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Assessing Nitrogen Legacies in Western Europe

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Intensive agricultural land use have introduced vast quantities of nutrients such as reactive nitrogen (N) to soils and subsequently to groundwater and surface waters. High nitrate concentrations are still a pressing issue for drinking water safety and aquatic ecosystem health e.g. in Europe, although fertilizer inputs have been significantly lowered in the last decades. This is partly due to a slow response of riverine nitrate concentrations to changes in nitrogen inputs attributed to N legacies in catchments. N can be stored organically bound as a biogeochemical legacy in soils or can be slowly transported as nitrate in groundwater forming a hydrologic legacy. Legacy can thus lead to a net retention of N in catchments and to substantial time lags in the response to input changes. Here, we systematically explore legacy effects over a wide range of catchment in the Western European countries France and Germany. We are making use of long observational time series of nitrate concentration in 238 catchments covering 40% of the total area of France and Germany. We apply a Weighted Regression on Time, Discharge, and Season (WRTDS) to derive continuous daily flow-normalized concentrations and loads. The temporal pattern of concentration and loads at the catchment outlet is compared to the N input time series evolving from agricultural N surplus, atmospheric deposition and biological fixation. We found that on long-term catchments retain on average 72% of the N input. Time lags between input and output were successfully explained by a lognormal transport time distribution. The modes of these distributions were found to be rather short with a median mode of 5.4 years across all catchments. Based on this data-driven assessment only the fate of N in the catchments is hard to assess as denitrification in soil and groundwater can lead to similar observations as the storage of N in legacies. Focusing on the mobile part of N that is exported by catchments, we estimate that a substantial amount of N is still stored in the subsurface that will be released in the coming years. We therefore analyzed how catchment nitrate export will evolve under the scenario of a total cut down, reduced or constant future N inputs. We report the expected timescale of reaction to implemented measures to help tackling this pressing water quality problem.