Agricultural land management and downstream water quality: Insights from Lake Erie

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Harmful algal blooms (HABs) have been a serious issue in Lake Erie since the 1960s. The blooms, which are harmful to wildlife and humans (NOAA 2009), occur when phosphorus levels are high within the lake. Recently, HABs have been increasing in extent and intensity in the western basin of Lake Erie. The cyanobacteria *Microcystis* produces toxins that pose serious threats to animal and human health, resulting in beach closures and impaired water supplies, and have even forced a "do not drink" advisory for the City of Toledo water system for several days in the summer of 2014.

The main driver of Lake Erie HABs is elevated phosphorus loading from watersheds draining to the western basin, particularly from the Maumee River watershed (Obenour et al. 2014). Although total phosphorus levels in Lake Erie decreased and stabilized during the 1980's and 1990's due to both farmer best management practices and other policies (e.g., phosphorus banned from detergents) (Pinto et al. 1986), data collected within the last decade have revealed an increase in dissolved reactive phosphorus (DRP). While there is some uncertainty about the current causes of this increase in DRP, experts are confident that the changes are likely due to agricultural runoff during large rain events, particularly in the Maumee watershed. Through the 2012 Great Lakes Water Quality Agreement (GLWQA 2016), the U.S. and Canadian governments agreed to revise Lake Erie phosphorus loading targets to decrease HAB severity below levels representing a hazard to ecosystem and human health. New targets limit March-July loadings from the Maumee River to 186 metric tonnes of dissolved reactive phosphorus (DRP) and 860 metric tonnes of total phosphorus (TP) – a 40% reduction from 2008 loads (GLWQA 2016).

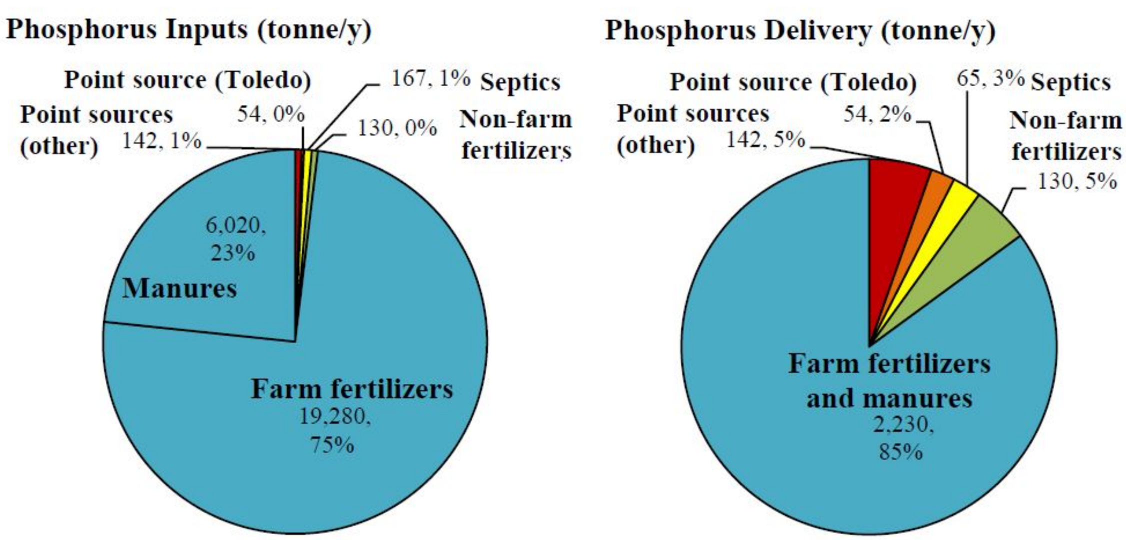


Figure 1: Maumee inputs and delivery of P to Lake Erie from major sources.

Note: Estimated delivery from farm fertilizers and manures (2,230 t/y) is 10% of applied (25,300 t/y). This delivery was estimated conservatively with respect to agriculture by subtracting the known inputs of point sources, failing septic systems, and non-farm fertilizers (assuming 100 percent delivery to the lake) from the average Maumee River load 2005-2014. The delivered load from farm fertilizers and manures includes legacy sources in soils and streams. This estimate is illustrative.

The Great Lakes region must now determine what policy options are most effective and feasible for meeting those targets. While all sources are important, our focus is on agriculture because it overwhelms other sources. In a conservative ballpark estimate we found that 85% of the Maumee River's load to Lake Erie comes from farm fertilizers and manures, even though this is only 10% of farmland fertilizer applications (Figure 1, Scavia et al. 2016). Load targets will not be met without reductions from agriculture.

What Farmers Are Doing?

Agricultural BMPs are meant to improve soil health (e.g., conservation tillage, cover cropping, controlled traffic), increase nutrient management precision (e.g., soil testing, grid sampling, comprehensive nutrient management planning), improve the filtration of surface and subsurface runoff (e.g., filter strips, grass waterways, biofilters), and improve manure management (e.g., following Natural Resources Conservation Service (NRCS) guidelines). Adoption of a variety of these practices can serve to curtail nutrient loss from agro-ecosystems, thereby decreasing the overall impact of agriculture on water quality. Preliminary findings from our project indicate that particular changes related to placement of fertilizer with the soil, avoiding application on frozen or saturated ground, delaying application in light of a major rainfall event, and cover crops may hold the most promise for decreasing DRP loss through field management strategies (Burnett et al. 2015).

Although many BMPs are known to be effective at reducing nutrient loss, their adoption is largely voluntary in Ohio. The purpose of this study was to 1) better understand the prevalence of a variety of BMPs in the Maumee watershed, 2) identify why farmers choose to adopt certain BMPs, and 3) identify what motivates individual farmer willingness to adopt additional practices on their farm. This information may reveal what, if any, methods may be employed to increase BMP implementation, thereby ultimately improving water quality and protecting associated ecosystem services. Previous research has focused largely on socio-demographic predictors of adoption and economic motivations. To evaluate these complex decision-making processes, this survey incorporates a variety of behavioral and psychological motivators.

The descriptive findings in this report are the result of a survey conducted in early 2014 among row crop farmers living within the Maumee watershed of Lake Erie (a watershed in the Western Lake Erie drainage basin, Figure 2). In particular, we conducted three mail surveys of corn and soybean farmers living in the western Lake Erie basin: in Ohio counties only 2011, over 3,000 respondents from Indiana, Ohio and Michigan counties in 2014, and a current survey across the Maumee and Sandusky watersheds. In general, we got a 35 to 43% response rate. Our farmer sample from the Maumee River watershed are 98% male, with an average age of 58.9 years old. Half of the respondents (50.9%) have only a high school degree or equivalent, while 10.7% have an associate's degree and 12.4% have a bachelor's degree. A small proportion (5.4%) of respondents have a graduate or professional degree. 67% of our farmers are third generation farmers, and the average acres of farms is 211 acres for corn farmers and 236 acres for soybean growers. While our sample may over-represent older, more experienced farmers with annual household income greater than 50,000, but 2012 Census of Agriculture reveals that in the western Lake Erie basin, almost 65% of the cropland is managed by farmers with operations of at least 500 acres (Zhang et al. 2016). As a result, it seems appropriate to focus on the larger farms, or the farmers who manage proportionally more acreage in the watershed, which is more important from both a behavioral and a water quality control perspective.

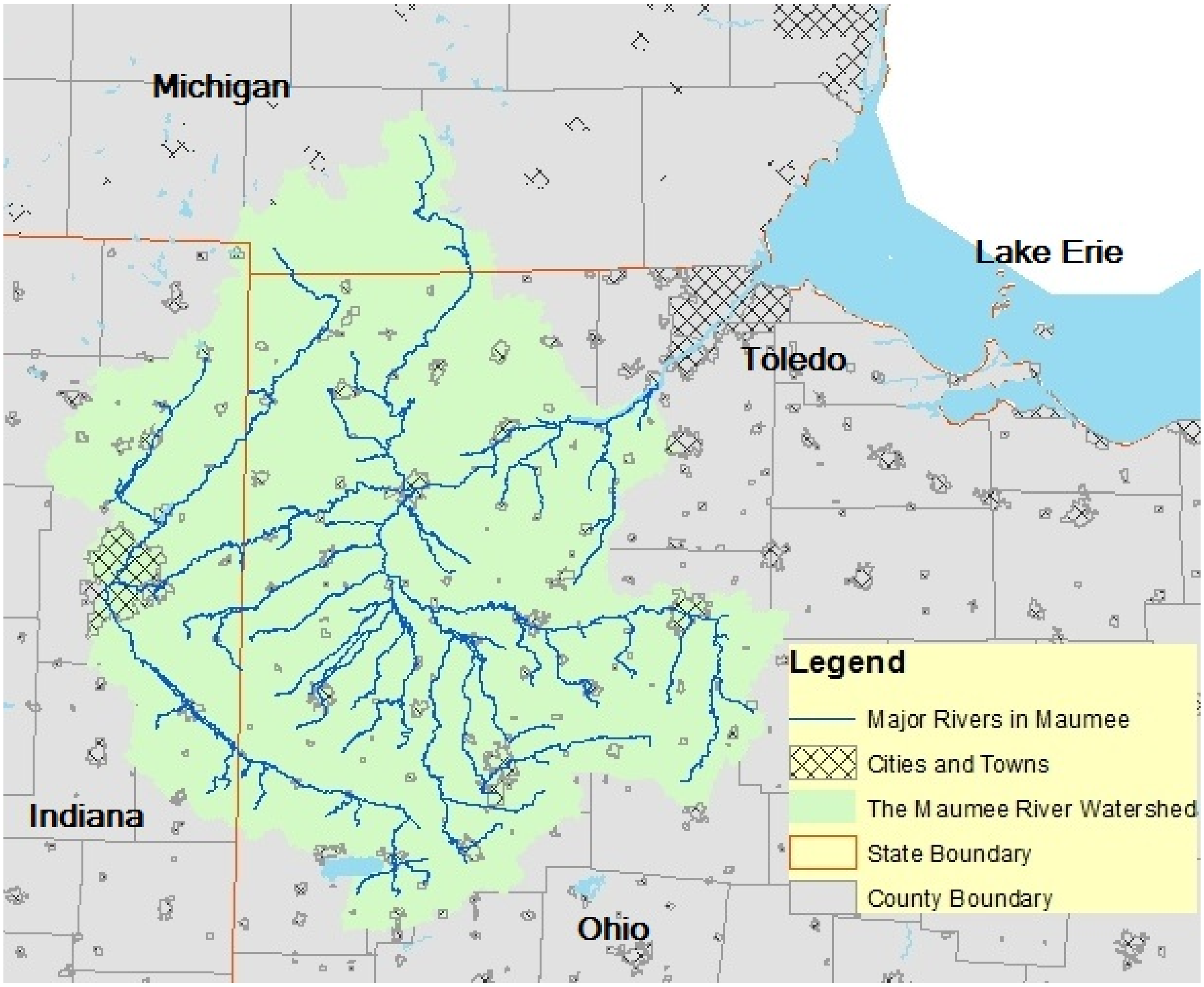


Figure 2. The Maumee River Watershed and the western Lake Erie basin

Key findings include (Burnett et al. 2015):

1. The majority of farmers in the Maumee watershed perceive that the water quality of the rivers, streams, and lakes near where they live is better than the water quality of Lake Erie. A third of the farmers are not familiar with 4R Nutrient Stewardship.

2. While a minority of farmers agrees that taking additional steps to reduce nutrient loss on their farms would be easy, a majority of farmers agree that they can engage in practices that reduce nutrient loss on their farms. Most farmers have a strong sense of responsibility to protect local water quality and to adopt BMPs that limit nutrient loss.

3. The majority of farmers believe that current practices on their own farms are sufficient to minimize nutrient loss. About a quarter of farmers believe that other farmer's practices are

insufficient to minimize nutrient loss, suggesting that many farmers feel that others in their community should be doing more. In fact, nearly a third of farmers believed that water quality issues in agriculture are the result of poor management among a small number of farmers. 54% of farmers

4. Farmers had a moderate perception of control, perceiving the most control over soil erosion and the least control over phosphorus lost during heavy rainfall events. They perceive relatively less control over subsurface drainage compared to surface runoff (Figure 3).

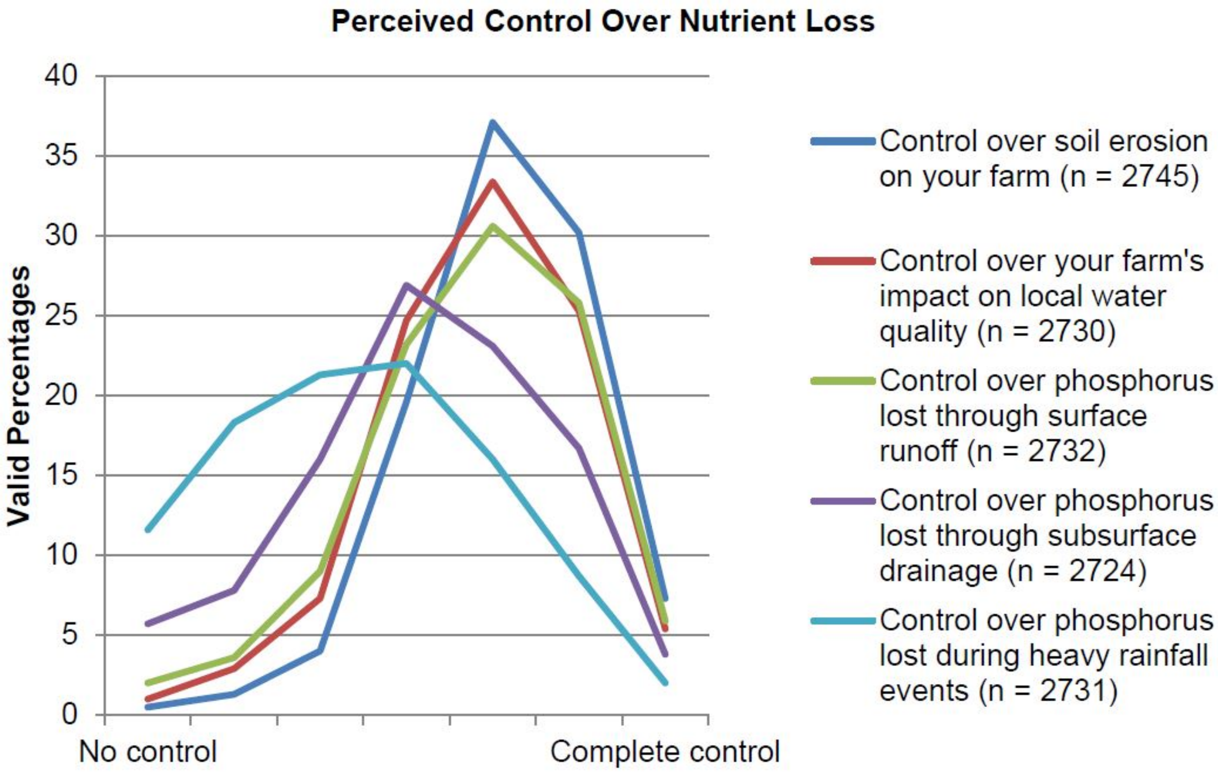


Figure 3. Farmer perceived control over five different aspects of nutrient loss.

5. The majority of farmers believe that the impacts of nutrient loss will be most serious for those on and around Lake Erie and for plants and animals, and the least serious for his/her own family or community. However, when it comes to the likelihood of negative impacts, farmers believed decreased crop yields and increased production costs were more likely than decreased water quality and soil health. 77% are concerned about the negative impact of nutrient loss to their farm’s profitability.

6. There is great potential for increased adoption of most BMPs that may help to address the current dissolved reactive phosphorus issues in Lake Erie. Adoption rates ranged from a low of 13% for hiring a 4R certified applicator over an applicator without certification, to a high of 57% for regular soil testing to inform management within the rotation (Table 1). Many of those who planned on adopting a particular practice next season were new adopters (18-50%), meaning they had not yet adopted those practices on the particular field.

Table 1 in particular shows the percentage of farmers who have already adopted conservation practices and the increase in this percentage of farmers who expressed that they are likely to adopt these practices.

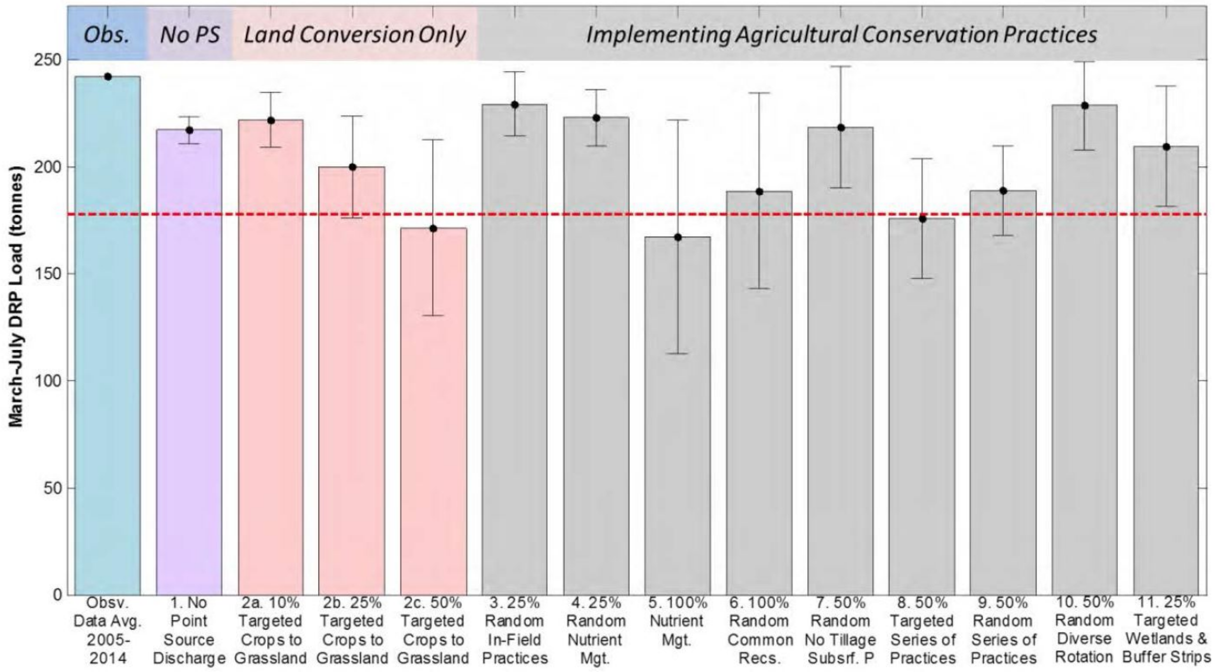
Table 1. Percentage of farmers already adopted or will adopt conservation practices

Practice	Low Quality Field		Medium Quality Field		High Quality Field	
	Already	Likely to adopt	Already	Likely to adopt	Already	Likely to adopt
Grid soil sampling with variable rate application	34.9	44.2	34.4	51.4	38.7	46.5
Planting cover crops after fall harvest	16.8	51.6	16.9	48	14.9	51.6
Delaying broadcasting when the forecast predicts a 50% or more chance of at least 1 inch of total rainfall in the next 12 hours	36	78.3	31.7	74.8	37.9	79.1
Managing field water levels with drainage management systems	14.6	50.2	17.8	41.8	22	38.8
Avoiding winter or frozen ground surface application of phosphorus	48.5	78.8	47.1	81.3	50.9	78.8
Avoiding fall application of phosphorus	30.2	56.8	29.6	54.6	29.1	53.4
Determining rates based on regular soil testing once within the rotation (or every 3 years)	51.8	83.2	52.3	82.1	56.6	80.3
Placement of fertilizer at least 2-3 inches below the soil surface	33.1	64.5	34.1	63.3	36.4	64.5
Following soil test trends to maintain the agronomic range for phosphorus in the soil (15 to 30 ppm)	39.9	84.8	40.7	83.9	44.7	80.8
Hiring a 4R certified applicator, which adheres to recommended management practices, over an applicator without certification	14.5	45	12.9	45.6	13.9	45.9

Conservation Practices: What Works and How Many Acres Are Needed

The SWAT (Soil and Water Assessment Tool) Model is a semi-distributed, process-based, watershed-scale, hydrological model that uses inputs of soils, slope, land-use, land management information, and climate variables (precipitation, temperature, etc.) to estimate hydrology, water quality, and plant growth (Arnold et al. 1998). Using the SWAT model, Scavia et al. (2016) use the SWAT model to simulate the impacts of bundled conservation practices on agricultural nutrient runoff especially the dissolved reactive phosphorus runoff. Our results suggest that there are pathways to achieve the new target loads for Lake Erie. However, all of the successful pathways require significant levels of implementation of both common and less common practices. For example, three scenarios that appear to be able to reach the TP goal (Figure 4) simulated both targeted (scenario 8) and random (scenario 9) treatment of 50% of croplands with a combination of nutrient management and in-field (cover crops) and edge of field practices (buffer strips) or a combination of wetland and buffer strip installations on 25% of cropland or subbasins, respectively (scenario 11). These scenarios also highlight the mportance of placing practices in areas where they are needed most. While identifying these specific locations was beyond the scope of this work, it can be done in consultation with conservationists and producers that have intimate knowledge of farm landscapes.

Figure 4. March-July Dissolved Reactive Phosphorus (DRP) for Simulated Conservation Practice Bundle Scenarios



Note: Average and standard deviation of the five SWAT models' March-July DRP loads during the 2005-2014 modeling time period. The average observed March-July loads from 2005-2014 are shown in the blue bars, the result for removing all point source discharges in the watershed is shown in the purple bars, and the GLWQA target loads (area-weighted to Waterville, OH gage station) are shown by the red dashed lines. Pink bars show a dose response as to how much land would need to be converted to grassland in order to meet the targets without going beyond current agricultural conservation measures. Gray bars show the effect of implementing more agricultural conservation.

Scenarios 8 and 5 achieved the DRP target loads (Figure 4). Scenario 5, which simulated implementation of nutrient management practices on 100% of the cropland acres, supports the importance of the right rate and right placement of P applications promoted by the Western Basin 4R Nutrient Stewardship Certification Program that was launched in 2014 which certified nutrient management plans on 26% of the cropland in the basin in just two years (Vollmer-Sanders et al. in press). Scenario 5 also produced TP reductions near the 40% goal.

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