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Trajectories of nitrate input and output in three nested catchments along a land use gradient

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Increased anthropogenic inputs of nitrogen (N) to the biosphere during the last decades have resulted in increased groundwater and surface water concentrations of N (primarily as nitrate). Although measures have been implemented to reduce N-inputs, they are not always reflected in decreasing instream nitrate concentrations and loads. This limited response to the measures can either be caused by an accumulation of N in the soils acting as a biogeochemical legacy or by long travel times (TTs) of inorganic N to the streams forming a hydrological legacy. Here we jointly analyze agricultural and atmospheric N inputs with long-term observations of nitrate concentrations and discharge in a mesoscale catchment in Central Germany to learn on time lags and the potential build-up of legacies. For three nested sub-catchments with increasing agricultural land use, we assess both, the catchment scale N budget and the effective TT of N to evaluate time lags and the potential for the buildup of N-legacies. We show that in the 42-year-long observation period, the catchment received an average N-input of 36.1 kg/(ha a), of which 97 % derived from agricultural sources. However, the riverine N-export sums up to 5.6 kg/(ha a) indicating that the catchment retained 85 % of the N-input. Removal of N by denitrification could not fully explain this imbalance hinting to the accumulation of an N-legacy in the catchment. Log-normal travel time distributions for N fitted as transfer function of the input and output time series differed seasonally, with modes spanning 8–17 years. Under low-flow conditions, TTs were found to be systematically longer than during high discharges. Systematic changes in C-Q relationships suggest a dominance of hydrological N-legacy rather than a biogeochemical N-fixation in the soils, which should result in a stronger and even increasing dampening of riverine N-concentrations after sustained high N-inputs. The input-output imbalance, the long time-lags and the lack of effective retention by denitrification in the catchment let us conclude that catchment management needs to address both, a longer-term reduction of N-inputs and shorter-term mitigation of today's high N-loads.