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

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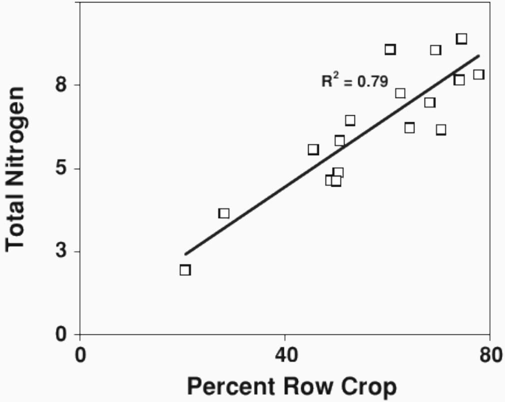
Ecological Society of America, 2019 August

Introduction

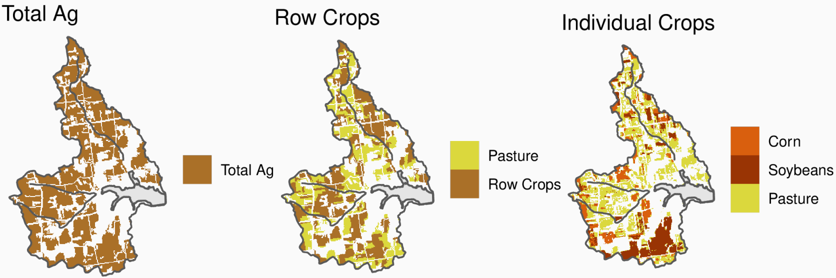
Ag land-use is associated with increased nutrient loading to lakes and higher nutrient concentrations.



(Daniel, Griffith, and Troyer 2010)

Background

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



Background

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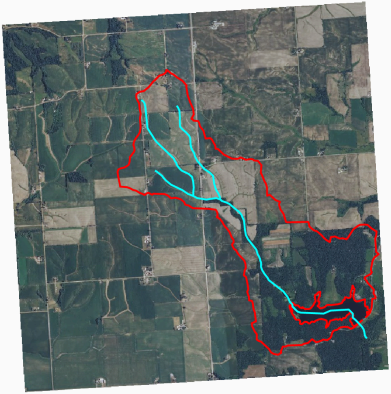

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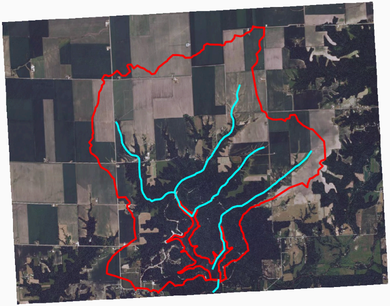


Research Question(s)

Are more granular measures of Ag activity related to lake water quality across hundreds of lakes and their watersheds?

Nutrient inputs

Nutrient transport

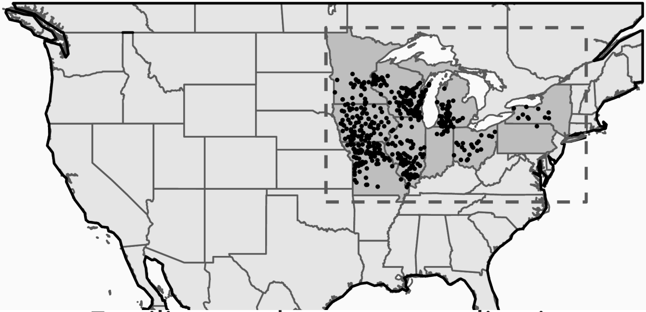
Nutrient proxies

Buffer composition

Lake characteristics

(Collins et al. 2017)

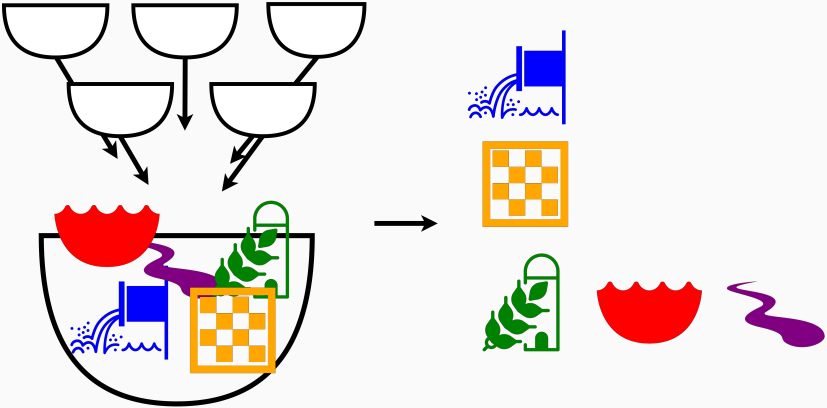
Methods - Data

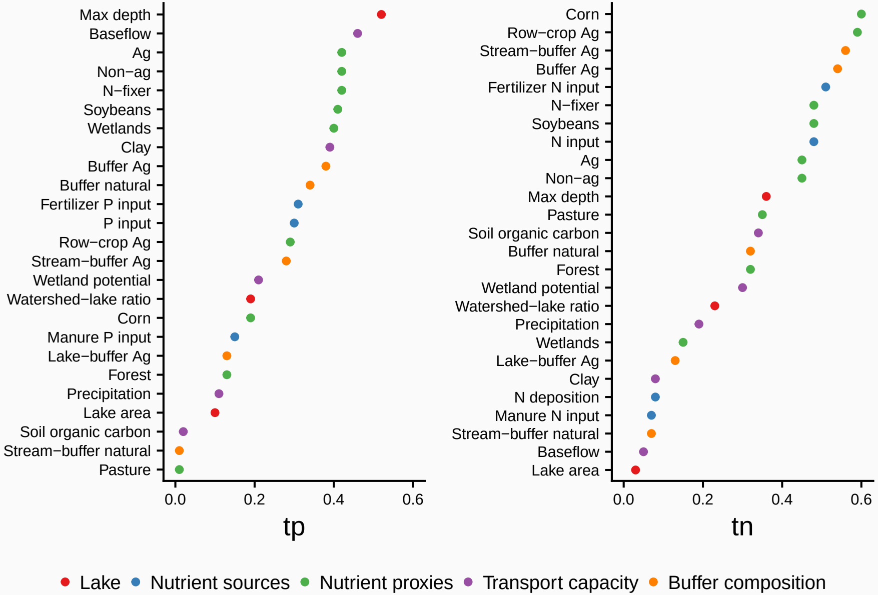


Inputs - Fertilizer and manure applications
Land use - Ag, Pasture, Row crop, Corn, Soybeans, N-fixers, Small grains
Transport - Baseflow, Soil characteristics, Precipitation
Buffers - See *Land use*
Lake Characteristics - Max depth, Area, etc.

Methods - Correlation analysis

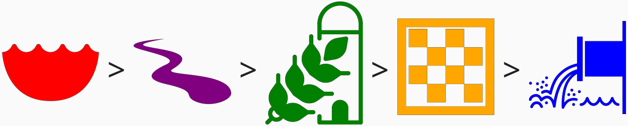
Exploratory analysis to determine how lake nutrients are related to predictors from each category.



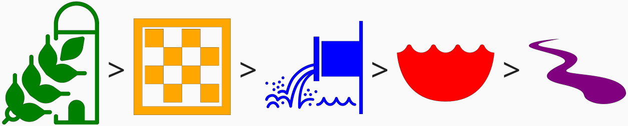

Max depth
Baseflow
Ag
Non−ag
N−fixer
Soybeans
Wetlands
Clay
Buffer Ag
Buffer natural
Fertilizer P input
P input
Row−crop Ag
Stream−buffer Ag
Wetland potential
Watershed−lake ratio
Corn
Manure P input
Lake−buffer Ag
Forest
Precipitation
Lake area
Soil organic carbon
Stream−buffer natural
Pasture
0.0
0.2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

Results - Correlation analysis

Lake phosphorus concentrations were most strongly associated with lake characteristics and measures of watershed nutrient transport.

TP ~ 

Lake nitrogen concentrations were most strongly associated with agricultural land use and the composition of riparian buffers.

TN ~ 

Methods - Regression Modelling

Many of the variables among predictor categories are related.

Choose the single strongest relationship from the prior correlation analysis to intrepret the relative influence of each *category* of predictors.

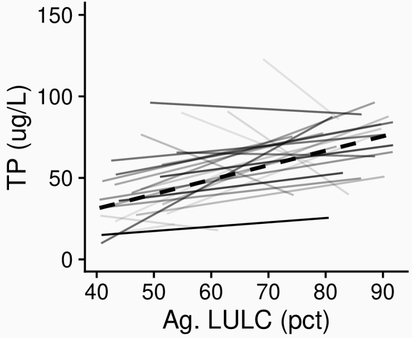
For TP, this is Buffer Ag, P fertilizer input, Baseflow, and Max depth.

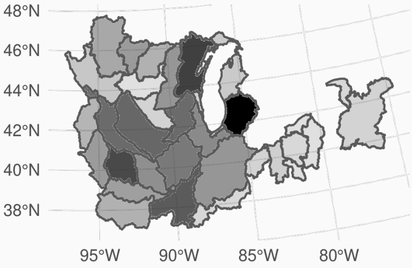
For TN, this is Buffer Ag, N fertilizer input, Soil organic carbon, and Max depth.

Methods - Regression Modelling

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

Evaluate spatial variation in the relationships between lake nutrients and Ag proxies.

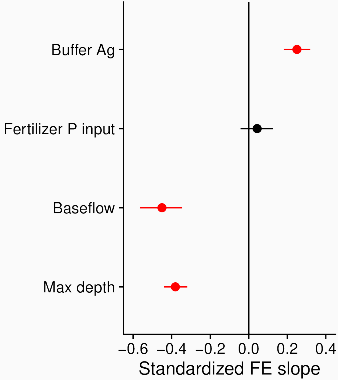


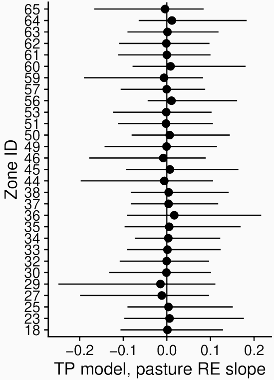


Results - TP Model

Fixed effect coefficients were markedly different among predictor categories.

Spatial random effects cleanly capture additional variation.

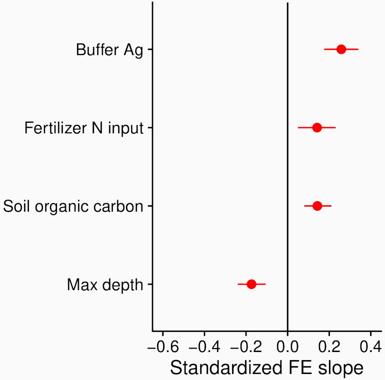


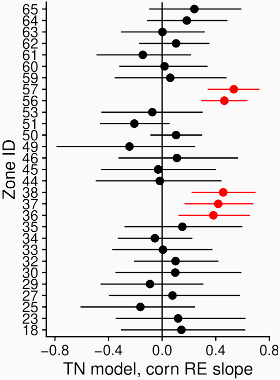


Results - TN Model

Fixed effect coefficients similar among predictor categories.

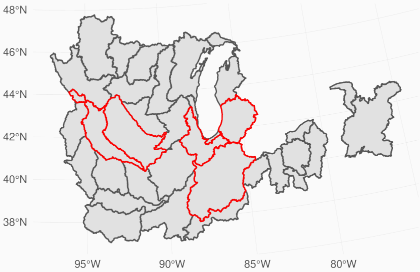
Specific regions have markedly different spatial random effect slopes.

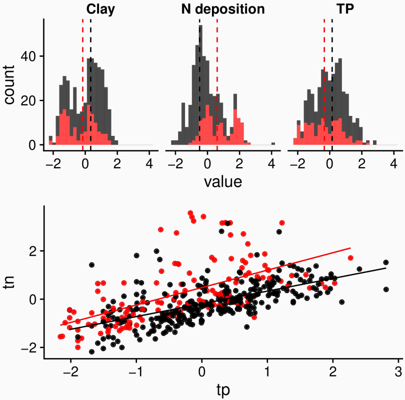




Results - TN Model

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 are more directly drained to make up for having 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.

Daniel, F. Bernard, Michael B. Griffith, and Michael E. Troyer. 2010. "Influences of Spatial Scale and Soil Permeability on Relationships Between Land Cover and Baseflow Stream Nutrient Concentrations." *Environmental Management* 45 (2): 336–50. https://doi.org/10.1007/s00267-009-9401-x.

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.