Science Societies

Managing phosphorus loss to Lake Erie with regional recommendations

By DJ McCauley

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Managing Phosphorus Loss to Lake Erie with Regional Recommendations, CSA News

- The Lake Erie watershed spans two countries and four states, powering US$12.9 billion in tourism and providing water for 12 million people each year.
- Algal blooms have increased in Lake Erie over the past several decades, and nonpoint phosphorus losses from agriculture contribute to the problem.
- New *Journal of Environmental Quality* research synthesizes phosphorus loss data to create four distinct regions to strategically manage phosphorus loss, providing region-specific options for farmers to choose from when designing conservation strategies.

When I was a kid, we used to spend our summers swimming in the reservoir. The water was clear and crisp in June, but by August, we doggy-paddled and frog-kicked in tangles of scum, green algae plastered to our skin when we slogged through the slimy shallows to dry off. We dubbed it "Pickle Lake"—the water had the same eerie sheen as a ray of sun through a pickle jar.

A satellite image shows a toxic algal bloom surrounding Pelee Island in western Lake Erie, fueled by an abundance of nutrients, sunlight, and warm water temperatures. The algal bloom season runs through the summer and peaks in September. Photo courtesy of NASA's Earth Observatory.

Algal blooms decrease the amount of oxygen in the water, killing aquatic life. They create elevated levels of toxins and bacteria that can cause illnesses. They contaminate drinking water. They utilize excess nutrients to grow—phosphorus fuels a population boom while excess nitrogen increases the toxicity of the bloom.

Glossing over my childhood ignorance of the dangers of lounging in potentially toxic algae, let's zoom out a little and look at Lake Erie. Massive toxic algal blooms were common in the lake in the 1950s and 1960s, particularly in the shallow western basin. The blooms were driven by sewage dumping and agricultural runoff, and regulations in the 1970s like the Clean Water Act curbed seasonal eutrophication. But the last 20 years have seen Lake Erie's algae come surging back.

"It only takes phosphorus loss of about one pound per acre to have a pretty significant environmental impact," says Pete Kleinman, an ASA and SSSA Fellow and research soil scientist for the USDA. “Agronomically, that’s almost unnoticeable. You don’t manage in a pound an acre, you manage in tens of pounds, dozens of pounds.”

Kleinman is part of an international team with researchers from all different parts of the Lake Erie watershed. Headed by SSSA member Merrin Macrae, a professor in the Geography and Environmental Management department at the University of Waterloo, they recently published their analysis of how regional factors contribute to P loss across four states and two countries in the *Journal of Environmental Quality* (**https://doi.org/10.1002/jeq2.20218**).

To curb phosphorus losses, the team is targeting small changes in regional practices. They found that climate conditions coupled with certain conservation practices, management styles, and soil types contribute to P movement, and they outline plans to create lists of easy-to-follow, region-specific management recommendations from which producers can choose the best fit for their operations.

Ultimately, the team hopes a more detailed understanding of the specific characteristics that contribute to P loss across the watershed, from Ohio to Pennsylvania to Ontario, Canada, can help farmers make manageable, strategic changes with big impacts on algal blooms and eutrophication.

Mapping Phosphorus Loss by Region

Lake Erie’s surface area is nearly 10,000 mi^2—about the same size as the state of Vermont. The lake serves as a source of drinking water for 12 million people in the United States and Canada and hosts US$12.9 billion worth of tourism and fishery activities, according to the **USEPA**. Eutrophication, algal blooms, and hypoxia all negatively impact these industries, and targeting P runoff could be one way to keep them thriving.

Nonpoint sources are the primary contributions of P to Lake Erie—that is, widely dispersed activities that all cause a little bit of P loss. However, the cause of P loss varies by region, and some management practices that have great soil health benefits might have unintended consequences for nutrient conservation. To make matters more complicated, the primary contributors in the northernmost regions are not the same as those in the south, so providing sweeping management recommendations could sow confusion.

Lake Erie serves as a source of drinking water for 12 million people in the United States and Canada and hosts US$12.9 billion worth of tourism and fishery activities. Photo courtesy of Flickr/Ohio Sea Grant.

Here's the breakdown: Phosphorus loss in any part of the Lake Erie watershed is due to some combination of soil type, climate, and management practices. But to compare what's going on in two different countries, the team had to track down comparable data sets from the U.S. and Canada and then merge their terms to create and compare the maps. Some team members compiled raw data while others provided local knowledge.

Grant Gunn, a coauthor on the paper and assistant professor at the University of Waterloo, did the heavy lifting when it came to generating maps. Using layer upon layer of data, he stacked averages for annual precipitation, temperature, and snow cover duration. He incorporated biogeochemical and hydrological soil properties, crop types, and management practices, creating heat maps that show common factors as differences in color.

Maps in hand, the team started divvying the watershed up into regions with shared characteristics. They settled on four initial zones: the distinct Northeast and Southwest regions, with transition zones in both the north and south.

"These zones are a first cut—they're not hard boundaries," Macrae says. "When we go down and look more closely at the landscape, we're hoping to make more distinctions, especially in these transition regions."

Cover crops and no-till practices increase soil health, increasing aggregation and macroporosity by encouraging populations of larger organisms to take up residence in the soil. However, these macrofauna create large pores, which act as conduits for phosphorus directly from the surface down to tile drains. Photo courtesy of Raymond Weil.

Tailoring Regional Recommendations

What makes the Northeast (NE) and Southwest (SW) regions distinct, and how can management recommendations help farmers make changes that contribute to conservation?

“Farmers grow a lot of the same crops in these regions,” Macrae says, “but the climate is really different during the non-growing season, and that’s actually when you see most of your phosphorus loss.”

Cropping systems in both regions are dominated by corn and soybean rotations with winter wheat and some spring grain. Producers in the NE use more land for pasture and forage while a greater portion of land in the SW region incorporates seed corn, vegetable, and sugarbeet production.

The SW is flat, with poorly draining clay soils and tile drainage on 60–100% of the land. The winters are moderate, snowpack is relatively light, and the summers are hot and dry. In the spring, multiple freeze–thaw events send both subsurface and surface runoff into drainage from fields.

The landscape in the NE undulates a bit more, the soil is silt loam or sandy with pockets of clay, and the winters are much harsher with a greater degree of snowpack. Only 40–60% of the land has tile drains.

Two big differences divide drivers of phosphorus loss in these regions: patterns of snowmelt in the spring and phosphorus placement.

Confusing as it may be, there could be an interesting cocktail of unintended consequences when producers implement no-till and cover crops with tile drainage. Cover crops and no-till practices increase soil health, increasing aggregation and macroporosity by encouraging populations of larger organisms to take up residence in the soil. These macrofauna create large pores, which act as conduits for phosphorus directly from the surface down to tile drains. Meanwhile, tile drains blocked at intervals below a field encourage "quick flow" of water, nutrients, and sediments through the subsurface to drainage points, into ditches and riparian areas.

"When you put tile drains in, you shorten the amount of time that water is in the system," Kleinman says. "When we monitor tile drains during storms, that water has a signature that looks very much like overland flow, just like the surface runoff you'd get if the tile drains weren't there."

Mark Williams, a coauthor on the study in the Journal of Environmental Quality and USDA-ARS agricultural engineer, describes tile drains as a "Catch-22" because when you have them, "most of your phosphorus is in the top part of the soil. So you want [water] infiltration because you don't want surface runoff, but when you increase infiltration, you also increase your delivery of phosphorus to tile drains." Photo courtesy of Adobe Stock/JJ Gouin.

In short, multiple spring freeze–thaw cycles drive P loss in the SW region during frequent, short-term flow events. In this region, phosphorus on the soil surface is not percolating through with enough time to encourage sorption in the clay layers. The team thinks the combination of macropores and tile drains means water runs straight through the soil into drains. When coupled with surface applications of phosphorus, these short-term flow events move P directly from the surface through the tile drains and eventually into the lake.

“It’s a Catch-22,” Mark Williams, a coauthor on the study and USDA-ARS agricultural engineer, explains. “When you have tile drains, most of your phosphorus is in the top part of the soil. So you want [water] infiltration because you don’t want surface runoff, but when you increase infiltration, you also increase your delivery of phosphorus to tile drains. It’s a tricky management scenario.”

Subsurface placement of phosphorus could be a farmer’s best bet, along with decreasing stratification of P in the soil with conservation tillage. The team recommends avoiding the combination of strict no-till coupled with surface broadcast phosphorus. Doing so contributes to that quick-flow P loss—even though cover crops decrease surface erosion, the tile drains increase the speed of flow of water through the soil, increasing the transport of phosphorus through subsurface flow.

“It’s all about balancing trade-offs,” Williams says. Subsurface P placement minimizes soil disturbance and maximizes soil–fertilizer contact. The right placement walks the line between the risk of dissolved and particulate P loss based on all the factors the team analyzed—from soil properties to topography to climate across the watershed.

In the NE, one massive spring thaw dominates phosphorus loss. Even though tile drains are flowing at their maximum capacity during the big thaw, most P loss is overland. For this region, the team emphasizes controlling flows during peak periods, decreasing surface soil erosion using cover crops, and incorporating no-till. Subsurface phosphorus placement is a great option, as well—anything that keeps P from moving along the soil surface.

These subtle differences in climate and application method could have big positive outcomes for conservation if they prevent even just a pound per acre of phosphorus loss.

In the Northeast region surrounding Lake Erie, one massive spring thaw dominates phosphorus loss. Photo courtesy of Flickr/Putneypics.

Next on the List

"If you can only choose one thing to implement, you better make sure it's the right one for your landscape," Macrae says. "We want to be able to give growers a list of 'green-light' practices that work for their region and let them choose from the list."

The team has ambitions to refine their recommendations and create an easy-to-use system for getting information to growers. Their focus is on finding ways to increase adoption of practices through strategic implementation, rather than just recommending every beneficial practice to growers who are already juggling a complex set of priorities.

"Menus of options are much more palatable than prescriptions," Kleinman says. "A checklist is a benign way of saying, 'prioritize and select' instead of sending people down one path."

By streamlining recommendations and working with growers to find solutions that fit their management systems, while still conserving P loss for their region, we can start to winnow down P losses that, though small, might have big downstream consequences in watersheds like Lake Erie.

The team also hopes that their methods can serve as a model for developing regional conservation practices in other areas or for other nutrients. It's a great first step toward understanding how to foster adoption and make big impacts on waterways that so many people on both sides of the international border enjoy.

When it comes down to it, the *Journal of Environmental Quality* laid the foundation for large-scale research on phosphorus movement that can help us solve problems plaguing widescale watersheds.

"Phosphorus has this symbiotic tie with *Journal of Environmental Quality*," Kleinman explains. "JEQ built the field. This journal has moved the understanding of non-point phosphorus loss in a way that no other publication has."

Dig Deeper

You can read the original *Journal of Environmental Quality* (JEQ) article, "One Size Does Not Fit All: Toward Regional Conservation Practice Guidance to Reduce Phosphorus Loss Risk in the Lake Erie Watershed," here: **https://doi.org/10.1002/jeq2.20218**.

If you like this topic, these other JEQ special sections may be of interest:

- Phosphorus Fate, Management, and Modeling in Artificially Drained Systems: **https://bit.ly/3vp2A5e**
- The Evolving Science of Phosphorus Site Assessment: **https://bit.ly/2RUfE57**
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