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Modelling water and nutrient dynamics in boreal forested catchments: evaluation and application of a distributed model

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Both monitoring and model simulation are useful for understanding and detecting environmental changes. Water quality models are increasingly used to predict and better understanding of hydrological and nutrient processes in impacted catchments. In this study, we develop a novel grid-based catchment-scale water quality model (NutSpathy) for predicting nitrogen (N) and phosphorus (P) leaching in boreal forested catchments based on a simplified and computationally efficient hydrological model (SpatHy). The model framework includes (1) a nutrient balance component where nutrient uptake, release and storage are quantified grid by grid at daily scale based on meteorological drivers and open GIS data (soil fertility classes, species, stand volume, height, age, etc.), and (2) export loading component which includes an exponential delay function and is built upon the hydrological simulation and nutrient balance quantification.

The model was further applied and evaluated in 9 selected boreal forested catchments with varying areas from 33 ha to 2100 ha across the whole Finland, which were calibrated separately using local monitoring data in terms of nutrient concentration, daily runoff and export loading. The temporal and spatial N and P leaching corresponding to variability of hydrological regimes and catchment characteristics were also investigated. Results show that runoff was well reproduced for both calibration and validation, with good Nash–Sutcliffe efficiency and small bias. It is manifested that NutSpathy is capable of predicting N and P concentrations on satisfactory level, and simulating export loading with an even better performance during climatological events in boreal forested catchments. This verifies the controlling role of hydrology on nitrogen and phosphorous transport processes. In addition, the uncertainty parameters are identified and model performance in various cases is discussed.