Evaluating the impact of fertilizer and crop prices on phosphorus concentrations in midwestern watersheds

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Abstract

Crop and input prices affect agricultural production and water pollution. Over the past two decades, fertilizer prices fluctuated and recently increased substantially. Corn prices also increased after the Renewable Fuel Standard. This paper estimates the effect of fertilizer and corn prices on total phosphorus (TP) and dissolved phosphorus (DP) concentrations across 226 watersheds in the Great Lakes region. Findings indicate that a 10% rise in fertilizer prices reduces TP by 3% and DP by 6.9%. Counterfactual analysis shows that without recent fertilizer price hikes, nutrient concentrations would be higher, underscoring the impact of crop and input prices on phosphorus pollution.

Introduction

- In the Great Lakes Basin, large soil phosphorus (P) reserves, intensive fertilizer application, and increased precipitation have led to high quantities of excess P in many watersheds.
- Nonpoint sources, especially agriculture, remain a concern for nutrient runoff.
- Corn prices and fertilizer prices affect both intensive and extensive margins of production.
- During 2005-2022, corn and fertilizer prices increased sharply.
- We analyze how corn and fertilizer prices affect TP and DP concentrations in 226 Great Lakes watersheds across 7 states – MI, OH, IL, IN, WI, NY and PA.

Data

- TP and DP data were obtained from Water Quality Portal and National Center for Water Quality Research, weather data from PRISM, soil erosion data from EPA WSIO, soil P data from He et al. (2021), land use data from National Land Cover Dataset, crop prices from USDA NASS, and fertilizer price from USDA ERS.

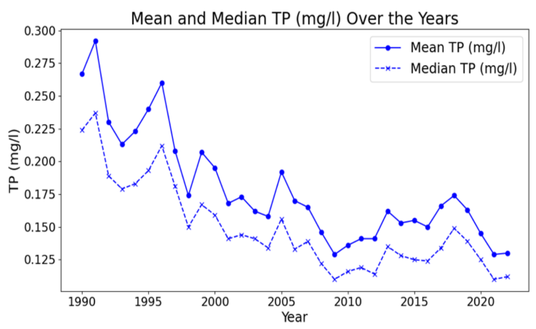

Figure 1 shows mean and median TP concentration over the years, where TP concentration shows a downward trend

***Figure 1**: Mean and median TP concentration*

Figure 2 shows mean and median DP concentration over the years, where DP trend is less pronounced compared to TP

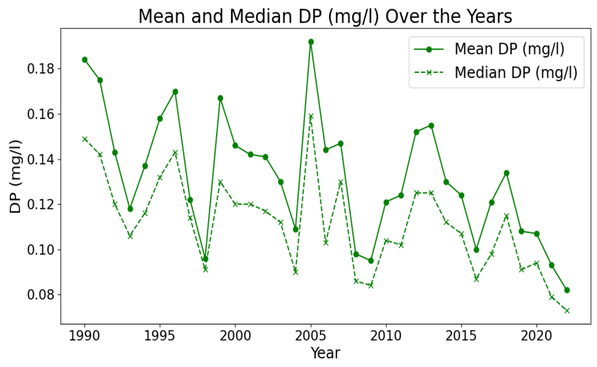

***Figure 2:** Mean and median DP concentration*

Study Area

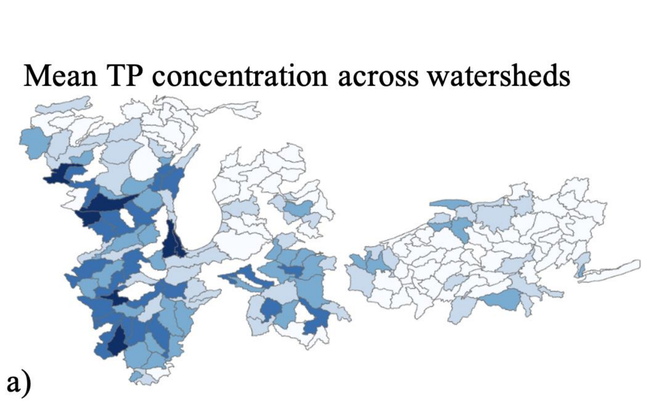

***Figure 3a:** Mean TP across watersheds*

***Figure 3b:** Mean DP across watersheds*

Empirical Strategy

- To estimate the effect of corn and fertilizer prices on TP concentration, we use the following fixed effects estimation strategy:

$$\ln(Y_{imt}) = \beta_0 + \beta_1 \ln(P_{DAP})_{rt} + \beta_{2_q} [\mathrm{q} = 1| \, season] * \ln(P_{corn_{mt}}) + \boldsymbol{\eta X_{imt}} + \boldsymbol{\psi Z_{it}} + \delta_i + \gamma_m + \sigma_t + \epsilon_{imt}$$

where, i = watershed, m = month, r = region, t = year, and t = 1990 to 2022. Y_{imt} is the average TP concentration for watershed i, in month m and year t. P_{DAP} is the price of fertilizer, P_{corn} is the national price of corn. $\boldsymbol{X_{imt}}$ is a vector of all other variables which varies across watershed, month and time. $\mathbf{Z_{it}}$ is a vector of variables that vary across watersheds over the years. δ_i, γ_m, and σ_t are watershed, month and year fixed effects. For DP, we run similar regression with Y_{imt} as the mean DP concentration in watersheds.

- Controls include temperature, precipitation, quadratic terms for both, lagged TP concentration, upstream precipitation, upstream pollution, an interaction between upstream precipitation and upstream pollution, land use changes, interaction of soil erosion and extreme precipitation days in the agricultural season, and manure use.

Results

Variables	TP	DP
Ln(Fertilizer Price)	-0.317***	-0.699***
Ln(Corn Price)_winter	0.210***	0.168**
Ln(Corn Price)_spring	0.100**	0.087
Ln(Corn Price)_summer	0.0339	0.0284
Ln(Corn Price)_fall	0.071	-0.027
Controls	Yes	Yes
Constant	-0.013	5.533***
Month fixed effect	Yes	Yes
Year fixed effect	Yes	Yes
HUC8 fixed effect	Yes	Yes
N	35934	23307

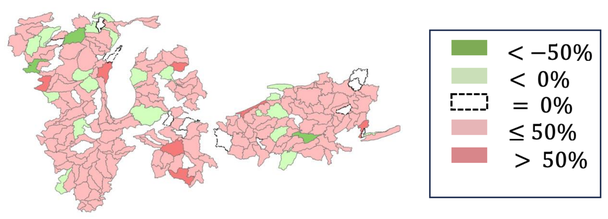

Figure 4: Model predicted changes in mean TP without fertilizer price increases of 2006-2022

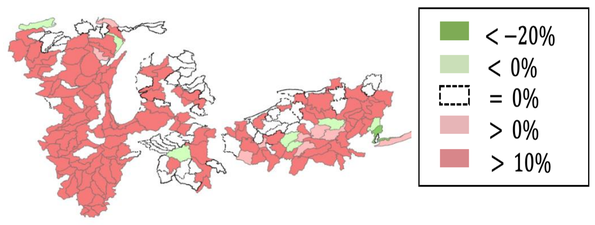

Figure 5: Model predicted changes in mean DP without fertilizer price increases of 2006-2022

Conclusions

- A 10% increase in fertilizer price reduces TP by up to 3.1% and DP by up to 6.9%.
- Winter corn prices positively affect TP and DP concentration, where a 10% increase in winter corn prices can lead to a 2.1% increase in TP concentrations and 1.6% increase in DP concentrations.
- Higher fertilizer prices helped to reduce TP and DP concentration in Great Lakes watersheds.

References

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- Keiser, David A. 2020. "Policy Brief—The Effectiveness of Phosphate Bans in the United States." *Review of Environmental Economics* and Policy 14 (2): 331–38.
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