Analysis of 500 lake catchments reveals the relationship between crop type, fertilizer and manure inputs and lake nutrient concentrations

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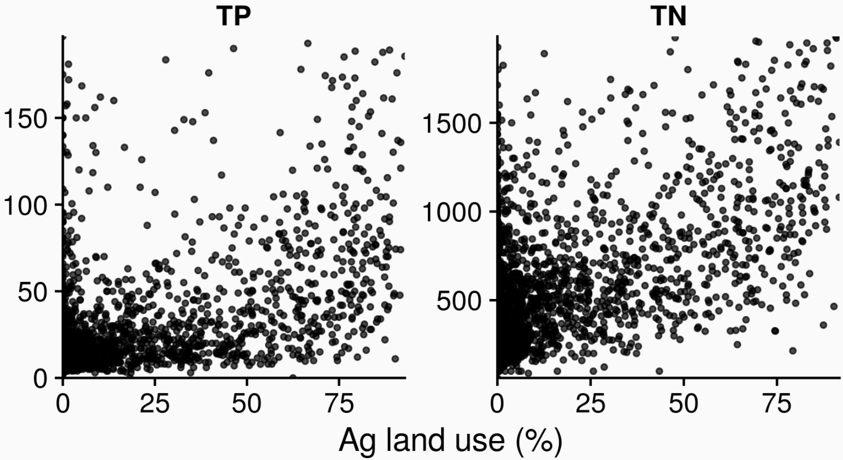
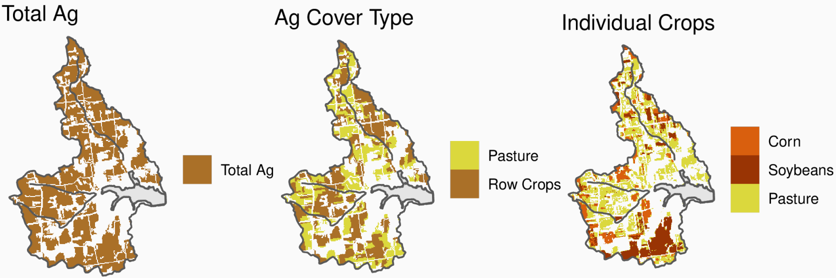
Introduction

Ag land-use is associated with increased nutrient loading to lakes and higher nutrient concentrations.



Background

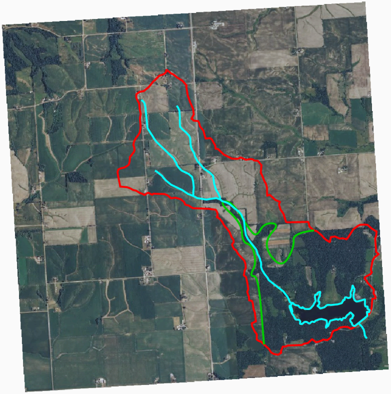
Ag land-use is an aggregated measure that may mask underlying relationships.



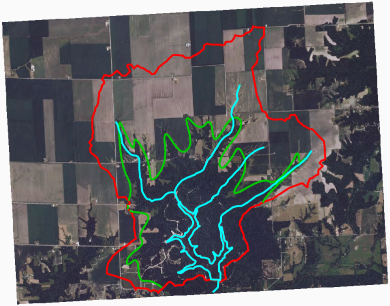
Background

Watershed land-use summaries are spatially coarse measures that may mask underlying relationships.

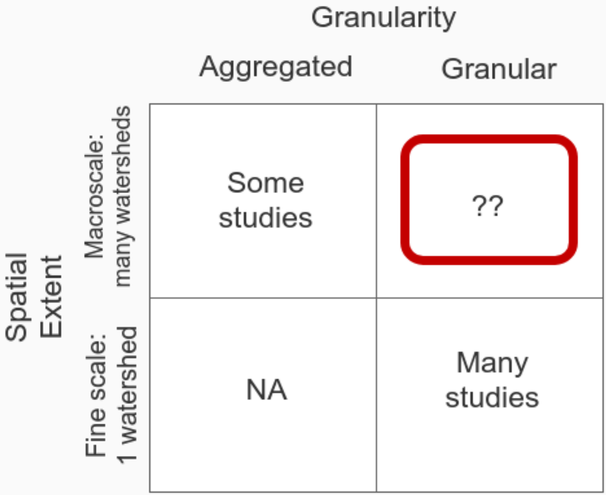
Lake Carlton – IL



Argyle Lake – IL



Background



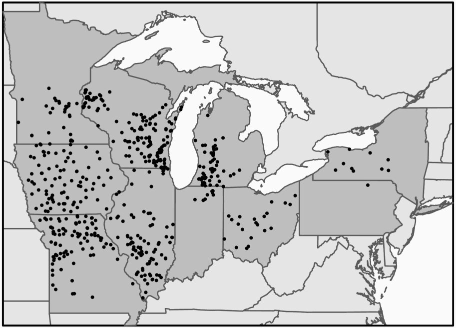
What are some things we've learned from fine scale, granular-data studies? What are some things we've learned from macroscale, aggregated-data studies?

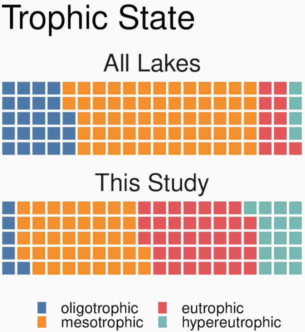
Research Question(s)

1. **Are more granular measures of Ag activity related to lake water quality (TN, TP) across hundreds of lakes and their watersheds?**

2. **Do relationships between Ag activities and lake water quality vary spatially among hydrologic and climatic regions?**

Methods - 500 high Ag lake catchments





Lakes have high Ag land use (> 40%)

Methods - Granular Ag data

Nutrient inputs - Fertilizer and manure applications

Nutrient transport - Baseflow, soils, precipitation

Nutrient proxies - Land use, specific, crops, etc.

Buffer composition - *Land use*

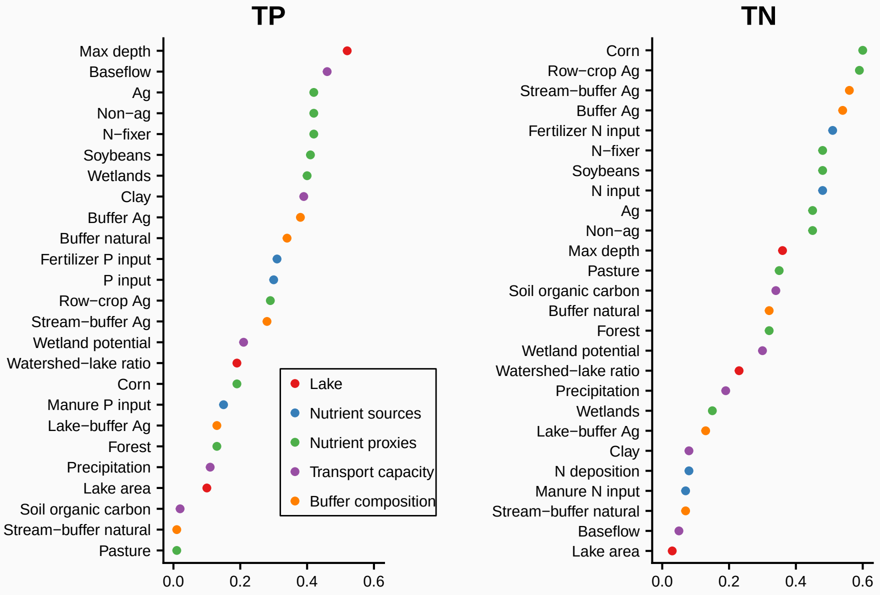
Lake characteristics - Depth, area, etc.

(Collins et al. 2017)

Methods - Statistical modelling

Build a multivariate model to explain nutrients in lakes that is:

1. **Tractible - Limited number of predictors, avoids multicolinearity**
2. Informative - Allows for interpretation of variable importance
3. Reliable - Provides an estimate of parameter uncertainity



TP
Max depth
Baseflow
Ag
Non−ag
N−fixer
Soybeans
Wetlands
Clay
Buffer Ag
Buffer natural
Fertilizer P input
P input
Row−crop Ag
Stream−buffer Ag
Wetland potential
Watershed−lake ratio
Corn
Manure P input
Lake−buffer Ag
Forest
Precipitation
Lake area
Soil organic carbon
Stream−buffer natural
Pasture
0.0
0.2
0.4
0.6
Lake
Nutrient sources
Nutrient proxies
Transport capacity
Buffer composition
TN
Corn
Row−crop Ag
Stream−buffer Ag
Buffer Ag
Fertilizer N input
N−fixer
Soybeans
N input
Ag
Non−ag
Max depth
Pasture
Soil organic carbon
Buffer natural
Forest
Wetland potential
Watershed−lake ratio
Precipitation
Wetlands
Lake−buffer Ag
Clay
N deposition
Manure N input
Stream−buffer natural
Baseflow
Lake area
0.0
0.2
0.4
0.6

Methods

[**I’m building a model...**]

Methods - Regression Modelling

Choose fixed effect variables based on the single strongest relationship from the prior correlation analysis.

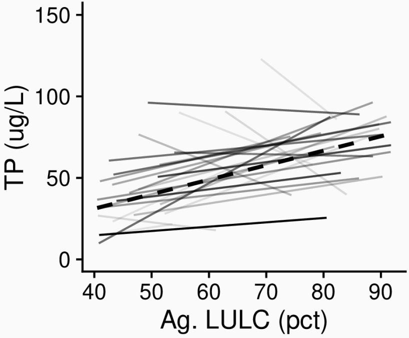
For TP, this is Buffer Ag, P fertilizer input, Baseflow, and Max depth.

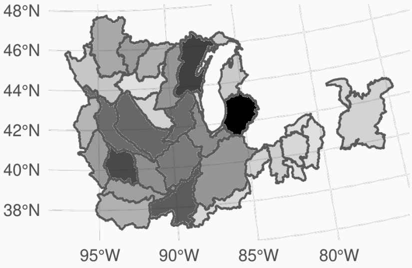
For TN, this is Buffer Ag, N fertilizer input, Soil organic carbon, and Max depth.

Methods - Regression Modelling

Choose random effect variable(s) that we expect to vary regionally.

Ag land use is a proxy for many different specific activities which are likely to be regionally variable.
(Burcher, Valett, and Benfield 2007)

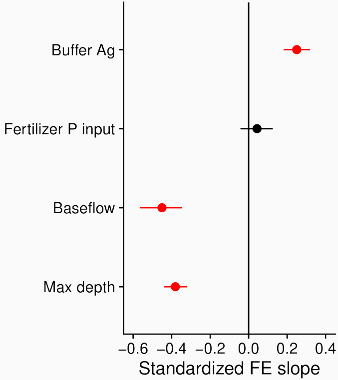


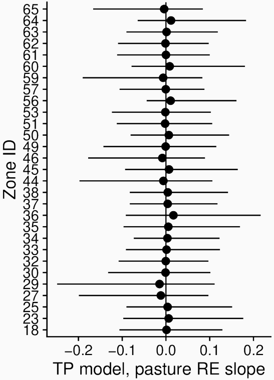


Results - TP Model

Fixed effect coefficients were markedly different among predictor categories.

Spatial random effects cleanly capture additional variation.

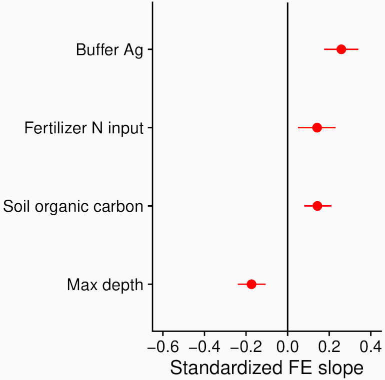


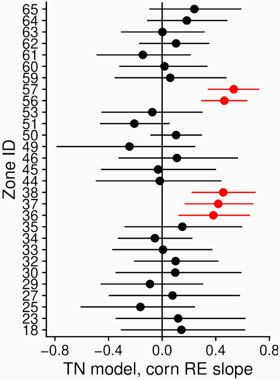


Results - TN Model

Fixed effect coefficients similar among predictor categories.

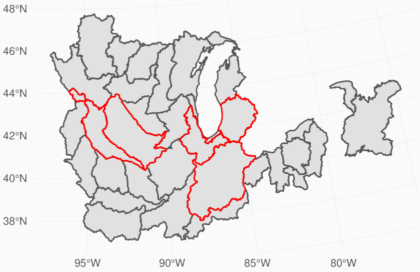
Specific regions have markedly different spatial random effect slopes.

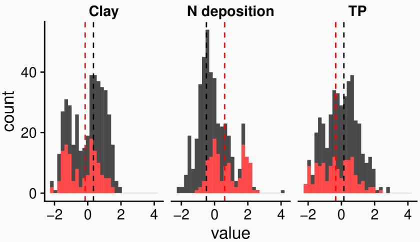




Results - TN Model

Lake TN in highlighted regions is more sensitive to Ag relative to other regions.





Discussion

Lake TN in highlighted regions may be more sensitive to Ag because:

Fields in these regions have more direct drainage because they have wetland soils.

Lakes in these regions are P limited so excess TN accumulates in the water column (Filstrup and Downing 2017)

Lakes in these regions are less hypereutrophic (Wagner et al. 2011)

Lakes in these regions are affected by an interaction among multiple land use types.

Conclusions

Lake TP was most strongly related to Non-ag and transport variables like lake depth and baseflow.

Lake TP is well described by a global model not accounting for inter-regional variation in predictor relationships.

Lake TN models were notably improved by using more granular Ag information (Corn cover, riparian buffer composition).

Lake TN is well described by a hierarchical model where relationships with land use are allowed to vary among regions.

Regional differences may be related to lake TP, atmospheric nitrogen deposition, or soil clay content.

References

Burcher, C. L., H. M. Valett, and E. F. Benfield. 2007. "THE LAND-COVER CASCADE: RELATIONSHIPS COUPLING LAND AND WATER." *Ecology* 88 (1): 228–42. https://doi.org/10.1890/0012-9658(2007)88[228:TLCRCL]2.0.CO;2.

Collins, Sarah M., Samantha K. Oliver, Jean-Francois Lapierre, Emily H. Stanley, John R. Jones, Tyler Wagner, and Patricia A. Soranno. 2017. "Lake Nutrient Stoichiometry Is Less Predictable Than Nutrient Concentrations at Regional and Sub-Continental Scales." *Ecological Applications* 27 (5): 1529–40. https://doi.org/10.1002/eap.1545.

Filstrup, Christopher T., and John A. Downing. 2017. "Relationship of Chlorophyll to Phosphorus and Nitrogen in Nutrient-Rich Lakes." *Inland Waters* 7 (4): 385–400. https://doi.org/10.1080/20442041.2017.1375176.

Wagner, Tyler, Patricia A. Soranno, Katherine E. Webster, and Kendra Spence Cheruvelil. 2011. "Landscape Drivers of Regional Variation in the Relationship Between Total Phosphorus and Chlorophyll in Lakes: Relationship Between Total Phosphorus and Chlorophyll." *Freshwater Biology* 56 (9): 1811–24. https://doi.org/10.1111/j.1365-2427.2011.02621.x.