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Prediction of drain flow fraction at high spatial resolution by combining physically based models and machine learning

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In Denmark, about half of the agricultural land is artificially drained. These drainage systems have a significant effect on the hydrological system. Knowledge about the spatio-temporal distribution of drain flow is crucial to understand aspects such as groundwater recharge, streamflow partitioning and nutrient transport. Still, quantification of drain flow at regional and large scale remains a major challenge: Data on the distribution of the installed subsurface drainage system are scarce, as are measurements of drain flow. Large-scale simulations of drain with physically-based hydrological models are challenged by scale, as drain flow is controlled by small-scale variations in groundwater depth often beyond the model resolution. Purely data-driven models can struggle representing the complex controls behind drain flow.

Here, we suggest a metamodel approach to obtain a more accurate estimate of generated drain flow at high spatial resolution of 10 m, combining physically-based with data-driven models. Our variable of interest is drain fraction, defined as the ratio between drain flow and recharge per grid cell, which is an indicator for flow partitioning between drain and recharge to deeper groundwater.

First, we setup distributed, integrated groundwater models at 10 m grid resolution for 28 Danish field-scale drain catchments with observations of drain flow timeseries. A joint calibration of these field-scale models against observed drain flow resulted in an average KGE of above 0.5. Subsequently, the simulated drain fractions from the field-scale models were used to train a decision tree machine learning algorithm. This metamodel uses various mappable covariates (topography and geology-related) available at high resolution for all of Denmark. The metamodel then is used to predict drain fractions, within its limits of applicability, across relevant areas of Denmark with significant drain flow outside of the field-scale models.

Eventually, the predicted drain fractions are intended to inform national, large-scale physically based hydrological models: An improved representation of drain can, for example, make those models more fit to improve national targeted nitrate regulation.