Nitrogen Legacies in the Transboundary Lake Erie Basin

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Lake Erie is a source of drinking water, recreation, and commercial opportunity for both the United States and Canada, making the protection of its water quality essential. In the past decades, Lake Erie's ecosystems have been adversely impacted by recurring toxic algal blooms. These algal blooms are attributed to nitrogen (N) and phosphorus pollution from agricultural runoff. Despite recent efforts to reduce N application in the Lake Erie basin, high levels of N concentration persist in surface and groundwater systems. One of the reasons for this apparent stasis in N concentrations is legacy stores of N in landscapes that contribute to lag times in water quality response, even after inputs have ceased. Legacy N is stored in the soil and slow-moving groundwater and makes up a large portion of current N contamination. Here, we aim to quantify N legacies across the entire Lake Erie basin to predict time lags in water quality improvements in surface and groundwater. We use a process-based model, ELEMeNT, to quantify legacy N stores and watershed-scale N dynamics over the past century across the basin. Such models inform nutrient management practices across the Lake Erie basin by explicitly incorporating legacy dynamics.

Our study shows that N surplus (the difference between N inputs and non-hydrological N outputs) has been rising across most Lake Erie sub-watersheds since 1950 and has only started to plateau or decrease around 2000. Agricultural inputs from manure, fertilizer, and biological fixation were the lead contributors to N surplus in agricultural sub-watersheds, and domestic N was the lead N contributor in urban sub-watersheds. Since 1950, between 4% and 44% of N has been stored as legacy N (23% median). On average, 92% of this N legacy is retained in the soil and 8% is in the groundwater. Through correlation analysis, we have found that higher fractions of groundwater N and SON legacy accumulation are correlated with slower travel times and lower tile drainage, while wastewater denitrification emerged as the dominant component in urban sub-watersheds. These results provide insight into drivers of legacy N and N release in sub-watersheds, which could aid in targeted nutrient management across the watershed.