Reducing Unintended Consequences of Agricultural Phosphorus

By Don Flaten, Andrew Sharpley, Helen Jarvie, and Peter Kleinman

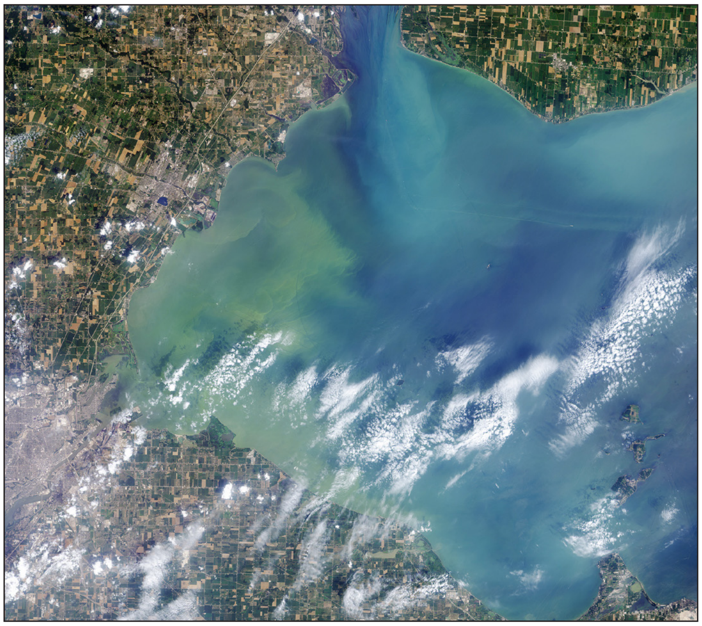
Phosphorus nutrition of crops provides a foundation for food, bioenergy, and biomaterial production. Indeed, it has been argued that P is at the heart of the food, water, and energy nexus (Jarvie et al., 2015). However, small, agronomically insignificant amounts of P in water that drains from agricultural land can cause large problems with surface water quality, especially in freshwater systems, where growth of algae is very sensitive to the concentration of P in the water (Schindler, 1977). As a result, the impairment of surface water bodies by P, especially nonpoint sources, remains a challenging, persistent, and widespread problem that threatens not only water quality but also water security (Shortle and Horan, 2017).

Beneficial Conservation Practices that Reduce Agricultural Phosphorus Loss

Nutrient management conservation practices (CPs) provide an essential toolbox for reducing P losses from agricultural land to surface water. Fortunately, the core principles for using the "right" nutrient application rates, sources, placements, and timings (i.e., the "4Rs" of nutrient stewardship; International Plant Nutrition Institute, 2014; International Fertilizer Association, 2009) are applicable to the management of agricultural P losses and effective over a wide range of geographic and land management situations. Many common nutrient management CPs have proven their effectiveness for reducing agricultural P losses in many regions of the world. These include measures such as:

- applying P at rates recommended from soil tests to avoid excessive accumulation of P in soil;
- avoiding repeated annual applications of livestock manure to meet crop N requirements on the same land;
- applying or incorporating fertilizer and manure P to place it under the soil surface; and,
- avoiding application of fertilizer or manure on frozen or snow-covered soils.

Soil and water management focused CPs provide another important toolbox for reducing P loss. Most soil and water management CPs are designed to prevent P movement off fields or intercept P that is moving away from the field and into surface water. This group of CPs includes a broad range of erosion control practices, such as conservation tillage or no-till, vegetative buffers, streambank stabilization, and wetland protection. However, the effectiveness of soil and water management practices in reducing P loss varies with the biophysical environment of agricultural land within local watersheds. For example, conservation tillage systems can reduce losses of particulate P, but the accumulation of fertilizer, manure, and vegetative P at the surface of conservation-tilled soil can lead to increased losses of dissolved P (Sharpley and Smith, 1994; Tiessen et al. 2010).


NASA MODIS Sensor/NOAA Centers for Coastal Ocean Science

Algal blooms in Western Lake Erie demonstrate the effect of excess P on water quality and the unintended consequences of some conservation practices (Jarvie et al., 2017).

Conservation Practices for Improving Water Quality are Often Less Effective and More Complex than Expected

Worldwide, flagship programs (e.g., Mississippi Basin, Baltic Sea, Murray Darling River) have promoted adoption of CPs to reduce P runoff, but often the improvement in water quality has been less than, or slower than, expected (Jarvie et al., 2013). In some cases, for example the Lake Erie Basin of North America, water quality has actually worsened, linked to increased riverine loads of soluble P, despite

SUMMARY

This article reflects upon the challenges we face in agricultural P management and provides a discussion about opportunities to promote more comprehensive and sustainable management of this valuable resource (Sharpley et al., 2018).

KEYWORDS:

conservation practices; P loss; adaptive management; environmental health

ABBREVIATIONS AND NOTES:

N = nitrogen; P = phosphorus

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the implementation of CPs (Jarvie et al., 2017). These slow and/or undesired water-quality responses may arise from a range of factors, such as:

- incompatibilities and trade-offs between CPs (Smith et al., 2015; Jarvie et al., 2017);
- lag times associated with hydrologic flow paths and watershed response times (Meals et al., 2010);
- legacies of historic land management whose continued impact cannot be readily reversed (Sharpley et al., 2013; Vadas et al., 2018).

Nevertheless, experience with nonpoint source P management has yielded valuable lessons that can help us improve the effectiveness of CPs. For example, implementation of CPs requires more attention to locally relevant and precise approaches that maximize benefits and minimize trade-offs; the 'right strategy, right place' principle (Dodd and Sharpley 2016). Also, new information and performance assessments necessitate continuous refinement of CPs, so adaptive management is almost universally required (Kleinman et al., 2015).

"....perhaps we should treat environmental health more like human health."

As we consider the complexity of interactions between various agricultural nutrient, water, and soil management CPs, and their effect on water quality, perhaps we should treat environmental health more like human health. In doing this, we should invest more effort to precisely diagnose and treat the root causes of poor water quality, as well as the broader goal of improving overall environmental health. This would be of particular importance where different components of environmental health might be compromised as the result of an unexpected trade-off, or "side-effect" from a "beneficial" management practice aimed at another component of environmental health.

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Riparian and grassed buffers can stabilize streambanks and intercept P in runoff In many situations.

Benefits of this approach are:

1. *Triage:* It is useful to target nutrient, soil, and water management CPs where they can generate the most benefit for the least cost. Such targeting is a form of "triage" where situations are prioritized to make the best use of limited resources. For example, the concept of identifying locally valid, critical source areas can be a helpful tool for this purpose.

2. *Carefully diagnose the real cause of the problem on an individual basis:* Agricultural P management strategies should be considered like treatments for human health where the benefits, as well as the risks and side effects of prescribed medications are carefully considered and clearly stated. In order to ensure that the correct cause is identified, it is important to assess each case individually and comprehensively, and to identify the real cause of the most important problems, weighing known benefits and risks (e.g., side effects or trade-offs) for that local situation. Here, consideration of systemic issues as well as proximate concerns are needed. For example, are dissolved or particulate P species the main source of impairment? Does the P source originate from in-field management or from instream recycling? Is the main pathway of P transport surface runoff or subsurface flow?

3. *Prescribe and treat with a "cure" that works for that individual case:* Once a diagnosis is completed, the next step is to prescribe the right cure, making sure the "cure" works for that local situation, then implement the treatment with care and precision. Many well-established conservation practices decrease P-related impairment of water quality under a wide range of geographic and land management settings. This can translate to unrealistic expectations of CPs as "cure-alls" … effective all the time, in all situations, and won't have any undesired side effects.

In addition, and somewhat lacking in the past is to consider all the co-benefits, as well as all the side effects and potential incompatibilities and negative interactions between management practices. Just as one would monitor a patient, it is necessary to continuously monitor CPs so that, if undesired side effects are detected, strategies can be altered or, more commonly, fine-tuned. We also need to consider a variety of other broad challenges, such as: How do we integrate the criteria for P loss and water quality into an overall assessment of environmental health? How do we balance among environmental objectives, for instance P loss versus N loss, versus greenhouse gases? How do we balance economic, social, and political perspectives with the biophysical aspects of environmental health?

4. *Provide long term, on-going care:* Similar to the long-term value of healthy diet and appropriate exercise for human health, many nutrient, soil, and water management CPs for reducing agricultural P loss require sustained effort over a long period to achieve the desired benefits. However, one of the challenges of these long-term CPs is that, to be effective, they must be maintained long after a nonpoint source mitigation program's initial resources have waned.

Conclusion

There are many challenges to developing and implementing locally relevant, precise, yet comprehensive approaches to reducing agricultural P loss and improving surface water quality. However, if we employ some of the same strategies for improving environmental health as we successfully use for improving human health, we have many opportunities to progress towards more sustainable use of agricultural P. **BC**

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Regular innovation and adaptation is required to ensure the conservation practices complement and enhance existing management systems. This implement was designed to band P under the soil surface in a strip-till system, in this case, into winter wheat stubble in the fall.

Dr. Flaten (e-mail: donflaten@umanitoba.ca) is with the Dept. of Soil Science, University of Manitoba, Winnipeg, Manitoba, Canada. Dr. Sharpley (e-mail: sharpley@uark.edu) is with the Dept. Crop, Soil, and Environmental Sciences, University of Arkansas, Fayetteville, AR. Dr. Jarvie (e-mail: hpj@ceh.ac.uk) is with the Centre for Ecology and Hydrology, Wallingford, UK. Dr. Kleinman (e-mail: peter.kleinman@ars.usda.gov) is with the USDA-ARS, Pasture Systems and Watershed Management Research Unit, University Park, PA.

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