A Viable Solution to Phosphate Eutrophication of the Western Basin of Lake Erie

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The recurring harmful algal blooms (HABs) in the western basin of Lake Erie are now well-known, well-characterized, and clearly understood to be caused by elevated levels of algal nutrients, particularly phosphates originating mostly from row-crop agricultural fields in the Maumee River and other watersheds. Simply, HABs can be prevented by retaining agricultural phosphates in upland row-crop fields.

Presently, the problem is primarily being addressed by attempting to limit the applications of nutrient-rich fertilizers, both in regard to field conditions and in regard to quantities. Enacted Ohio Senate Bill 1 has a number of fertilizer application conditions and restrictions intended to reduce nutrient escape in agricultural runoff processes and events. Whether or not widespread implementation of Senate Bill 1's provisions, alone, throughout the Maumee and Sandusky River watersheds can effectively prevent seasonal and storm-event phosphate build-ups is yet problematic, for several reasons.

First, relatively high, functional applications of phosphate-containing fertilizers will be an essential, continuing practice. Without such fertilizers, crop yields are markedly restricted. These fertilizers are expensive, but their economic returns in increased crop production warrant their continued use. Phosphates will continue to be applied to row-crop fields in the Maumee River drainage (and other smaller watersheds).

Until recently, however, fertilizer applications have often surpassed what is required for optimal crop production. Farmers (a) have been unable to physically assess optimal fertilizer "make-up" applications in their fields, or (b) simply have not done so. A "more is always better" perspective has too-often prevailed.

Consequently, excess fertilizers have rather freely drained off row-crop fields, especially in high-runoff storm events or periods of seasonally-excessive precipitation. The occurrence, severity, and duration of these events cannot be controlled. They must be accommodated into any effective phosphate-runoff solution. There is the strong prospect that diligent adherence to the fertilizer restrictions of Senate Bill 1 may not sufficiently retain fertilizer phosphates on upland sites during strong storm events or sequences. Additional solutions must be examined. One extremely effective land-use practice can do this: a viable innovative new practice (for Ohio) for which there is abundant, detailed evidence of profound efficacy.

So far, this new fertilizer retention practice has not yet been practiced or assessed in northwest Ohio. It is virtually unknown here. In Iowa, however, six years of detailed field assessment data have shown a remarkable 95% soil loss (erosion) reduction, an 84% nitrogen loss reduction, and an astonishing 90% reduction in phosphate runoff, all in conventional row-crop (corn, soybeans, et al.) farm production fields.

Clearly, reducing phosphate runoff into the Maumee, Sandusky, and other rivers and streams terminating in the western basin of Lake Erie by 90% would absolutely terminate phosphate-induced HABs.

So, just how can this remarkable and rather complete phosphate reduction occur? It is not by any conventional or regulatory means: no new, more restrictive fertilizer use or application prohibitions; no re-engineered drainage ditches or river feeder streams; nor any innovative use of cover crops, reduced tillage practices, or imposed crop rotations.

Instead, the little-known but well-documented nutrient capture traits of selected native vegetation is artfully utilized. A number of herbaceous plants native to the Midwest are remarkably able to capture and utilize various nutrient ions in water runoff; particularly phosphates and nitrates. Better than any others that can naturally grow on upland sites in

Ohio, these plant species are a continual, strong nutrient "sink," microbially and biochemically capturing soluble nutrient ions and incorporating them into both their biomass and in the soil matrix in their rhizospheres, root zones.

These plants, of course, are the tallgrasses and forbs ("wildflowers") of native tallgrass prairies, including big bluestem (*Andropogon gerardii*), Indiangrass (*Sorghastrum nutans*), switchgrass (*Panicum virgatum*), and a dozen or more forb species. All of these grow naturally in northwest Ohio in a few remnant prairie ecosystems, and can be commercially planted with success. These are not non-natives at the margins of survivability in northwest Ohio soils and climatology. When properly planted (essential), they thrive here, with minimal management in all soils that otherwise support row-crop operations. None of these plants are weedy or invasive. If they were, tallgrass prairies would not be so rare. They don't "leave" the plots were they are planted to cause weed-like competition in adjacent pastures or row-crop fields. They stay were planted.

But, crucially, what is the actual evidence that tallgrass prairie vegetation can lock up and retain up to 84% of soluble nitrogen species and 90% of bioavailable phosphates? On the face of it, those are overly-impressive numbers. Other than slowly filtering runoff through mature, massive upland wetlands (not a viable cost option), no other method can match these nutrient retention numbers in row-crop fields. Nothing else comes close.

But seven years of field data from the primary research site demonstrating this new technology solidly confirm the numbers. Specifically, the *Science-based Trials of Rowcrops Integrated with Prairie Strips* (STRIPS) project of Iowa State University has definitively shown the numbers to be accurate. The Iowa State University STRIPS project shows that nutrient runoff can be efficiently and economically reduced using strips of prairie vegetation at the downslope borders of row-crop fields, and in larger fields, with other runoff-intercepting strips or bands of prairie vegetation.

The remarkable ability of prairie vegetation to capture and sequester soluble nutrients, in both the growing and dormant seasons, is utilized. A cursory understanding of tallgrass prairie nutrient physiology is helpful, inasmuch as it is so different from that of either woody plants (trees and shrubs), conventional cool-season grasses or forbs (pasture or old-field meadow species), or agronomic plants (crops). Neither woody plants, pasture or meadow plants, nor row-crop plants are as capable of effectively binding to and sequestering fertilizer nutrients as effectively as tallgrass prairie species – by a wide margin.

Prairie plants are superior for several reasons. One of the major ones is the exceptional biomass and surface areas of the roots and rhizomes of prairie grasses and forbs, particularly the tallgrasses. Trees and shrubs (commonly recommended for planting in ditch margins and small stream beds to reduce erosion, and putatively to reduce nutrient runoff) have comparatively small root volumes and surfaces, with only a few roots extending into the soil beneath these woody plants. These, and all plants, capture soil-water nutrients for growth, but the small biomass volumes and surface areas of woody plants make them relatively inefficient for nutrient capture.

Greater root and rhizome volumes and surface areas are present under common cool-season turf and pasture grasses; and these species are more capable of sequestering phosphate and nitrogen ions in row-crop field runoff. Forcing row-crop field runoff over and through conventional cool-season grass filtration strips can moderately reduce nutrient loss to adjacent ditches and streams. Nonetheless, extraction of a volume of soil beneath a pasture or cool-season grass plot will reveal the very moderate volumes and surface areas of the living roots and rhizomes of those species, compared to the dense roots and rhizomes beneath a square foot of tallgrass prairie.

Lastly, there is very little nutrient runoff capture by the roots of annual row-crop species such as corn and soybeans (as annuals, they have no rhizomes). Corn and soybean stubble, after harvest, can moderately retard runoff flow velocities, but this does not retard eventual loss of nutrients to downslope streams and ditches.

All of this is different with established tallgrass prairie grasses and forbs. When one views a 6-ft tall native Ohio tallgrass prairie in full growth in August, one is seeing only about one-third of the plants' living biomass. Unseen and unknown by most (including professional agronomists who have never studied or encountered authentic Ohio tallgrass prairies) is the remarkable root zone, the rhizosphere, comprising about two-thirds of the living biomass of the prairie.

This is primarily where nutrient capture occurs. Unlike the other mentioned vegetation (woodies, cool-season grasses, and row-crops), prairies are powerfully adapted to annual disturbances, primarily fire-loss of above-ground stems and leaves, and equivalent above-ground losses to grazing animals. After a spring prairie fire, it appears that a prairie has been utterly destroyed, leaving merely black soot-stained soil surfaces. The prairie appears to have been utterly obliterated and lost.

Not so, however. All that was lost was the dead cellulosic above-ground tissues remaining from the previous year's growing season. The dense (up to nine tons per acre) of dead stems and leaves were converted by the fire primarily to water vapor and carbon dioxide, with moderate volumes of pure carbon soot — much of which remains on the soil surface as prairie "biochar." Soil scientists are familiar with the ability of soil carbon and biochar to capture and hold mineral ions, including phosphates and fixed nitrogen species. Much of the dark, black coloration of prairie soils derives from soil organic carbon (SOC) and included post-fire biochar, all of which freely capture soluble nutrients in water passing over or through the prairie rhizoshere (root zone). The presence of SOC and biochar in the other plant ecosystems, trees and shrubs, pasture grasses, and row-crops, is but a small fraction of that in established prairies. First-year chemistry students would understand that the passing of a volume of nutrient-laden water through activated carbon (charcoal) will remove the bulk of those nutrients. Activated charcoal and activated carbon filtration is a well-known water purification process. It also occurs, to a useful degree, beneath and on the surface of tallgrass prairies.

But what if a prairie stand is not burned and no prairie soot biochar is formed, can the prairie still capture and sequester nutrient ions in runoff waters? Quite so. Other nutrient-capture mechanisms prevail, related to the remarkable growth physiology of tallgrass prairie plants. In Ohio, an established tallgrass prairie can produce up to nine tons (dry) of new above-ground biomass (stems and leaves) each growing season. In June and July, into August, Ohio prairie grasses can grow literally an inch a day. At the start of the growing season, in May and June, there is not enough exposed leaf area to photosynthetically support such rapid growth. It occurs because of translocation up through xylem tissues of stored carbohydrates and mineral nutrients (including phosphates and fixed nitrogen) from the grasses's below-ground roots and rhizomes. These nutrients have been densely stored below ground since the previous September or October, when those essential growth components were translocated down through phloem tissues to the roots and rhizomes. The above-ground prairie fires, or grazing or mowing, do not diminish or reduce the prairie plants' nutrient storage capabilities.

The up and down seasonal translocation and capture of essential nutrients is unique in prairie species. These processes are remarkably efficient and protective. Little is lost, particularly mineral nutrients such as the phosphates. The prairie concentrates both mineral nutrients and organic species either in rhizosphere tissues, or in rhizoshere soils, the prairie topsoil (12 to 16 inches deep). Deep prairie roots (typically 6-ft or more for the grasses and some forbs) capture and translocate both water and minerals (such as phosphates) at depth, taking and concentrating them into rhizosphere tissues and soil strata.

The essential nutrient-capture roles of prairie soil microbiota, fungi, bacteria, and cyanobacteria, must also be considered. Mycorrhizae, species-specific soil fungi, need special understanding. Botanists and agronomists clearly understand that many (probably most) plants when grown in sterile media, lacking any bacteria or fungi, become nutrient deficient and fail to thrive, or die. Most wild plants, particularly prairie plants, have unique soil fungi, the mycorrhizae, that specifically capture soil nutrients and chemically pass them on to their host vascular plants. In return, the unique mycorrhizae are powered by carbohydrates the prairie plants transfer to the fungi. This symbiosis allows the prairie plant to efficiently capture and store mineral and organic nutrients first captured by the mycorrhizae. Importantly, the nutrient-capturing loads of mycorrhizae and other microbes are greater under tallgrass prairies than any other upland plant community that could occupy row-crop agricultural fields. These microbes efficiently bind to and ingest phosphates and other runoff nutrients.

Importantly, all of this runoff nutrient capture occurs in all seasons, except when soils are deeply frozen (when there is little nutrient runoff). When viewing surface water filtering through an actively-growing prairie in summer or early autumn, its ability to filter and capture runoff nutrients appears reasonable. But what about heavy precipitation events in winter or spring, when there is no above-ground growth, when the prairie is dormant? Would not the runoff nutrients merely trickle past the dead stems or leaves of the dormant prairie plants; or worse, after a spring prairie fire, when there were no remaining dead stems or leaves and soil surfaces, would the runoff then drain uninhibited and unchangedinto adjacent ditches or streams and end up in Lake Erie, causing HABs?

Surely, tallgrass prairies can absorb more runoff nutrients during the active growing season. But because of the presence of unique prairie soil microbiota, the nutrient-capturing bacteria, cyanobacteria, and fungi – especially the unique mycorrhizae – effective nutrient capture continues to occur significantly also in dormant season conditions.

Altogether, as the field results from the Iowa State University STRIPs project have shown, strips or bands of tallgrass prairies placed so as to intercept row-crop field runoff before emptying in ditches and streams retain vast quantities of phosphates and fixed-nitrogen in the field, keeping them from flowing downstream to larger bodies of water.

In Iowa, the primary concern is the loss of fixed nitrogen, which ends up in the Gulf of Mexico off the delta of the Mississippi River, where these excessive nutrient loads then prompt marine microbial growth. Those microbes then die and are consumed by bio-degrading bacteria. The entire process consumes dissolved oxygen in the ocean, creating large anoxic zones where no oxygen-requiring organisms can live.

In Ohio, the primary concern is excessive phosphate runoff, which ends up in the western basin of Lake Erie, where toxin-producing cyanobacteria thrive, in the now-infamous harmful algal blooms. In the absence of elevated concentrations of phosphates, those cyanobacteria cannot proliferate and cause harm. To solve the problem, excessive concentrations of soluble phosphates must be kept out of Lake Erie and retained on upland agricultural fields, were the phosphates allow efficient crop production. Prairie plants can do this, remarkably.

How, then, can functioning prairie strips or bands be placed in row-crop fields so as to effectively suppress nutrient runoff into ditches and streams in the watersheds of western Lake Erie? A number of measures are proposed.

First, the Iowa State Universtiy STRIPS project must be replicated on the flat, low-slope row-crop fields of the Maumee or Sandusky River basins. The Iowa project occurred on rolling, sloped topography, where water runoff speeds were much higher than on the flat, low-slope fields of northwest Ohio. The Iowa data show that prairie vegetation will be a significant phosphate sink. But, for Ohio, one big question must be answered: how wide must the prairie strips be to be effective?” In the Iowa project, prairie runoff interception strips were typically 50 to 100 ft. wide. But because of the extremely flat, low-slope topography of typical northwest Ohio soils, with reduced drainage velocities, narrower prairie strips may be effective. Prairie strips of various widths need to be planted and their effectiveness prudently evaluated.

A second, related question asks how much drainage area must each prairie strip filter. On a, say, typical 500 acre field, will prairie strips have to be installed not just at the downslope edges, but at various intervals across the interior of the field? A strip may have to be placed, perhaps, every 500 ft. within the field.

Prairie strips will need to be placed at varying widths and intervals in a number of northwwest Ohio row-crop fields, and runoff will need to be collected and analyzed in each, as per the methods used in the Iowa study.

After all of this emerges the greatest impediment to the use of prairie runoff interception strips will be, the landowner's loss of crop production area, incurring a crop revenue reduction. On top of this will be initial strip installation costs (a one-time event). How might these two costs be recovered?

Here are some field area numbers. Let's imagine that a 229-acre row-crop field, 2000 x 5000 ft, is to be bordered on two adjacent, downslope edges with a 50-ft prairie strip. This total strip equals about 7.9 acres, which is about 3.5% of the entire field. The use of a prairie runoff interception strip of this size in this field will reduce production (and revenues) by about 3.5%.

But, in fact, several additional interior prairie strips may be needed, at, say, 500 ft intervals across the field. This would be one 5.7-acre strip along the long, downslope edge of the field, with nine interior cross-field strips on 500 ft intervals. In total the field would then have 25.5 acres in prairie, out of row-crop production. That would be 11.1% of the entire field.

No farmer is likely to volunteer to remove approximately 10% of his land from production, let alone 3.5% just along two borders, merely to grow otherwise useless prairie.

This matter, too, needs to be examined. In fact, tallgrass prairies can be harvested, yielding monetary returns. Two prairie harvesting methods are possible (but both will have to be regionally developed).

Because the prairie strips so efficiently capture plant nutrients, they grow well. They can be cut, dried on the ground, and baled, exactly in the manner of alfalfa ofields, yielding high-quality baled forage to feed livestock, particularly cattle. The economic viability of this must be determined by proficient agricultural economists, assessing local hay forage markets, contract hay harvesting and transport contractors, etc.

Unlike conventional pasture and hay fields, harvested prairie fields require no fertilizers or pest control treatments. After establishment, prairies have no on-going productivity maintenance or enhancement costs.

A second economic return could be gained from the prairie strips. If they were planted with monocultures of high-yield switchgrass, up to nine tons (dry) of lignocellulosic biofuels feedstock could be harvested per acre. These materials could be used for chemical fermentation into cellulosic ethanol fuels, or compressed into heating fuel pellets (equivalent to those made from wood feedstocks).

In summary, the short story is this. Widespread installation of prairie runoff interception strips can clearly remove enough runoff phosphates so as to obviate harmful algal blooms in Lake Erie.

But the sizes and frequencies of these strips need to be determined and demonstrated on typical row-crop fields in northwest Ohio. That will have to be done by ag researchers, probably at Ohio State University.

Secondly, determining how prairie strips could be harvested, whether for livestock forage or as a biofuels feedstock, needs to be similarly examined and determined. This, too, would need to be done by ag researchers at OSU, or perhaps by a grant to a soil conservation agency or regional water quality interest group.

Or, instead of harvesting the prairie strips for revenue generation, governmental grants might be offered to cover field area losses. This would be a political solution, beyond mere field research by a university or ag experiment station.

One last observation, unrelated to water quality issues. If in five or ten years the majority of row-crop fields in northwest Ohio became bordered and interspersed with prairie strips, the visual, aesthetic outcomes would be stunningly beautiful. In summer, fields would be framed by colorful lengths of beautiful prairie wildflowers, with abundant birds, butterflies, domestic and wild bees, and other pollinating insects. Local rural landscapes would change and develop throughout the growing season as the prairies progress through their varying seasonal stages. In autumn and winter, the tall dead grasses would present colored, plumy masses with varying forms and textures. The landscape aesthetics of prairie field borders and interior strips would be remarkable.

Please scrutinize the supporting data and information from the Iowa State University STRIPS project, here:

http://www.nrem.iastate.edu/research/STRIPs/

http://www.nrem.iastate.edu/research/STRIPs/files/publication/Small-changes-big-impacts-prairie-conservation-strips%20201407.pdf

http://www.nrem.iastate.edu/research/STRIPs/files/publication/2014-11%20STRIPS_LandownersGuide-REVISED.PDF

http://www.nrem.iastate.edu/research/STRIPs/publications

Harvest of prairie biofuels information is here:

http://www.reap-canada.com/online_library/grass_pellets/Switchgrass%20for%20BioHeat%20in%20Canada%20(Samson%202008)%20-%20agriwebinar%20english.pdf

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The author has over 40 years of prairie planting and management experience in northern Ohio, and would be delighted to confer with parties interested in promoting a prairie solution to harmful algal blooms in Lake Erie.