Assessment of Fertilizer and Manure Application in the Western Lake Erie Basin - Supplement

Supplemental
report for:
International Joint
Commission
Science Advisory Board

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LimnoTech
Water Environment | Scientists Engineers

Key Findings and Recommendations

In 2017, LimnoTech completed a study for the International Joint Commission's Science Advisory Board (Science Priority Committee) of commercial fertilizer application and manure generation in the Canadian and U.S. watersheds of western Lake Erie (LimnoTech 2017). The study found that, in 2007, applied phosphorus in commercial fertilizer in the U.S. watershed was approximately four times greater than the phosphorus contained in generated manure, while the amounts of phosphorus in applied commercial fertilizer in the Canadian part of the watershed were similar to those in generated manure. The total of 56 million kilograms of phosphorus in commercial fertilizer and generated manure for the two countries was calculated as approximately 70% of the total mass applied or generated in the U.S. watershed, and 30% in the Canadian watershed.

Building on the results of this previous study, LimnoTech updated Ontario data on commercial fertilizer application to 2011, using farm expenditures as a proxy, so that results could be compared to the latest U.S. data collected in 2012 for the western Lake Erie watershed that were reported in that study (LimnoTech 2017). New Ontario data and analyses show that upward trends in commercial fertilizer application in the Ontario portion of the western Lake Erie watershed that were observed between 2001 and 2006 generally continued and even accelerated in some cases through 2011.

There was relatively little change in manure generated over the 2007-2012 interval, which was documented in the previous studies. Note that 'generated' manure is used in this report rather than 'recoverable' or 'applied' manure, except where noted, as this value was easier to calculate across all jurisdictions based on available data, and is a conservative estimate of the upper limit of total phosphorus potentially available on the landscape from livestock sources.

Commercial fertilizer as a proportion of farm expense for the two countries took up a substantially greater percentage of U.S. farm costs in 2012 than in 2002 (more than 50% increase), primarily due to higher fertilizer prices rather than changes in application rates. Canadian commercial fertilizer expenses also increased over this period, but not as much as in the U.S. on a farm percent cost basis.

As previously reported, the overall change from 2007 to 2012 in U.S. western Lake Erie watersheds was a decrease in P application in commercial fertilizer of 19 percent, or a decrease of 6.5 million kg of P in applied commercial fertilizer. New results show that over this same time period commercial fertilizer P application in the Ontario portion of the western Lake Erie watershed increased 72%, or by 5.7 million kg. Although some of this increase is associated with the growth of the greenhouse industry in Ontario, which results in an over-estimate of land application rates of P when this mode of use is not factored out of commercial fertilizer expense data, the trend is still significant and may have water quality impacts if application rates exceed crop needs and excess P is not retained in agricultural soils. Note that Canadian contributions to watershed P application overall (37%) still remain smaller than U.S. contributions (63%), but Canadian relative contributions increased by 9% from 2006/2007 to 2011/2012. The overall combined applied mass of P for the two countries has declined by 3% since 2006/2007 in the watershed. The net ratio of commercial fertilizer to manure in terms of P application has remained nearly identical (about 3:1), although the ratio in the U.S. has decreased from 4.3:1 to 3.5:1, while it has increased substantially from 0.9:1 up to 2.0:1 in Canada.

Ongoing research is improving understanding of P movement through agricultural systems, stream networks, and lake food webs. New numerical models are helping to link data with emerging process understanding and are making it possible to simulate different management scenarios to assess their impacts. Continuing investment is needed in these lines of research and their associated infrastructure. As emphasized in the earlier reports, and further demonstrated here, tracking of the following data in the following forms is also essential to supporting informed management decisions for the Lake Erie basin:

- commercial fertilizer and manure application at annual or shorter scales, released as soon as possible after collection,
- sufficient distinction of nutrient sources (commercial fertilizer, specialty crop and greenhouse fertilizer, manure generation and application location by livestock type at all farm sizes),
- tracking of changes in farm practices (crop rotations and acreage, tillage, tile drainage,), and
- spatial reporting that facilitates easy conversion to subwatershed values from administrative units (province, states, counties, townships, census tracts).

Likewise, high-resolution (spatial and temporal) water quality monitoring in the watersheds and lake areas of both countries in near real-time is an essential element of adaptive management that is required to effectively implement Domestic Action Plans and target resources to maximize the environmental benefits of nutrient mitigation investments. Until these tracking activities are standardized, synchronized, and operationalized, management decisions will continue to be made with suboptimal information.

Background

In 2016-2017 the International Joint Commission's Science Advisory Board, Science Priority Committee, completed an analysis of commercial fertilizer and manure application in the western Lake Erie basin. That analysis was supported by a detailed technical report prepared by LimnoTech (2017), *Assessment of Fertilizer and Manure Application in the Western Lake Erie Basin*. The Science Advisory Board's report was adopted by the International Joint Commission and published in February, 2018 (*Fertilizer Application Patterns and Trends and Their Implications for Water Quality in the Western Lake Erie Basin*, accessible at: https://legacyfiles.ijc.org/tinymce/uploaded/Publications/IJC_FertReport.pdf). Although that report focused almost exclusively on fertilizer amounts or rates applied, it acknowledged that responsible management of crop nutrition involves consideration of all of the 4Rs of nutrient management, including source, location, rate, and timing.

This supplemental study was undertaken to include analysis of 2006-2011 Canadian commercial fertilizer data that were not available at the time that the original LimnoTech report was completed (August 2017). Summaries of the original task descriptions from the project are included in Table 1 below. The supplemental task (Task 9) consisted of expansion of Task 1 to include additional Canadian commercial fertilizer data through at least 2011/2012, analysis of the additional data and other more recent province-level or state-level data, and preparation or updating of corresponding figures, tables, and text from the final report that summarize these data and their implications for the assessment's broader findings and recommendations. The data analysis required complex manipulations similar to those used in the previous report in order to retain consistency. The novel approach used previously consisted of converting Canadian commercial fertilizer data from census data on farmer expense to estimate watershed application rates. The geospatial data analysis includes commentary on trends in commercial fertilizer use and implications for legacy soil P and bioavailability for Lake Erie HABs and hypoxia, with special emphasis on temporal or spatial changes since the prior datasets were collected.

Table 1. Project Task Descriptions, Including Supplement

Task #	Description	Date Delivered
1a/b	Compile data on commercial fertilizer sales and application	Complete
2a/b	Compile data on livestock and manure application	Complete
3	Compile data on greenhouse agriculture	Complete
4	Compile data on other soil amendments	Complete
5	Summarize knowledge about relative importance of fertilizer types to eutrophication	Complete
6	Identify data gaps and influence of 4Rs	Complete
7	Review watershed nutrient modeling	Complete

8	Prepare technical report, non-technical summary, and PowerPoint presentation	Complete (August 2017)
9 (New task)	Update, analyze, and prepare figures and maps of Canadian commercial fertilizer data using methods from original Task 1a/1b; deliver in memo or short report format (herein)	September 30, 2018 (draft) January 25, 2019 (revised draft) March 25, 2019 (revised draft) May 13, 2019 (revised draft) June 21, 2019 (revised final draft)

Methods

The method for conversion and allocation of Ontario commercial fertilizer sales data into metric tonnes of P_2O_5 applied to watersheds is described here, and is similar to the original method used in the full 2017 technical report prepared for the Work Group. Currently available publications on commercial fertilizer use in the U.S. include estimates at county levels, as discussed in the report. Analogous recent publications that also discuss Canadian commercial fertilizer use are available at the level of the whole province of Ontario (Bruulsema et al., 2011), thus estimates of county level and watershed level commercial fertilizer use are not currently available for Canada for the most recent census years. The methods used in the U.S. studies have in common that some fertilizer *sales* data at the state level are allocated to counties as commercial fertilizer *use* on the basis of farm fertilizer expenses paid at the county level. In order to generate similar estimates of commercial fertilizer use or application for the Cedar (actually representing all of Essex County throughout this supplemental report), Sydenham, Upper Thames, and Lower Thames watersheds in Ontario, we adapted this method in simplified form.

For any given year, Canadian commercial fertilizer use in the watershed for the western Lake Erie basin (FERTWS) is estimated as the commercial fertilizer use on all Ontario farmland (FERTON) weighted by the proportion of total Ontario expenses (EXPON) that were incurred for farmland in the watershed (EXPWS):

$$\text{FERTWS} = \text{FERTON} \times (\text{EXPWS}/\text{EXPON})$$

It is important to note that this is an estimate--we did not take into account farm vs. non-farm use of sales, nor did we conduct a thorough review of possible errors in the data sets, or consider suppressed county-level expense data within the interpolated watershed expense records. In addition, farm uses that do not include land application (e.g., use of commercial fertilizer in large-scale hydroponic greenhouse operations in Essex County, Ontario) were not considered separately from overall farm usage. Separation of farm from non-farm use, however, was generally done in the cited studies that estimated commercial fertilizer use in the U.S. We recommend a further refinement of the method, if sufficient information can be acquired on the input data, to enhance binational harmonization of results. Note also that these calculations are a disaggregation of province-level commercial fertilizer use, while the U.S. calculations are an aggregation of county-level commercial fertilizer use from IPNI-NuGIS – whose results we report. Gronberg and Spahr (2012) followed a similar disaggregation method. Thus, although there are differences between the methods used for the U.S. and Canada, the approach employed allows us to examine large-scale patterns and changes through time, and to begin to develop hypotheses about the drivers of change. Further testing and confirmation of observed differences between the countries is warranted, particularly for proper interpretation of small changes and differences and fine spatial and temporal scales.

IPNI-NuGIS (2013) reports Ontario commercial fertilizer shipment data from suppliers for the years 1954 to 2007 (i.e., FERTON). While these data are reported as commercial fertilizer use, based on the methods described in Bruulsema et al. (2011) the numbers represent the commercial fertilizer sold in Ontario, because at the province level the two are approximately equivalent. Considering the large size of the province of Ontario, the error resulting from equating shipment with use can be assumed to be small (e.g., error due to commercial fertilizer sales near Ontario borders that are transported across the provincial boundaries, error from commercial fertilizer purchased but not applied in the same year). While commercial fertilizer expense data compiled from farmer surveys (directly from StatCan) could also have been used up to the year 2007, the available IPNI-NuGIS shipment data (seller data) are more readily accessed and were used instead for evaluating trends at the province scale. For the year 2011 update, farm commercial fertilizer expense values (i.e., EXPON) from StatCan farmer surveys (buyer data) were used instead at this scale.

The Interpolated Census of Agriculture reports watershed commercial fertilizer expenses for Ontario census units for 5-year intervals between 1971 and 2006 (i.e., EXPWS), but more recent interpolated data are not yet available by watershed. In order to generate similar results at this geographic scale for the year 2011, commercial fertilizer expense data reported by census unit rather than by watershed were downloaded on a census unit basis. These were rescaled to the same watershed boundaries reported in the earlier interpolated data by weighting the commercial fertilizer expenses in each census unit on the basis of the percent of its area that lies within the watershed, and then summing the fractional expenses to generate values for the whole watershed unit (Sub-sub Drainage Area or ‘ssda’ in StatCan nomenclature).

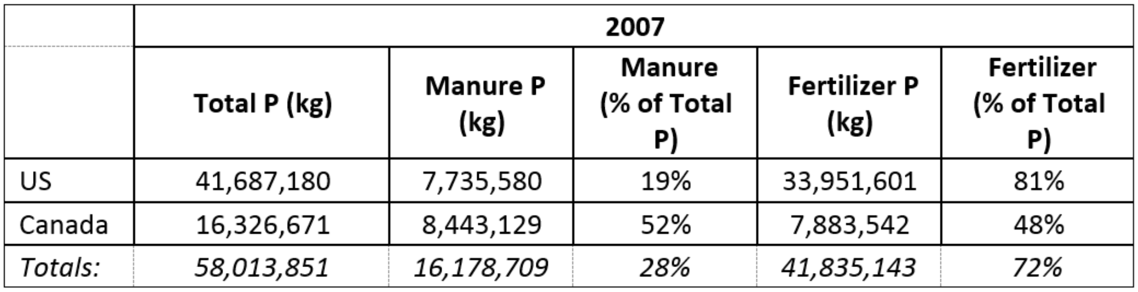
Results and Discussion

Over the period of interest in this update, 2007 to 2012, the new data indicate that commercial fertilizer application rates and total commercial fertilizer applied in the Canadian portion of the western Lake Erie watershed have increased substantially (Table 2,3), continuing a trend that was observed between 2002 and 2007. In 2007, total P from generated manure and commercial fertilizer in Canada were approximately equal (Table 3), but by 2012 commercial fertilizer accounted for 65% of total P in the Ontario portion of the western Lake Erie watershed, and the country total P had increased from 28% to 37%, relative to the U.S. share.

Table 2. Summaries of P from manure generation and commercial fertilizer application.

	2011 (Canada) and 2012 (U.S.)					
	Total P (kg)	Country % of Total P	Manure P (kg)	Manure (% of Total P)	Fertilizer P (kg)	Fertilizer (% of Total P)
U.S.	35,366,702	63%	7,877,022	22%	27,489,680	78%
Canada	20,931,075	37%	7,333,063	35%	13,598,012	65%
Totals:	56,297,777	100%	15,210,085	27%	41,087,692	73%

Table 3. Summaries of P from manure generation and commercial fertilizer application from 2007, reproduced from original report Table 3-14 (U.S. country total P was 72%, and Canada was 28%).



	2007				
	Total P (kg)	Manure P (kg)	Manure (% of Total P)	Fertilizer P (kg)	Fertilizer (% of Total P)
US	41,687,180	7,735,580	19%	33,951,601	81%
Canada	16,326,671	8,443,129	52%	7,883,542	48%
Totals:	*58,013,851*	*16,178,709*	*28%*	*41,835,143*	*72%*

The changes through time in commercial fertilizer P application rate and mass by state or province for western Lake Erie watershed areas are shown in Figure 1, including the updated data. Manure generation trends are plotted in Figure 2 for comparison (no new data). There was relatively little change in manure generated over the 2007-2012 interval. Figure 3 shows commercial fertilizer as a proportion of farm expense for the two countries, and indicates that commercial fertilizer costs took up a substantially greater percentage of U.S. farm costs in 2012 than in 2002 (more than 50% increase). This was primarily due to higher fertilizer prices rather than changes in application rates. Canadian commercial fertilizer expense also increased over this period, but not as much as in the U.S. on a farm percent cost basis.

Data for commercial fertilizer application rates through 2012 by subwatershed are shown in Table 4, plotted in Figure 4 and Figure 5, and mapped in Figure 6. The most substantial increases over the 2002 to 2012 interval can been seen in the Cedar/Essex subwatershed (not technically a single watershed) and in the Lower Thames subwatershed in Ontario, where application rates nearly doubled (although Lower Thames values were only 65% of Cedar/Essex values). Note that Cedar/Essex application rate values are strongly influenced, in comparison to other watersheds, by the abundance of specialty crop usage of commercial fertilizer in this region (52% of total by cost in 2011). This skews the non-specialty crop application rates here higher than they actually would have been, given the use of commercial fertilizer expense as a proxy for application rate in this study, although specialty crop commercial fertilizer expense was also included in previous years and not treated separately.

Specialty crops in this region commonly include field tomatoes, which are cultivated differently but experience many of the same P export processes as grains or oilseeds. The category of specialty crops in this region also notably includes commercial fertilizer use by the greenhouse industry. Data are not available to separate greenhouse usage from that used for non-greenhouse specialty crops.

Most greenhouses use hydroponic systems and more expensive soluble fertilizers over an extended growing season, primarily for vegetable production. The aspects of high greenhouse plant density, extended growing days and seasons due to artificial heat and lighting, and higher cost per pound of greenhouse fertilizer collectively raise commercial fertilizer expense for greenhouse use (not traditional commercial fertilizer application) substantially on a per-acre basis. Given that county-wide land application rates were derived from commercial fertilizer expense data, the influence of greenhouse commercial fertilizer on expense data results in an overestimate of non-greenhouse P application rates, and in changes to those rates through time. The greenhouse area in Essex County increased from 397 hectares in 2001, to 617 hectares by 2011, and 781 hectares by 2016, or almost a two-fold increase over this 15-year period (Planscape 2006, OMAFRA County Statistics, http://www.omafra.gov.on.ca/english/stats/county/index.html). The legalization of cannabis in Canada is expected to further accelerate greenhouse expansion, given its suitability for greenhouse cultivation (e.g., https://www.cbc.ca/news/business/cannabis-greenhouse-boom-1.4863171).

Although greenhouse commercial fertilizer is mostly delivered hydroponically, not all greenhouse fertilizer P is contained in closed systems or exported in harvested crops. Monitoring studies in the region in 2007, 2010, and 2012 through 2016 detected elevated concentrations of P in Lake Erie tributaries, ditches, and municipal drains that were impacted by greenhouse effluent (Ontario Ministry of the Environment 2012; Maguire et al. 2018). The Municipality of Leamington is in the process of expanding its sewer system to capture some of this effluent for treatment (AECOM 2018).

As shown in the previous LimnoTech and IJC reports, many U.S. subwatersheds showed increased commercial fertilizer P application rates from 2002 to 2007, and some of these continued to rise through 2010, but most declined to near or below 2002 rates by 2011. Rates increased in many U.S. subwatersheds in 2012, but generally stayed at or below 2007 rates. The overall change from 2007 to 2012 in U.S. Lake Erie watersheds was a decrease in P application of 19 percent or a decrease of 6.5 million kg of P in applied commercial fertilizer. Additional comparisons of changes in P application between the U.S. and Canada over this time period can be made by examining Table 2 and Table 3 above.

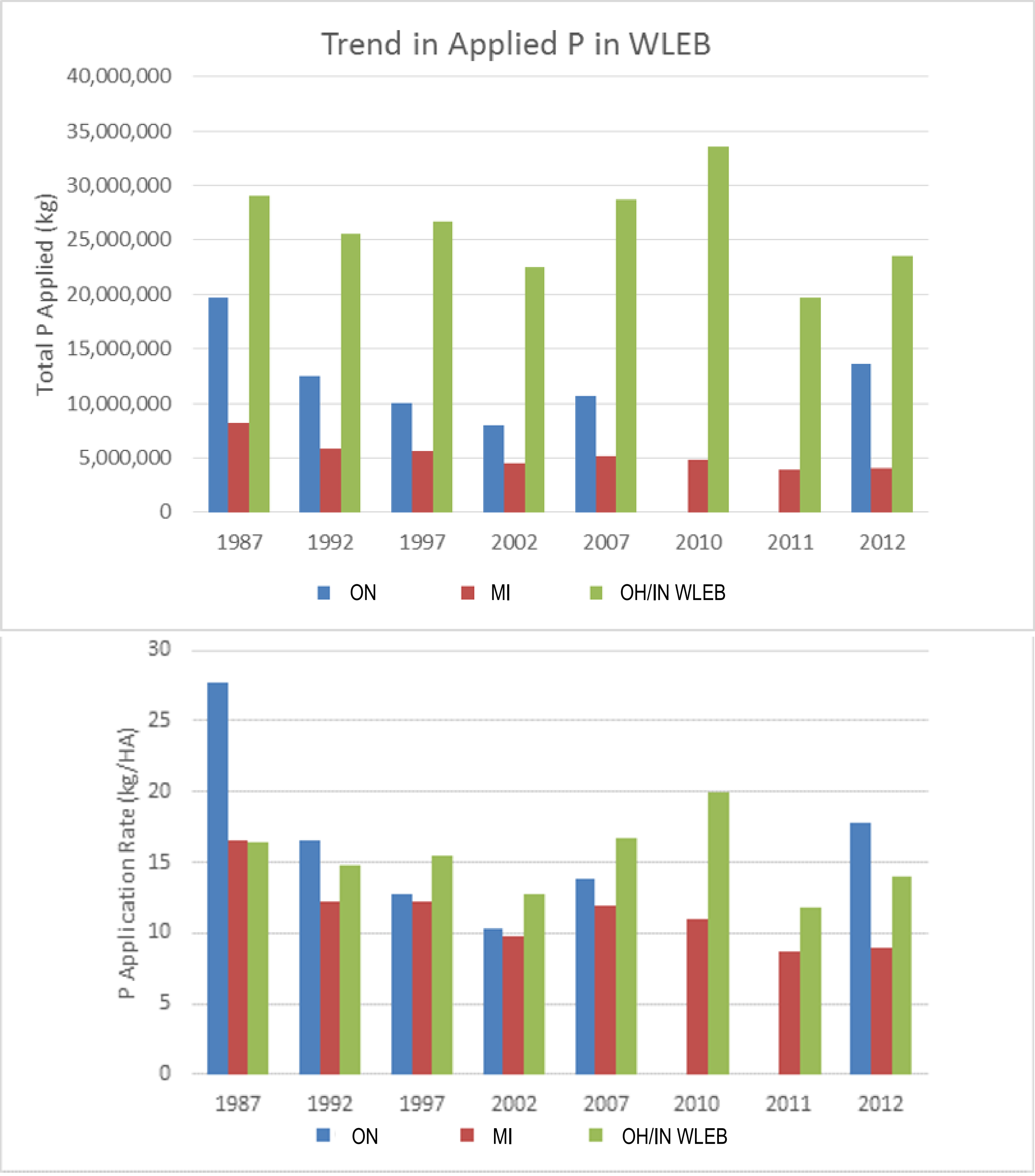


Figure 1. Total applied commercial fertilizer P by province (ON = Ontario) or state (MI = Michigan, OH/IN = Ohio/Indiana) through time for the Western Lake Erie Basin (top), and total P divided by cropland area (bottom), updated from Figure 3-14 in the original report. Note that all Canadian data are offset by one year later than the actual year collected for comparison with U.S. data; this convention is continued in plotting of 2011/2012 data, even though 2011 data are also shown for the U.S.

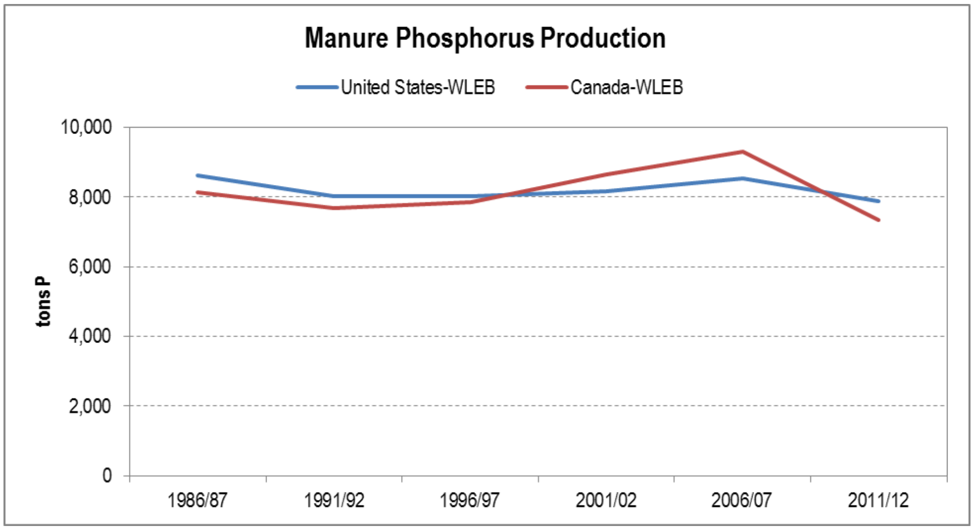


Figure 2. Total manure P generation trends as P for comparison with commercial fertilizer trends (reproduced from Figure 3-21 in original report).

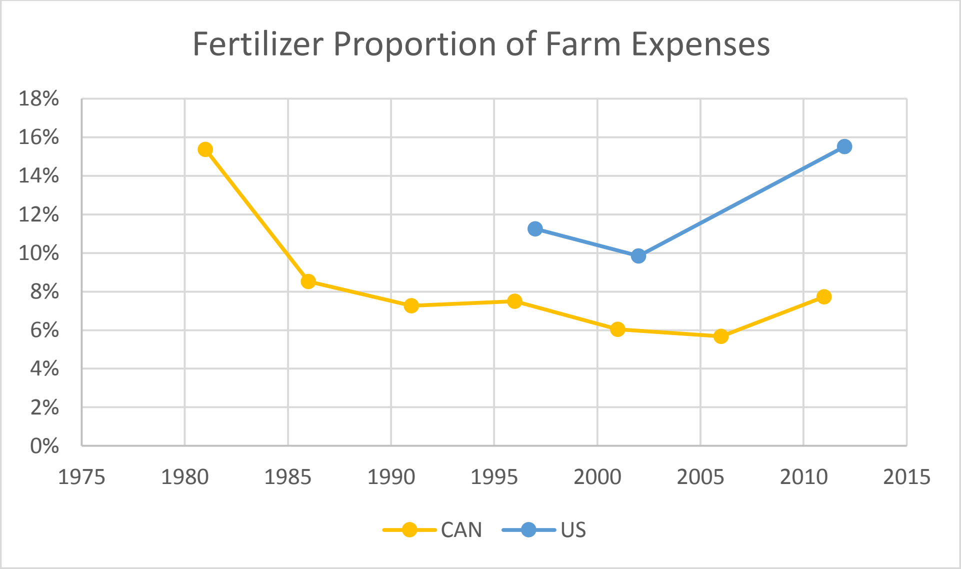


Figure 3. Plots showing changes through time in the commercial fertilizer proportion of farm expenses for the U.S. and Canada in the watershed. The U.S. values increased substantially between 2007 and 2012, but the application rates remained steady or declined over the same period, indicating a relative change in commercial fertilizer prices, rather than an increase in average commercial fertilizer application. Prices were substantially more volatile on an interannual basis between 2006 and 2013 than indicated by the data shown, including a sharp increase from 2007 to 2008 that is not captured at this five-year resolution.

Table 4. Commercial fertilizer application rates through time (kg P/hectare of cropland) for subwatersheds; new data highlighted with green shading; data plotted below in Figure 4 and Figure 5.

HUC08 Name	1987	1992	1997	2002	2007	2010	2011	2012
St. Joseph (IN/OH/MI)	19	15	13	12	14	14	11	11
St. Marys (IN, OH)	19	16	17	12	17	18	12	14
Upper Maumee (IN/OH)	16	16	12	10	13	13	10	10
Clinton (MI)	15	17	13	8	9	6	6	6
Detroit (MI)	17	7	9	10	13	9	9	11
Huron (MI)	16	10	12	12	11	8	7	8
Lake St. Clair (MI)	14	15	11	6	9	7	6	7
Ottawa-Stony (MI)	19	13	15	13	16	18	13	12
Raisin (MI)	17	10	12	11	13	12	9	10
St. Clair (MI)	16	14	11	6	10	7	6	7
Auglaize (OH)	15	12	11	11	15	17	10	13
Blanchard (OH)	15	13	15	13	15	20	10	14
Cedar-Portage (OH)	17	17	17	15	17	21	13	15
Lower Maumee (OH)	18	15	14	13	19	26	13	14
Sandusky (OH)	15	17	23	16	21	25	14	19
Tiffin (MI/OH)	15	12	12	12	15	18	10	10
Cedar/Essex	29	19	17	18	26	N/A	31	N/A
Lower Thames	29	17	13	10	13	N/A	20	N/A
Upper Thames	27	16	11	8	11	N/A	14	N/A
Sydenham	26	16	12	9	12	N/A	13	N/A

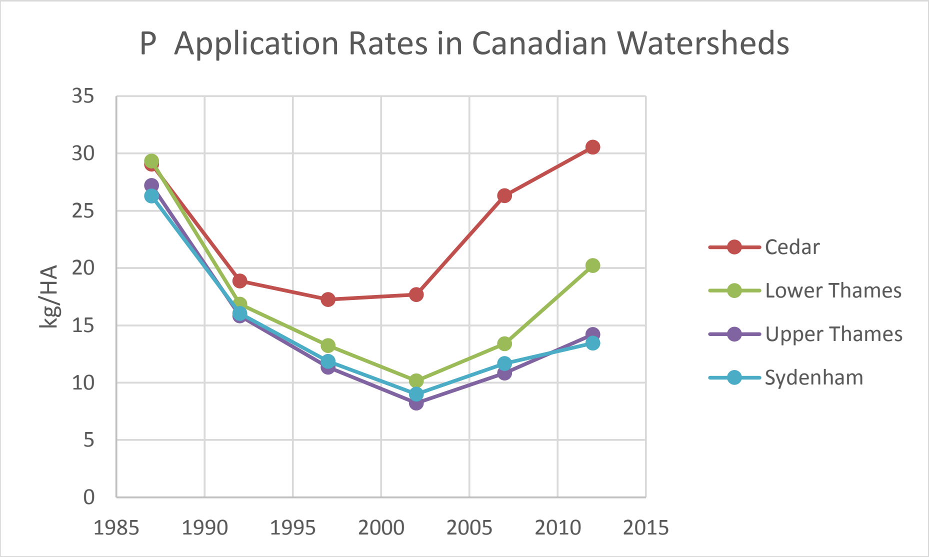


Figure 4. Application rates of P from commercial fertilizer through time on cropland in Canadian subwatersheds, showing recent increases (updated version of Figure 3-16 in original report). Cedar (Essex County) watershed values since approximately 2002 are influenced by intensive fertilizer usage in expanding commercial greenhouse operations in the watershed. See related discussion in the text. Note that years shown on this plot are offset one year later than actual collection years for consistency with U.S. data.

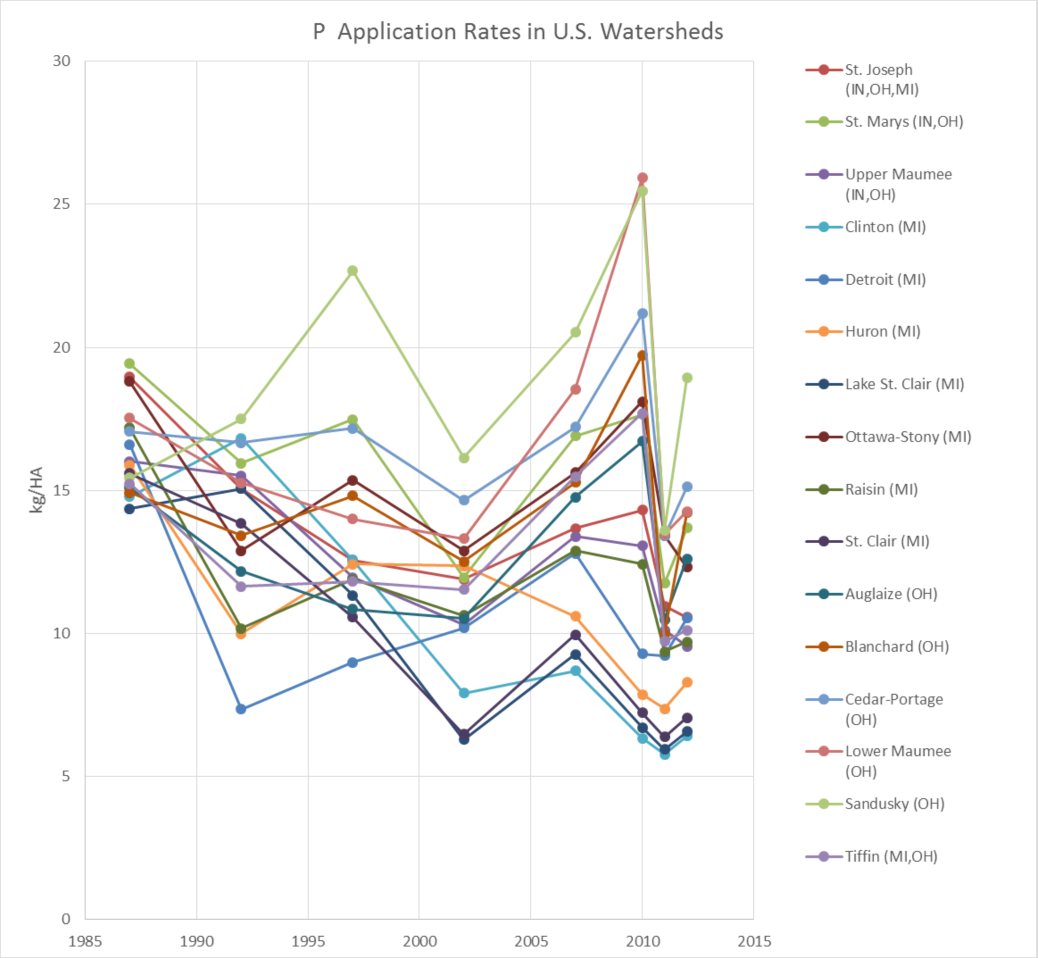


Figure 5. Commercial fertilizer application rates as kg P per hectare of cropland for U.S. subwatersheds, which do not show the same consistent pattern of increases as in the Canadian watersheds (Figure 4). (OH = Ohio, IN = Indiana, MI = Michigan)

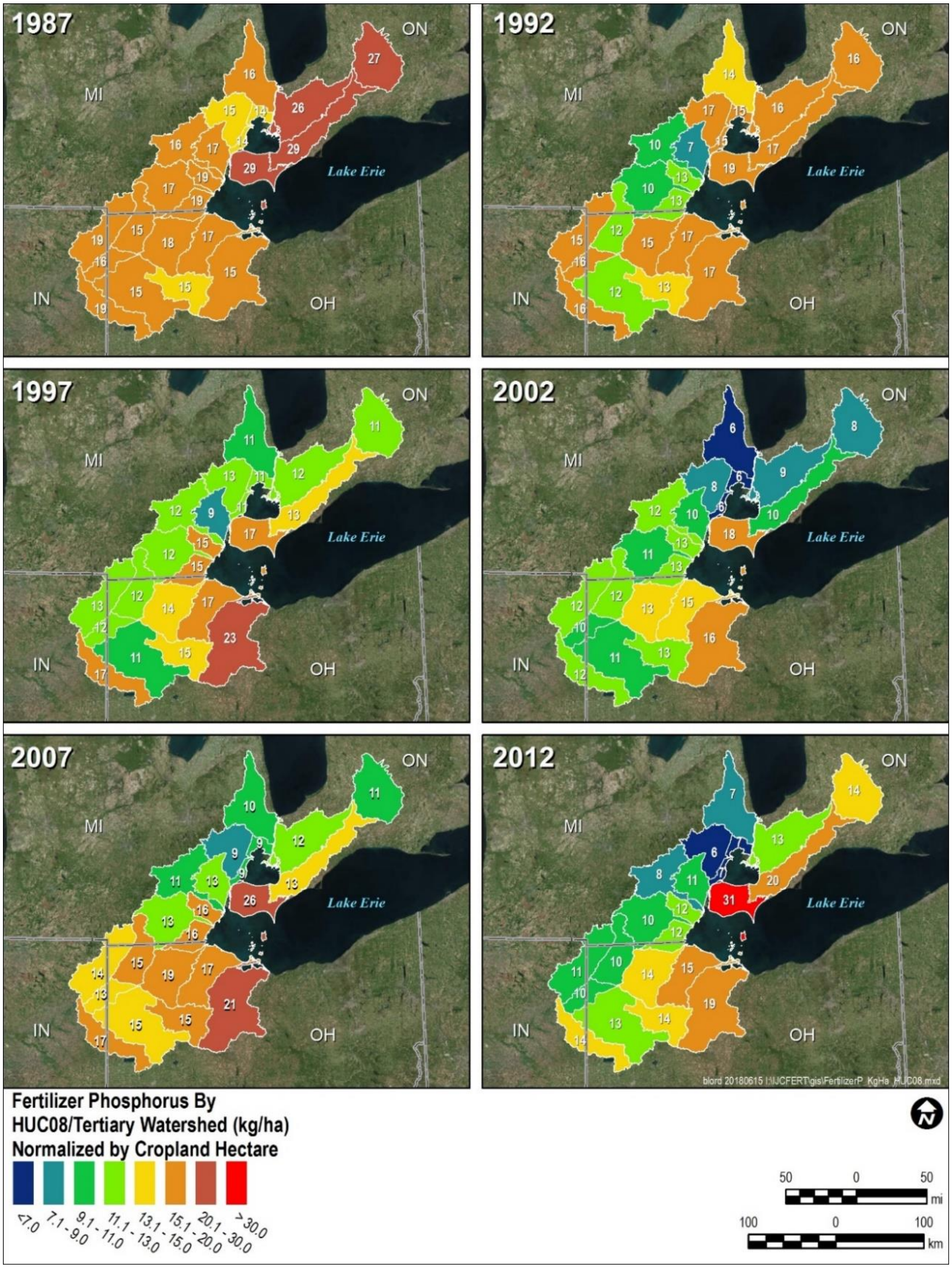


Figure 6. Evolution through time of normalized commercial fertilizer application intensity for cropland by watershed for six consecutive census periods (updated version of Figure 3-15 from original report, with rates labeled by watershed). Cedar (Essex County) watershed values since approximately 2002 are influenced by intensive fertilizer usage in expanding commercial greenhouse operations in the watershed; see related discussion in the text. Note that years shown on this plot for Canadian data are offset one year later than actual collection years for consistency with U.S. data.

Bruulsema and others have compiled lower spatial resolution but higher frequency and, in some cases, more recent province-level (Ontario) and state-level (Ohio) data for rates of manure application, commercial fertilizer application, and crop removal of P from IPNI-NuGIS, USDA-NASS, and StatCan data. These data are shown in Figures 7-9. Bruulsema also presented similar data in 2017 for the U.S. portion of the western Lake Erie watershed (Figure 10). These compilations show that manure application rates have been quite consistent through time in Ontario and Ohio, and that crop removal has gradually increased on average over the last 30 years. Commercial fertilizer application rates have been more irregular, with average application rates below annual crop removal in Ontario for the six-year period from 2005 through 2010 (Figure 7, Figure 8), but higher commercial fertilizer application rates from 2011 through 2016, the last year of plotted data. Ohio data do not show comparable deficits or increases over this time, except for a high application year in 2010 (Figure 9). The years 2011-2014 show fertilizer deficits for the U.S. part of the western Lake Erie watershed (Figure 10); more recent data are not available for the U.S.

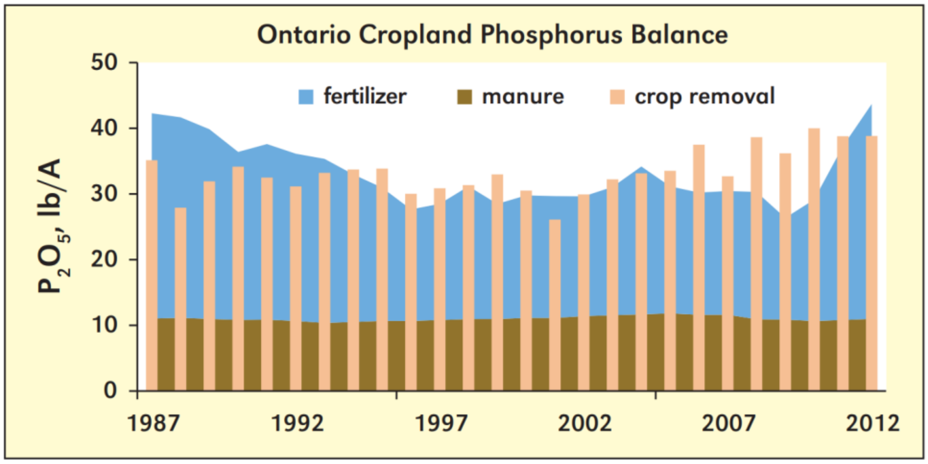


Figure 7. Partial balance for cropland P in the entire province of Ontario, including applied commercial fertilizer and manure, and crop removal estimated from reported yields, using methods similar to those in IPNI (2016; NuGIS). Source: Bruulsema et al. (2011). Note that 'recoverable manure' is depicted; the P in recoverable manure is considerably less that the total amount of P in manure as excreted, but is the best representation of the amount applied to cropland in these regions. Recoverable manure is generally understood to be manure that is generated by livestock in a concentrated small area, whereas non-recoverable manure is generally dispersed over the landscape, as in the case of grazing animals in a pasture (Gollehon et al. 2016).

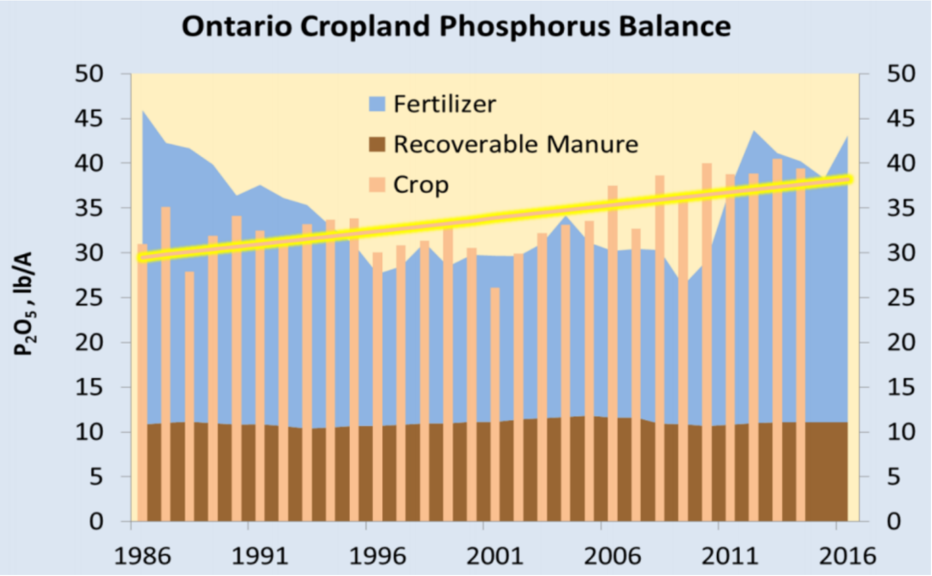


Figure 8. Cropland P balance for the entire province of Ontario through time showing a gradual increasing trend in crop P removal (right axis; yellow highlighted trend line, extrapolated beyond 2014), and a period of increased commercial fertilizer application rates from 2009 to 2012 following a period of P deficit (2005 - 2010). Source: Bruulsema (2017) presentation. Note that 'recoverable manure' is depicted; the P in recoverable manure is considerably less that the total amount of P in manure as excreted, but is the best representation of the amount applied to cropland in these regions. See the Figure 7 caption for additional details.

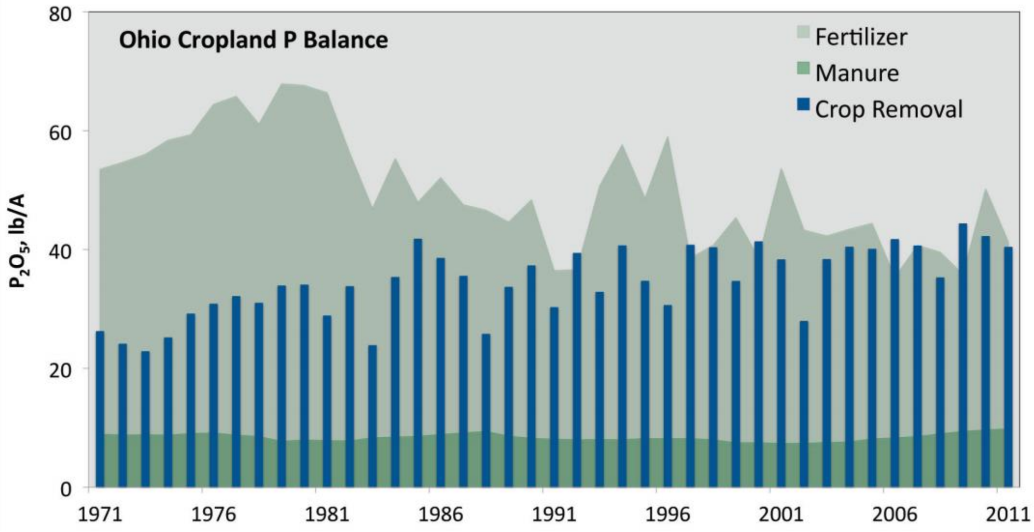


Figure 9. Phosphorus balance trend over time for cropland in the state of Ohio, including estimated 2011 commercial fertilizer values. Figure is reproduced from Bruulsema et al. (2012), Figure 2. Note that 'recoverable manure' is depicted; the P in recoverable manure is considerably less that the total amount of P in manure as excreted, but is the best representation of the amount applied to cropland in these regions. See the Figure 7 caption for additional details.

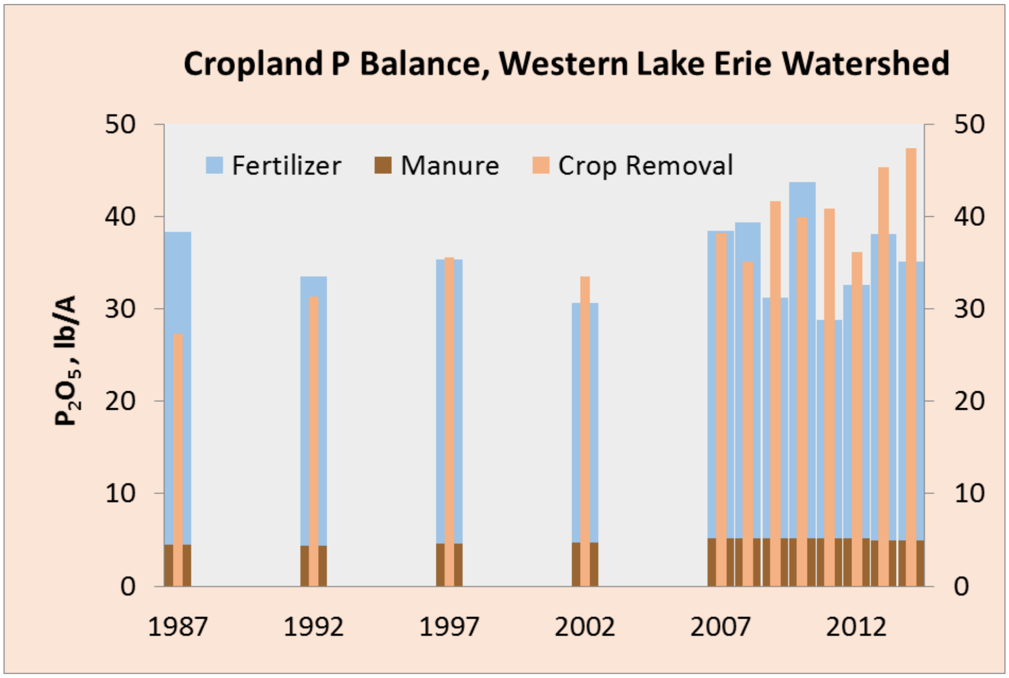


Figure 10. Cropland P balance for the western Lake Erie watershed (U.S. portion), showing general trend of increased crop removal (right axis) through 2014, but fairly steady commercial fertilizer application rates and steady manure application rates. Source: Bruulsema, personal communication, 2018. Note that 'recoverable manure' is depicted; the P in recoverable manure is considerably less that the total amount of P in manure as excreted, but is the best representation of the amount applied to cropland in these regions. See the Figure 7 caption for additional details.

In addition to changes in P application rates from commercial fertilizer, other recent developments that could influence P loading to Lake Erie include changes in geopolitical economic factors beginning in approximately June of 2018, particularly China's 25 percent tariff on U.S. soybean imports, and changing ethanol markets, which use approximately 40% of the U.S. corn crop. It is unclear whether these factors will result in substantial changes in total acres planted or major changes in plantings of soybeans versus corn in 2019 and in future years in the Western Lake Erie Basin. Nationally, U.S. corn and soybean acreage decreased 1% from 2016 to 2017 (NASS, 2018). Total crop acres planted in the Great Lakes states and Ontario have been quite steady over the last decade or so, as shown in the earlier IJC report. From 2016 to 2018, Ohio total crop acres grew at an annual rate of only 0.8% (NASS, 2018), and rates in Michigan and Indiana were of a similar magnitude.

Since the technical report was completed for the IJC-SAB Work Group in 2017, several important publications have become available that inform topics discussed in that report. The IJC released its report that built on results of the 2017 technical report in February 2018 (IJC 2018). Kalcic et al. (2018) and King et al. (2018) published papers relating both in-field 4R nutrient management practices, and beyond-field practices to P transport by surface runoff and tile drainage. Daniels et al. (2018) reported results from edge-of-field monitoring experiments. Long et al. (2018) published the research on manure transportation that was referenced in the 2017 technical report, and Wilson et al. (2018) reported results of research on farmer behavior that influences reduction of P loading to Lake Erie and associated policy development. In-lake bloom processes were examined as they relate to remote sensing (Binding et al. 2018, Soontiens et al. 2018), algal seed stock in sediment (Kitchens et al. 2018), and the influence of nitrogen on bloom growth and toxicity (Chaffin et al. 2018, Newell et al. 2019). Choquette et al. (2019) reported on statistical methods for handling variability in streamflow for P loading calculations, and Scavia et al. (2018) published results of new modeling studies that inform P loading from the St. Clair-Detroit River system to Lake Erie. A companion report to the Scavia et al. (2018) paper was released in 2019 (Scavia et al. 2019). The project website is here: http://graham.umich.edu/project/assessing-detroit-river-nutrient-loads-lake-erie .

As described in the original technical report, many questions remain to be answered about the complex agricultural, watershed, and lake processes that control movement of nutrients from fields to Lake Erie. Active numerical model development and refinement of monitoring programs is underway in the lake and watershed, and Domestic Action Plans are now being implemented in the U.S. and Canada with the aim of reducing nutrient impacts in the lake. As understanding of this system continues to grow, refinement of policies and practices will hopefully lead to reductions in algal blooms and hypoxia in Lake Erie, and corresponding improvement in ecosystem services and protection of human health. Tracking of commercial fertilizer and manure application at high temporal and spatial scales, as well as high-resolution water quality monitoring in the watersheds and lake are essential elements of adaptive management. These activities are necessary to effectively implement Domestic Action Plans and target resources to maximize the environmental benefits of nutrient mitigation investments.

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Listing of Data Files

The newly downloaded commercial fertilizer data are available in this file:
“CANcensusFarmExpenses2011.xlsx”

It contains the 2011 census expense data from STATCAN. It also contains the calculations that rescale the expenses from census units to watersheds, based on the proportion of census unit area within each tertiary watershed.

The following list of “attachment” files and figure files have been updated and replace the files by the same names in the original submission:

- AttachmentFert2_FertilizerShipmentCAN.xlsx
  Updated 2011 data.
- AttachmentFert4_CAN_Fert_Expense_1971_2016.xlsx
  Updated sheet “AAFC 2017 WLEB”.
  Added 2011 Fertilizer expense data, and updated Figure 3-2 from original report.
- AttachmentFert7__IPNINUGISdata.xlsx
  Added 2011 data and calculations for Canada.
- FertilizerSectionFigureData.xlsx
  Edited sheet “P Application US CAN” to include 2011 data and updated Figures 3-14 and 3-16 from original report.

For further information on data files please contact the IJC’s Great Lakes Regional Office.