PHOSPHORUS POLLUTION IN LAKE ERIE

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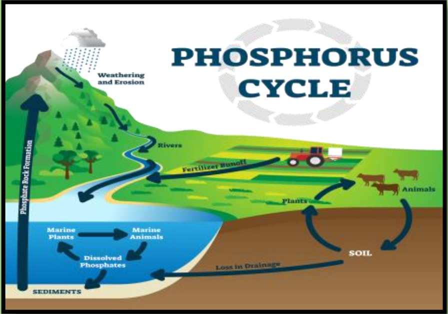
Introduction

Large amounts of phosphorus accumulation in lakes can lead to algae blooms, causing water toxicity. Prevalent sources include fertilizer and manure, both of which have agricultural roots, making areas with vast farmland especially common sources of excess phosphorus. This excess often lies near the soil surface, letting precipitation carry it into rivers and lakes. **Understanding this relationship between precipitation and phosphorus loads in rivers is imperative in determining the extent to which watershed management practices can relieve the effects of phosphorus surpluses in the environment.** In this project, we investigated the Maumee watershed, an agricultural region of Ohio that drains into Lake Erie. We created an annual phosphorus budget of the watershed to account for inputs and outputs of phosphorus. Further, we analyzed the relationship between precipitation and total phosphorus (TP) loads and used information theory to examine the relationships between streamflow variables.



Key Questions

Question 1: What is the phosphorus accumulation history of the Maumee watershed?
Question 2: How does precipitation drive phosphorus loading at an annual scale?
Question 3: How much information do certain flow statistics give about phosphorus loads?

Methods

__Data Collection__: Data for the following variables was collected from various databases: crop harvest (corn, soybeans, wheat, hay), manure (cattle, dairy cows, hogs, sheep), fertilizer, precipitation, streamflow, and phosphorus concentrations.
__Gap Filling__: **For animal data**, linear interpolation was used. **For crop data**, the percentage of total yield across all crops was interpolated rather than the raw values, in order to account for year-to-year confounders like drought and disease. **For fertilizer data**, a fertilizer graph from a research paper was used for years 1975-1986, and then taking the average fertilizer application between 1987-2012 and extrapolating that forward to 2020. **For phosphorus data**, gaps needed to be filled, and days with multiple observations needed to be condensed into a daily time series. This process was done using a series programs, including WRTDS (Weighted Regressions on Time, Discharge, and Season).
__Data Aggregation__: Gap-filled data was combined into a phosphorus budget.
__Information Theory__: Another series of programs were run on Flow and TP load data. These programs produced the mutual information between certain variables and TP load data, along with creating graphics like **Figure 3**.

Figure 1 (right): The most variable and significant inputs and outputs of phosphorus were plotted together from 1975 – 2020. The black line represents the net accumulation of phosphorus over this time period.

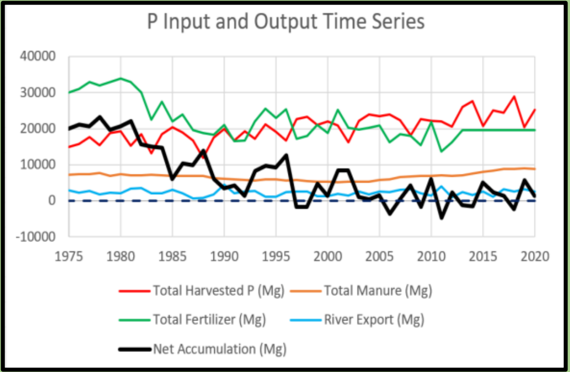
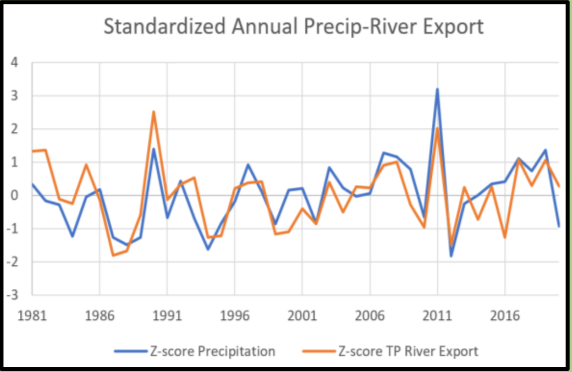


Figure 2 (right): Annual TP loads were plotted alongside annual precipitation values (both standardized), from 1981 – 2020. The graph shows a moderately strong direct relationship between the variables.



Results

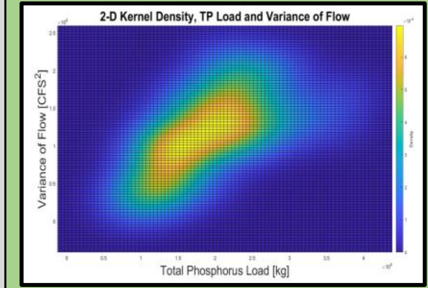


Figure 3: Joint probability density plot of Variance of Flow and TP Loads. This plot reveals a positively correlation between the two variables: as flow variance increases, TP loads do as well.

	Mean Flow	Flow Variance	Number of 90th % Flow Days
Mean Flow	0.5316	0.5239	0.5443
Flow Variance	-	0.3037	0.4661
Number of 90th % Flow Days	-	-	0.4262

Table 1: The mutual information stored between pairs of three flow statistics and TP loads.

Conclusions

In this project, we found that **precipitation and TP loads were positively correlated on both a daily and annual scale**. Additionally, we learned that while Mean Flow provides the most mutual information about TP loads individually, **Mean Flow and Number of 90th % Flow Days provide the most amount of mutual information**, despite considerable redundancy between every source pair.

References

Databases: NCEI, "Daily Summaries Map".
NCWQR, "Tributary Data Download".
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USGS, "County-Level Estimates of Nitrogen and Phosphorus from Commercial Fertilizer for the Conterminous United States, 1987-2012".
USGS, "National Water Information System: Mapper".
Images: MooMooMath and Science, "Phosphorus Cycle Steps".
Papers: Baker at. Al, 2002, Phosphorus Budgets and Riverine Phosphorus Export in Northwestern Ohio Watersheds.