Legacy Phosphorus Across Canada: Insights from a 60-Year Dataset

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1. Background and Questions

- Canada has a long history of cyanobacterial blooms, dating back to the 1970s.
- Phosphorus (P) loading to surface water from to intensive agricultural practices is the key driver of the degradation of water quality.
- According to Environment Canada in 2011, **32**% of water quality monitoring sites in Canada exceeded P guidelines during 2005-07.
- In 2013, Lake Winnipeg was named as the world's most threatened lake.

Algal bloom in Lake Winnipeg in 2017 (Ref: ESA; CBC)

Given the need to manage P to protect water resources/improve water quality, it is critical to analyze the history of P use across Canada and the sources of P contribute to the accumulation of P in the landscape. Our study attempts to answer the following questions:

1. How do P inputs and non-hydrological P outputs changes across Canada from 1961-2021?
2. How does PUE change across space and over time?
3. How can we use both P accumulation and PUE metrics to create a framework to better understand both the socioeconomic and environmental impacts of P use across Canada?

2. Methodology

- A mass balance approach is used to quantify P surplus across Canada.

->Agriculture P surplus = fertilizer P + livestock P - Crop and Pasture P

->P Surplus = human waste + food waste + detergent + fertilizer P + livestock P - Crop and Pasture P

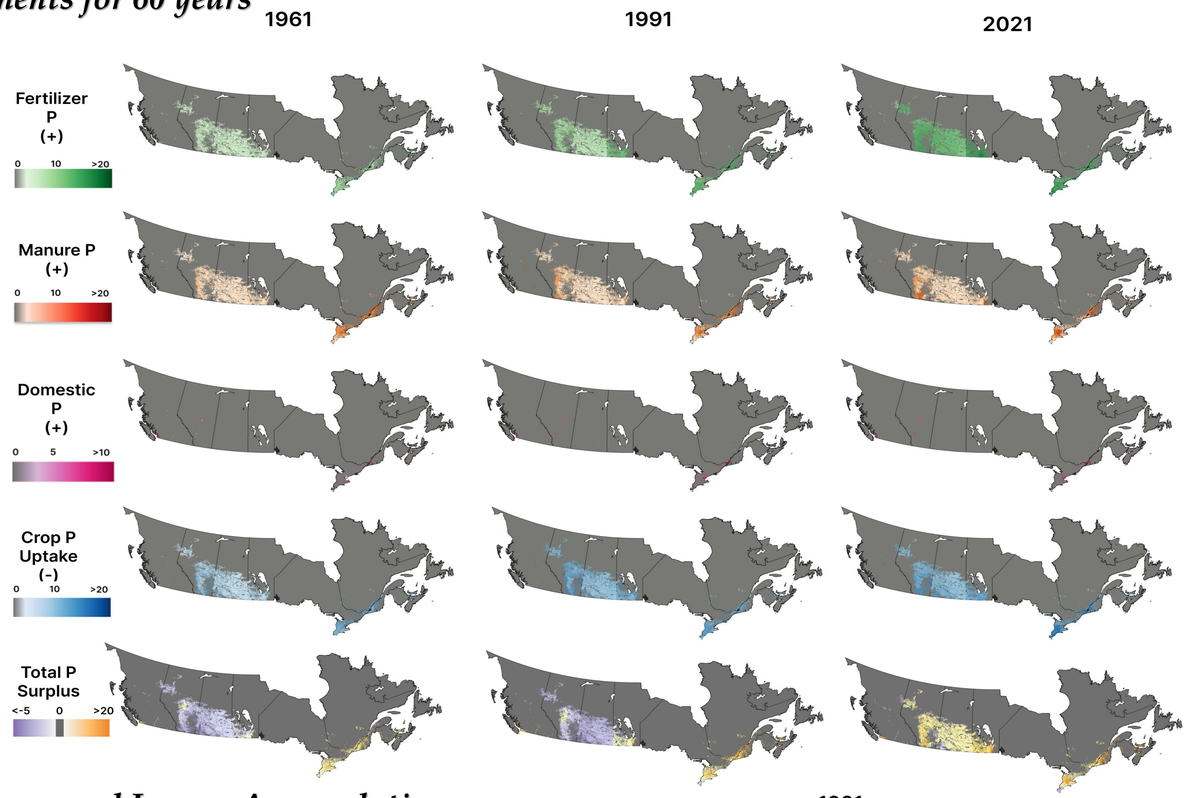
- County scale data for 22 major field crops and 10 different livestock type was aggregated from Canadian Agricultural Census for the period of 1961-2021. Population data was collected from Canadian Census of population.

- The dataset were then downscaled to the 250-m grid scale using the land use data from Annual Crop Inventory (ACI) map.

3. Results

❑ *Trend of P Surplus and its Components for 60 years*

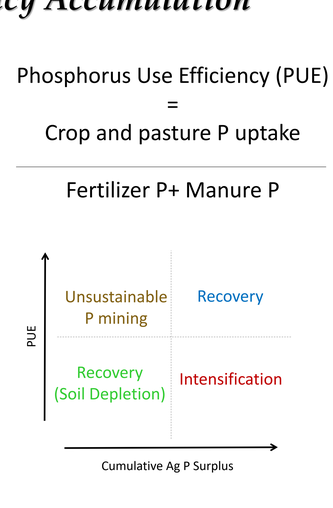
- Total P surplus has increased over the years. We observe 3-fold increase in the median P surplus from 2001 to 2021.
- *Fertilizer* is the main P input source in Canada. P fertilizer use increased up to 1980s and then drops till 2001, however currently, we see increase in median P fertilizer use from 2006.
- National magnitudes of livestock P have not changed much over the years; however, we see an intensification of manure P production in some localized regions in Ontario, Manitoba, Quebec and British Columbia.
- We observe increase in crop and pasture uptake in prairies. However, median crop uptake remains steady.
- Domestic waste contributes only 3% of Canada's total P input .

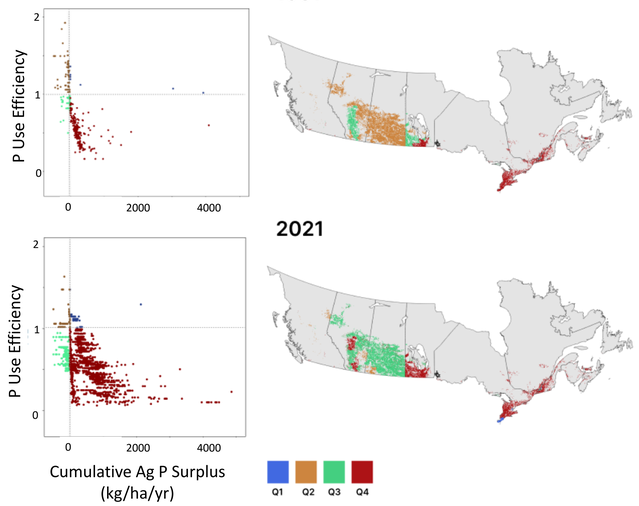


❑ *Relationship between P Use Efficiency and Legacy Accumulation*

- Legacy P accumulation is observed in Ontario, Manitoba and Quebec. Indicated by red and blue areas.
- The quadrant plot of cumulative P surplus and PUE demonstrates that areas of Ontario and Quebec in 1981 underwent intensification with a PUE < 1 and a positive cumulation P surplus. Whereas prairie region have observed unsustainable mining of soil P even those areas do not have cumulative store.
- By 2021, more areas including Manitoba and parts of Alberta showed P intensification. These red areas are of concern, and we need targeted measure to reduce P input.
- Prairie areas moved to the recovery state where soil P is being replenished as a result of increase in P input, indicated by PUE < 1. A possible explanation could be that farmers mined P from the P rich soils and are now in need to add fertilizer.

Phosphorus Use Efficiency (PUE)
=
Crop and pasture P uptake
—————————
Fertilizer P+ Manure P





4. Conclusions

- P surplus increased in recent years and fertilizer is the main P contributor in Canada.
- Legacy P accumulation has been observed in ON, MN and QC.
- Our 250-m gridded can be used for future watershed- scale P analysis works.

Acknowledgements

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