Changes in Lake Phosphorus Loading and Cycling Accompanying the Transition from Agricultural to Urban Land Use in a Watershed of the Greater Toronto Area

Stephanie Slowinski[1†], Jovana Radosavljevic[1†], Alyssa Graham[1], Isabella Ippolito[3], Kathryn Thomas[4,5], Fereidoun Rezanezhad[1,2], Mahyar Shafii[1], Chris T. Parsons[1,6], Nandita B. Basu[1,2,7], Johan Wiklund[3], Roland Hall[2,3], Philippe Van Cappellen[1,2]

[1]Ecohydrology Research Group, Department of Earth and Environmental Sciences, University of Waterloo, Canada; [2]Water Institute, University of Waterloo, Canada;
[3]Department of Biology, University of Waterloo, 200 University Avenue W, Waterloo, ON, N2L 3G1, Canada ; [4]Faculty of Science, Ontario Tech University, 2000 Simcoe St N, Oshawa, ON, L1H 7K4, Canada; [5]Stillwater Environmental, Paris, ON, N3L2K6, Canada;
[6] Environment and Climate Change Canada, Canada Centre for Inland Waters, 867 Lakeshore Road, Burlington, Ontario, Canada; [7]Department of Civil and Environmental Engineering, University of Waterloo, 200 University Avenue W, Waterloo, ON, N2L 3G1, Canada.

Background & Motivation

- Phosphorus (P) = important (co-)limiting nutrient whose excess loading can cause eutrophication and associated water quality deterioration
- Land use land cover (LULC) = important control on P loading to lakes
- P loading from agricultural LULC is well-studied whereas impact of urban LULC on receiving lakes is less well-studied

Research objective: Analyze impact of historical LULC changes in Lake Wilcox watershed on in-lake biogeochemical P cycle, trophic state, and bottom water oxygenation by reconstructing lake P budgets for 4 identified watershed development phases using dated sediment core chemical profiles

Study site & Methods

Lake Wilcox

- Natural kettle lake in Richmond Hill, near Toronto
- Water residence time = 2 years
- Sediment core (76 cm) collected in 2019, analyzed to reconstruct time series of in-lake chemistry, with focus on P cycle

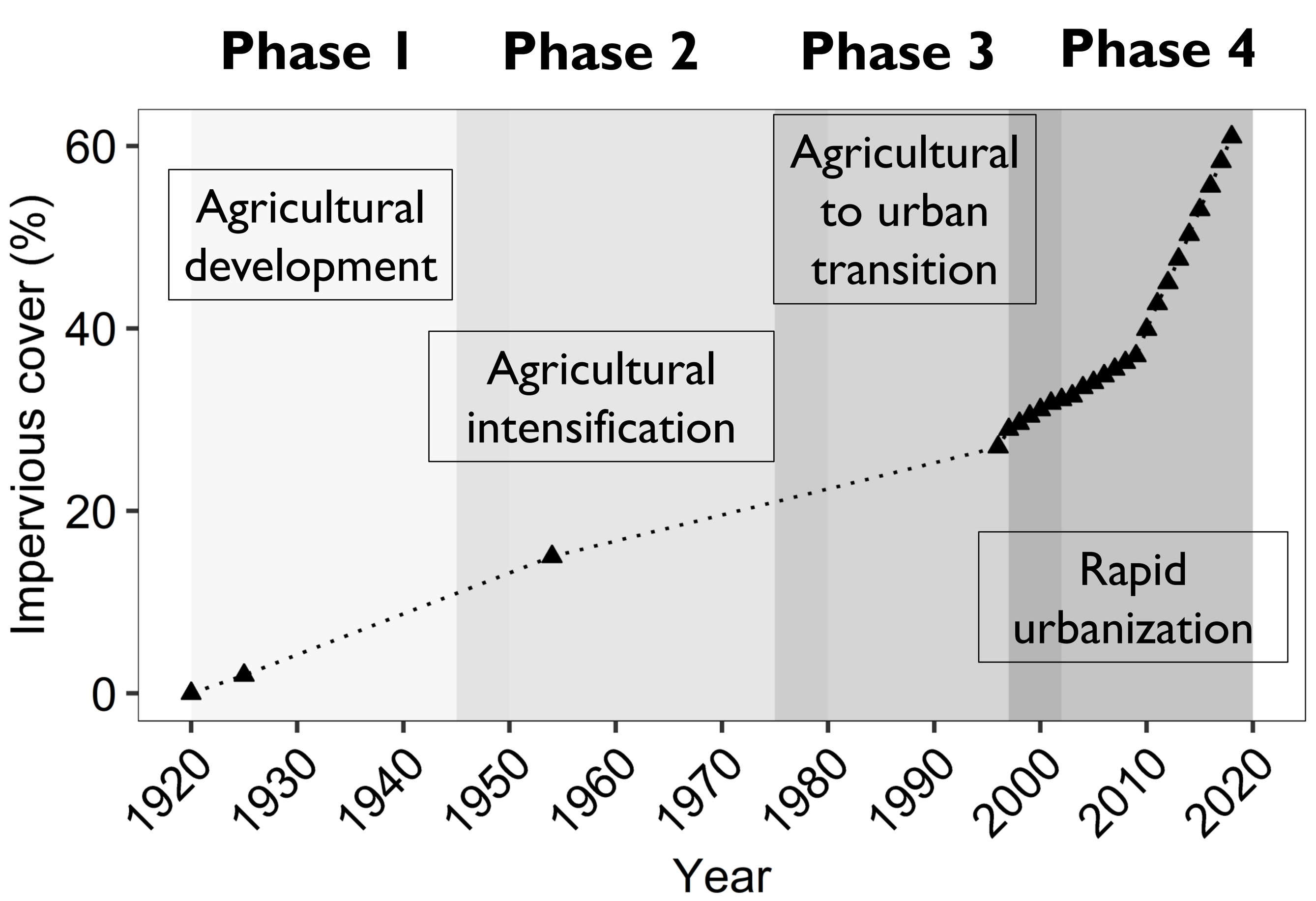

Figure 1. Impervious cover time series and identification of 4 watershed development phases

Key findings

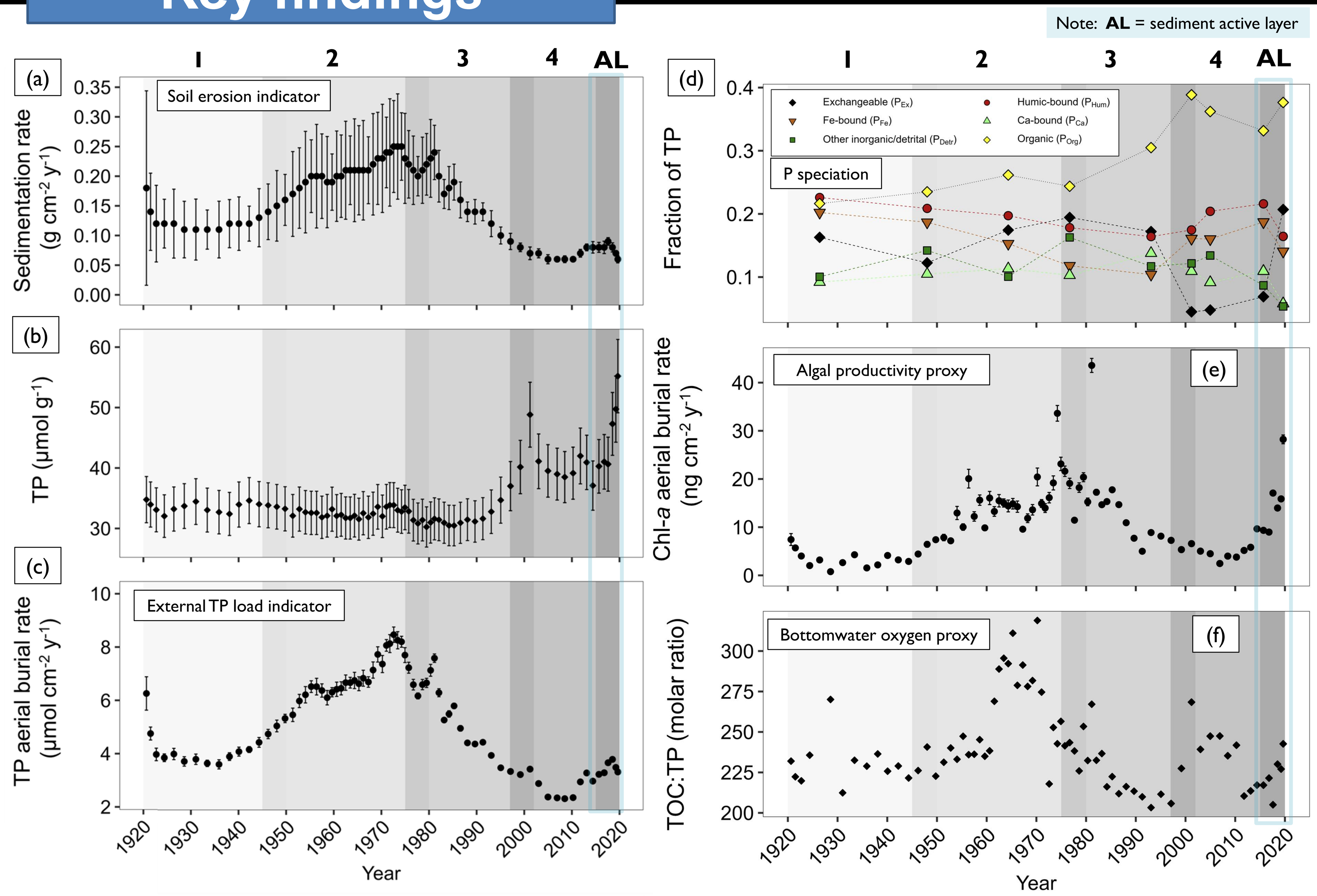

Figure 2: Sediment core-derived chemical profile time series: sediment accumulation rate (a), TP concentration (b), TP burial rate (c), P species fractions (d), chlorophyll-a burial rates (e), and TOC:TP molar ratios (f)

Agricultural intensification (phase 2):

- Increase in watershed (external) sediment and TP loading
- Increase in algal productivity, lake becomes eutrophic, accompanied by increase in bottom water hypoxia
- Organic P becomes the dominant fraction (~25%) in TP burial

Transition to urban LULC (phase 3):

- Decrease in watershed (external) sediment and TP loading
- Decrease in algal productivity
- Reason: soil conservation measures and removal of septic systems

Urban expansion (phase 4):

- Sediment TP concentration increases but TP burial decreases further
  - Reason: Increased sediment retention by stormwater ponds (SWPs)
- Increase in sediment TP recycling efficiency (internal P loading)
  - Reason: intensification of water column stratification due to salinization, and (potentially) loss of detrital P sink due to mineral element retention in SWPs

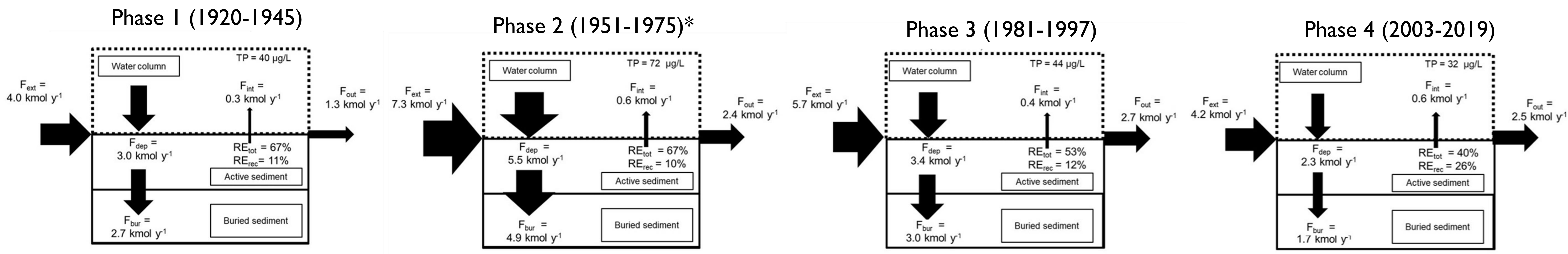

Figure 3: Reconstructed total P (TP) budgets for LW for four phases of LULC. Note that for phase 2, the most severe eutrophic state conditions which occurred at the end of the phase are represented in the budget (*)

Take-home messages

- Transition from intensive agricultural LULC to urban development accompanied by:
  - ➢ ~50% decrease in external TP loading due to installation of stormwater management infrastructure, mainly sediment retention ponds
  - ➢ Increased contribution of sediment P recycling (i.e., internal loading) (from 10 to 25%)
- Urbanization causes salinization of the lake, which in turn strengthens water column stratification and leads to increased bottom water anoxia → Increased anoxia promotes internal P loading
- Agricultural soil conservation practices and urban stormwater ponds are very effective at lowering watershed P exports
- Curbing salt inputs will be essential to restore the lake