data loggers are installed. In the case of groundwater monitoring sites water samples are collected four times a year covering conditions different hydrological conditions including high and low groundwater level. Water samples are analyzed in an accredited laboratory for three forms of nitrogen and two forms of phosphorus according to the national standards, in this study only the results on nitrate – nitrogen (NO3-N) concentrations and loads are included.
The study results show a large variation in NO3-N concentrations among the spatial scales of monitoring with the lowest mean annual concentrations in groundwater (below 1.0 mg l-1) and the highest in the discharge from subsurface drainage fields and experimental plots (over 7.0 mg l-1). Overall, NO3-N concentrations follow the discharge patterns having the highest concentrations during high flow conditions in winter and spring, while the lowest concentrations during low or no flow conditions in summer and autumn. These patterns highlights the great importance of subsurface and surface drainage systems, which act as pathways for transport of excess water and soluble forms of nitrogen from agricultural fields to surface waters. At the river scale NO3-N concentrations tend to have a strong relationship with the share of agricultural land in the catchment area indicating for a direct relationships between agricultural activities and water quality. This determines the need for further implementation of measures targeted to reduce nitrogen losses from agricultural lands including edge-of-field and in-field practices.
Overall, it is essential to continue ongoing activities within the Agricultural Runoff Monitoring Programme also in the future, especially in the light of need to quantify changes in water quality as related to climate change and implementation of the Farm to Fork strategy aiming to reduce application of fertilisers by at least 20% and nutrient losses by at least 50% by 2030.

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Long-term monitoring of runoff from agricultural areas in Latvia

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Monitoring activities are essential to access long-term patterns in the quantity and quality of the agricultural runoff. The monitoring data on runoff in the Berze, Mellupite, and Vienziemite monitoring sites, were obtained within the Agricultural Runoff Monitoring Programme, which is determined by The Environmental Protection Strategy and carried out by the Department of Environmental Engineering and Water Management of Latvia University of Life Sciences and Technologies.
In order to assess long-term variability in runoff, the data collected in two spatial scales - drainage field and small catchment scale, were used in the study. Hydrological measurements were carried out using data loggers and measurement structures (V-notch weir, Crump weir, modified Crump weir). The time frame of the study is from 1995 to 2021.
The monitoring sites are located in different parts of Latvia: the Berze monitoring site is located in the central part, the Mellupite monitoring site in the western part and the Vienziemite site in eastern part of Latvia.
In the drainage field scale, the annual runoff in the Berze monitoring site ranges from 56.6 to 331.8 mm, with the average value of 172.9 mm, while in the small catchment scale the range is from 39.9 to 305.7 mm, with the average value of 162.1 mm. In the drainage field scale of the Mellupite monitoring site the annual runoff data range is from 97.5 to 449.8 mm, with the average value of 239.9 mm and in the small catchment scale data range is from 119.5 to 458.6 mm, with the average value of 241.4 mm. In the Vienziemite monitoring site, at the drainage field scale the annual runnof data range is from 110.9 to 516.8 mm, with the average value of 268.6 mm and in the small catchment scale data range is from 106.2 to 467.5 mm, with the average value of 272.0 mm.
Differences in the spatial scales and the overall range of runoff can be explained by different precipitation distribution in the area, as the relationship between annual precipitation and runoff at the Berze, Mellupite, and Vienziemite study sites can be described as positive and close or positive and moderate. For the Berze, Mellupite and Vienziemite monitoring sites drainage field scale, correlation coefficients of 0.72, 0.78, and 0.46 between annual precipitation and runoff were determined. For the Berze, Mellupite and Vienziemite monitoring sites subsurface drainage field scale correlation coefficients of 0.80, 0.74, and 0.48 were detected, respectively.
The long-term variability of runoff indicates climate change and can increase the risks of nitrogen and phosphorus losses from agricultural catchments and should be considered when it comes to fulfilling the water quality requirements set in the Water Framework Directive (2000/60/EC).

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Groundwater levels in the Baltic states: from data curation to revealing patterns

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Groundwater level time series are crucial for various groundwater-related studies and can be used to link patterns in groundwater levels to environmental factors. However, historical datasets often contain gaps and errors, leading to false results or large uncertainty if not properly treated. In this study, we present a comprehensive work on error treatment and gap imputation in the long-term

groundwater level monitoring datasets, as well as groundwater level pattern linkage to environmental factors.
The first objective of this study is to prepare groundwater level time series obtained from the national monitoring network in Latvia, Estonia and Lithuania for groundwater modelling studies. To achieve this goal, we identified the most common data errors found in long-term groundwater level monitoring datasets, presented techniques for visually detecting such errors, and proposed effective methods for treating them. Additionally, we included confidence levels to aid in the identification and decision-making process.
The second objective of the study is to impute missing values in groundwater level time series. We investigated the impact of missing value patterns on the performance of gap imputation methods commonly used to deal with regional-scale datasets. We present a new typical gap pattern introduction technique that mimics realistic gap patterns characteristic of regional-scale groundwater hydrographs. We applied this approach to groundwater level time series covering all three Baltic states and compared the performance of missForest, imputePCA, and linear interpolation. Our results showed that missForest significantly outperformed the other methods but struggled with imputing previously unseen extremes and anthropogenically affected time series.
The third objective of this study is to identify clusters of patterns in groundwater level dynamics in the Baltic region and to link these patterns to environmental features. We used backward variable elimination approach and random forest algorithm to reveal the most important features that govern groundwater dynamics in the study area. The results showed that clusters show a spatial pattern that can be linked to various features. The most important features for the clustering were mean groundwater level, temperature, precipitation, and relative position of the well, while some Soilgrids and Hydrogrid features also show importance.
Our approach provides valuable insights into groundwater dynamics in the Baltic States and can serve as a basis for sustainable groundwater management.

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Year-to-year meteorological variability is amplified in the hydrological response of the peat soils

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Soil water regime along with nutrient supply is controlling the forest type and its productivity. Generally, increased water supply leads to prolonged periods of soil water logging and poor soil aeration that in turn inhibit successful development of most temperate tree species.

In this study we configurated a Hydrus-1D soil water model for each of three specific wet forest plots in Latvia. Two year of soil-water regime observations were used for manual model calibration. In addition, forest plot-scale tree-ring chronology was used for model validation. To investigate the interaction between the soil properties and hydrological regime we explore "what-if" type scenarios, by implementing 0, 0.05, 0.15 and 0.45 m thick peat layer in the top of the soil column in each of the three models. In essence, increasing peat layer thickness increases soil water storage capacity as it replaces denser, less porous mineral soil in the root zone.

We find that increasing thickness of the peat layer leads to on average smaller depth to groundwater, smaller seasonal groundwater level fluctuations, and increasing corelation of year-to-year average groundwater level (temporal autocorrelation), that can be considered as a soil water memory effect. This memory effect is manifested as multi-year periods of low or high average groundwater depth that can lead to inherent instability of the soil hydrological regime amplifying the atmospheric (meteorological) variability. The soil water regime instability can have a range of ecosystem feedbacks such as adverse effects for the growth of certain tree species sensitive to soil water logging and fluctuations in greenhouse gas (CO_2 and CH_4) emissions from the forest soil.

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