Modelling Legacy Nitrogen Dynamics in the Transboundary Lake Erie Watershed

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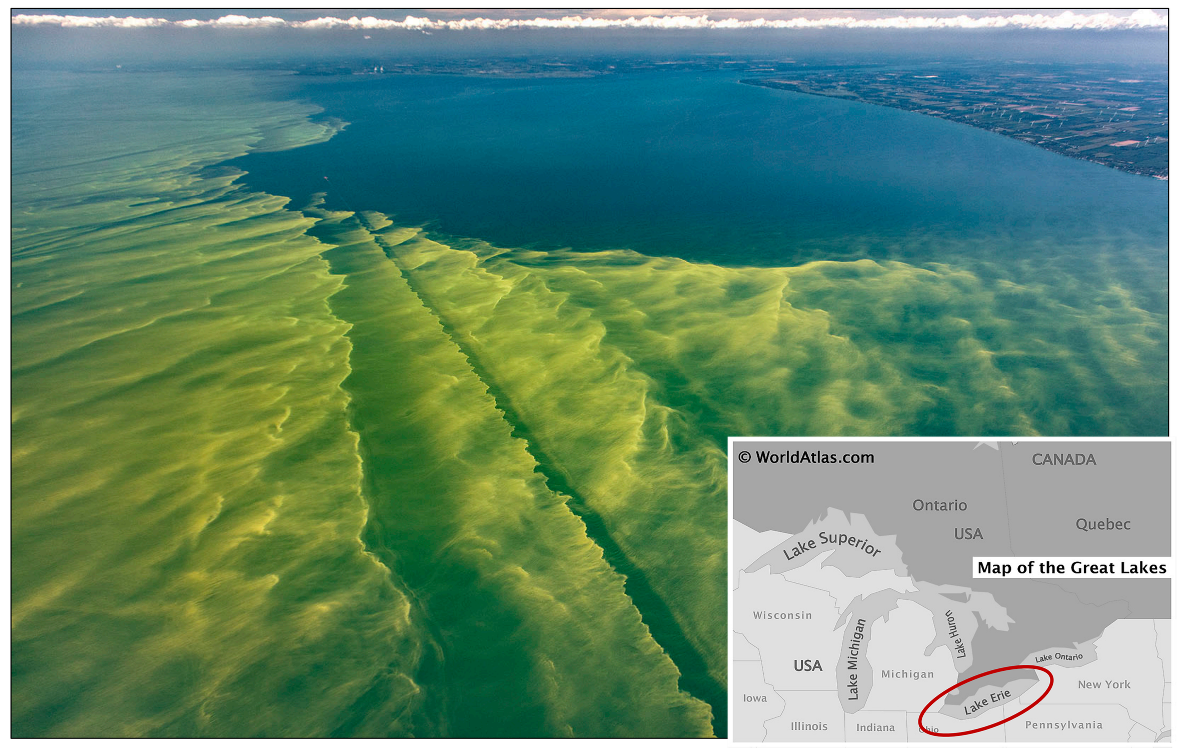
Motivation: Lake Erie N Pollution



The problem: In the past few decades, Lake Erie has experienced extreme algal blooms and eutrophication. It is widely acknowledged that these nearly-annual algal blooms are driven by an overabundance of nitrogen carried by rivers into the lake. Policies across the Great Lakes and the globe have been put in place to reduce the application of N in impacted watersheds. Despite these efforts made to reduce nutrient application, we have not seen a matching reduction in N stream concentrations. One of the reasons behind this apparent stasis in N concentrations, is legacy stores of N in landscapes. These sources contribute to lag times in water quality response, even after inputs have ceased [1,2,3].

Our Goal: Using a data analysis and computational modelling approach, we hope to identify and quantify historical N legacy stores across the Lake Erie Basin across time and space.

Capturing a Legacy of N

The **ELEMeNT** model is a semi-distributed process-based model. It stands out when compared to many other models due to its *long-term* input structure and its focus on legacy N dynamics. The model considers spatially distributed long-term N application, N removal, streamflow, and land use for a given watershed and produces informed estimates of current N legacies[3,5,6].

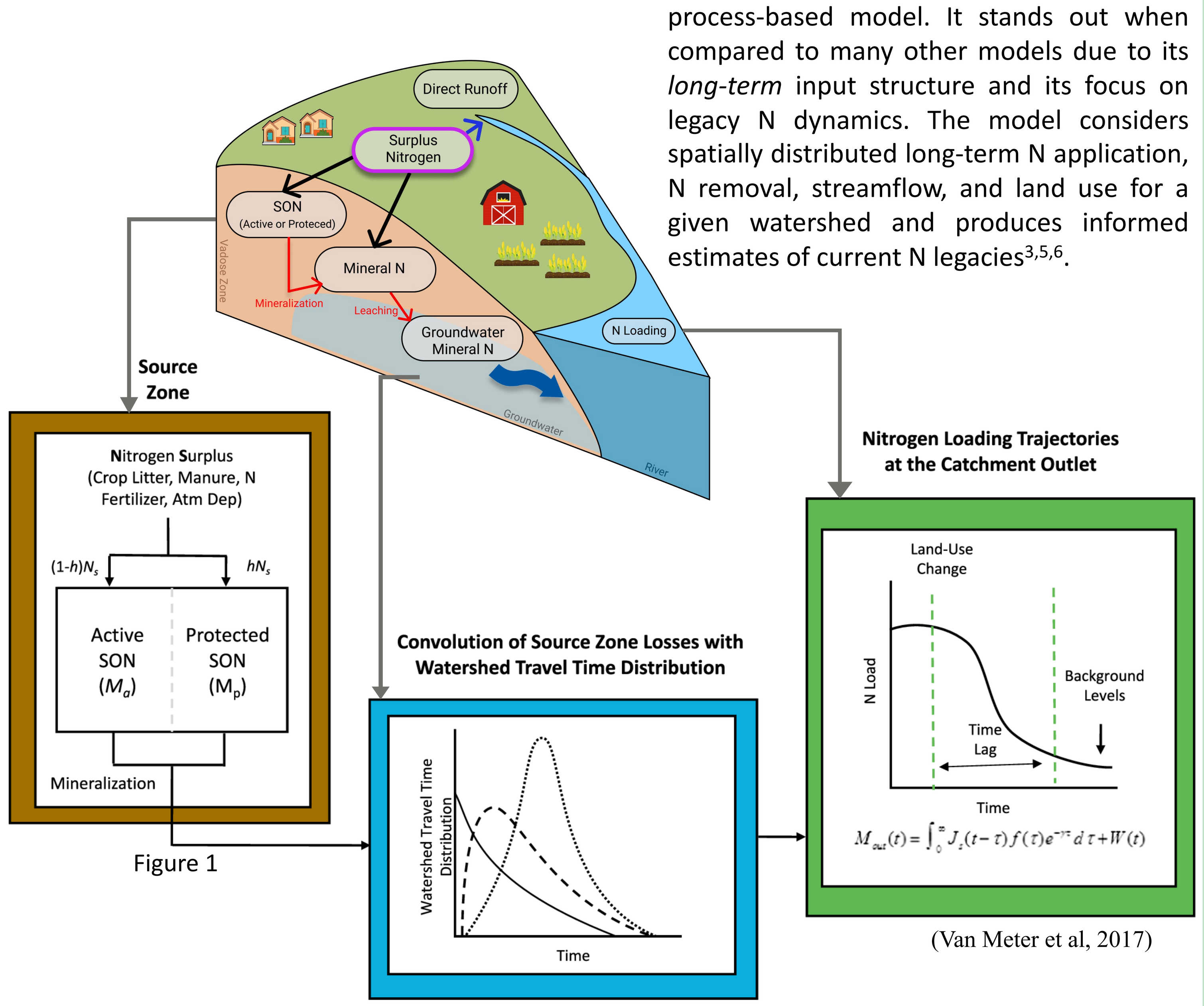


Figure 1

(Van Meter et al, 2017)

Lake Erie N surplus over Time

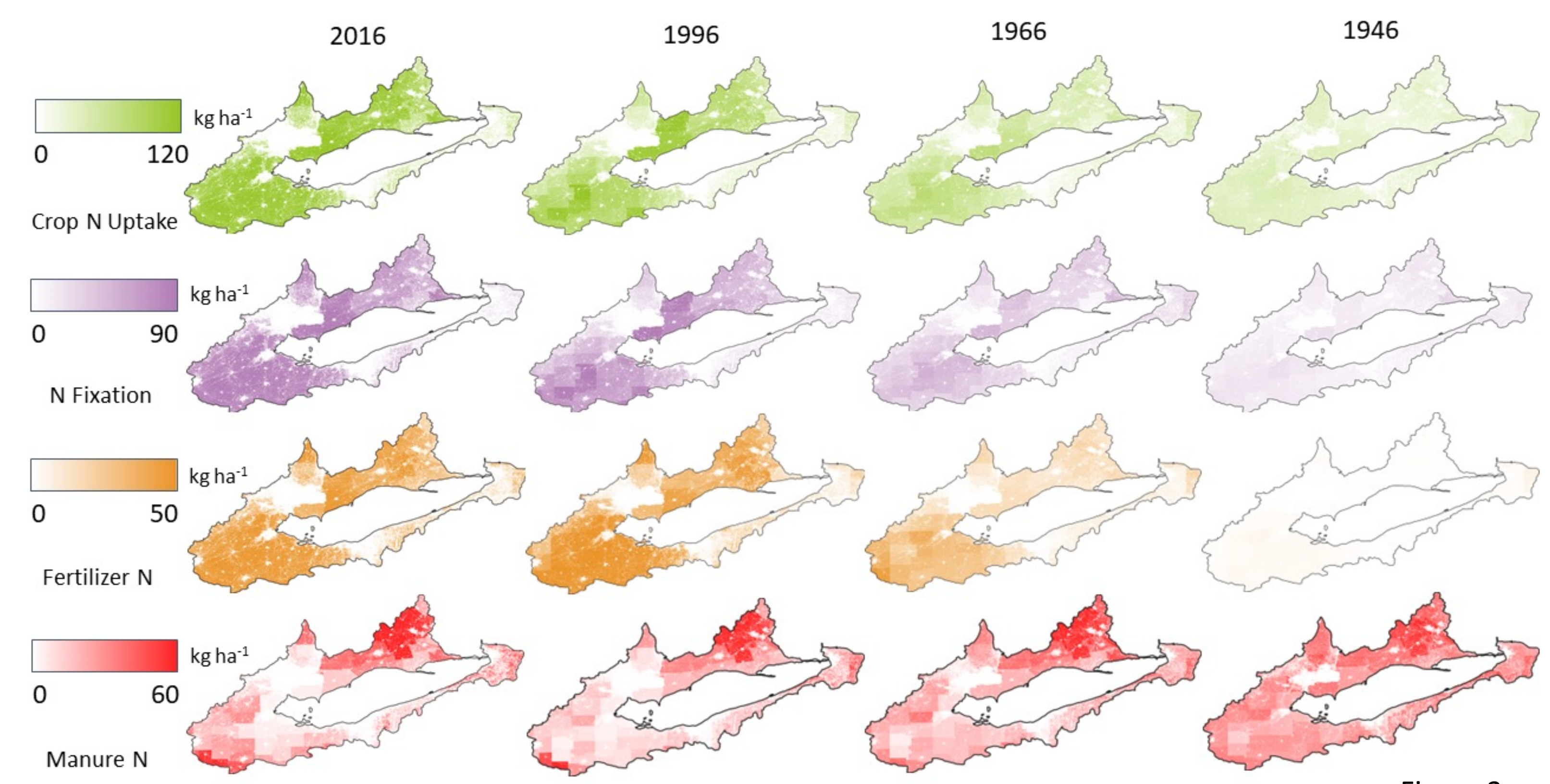


Figure 2

We gathered 86 years of binational **N Inputs** (manure, atmospheric deposition, fertilizer application, biological N fixation, and human waste N). By subtracting yearly **N uptake** (crop removal), we are left with 'surplus' N left in the landscape to reach our waterways. Surplus trends for the basin vary across space and time. The **TREND**[4] dataset was used for all U.S.A counties, and a comparable framework was used for the Ontario Counties.

Examples of watershed-scale N surplus trajectories and components for three Lake Erie sub-watersheds

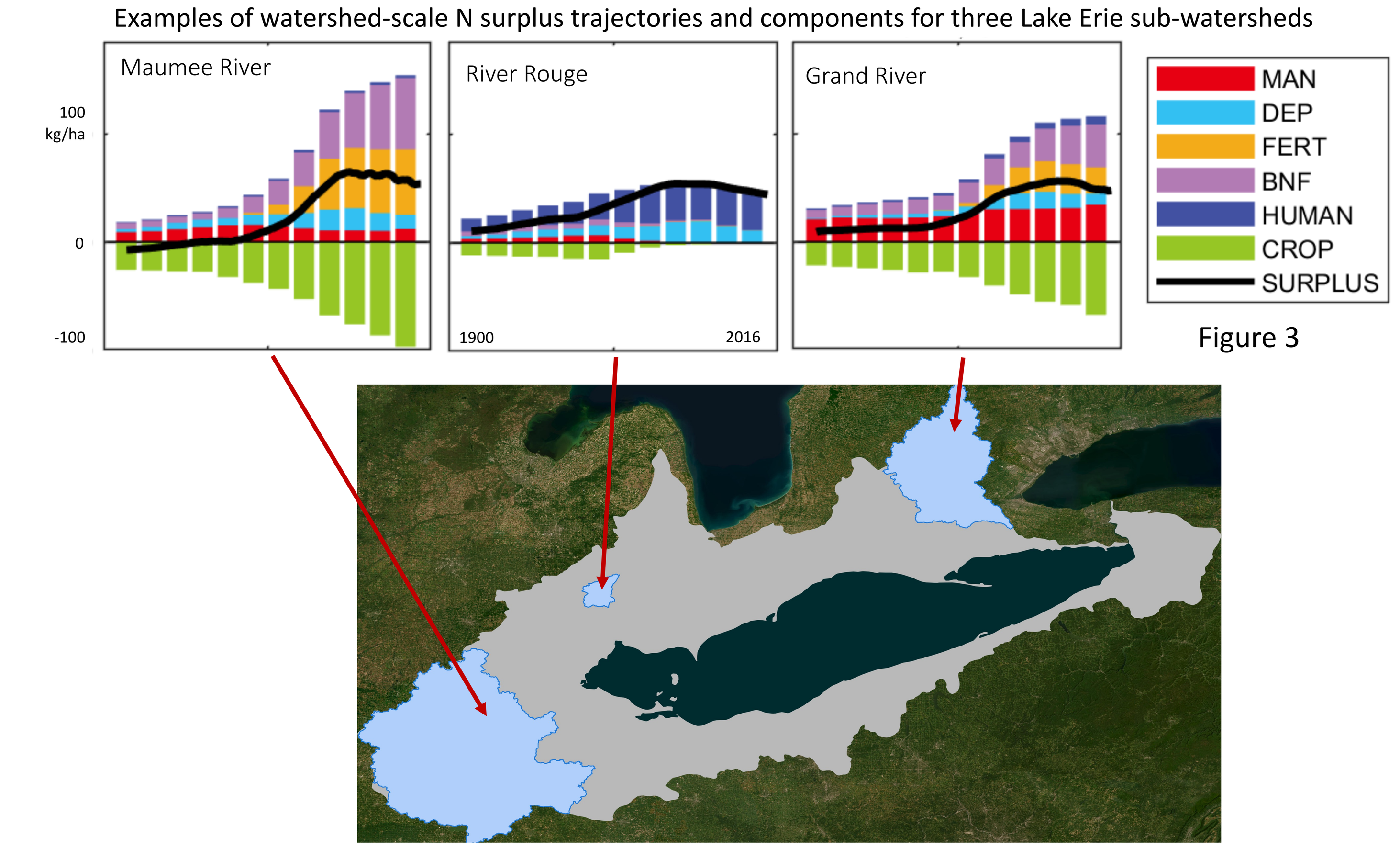


Figure 3

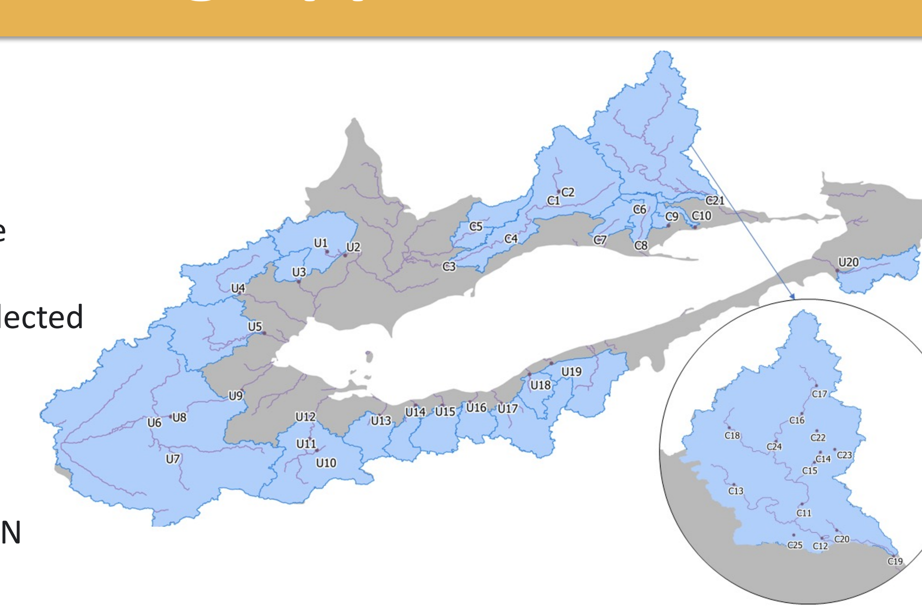
Modelling Approach

In this project:

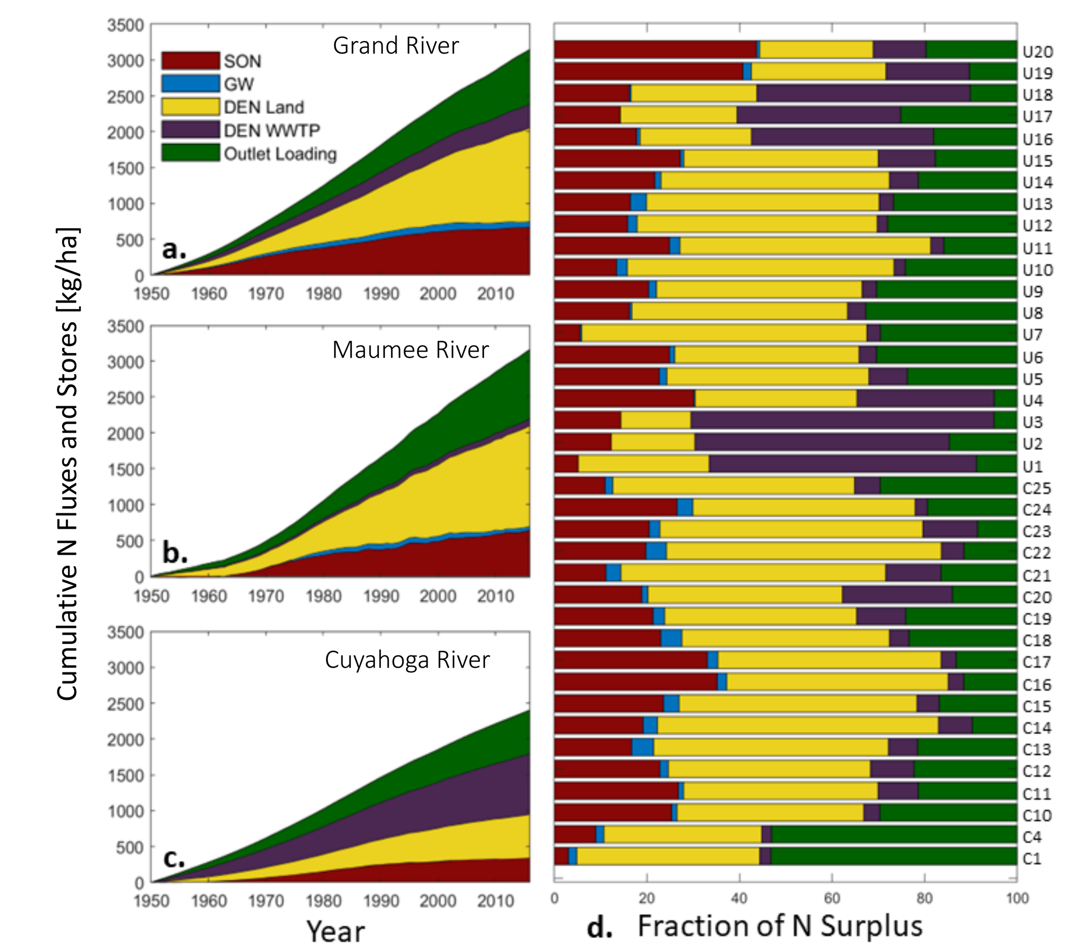
- We studied **45 basins**
- Each basin's **model parameters** were calibrated to **N loading**, and **SON**
- **Top performing** parameters were selected for each basin

Leading to:

- 45 model **parameter sets**
- 45 model **ensemble** runs simulating N loading and N legacy accumulation

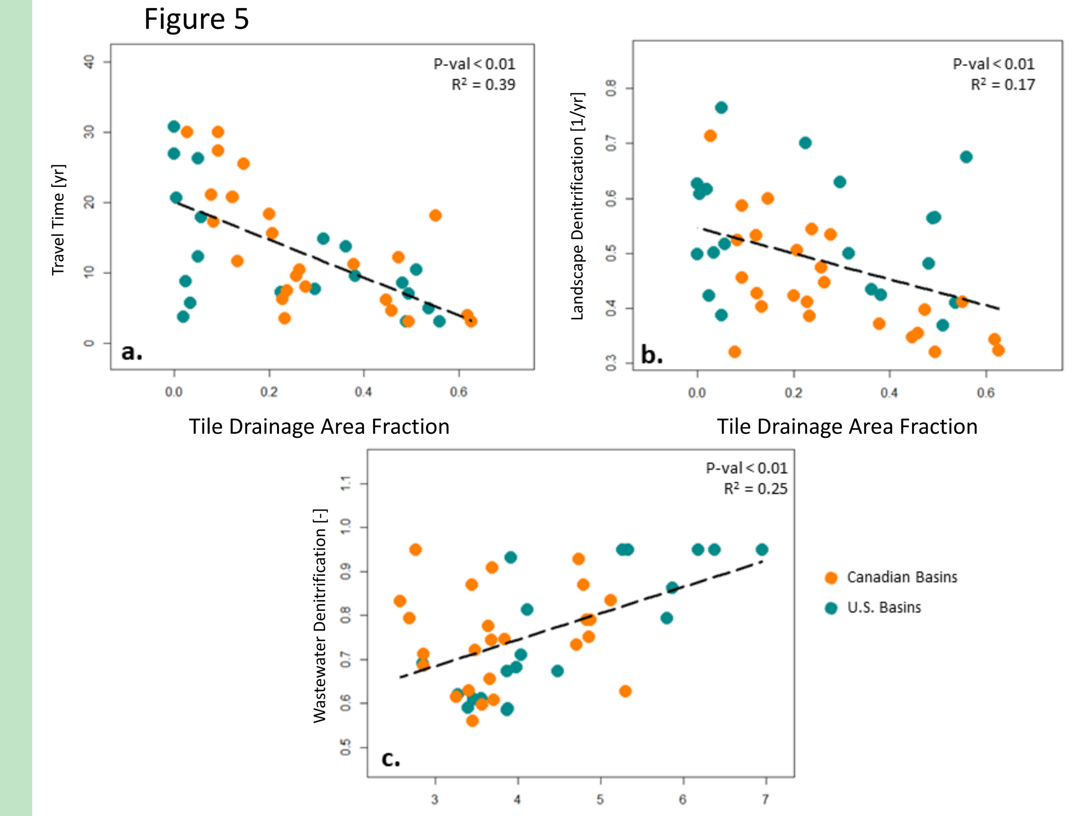


Model Results: Lake Erie N Accumulation



The stores of legacy N across the LEB have been **increasing** from **1950 to 2016**. Sub-watersheds have experienced up to **952 kg/ha of legacy N storage** (median: 603 kg/ha). Up to 910 kg/ha of N has been stored in the soil and as much as 187 kg/ha has been stored in the groundwater. Across all of the sub-watersheds, **only 5% to 53% of applied N has reached the stream** (20% median); the rest has been either denitrified or stored as legacy N. Among the sub-watersheds, up to 44% of surplus N has had the potential to build up as legacy N.

What Drives this Accumulation?



Using a correlation analysis between watershed features and model parameters, we were able to establish some drivers of N retention across the Lake Erie watershed.

Groundwater **travel times** range from 5 to 35 years and was significantly **negatively correlated** with the amount of **tile drainage** in the sub-watershed.

Soil and groundwater **denitrification rates** are also **negatively correlated** with the degree to which **tile drainage** is used in the watershed.

More tile drainage = Less legacy N accumulation

Wastewater denitrification rates were **positively correlated** with the population density of sub-watersheds, so the more urban the watershed, the higher the wastewater denitrification rates.

More urban = More N removed from WWTP

References

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