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Land use control of nitrate export behavior across catchments

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Nutrient exports from catchments and their temporal and spatial variability significantly affect downstream water quality and ecosystem health. There is hence a need to better understand and classify catchment nutrient export dynamics in order to reproduce catchment functions (such as nutrient mobilization and retention) and predict the response of these functions to changing boundary conditions. However, the complexity of catchment structure and the multitude of the processes involved challenge this objective. One approach to meet this challenge is a top-down, data-driven analysis of integrated catchment responses, such as discharge and solute concentration time series. For top-down analysis, different catchments are compared to identify key variables governing catchment response. We conducted a multi-catchment study applying top-down methods to analyze nitrate concentration and discharge time series from streams draining nine catchments in central Germany. The studied catchments, ranging from "pristine" mountains to agriculturally-managed lowlands, span gradients in land use, geology, and climatic conditions. We hypothesized that land use type is the main control on stream nitrate concentrations and catchment export behaviour, with more chemostatic export behaviour occurring in catchments with higher percentages of agricultural land use due to the presence of large nitrate stocks that effectively function as an unlimited nitrate storage. Consistent with this hypothesis we found that median nitrate concentrations were positively correlated with the percentage of agricultural land use in the different catchments despite differences in catchment climatic and geological conditions. Magnitude and direction of concentration-discharge relationship was evaluated using the slope b of the linear regression of log nitrate concentrations vs. log discharge as a metric for export behaviour. All catchments exhibited a positive slope b indicating concentrations increase with increasing discharge. The slope b was positively correlated with the percentage of agricultural land being artificially drained, which suggested that a higher share of drained agricultural land within the catchments results in a more dynamic export behaviour. Thus, a high percentage of agricultural land use, and subsequent higher nitrate input and storage, does not necessarily lead to chemostatic export conditions. While median concentrations were a function of agricultural land use, concentration dynamics and export behaviour were controlled by the presence of artificial drainage as the dominant input pathway of nitrate to surface waters. These results illustrate that it is feasible to use a multi-catchment top-down analysis to evaluate both dominant controls of nutrient export and the importance of land management on nutrient dynamics in the receiving surface waters.