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Groundwater recharge modeling – the importance of distributed soil information in hydrological models

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Spatially distributed soil information as input for hydrological models has the potential to improve the representation and physical realism of spatio-temporal hydrological processes. Since spatially distributed soil information is often not available, lumped parameters are frequently used in hydrological models to describe soil functions. However, especially the modeling of hydrological processes in the vadose zone – and consequently groundwater recharge – requires information on soil hydraulic properties. The main objective of this study is the prediction of future groundwater recharge rates for the extent of Austria under changing climate conditions. To reach this goal, we use Machine Learning (ML) based soil hydraulic maps as a basis for the parameterization of the COntinuous SEmi-distributed RunOff model (COSERO).

For the spatial prediction of the soil parameters, XGBoost, a boosting ML-algorithm, was trained with soil hydraulic maps of the federal state of Lower Austria and available environmental raster datasets (e.g. climate data, digital elevation model, landcover etc.). Based on the Austrian wide available environmental covariates, the trained XGBoost model was then used to predict relevant soil hydraulic properties for the whole area of Austria (approx. 83 900 km^2) at a target resolution of 1 x 1 km^2.

For our hydrological model set-up, we rescale the predicted soil hydraulic properties into the model parameter range and domain. After parameter optimization, i.e. in our case scaling the mean and thereby keeping the spatial patterns of the parameters, the conceptual rainfall-runoff model COSERO simulates spatially distributed discharge for the study area. We compare our model results to simulations of a model version using lumped soil parameters to assess the differences in the spatial distribution of groundwater recharge rates. Additionally, we analyze the quality of discharge simulations depending on the respective parameterization of the model. Overall, the results show an increased performance when using distributed soil hydraulic properties.

In summary, this study demonstrates the importance of considering the variability of soil information in a hydrological model framework and evaluates the suitability of implementing digital soil mapping products in groundwater recharge modeling.