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# Nitrogen transport and retention dynamics across central European catchments using large-sample data

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Human activities, especially agricultural practices, have significantly altered the Earth's landscape and the global cycle of nitrogen. In Europe, diffuse nitrogen (N) input from agriculture has been identified as a major driver of marine eutrophication. Despite a long history of measures, little improvement in groundwater and surface water quality has been observed. Recent studies have attempted to provide insights into nitrogen dynamics at the catchment scale, helping to explain the causes and effects of persistent water quality problems. However, there is a lack of large-scale, long-term studies that provide insights into both biogeochemical and hydrological N legacies under different landscape settings. Here using data of more than 100 German catchments of the last seven decades, we synthesis the nitrogen transport and retention dynamics, as well as their dominant (landscape and climate) controls in a large-sample setting. To this end, we adapted the mHM-SAS model (Nguyen et al., 2021) to reflect regional-scale biogeochemical and hydrological N legacies, taking into account the historical development of both diffuse and point sources. The underlying parameterizations were constrained using instream N concentrations. We found high heterogeneity in catchment responses to N inputs. The fractions of N surplus that were stored in the soil, removed by denitrification, stored in the subsurface, and finally exported to the stream vary over a wide range. Our analysis of the long-term (1950-2014) average N balances from all catchments suggests that a majority (mean = 57%) of N surplus was removed by denitrification, followed by stream N export (27%) and the rest was stored in the catchment (16%). Despite the reduction in N surplus after 1990s, biogeochemical legacy reflected in the soil N build-up showed an increasing trend over the analyzed period (1950-2014) across a majority of the study catchments. As for the hydrologic legacy, we found a varying range of mean transit times of discharge between 3.5 years and 13.1 years (95% confidence interval) among the analyzed catchments. Overall, our large-sample analysis provides a detailed overview of biogeochemical and hydrological N legacies across Germany; and thus provides useful insights for an improvement of agricultural practices and water quality management in Central European landscapes.

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