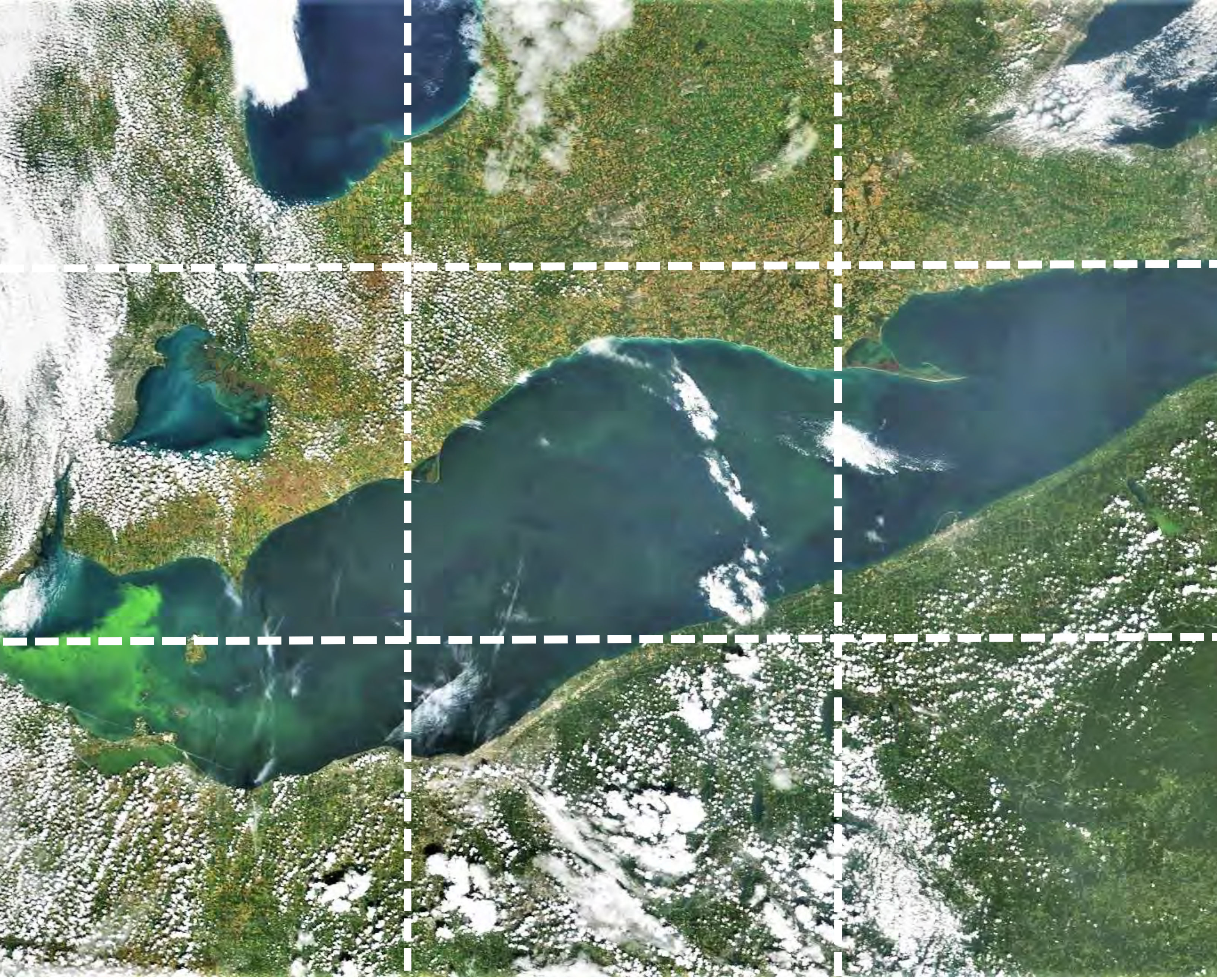


Lake Erie Retrospective Analysis

Agri-Environmental Cost-Share Programs and Water Quality Best Management Practices (BMPs) in the Lake Erie Basin, 2005 - 2018

July 2021

Prepared For: Ontario Soil and Crop Improvement Association

Acknowledgements

This report was prepared by Jen Hoesen.

The author would like to thank experts from the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA), Agriculture and Agri-Food Canada (AAFC), and the Ontario Soil and Crop Improvement Association (OSCIA), for providing valuable feedback and comments on an earlier version of this report. Their insight has greatly assisted the analysis presented in this report.

This project was funded by the Ontario Ministry of Agriculture, Food and Rural Affairs, as part of the Canadian Agricultural Partnership.

Lake Erie Retrospective Analysis: Agri-Environmental Cost-Share Programs and Water Quality Best Management Practices (BMPs) in the Lake Erie Basin, 2005-2018. 136pp.

Report Published July 27, 2021.

Front Cover Page Image Credit:
Satellite image of Lake Erie by NASA, Jeff Schmaltz, Goddard Space Flight Center (2010).

Table of Contents

List of Figures

List of Tables

Lake Erie

Lake Erie is vitally important to the health, quality of life and prosperity of farmers, Ontario families and communities. Over the last several decades, Lake Erie has been threatened by declining water quality and increasingly harmful algal blooms. The impacts from rising inputs of phosphorus, driven in part by changing agricultural land management practices, population growth, industrial pollution and climate change, continue to impede Lake Erie's ecological health and resiliency.

Out of the five Great Lakes, southernmost Lake Erie is the warmest, shallowest and smallest by volume (Figure 2). It is one of the most biologically productive of the Great Lakes, supporting a rich diversity of habitats and species. Lake Erie is naturally divided into three basins distinguished by trophic characteristics and depth. The western basin, with an area of 3,083 km^2, is the shallowest with an average depth of 7.4 meters. The central basin has the most uniform bathymetry over the largest area (16,425 km^2) and has an average depth of 18 meters. The eastern basin, with an area of 6,159 km^2, has an average depth of 24 meters; and it is here where the deepest point of Lake Erie can be found at 64 meters depth (Reutter, 2019).

The western basin receives the largest input of nutrients and is more eutrophic than the diluted waters of the central and eastern basins (Prepas et al., 2013). Primary inflow to Lake Erie comes from the Detroit River in the western basin, which originates from Lake St. Clair and Lake Huron, and accounts for 80% of total inflow. Precipitation contributes another 11%, while remaining tributaries contribute 9% to total water volume (USEPA, 2020).

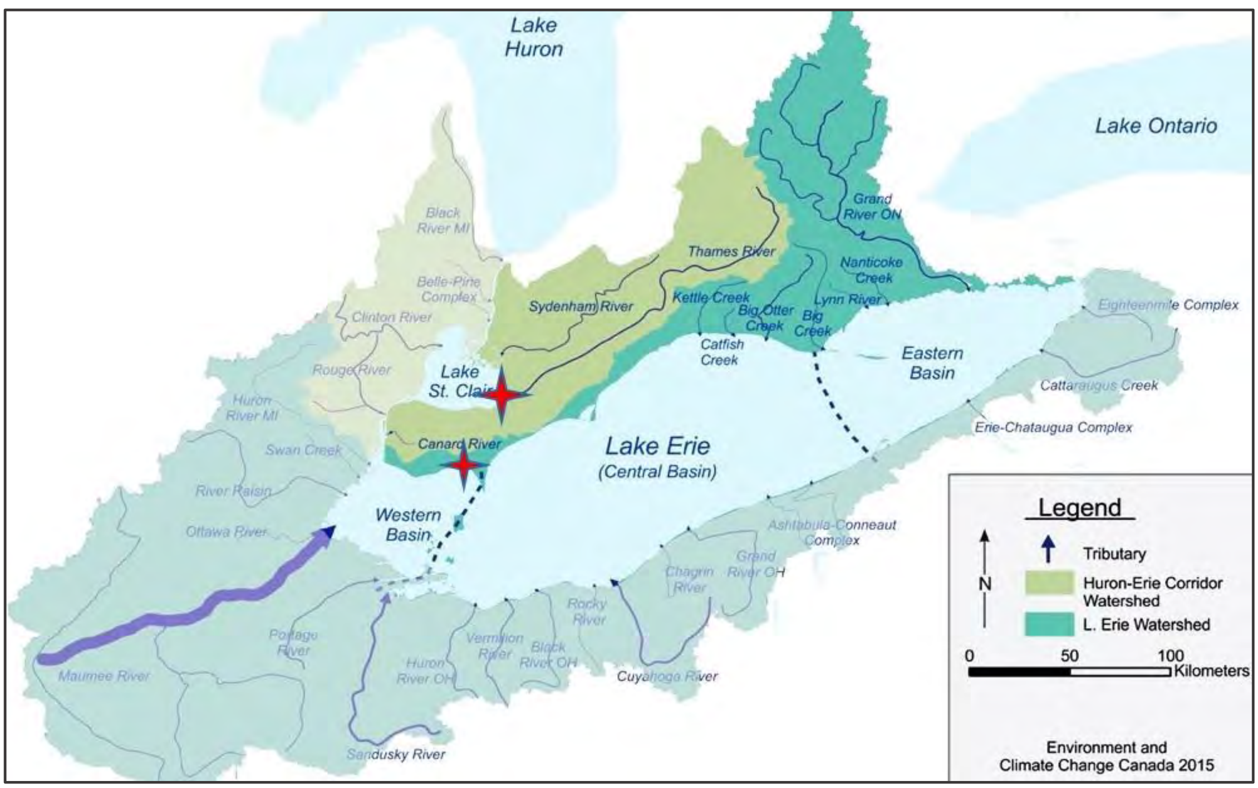


Figure 1: Map of Lake Erie showing its three basins and major tributaries.

Major tributaries that contribute to algal blooms on the Canadian side of Lake Erie are identified by the red stars in Figure 1. Source: Environment and Climate Change Canada, 2015.

Lake Erie has the shortest lake retention time out of the five Great Lakes. Water spends on average 2.6 years in Lake Erie, compared to 6 years for Lake Ontario, 22 years for Lake Huron and up to 191 years for Lake Superior. This means that addressing phosphorus pollution in Lake Erie can be achieved much sooner in comparison to the other Great Lakes (Reutter, 2019).

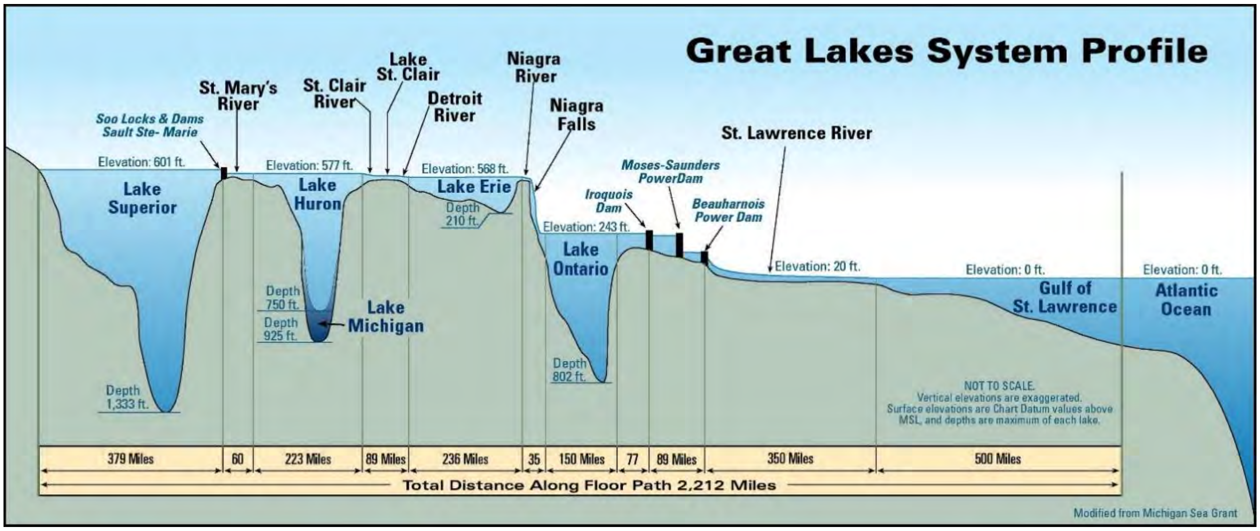


Figure 2: Great Lakes System Profile

Primary inflow of water to Lake Erie comes from the Detroit River, which originates from Lake St. Clair and Lake Huron. Source: Michigan Sea Grant.

Impacts of Excessive Phosphorus

Phosphorus is a naturally occurring essential plant nutrient that is vital to the health of Lake Erie; but too much can promote excessive algal growth. Elevated levels of phosphorus can negatively impact water quality through production of algal blooms and low oxygen zones which harm fish and wildlife populations (ECCC, 2018). Phosphorus loadings are typically higher during periods of weak lake circulation and higher precipitation, when there is a greater chance for surface waters to pick up and carry excessive phosphorus to the lake (ECCC, 2018; Michalak et al., 2013).

Lake Erie's physical characteristics in combination with human activities on both sides of the international border, make it particularly susceptible to water quality impairment. For over forty years, Canada and the United States have partnered together to address Lake Erie's environmental health as a shared responsibility (ECC & USEPA, 2014). Despite previous successes in reducing total phosphorus loadings, there has been a resurgence in toxic cyanobacterial blooms over the last decade (ECCC, 2018).

Canada contributes about 16% of the total phosphorus load to Lake Erie, with the remaining contribution from the United States (ECCC, 2018). Non-point sources, which include both agriculture and urban storm water runoff, are the largest contributors of phosphorus, accounting for as much as 77% of the total phosphorus load (ECCC, 2018). The majority of Ontario's contribution to Lake Erie is non-point runoff from agricultural lands, where 75% of the total basin land area is under agricultural production (ECCC, 2018). Agricultural non-point sources include soil erosion and nutrient runoff from fertilizers and manure amendments. Point-source contributions include wastewater treatment plants, combined sewer overflows and industrial discharges, among other sources.

Market pressures coupled with new technologies continue to impact the farm landscape across multiple scales. Over the last fifteen years, there has been an increase in the total number of annual tilled cropland acres and livestock concentrations in the Lake Erie basin (Statistics Canada, 2016). These factors have contributed to increased risks of runoff, especially during the non-growing season when soils are often bare. Through adjustments in production practices, the amount of perennially covered farmland such as hayfields and pasturelands have decreased (Statistics Canada, 2017). Bare soils have higher rates of erosion during snowmelt, winter rainfall and extreme storm events (ECCC, 2018).

While nutrient-use efficiency has increased with new planting techniques and precision fertilizer management strategies; land use changes continue to impact the amount of phosphorus that flows into streams and rivers (IJC, 2018). The loss of windbreaks, natural areas and perennially covered lands have also contributed to the acceleration of erosion and runoff to surface waters, bringing excessive phosphorus with it (ECCC, 2018).

Figure 3: Algal blooms Swirl Around Pelee Island in 2015.

There are many social, ecological and economic impacts of widespread toxic algal blooms. These include the increased costs associated with municipal drinking water systems and human health costs, a decline in tourism and coastal recreational opportunities, impacts to commercial fishing and impairment of many ecosystem services (ECCC, 2018). Excessive phosphorus inputs can lead to algal blooms which then degrades water quality and habitat for many fish and wildlife populations, and can magnify the impact of invasive species. It is estimated that left uncontrolled, algal blooms could cost Canada's Lake Erie Basin economy $272 million annually (ECCC, 2018).

Through binational agreements including the Lake Erie Action Plan (LEAP), Ontario has committed to reducing phosphorus loadings entering Lake Erie by 40% (from 2008 levels) by 2025. LEAP has established targets to: reduce phosphorus loadings, improve knowledge and education, and prioritize effective programs and policy (ECCC, 2018). Many agri-food and agricultural sectors in Ontario are working together to achieve these targets.

Agri-environmental policy tools like cost-share programs play an important role in mitigating phosphorus loadings to Lake Erie. Voluntary land stewardship programs can provide farmers with resources to address specific on-farm water quality risks. Water quality Best Management Practices (BMPs) help farmers to prevent, reduce and recover excessive phosphorus runoff before it leaves the farm. Sustainable land use changes and other stewardship behaviors that are performed routinely can provide protection to soil and water resources over the long term. These actions can help to improve the health of farmland throughout Lake Erie basin.

Objective

The Ontario Soil and Crop Improvement Association (OSCIA) has played a key role in the delivery of agri-environmental land stewardship programming in Ontario since the late 1980s. OSCIA has delivered a variety of sustainability focused cost-share programs through its province-wide connection to farmers. Through these programs, farmers have completed tens of thousands of voluntary BMP projects to improve water quality on their farms.

Water quality has been at the heart of many of these programs. A combination of education, financial incentives and technical assistance provides farmers with resources to identify and address a variety of environmental issues and risks that are specific to the farm. Changing land use practices such as minimizing tillage, retaining crop residues, preventing runoff and improving nutrient-use efficiency often work in tandem across multiple BMP focus areas. The evaluation of past program participation provides a unique opportunity to tell a story of water quality actions by farmers across the Lake Erie basin.

This report analyzed program participation between 2005 and 2018, compiling thousands of water quality BMP projects that were completed with the help of OSCIA-delivered cost-share programs. These programs are funded by a range of sources including federal-provincial-territorial funding agreements and other provincial ministries. This work builds upon previous retrospective data analyses and other past and ongoing research studies that have utilized cost-share program data to identify BMP adoption trends across all phases of program delivery[1,2,3,4].

The data provides a big picture look at what's been done, and how individual BMP actions are collectively addressing water quality issues in the Lake Erie basin. This report also aims to help the agricultural sector to assess progress in meeting phosphorus reduction targets, and inform the development of future environmental stewardship programs that are focused on water quality improvements in this region.

Many programs were delivered during this thirteen-year period, and each program supported hundreds of farmers in addressing environmental risks. These programs are just one of many tools in the region that are helping to accelerate environmental action in support Lake Erie's ecological health and resiliency.

---

1 Woyzbun, E. (2015). *Spatial Analysis of the Adoption of Nutrient Related BMPs in Ontario*.

2 Smith, P. (2008) *Progress in Adoption of Beneficial Management Practices and Environmental Farm Plans under the Agricultural Policy Framework 2005-2008.*

3 Environment Canada & the United States Environmental Protection Agency. (2014). *State of the Great Lakes 2011: Indicators to assess the status and trends of the Great Lakes ecosystem.*

4 Ontario Soil and Crop Improvement Association (OSCIA). (2018). Lake Simcoe Retrospective Analysis.

Statistical Profile of Agriculture in the Lake Erie Basin

It will be helpful to understand the overall profile of agriculture in the Lake Erie basin before reviewing the impact of OSCIA-delivered cost-share programs. Every five years, the Census of Agriculture collects statistical data on the number and type of farms, the type of farmland areas, land management practices, livestock inventories, the number of cropland acres, and gross farm receipts, among many other measures (Statistics Canada, 2016). This data provides an opportunity to measure changing characteristics and land use practices within the different watersheds that make up the Canadian portion of the Lake Erie basin.

Census data can also be used to evaluate spatial trends in land use practices. These trends can be compared to participation rates and other BMP project metrics to estimate the reach and impact of OSCIA-delivered cost-share programs delivered in the Lake Erie basin.

As a watershed analysis, and for the purposes of this report, data obtained from the Census of Agriculture was delineated by tertiary watershed and township. Figure 4 below shows the eight tertiary watersheds that make up the Canadian portion of the Lake Erie basin.

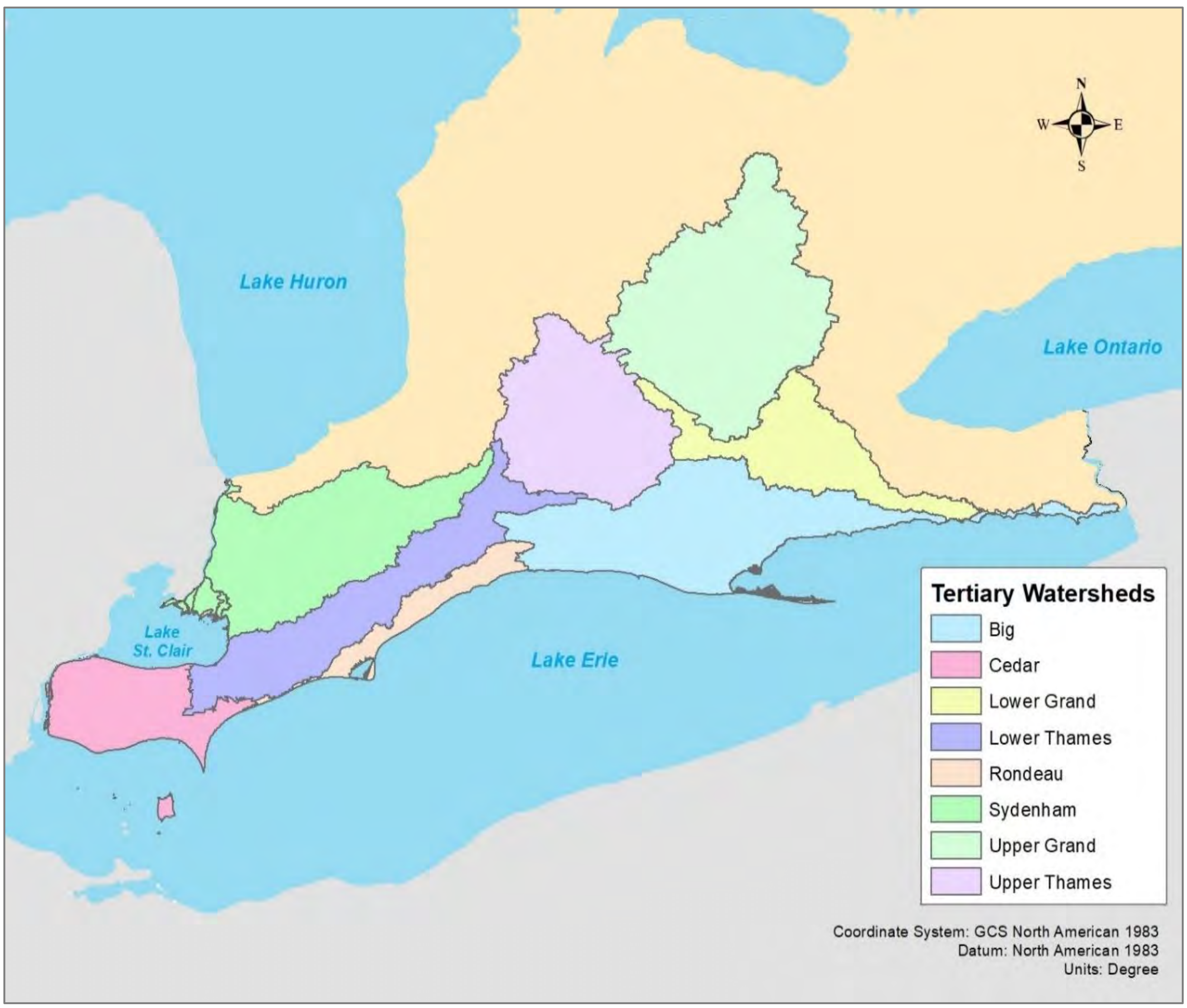


Figure 4: Tertiary Watersheds, Lake Erie Basin

Number of Farms

With more than 75% of total land area under agricultural production, the Canadian side of the Lake Erie basin supports a highly developed farm economy. According to the 2016 Census of Agriculture, there were 18,150 farms involved in crop, livestock, greenhouse, nursery and other agri-food and mixed operations. Between 2006 and 2016, there was a seven percent decline in the number of farms in the Lake Erie basin; this compares to a 13% decline for Ontario.

The change in the number of farms varies between watersheds. As shown in Table 1, Lower Grand was the only watershed where the number of farms increased over this period. Upper Grand, Big and Sydenham reported larger declines in the number of operating farms, while Rondeau and Lower Thames saw more modest declines.

Table 1: Number of Farms and Percent Change, Lake Erie Basin.

SOURCE: Statistics Canada, Agricultural Census (2006, 2011) and OMAFRA (2016).

Tertiary Watershed	Total Number of Farms			Percent Change (%)		
Name	**2006**	**2011**	**2016**	**2006-2011**	**2011-2016**	**2006-2016**
Upper Grand	4,474	4,172	4,040	-7%	-3%	-10%
Lower Grand	1,349	1,437	1,400	7%	-3%	4%
Big	3,487	3,130	3,109	-10%	-1%	-11%
Upper Thames	2,950	2,641	2,740	-10%	4%	-7%
Lower Thames	2,278	2,077	2,205	-9%	6%	-3%
Rondeau	595	544	570	-9%	5%	-4%
Sydenham	2,787	2,608	2,557	-6%	-2%	-8%
Cedar	1,629	1,485	1,528	-9%	3%	-6%
Total	**19,549**	**18,094**	**18,150**	**-7%**[1]	**-7%**[1]	**<1%**[1]

1. Average (not total) percent change.

Land Area Distribution

The Census of Agriculture defines total farmland area as the land owned or operated by an agricultural operation. This includes cropland, pasture, summer fallow (cropland intentionally kept out of production), woodlands and wetlands, and all other idle land and land on which farm buildings are located (Statistics Canada, 2016).

In 2016, total farm area in the Lake Erie basin covered 17,070 km^2, an increase of 457 km^2 from 2011. Total farm area in the Lake Erie basins accounts for 34% of Ontario's total farmland area (Statistics Canada, 2016). Agricultural production continues to intensify in the Lake Erie basin, with 87% of the agricultural land base managed as croplands (excluding Christmas trees). This is a slight increase from 2006, when 85% of the land was cropped.

Compared to Ontario, where 73% of total farmland is under crop production, farms in the Lake Erie basin have more agricultural land in crops and less in pasturelands and natural areas. This can be attributed to rich fertile soils, a shift away from certain animal production and pastureland farming, and economics that favor annual cropping instead of perennial production systems.

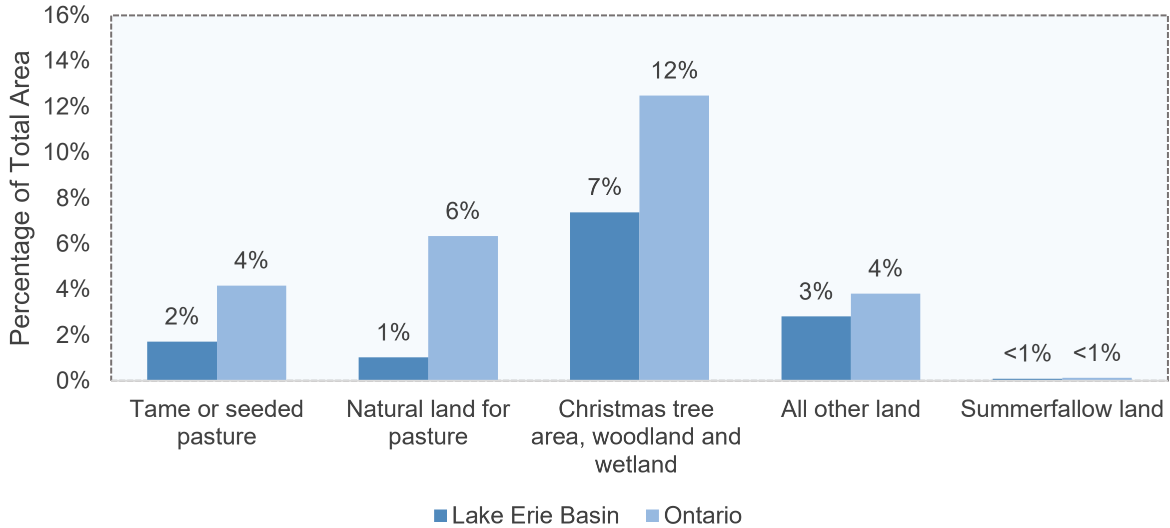
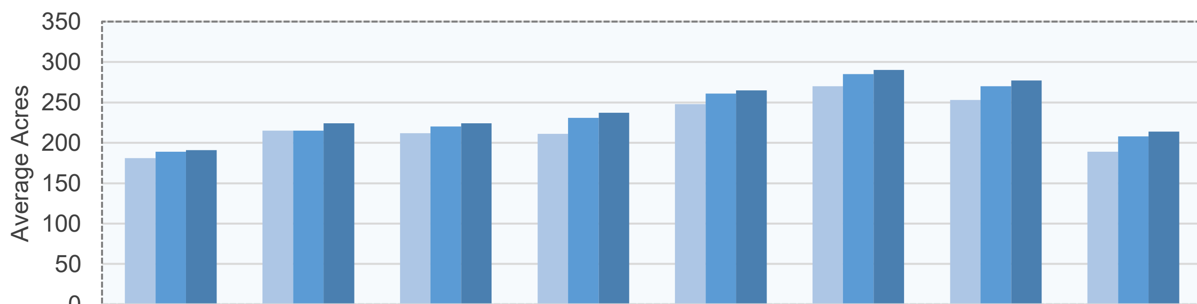


Figure 5: Non-Crop Farm Area Distribution, Lake Erie Basin, Statistics Canada, 2016

As shown in Figure 5, total acres classified as woodlands and wetlands (including Christmas tree production) increased to seven percent in 2016, but was lower than that of the province at 12% (OMAFRA, 2017). It is not known what proportion of tree covered land is attributed specifically to windbreaks and shelterbelts, or other areas that are intentionally retired from production or grazing. Some farms in the Lake Erie basin have removed fence rows to accommodate larger equipment implements and prepare more land for seeding (Statistics Canada, 2016). Natural pastureland decreased to 1%, while tame or seeded acreage slightly increased to 2% of total farm area. Summer fallow declined almost 3% between 2006 and 2016.

Average Farm Size

As the number of farms became fewer, the average farm size increased 8% between 2006 and 2016; this compares to a 7% increase in farm size for Ontario (Statistics Canada, 2016). As shown in Figure 6, all watersheds in the Lake Erie basin reported increases in average farm size. In 2016, Rondeau had the largest average farm size at 290 acres, while Upper Grand had the smallest at 191 acres (Table 2).



	Upper Grand	Lower Grand	Big	Upper Thames	Lower Thames	Rondeau	Sydenham	Cedar
2006	181	215	212	211	248	270	253	189
2011	189	215	220	231	261	285	270	208
2016	191	224	224	237	265	290	277	214

Figure 6: Average Farm Size, Lake Erie Basin, Statistics Canada, 2016

Table 2: Average Farm Size, Lake Erie Basin.

SOURCE: Statistics Canada, Agricultural Census (2006, 2011) and OMAFRA (2016).

Tertiary Watershed	Average Farm Size (Acres)		
Name	**2006**	**2011**	**2016**
Upper Grand	181	189	191
Lower Grand	215	215	224
Big	212	220	224
Upper Thames	211	231	237
Lower Thames	248	261	265
Rondeau	270	285	290
Sydenham	253	270	277
Cedar	189	208	214
Total	**215**	**227**	**232**

As shown in Table 3, more than one third of total farms in the Lake Erie basin are less than 70 acres in size. Small farms fewer than 10 acres account for 6% of total farms. The number of farms with farm areas larger than 760 acres increased 30% between 2006 and 2016. Farms in the 2,880-to-3,519-acre range saw the largest increase (74%), while those in the 180-to-239-acre range saw the largest decrease (19%). Farms larger than 1,119 acres account for 3% of total farms. In the Lake Erie basin, as farms become fewer but larger, the land use decisions of a single operation can have a much larger impact.

Table 3: Total Farm Area Distribution, Lake Erie Basin

SOURCE: Statistics Canada, Agricultural Census (2006, 2011) and OMAFRA (2016).

Total Farm Area	Total Number of Farms			Percent Change (%)		
Acres	**2006**	**2011**	**2016**	**2006-2011**	**2011-2016**	**2006-2016**
Under 10	1,143	967	1,048	-15%	8%	-8%
10 to 69	5,125	4,809	5,066	-6%	5%	-1%
70 to 129	4,646	4,402	4,172	-5%	-5%	-10%
130 to 179	1,965	1,708	1,702	-13%	<1%	-13%
180 to 239	1,758	1,553	1,433	-12%	-8%	-18%
240 to 399	2,297	2,034	2,026	-11%	<1%	-12%
400 to 559	1,051	1,021	1,004	-3%	-2%	-4%
560 to 759	630	600	621	-5%	4%	-1%
760 to 1,119	477	473	517	-1%	9%	8%
1,120 to 1,599	245	272	272	11%	<1%	11%
1,600 to 2,239	124	145	160	17%	10%	29%
2,240 to 2,879	42	52	60	24%	15%	43%
2,880 to 3,519	22	30	38	36%	27%	73%
3,520 and over	27	27	32	<1%	19%	19%
Total	**19,551**	**18,094**	**18,150**			

Land Area in Crops

As shown in Table 4, the number of cropland acres increased 3% between 2006 and 2016. In 2016, a total of 3.6 million acres were managed as crops, an increase of 103,888 acres from 2006. Lower Grand, Cedar and Upper Thames saw larger increases in the number of cropped acres over this period. Big and Upper Grand were the only watersheds that saw modest declines over the entire period.

Table 4: Total Land Area in Crops, Lake Erie Basin.

SOURCE: Statistics Canada, Agricultural Census (2006, 2011) and OMAFRA (2016).

Tertiary Watershed	Land Area in Crops (Acres)			Percent Change (%)		
Name	**2006**	**2011**	**2016**	**2006-2011**	**2011-2016**	**2006-2016**
Upper Grand	643,241	638,379	631,828	-1%	-1%	-2%
Lower Grand	238,102	257,046	263,537	8%	3%	11%
Big	598,165	564,893	579,292	-6%	3%	-3%
Upper Thames	535,303	534,549	572,202	<1%	7%	7%
Lower Thames	504,499	490,965	528,972	-3%	8%	5%
Rondeau	139,241	135,989	145,172	-2%	7%	4%
Sydenham	604,606	614,415	625,110	2%	2%	3%
Cedar	285,651	287,589	306,580	1%	7%	7%
Total	**3,548,806**	**3,523,825**	**3,652,694**	**-1%[1]**	**4%[1]**	**3%[1]**

1. Average (not total) percent change.

In the Lake Erie basin, 87% of total farmland area is managed as croplands, but this varies between watersheds. In Upper Grand, 82% of total farm area is cropland; this compares to Cedar where 94% of total farm area is cropped (Table 5). Generally, as a percentage of total farm area, there are fewer acres in crops in the most northerly watersheds of the Lake Erie basin, and more cropland acres in the southerly watersheds of the basin.

Table 5: Total Farm and Land Area in Crops, Lake Erie Basin, 2016

SOURCE: Statistics Canada, Agricultural Census (2016), OMAFRA (2016).

Tertiary Watershed	Total Farms	Total Farm Area	Land Area in Crops	Total Farm Area in Crops	Average Total Farm Area	Average Land Area in Crops
Name	**Number**	**Acres**	**Acres**	**Percent**	**Acres**	**Acres**
Upper Grand	4,040	771,777	631,828	82%	191	156
Lower Grand	1,400	313,359	263,537	84%	224	188
Big	3,109	696,680	579,292	83%	224	186
Upper Thames	2,740	649,562	572,202	88%	237	209
Lower Thames	2,205	584,495	528,972	91%	265	240
Rondeau	570	165,198	145,172	88%	290	255
Sydenham	2,557	709,356	625,110	88%	277	244
Cedar	1,528	327,787	306,580	94%	215	201
Total	**18,149**	**4,218,214**	**3,652,694**	**87%[1]**	**232[1]**	**201[1]**

1. Average (not total) percent change.

Rented or Leased Farmland

It is a common practice in rural Ontario to lease or rent farmland (OMAFRA, 2021). In 2016, over 1.2 million acres of farmland was rented in the Lake Erie basin, this accounts for 33% of the total land area in crops (Table 6). Between 2006 and 2016, the number farm acres rented increased nearly 3%. This compares to Ontario where the number of rented farm acres decreased 20% (OMAFRA, 2017).

In 2016, 2.9 million acres of farmland were owned, while 1.2 million acres were rented or leased from others. An additional 15,285 acres were leased from the government[5]. The number of acres impacted by crop-sharing increased 4.25% from 220,917 acres in 2006 to 230,820 acres in 2016; this type of land sharing agreement is not as common as other rental leases in Ontario.

Table 6: Land Area Rented or Leased, Lake Erie Basin

SOURCE: Statistics Canada, Agricultural Census (2006, 2011) and OMAFRA (2016).

Tertiary Watershed	Land Area Rented (Acres)			Percent Change (%)		
Name	**2006**	**2011**	**2016**	**2006-2011**	**2011-2016**	**2006-2016**
Upper Grand	254,910	248,547	243,816	-2%	-2%	-4%
Lower Grand	105,995	124,715	115,416	18%	-7%	9%
Big	214,362	227,803	228,443	6%	<1%	7%
Upper Thames	174,410	193,336	190,878	11%	-1%	9%
Lower Thames	142,655	142,808	140,242	<1%	-2%	-2%
Rondeau	41,719	43,178	39,730	3%	-8%	-5%
Sydenham	150,663	155,474	148,967	3%	-4%	-1%
Cedar	89,783	102,202	100,473	14%	-2%	12%
Total	**1,174,496**	**1,238,063**	**1,207,964**	**5%[1]**	**-2%[1]**	**3%[1]**

1. Average (not total) percent change.

Industry Groups

Agriculture is diverse in the Lake Erie basin; the upper portion of the basin supports a mix of livestock and crop production, while cash cropping, vegetable and fruit production is more prevalent in the south-central portions of the basin (Table 7).

There have been several changes within certain farm industry groups in the Lake Erie basin. The Census of Agriculture classifies farms by industry group, which is divided into crop and animal production categories. As shown in Table 7, the number of farms primarily engaged in oilseed and grain production increased 17% between 2006 and 2016. The only other industry group to report an increase in the number of farms was poultry and egg production, which saw a 7% increase over this period. This increase was driven by broiler chicken production and poultry and egg production facilities. The remaining industry groups all reported decreases in the number of farms, ranging from declines of 5% for sheep and goat farms to as much as 45% for hog and pig farms.

In the Lake Erie basin, oilseed and grain farming makes up 50% of total farms in the region, compared to 34% for Ontario (OMAFRA, 2017).

[5] Refers to land operated under licence, permit or lease (Statistics Canada, 2016)

Table 7: Number of Farms by Industry Group, Lake Erie Basin

SOURCE: Statistics Canada, Agricultural Census (2006, 2011) and OMAFRA (2016).

Type of Farm	Number of Farms			Percent Change (%)		
Industry Group	**2006**	**2011**	**2016**	**2006-2011**	**2011-2016**	**2006-2016**
Oilseed and grain farming	7,718	8,653	9,018	12%	4%	17%
Poultry and egg production	707	685	753	-3%	10%	7%
Sheep and goat farming	327	399	309	22%	-23%	-6%
Vegetable and melon farming	809	670	724	-17%	8%	-11%
Dairy cattle and milk production[1]	1,597	1,398	1,294	-12%	-7%	-19%
Other animal production	2,023	1,888	1,633	-7%	-14%	-19%
Greenhouse, nursery and floriculture production	866	732	656	-15%	-10%	-24%
Beef cattle ranching and farming, including feedlots[1]	1,959	1,344	1,441	-31%	7%	-26%
Fruit and tree nut farming	381	322	273	-15%	-15%	-28%
Other crop farming	1,929	1,310	1,372	-32%	5%	-29%
Hog and pig farming	1,236	692	677	-44%	-2%	-45%
Total	**19,551**	**18,094**	**18,150**			

1. Beef and dairy cattle are not classified as industry groups in the Agricultural Census, but are grouped together as cattle ranching and farming. For Table 7, they were divided to correlate with the capture of primary commodity information in cost-share participation. Other animal production includes apiculture, horse and other equine production, fur-bearing animal and rabbit production, deer, llamas and alpacas.

Number of Livestock

Despite the decrease in the total number of farms producing livestock, the entire animal production industry still accounts for more than 34% of total farms in the Lake Erie basin; this compares to 35% for Ontario. However, livestock numbers more accurately reflect the scale of this industry, and these trends are shown in Table 8. Coinciding with the increase in the number of poultry farms was a 24% increase in the number of poultry livestock from 17.8 million to 23.5 million. While the number of cattle farms declined by as much as 28%, the number of cattle only decreased by 5%. The beef industry previously saw large decreases in the number of beef cattle prior to this period as the result of the BSE outbreak which began in 2004 (Statistics Canada, 2004). In other livestock, while the number of pig and hog farms was almost halved, the number of pigs only decreased by 9%. This industry also faced biosecurity challenges with the Porcine Epidemic Diarrhea (PED) outbreak, of which many impacted farms were located in the Lake Erie basin (OMAFRA, 2021). These trends illustrate the impacts of biosecurity, market prices, and the continued shift towards concentration and intensification of these industries in this region. Note the larger increase in poultry numbers in the Lake Erie basin, and the smaller decline in cattle numbers compared to Ontario as shown in Table 8.

In other livestock numbers, there was a 23% increase in sheep and a 56% increase in the number of goats between 2006 and 2016; while the number of horses and other livestock saw decreases. Except for rabbit production and llamas and alpacas which had a small increase, the other livestock category saw fewer numbers as well.

Table 8: Number and Percent Change of Livestock, Lake Erie Basin
SOURCE: Statistics Canada, Agricultural Census (2006, 2011) and OMAFRA (2016).

Livestock	Number of Livestock		Percent Change (2006-2016)	
Type	2006	2016	Lake Erie Basin	Ontario
Poultry	17,833,331	23,568,069	24%	14%
Pigs	2,068,792	1,893,489	-9%	-11%
Cattle	533,963	506,675	-5%	-18%
Sheep	61,353	79,566	23%	3%
Goats	23,452	53,494	56%	NA
Other[1]	57,089	43,148	-32%	NA
Horses	28,259	19,590	-44%	-34%

1. Includes smaller industries such as llamas and alpacas, bison, deer and fur-bearing animals, including mink farms

Number of Cropland Acres

The increase in total cropland acres has been driven by major field crops like soybeans and corn. As shown in Table 9, grain corn acres increased 34%, while soybean acres increased 11%. Winter wheat decreased by 12%; however, it was still the third largest field crop in the Lake Erie basin in 2016. Most other crops saw decreases as well, with the exception of ginseng and canola.

When compared to Ontario, the Lake Erie basin had smaller increases in both soybeans and grain corn over the 2006 to 2016 period. There were also larger decreases in vegetables, barley, fall rye and nursery crops in comparison to Ontario.

Table 9: Major Crop Acres by Type, Ranked by Percent Change, Lake Erie Basin
SOURCE: Statistics Canada, Agricultural Census (2006, 2011) and OMAFRA (2016).

Type of Major Crop	Number of Acres (Lake Erie)			Percent Change 2006-2016	
Crop Name	2006	2011	2016	Lake Erie	Ontario
Ginseng	3,153	6,342	9,246	193%	37%
Canola	2,552	12,159	4,299	68%	-79%
Grain corn	762,801	953,075	1,025,529	34%	37%
Soybeans	1,172,613	1,199,652	1,300,641	11%	29%
Silage corn	116,314	106,312	118,504	2%	-8%
Sugar beets	6,897	6,876	6,692	-3%	5%
Winter wheat	561,124	501,585	491,533	-12%	-13%
Total vegetables	108,680	88,927	87,002	-19%	-14%
Dry field beans	68,340	33,131	52,759	-20%	-33%
Hay	412,739	339,278	308,869	-23%	-41%
Spring wheat	31,406	18,063	19,938	-25%	-20%
Total fruits, berries and nuts	15,583	12,352	9,288	-37%	-38
Oats	24,927	9,150	14,150	-40%	-47%
Mixed grain	41,893	26,975	22,046	-43%	-53%
Barley	36,788	21,566	17,047	-47%	-20%
Nursery products	4,300	4,488	1,510	-54%	-14%
Fall rye	45,101	20,518	11,513	-65%	37%

Number of Greenhouses

Greenhouse facilities in the Lake Erie Basin account for 2,536 acres, which is 70 percent of Ontario's total greenhouse area (Statistics Canada, 2021). The greatest concentration of greenhouses in the province is found in the Leamington and Kingsville area. Plant nurseries account for an additional 1,510 acres of croplands, which account for 7% of Ontario's total nursery area (OMAFRA, 2021). Greenhouses require large quantities of water and fertilizer; and facilities that do not adequately manage feedwater[6] can be considered point sources of phosphorus pollution (Maguire et al., 2018).

Between 2006 and 2016, the number of greenhouse operations in the Lake Erie basin declined by 20% (Statistics Canada, 2016). This is a highly technological industry, and while there are fewer operations, many of these specialized facilities have expanded. As shown in Table 10, total greenhouse area increased 46% over this period. This varied across watersheds, with the most expansion occurring in Rondeau and Sydenham. The total area of greenhouse crops under plastic, glass or other poly-film materials also increased by 44% (Statistics Canada, 2016). However, there was an 18% decline in the total area devoted to floriculture due to increasing imports of flowers from other countries (Statistics Canada, 2018). Areas devoted to greenhouse vegetables also declined by 6% over this period, while the area devoted to greenhouse products[7] increased 27% (Statistics Canada, 2016).

The cannabis sector is a recently expanding industry in the Lake Erie basin and it is expected to displace some floriculture and vegetable production. Cannabis greenhouse facilities in the Lake Erie basin, such as in Essex and Chatham-Kent, are also larger on average compared to the rest of the province (Prosperity Group, 2019).

Table 10: Greenhouse Area and Percent Change, Lake Erie Basin

SOURCE: Statistics Canada, Agricultural Census (2006, 2011) and OMAFRA (2016).

Tertiary Watershed	Number of Farms			Area (Square Meters)		
Name	**2006**	**2016**	**Percent Change**	**2006**	**2016**	**Percent Change**
Upper Grand	114	106	-7%	74,087	93,549	26%
Lower Grand	56	56	1%	211,237	313,446	48%
Big	185	135	-27%	732,085	677,989	-7%
Upper Thames	40	28	-30%	57,712	60,272	4%
Lower Thames	60	43	-28%	668,390	1,192,636	78%
Rondeau	10	7	-31%	55,225	146,982	166%
Sydenham	33	21	-37%	139,852	369,957	165%
Cedar	196	159	-19%	5,083,705	7,383,534	45%
Total	**694**	**556**	**-20%**	**7,022,292**	**10,238,365**	**46%**

[6] Nutrient solution that is no longer suitable for reuse is called greenhouse nutrient feedwater (GNF).

[7] Other greenhouse products include ornamental tree seedings, bedding plants, cuttings, transplants or plugs from both ornamental plants and vegetables.

Gross Farm Receipts

With fewer but larger farms in the Lake Erie basin, gross farm receipts have also increased. As shown in Table 11, the number of farms reporting more than $2 million in gross farm receipts increased 136% between 2006 and 2016; this compares to a 117% increase for Ontario. While there was a notable decline in the number of farms reporting less than $25,000 in receipts, this decline was smaller in the Lake Erie basin when compared to Ontario.

The only gross farm receipt categories that saw increases over this period were those farms reporting more than $500,000 in total gross farm receipts (Table 11).

Table 11: Number of Farms by Total Gross Farm Receipts, Lake Erie Basin
SOURCE: Statistics Canada, Agricultural Census (2006, 2011) and OMAFRA (2016).

	Number of Farms			Percent Change		
Total Farm Receipts[1]	**2,006**	**2,011**	**2,016**	**2006-2011**	**2011-2016**	**2006-2016**
Under $10,000	3,136	2,530	2,219	-19%	-12%	-29%
$10,000 to $24,999	3,202	2,666	2,696	-17%	1%	-16%
$25,000 to $49,999	2,692	2,533	2,431	-6%	-4%	-10%
$50,000 to $99,999	2,603	2,553	2,537	-2%	-1%	-3%
$100,000 to $249,999	3,393	3,065	2,977	-10%	-3%	-12%
$250,000 to $499,999	2,430	2,200	2,079	-9%	-6%	-14%
$500,000 to $999,999	1,263	1,421	1,601	13%	13%	27%
$1,000,000 to $1,999,999	567	733	989	29%	35%	75%
$2,000,000 and over	263	392	621	49%	58%	136%
Total	**19,551**	**18,094**	**18,150**			

1. Total gross farm receipts do not include sales of forest products. Receipts include agricultural products sold, program payments and custom work receipts (Statistics Canada, 2016).

Land Use Practices

The Census of Agriculture asks farm operators to self-report the use of different land use practices; some of these include: tillage, crop residue management, fertilizer application, solid and liquid manure application, and winter cover cropping, among others. These data include the number of farms reporting, and in some cases, the number of acres impacted in the calendar year prior to the census by a particular practice. From these values, the percent change over time can be estimated, and compared to other regions. These trends, for both the Lake Erie basin and Ontario are summarized in Tables 12 and 13.

Several land use practices appear to be more widely adopted in the Lake Erie basin; such as no-till or zero-till seeding and winter cover cropping. In the Lake Erie basin 43% of farms that prepare land for seeding use no-till methods, this compares to 40% for Ontario. However, when the percent change in acres is compared, the Lake Erie basin had 9% fewer no-till acres in 2016 compared to 2006, while Ontario reported a 3% increase over this same period. In 2016, winter cover cropping was used by 42% of farms in the Lake Erie basin, this compares to 35% for Ontario. However, the census did not collect acres for this land use practice, so the land area impacted cannot be examined further. These comparisons are detailed further in Table 14.

Table 12: Census Land Use Practices, Lake Erie Basin

SOURCE: Statistics Canada, Agricultural Census (2006, 2011) and OMAFRA (2016).

Land Use Practice	Number of Farms that Reported Land Use Practice		Percent Change in the Number of Farms	Percentage of Total Farms that Reported Land Use Practice[1]		Number of Acres Impacted by the Land Use Practice		Percent Change in the Number of Acres
Description	**2006**	**2016**	**2006-2016**	**2006**	**2016**	**2006**	**2016**	**2006-2016**
1. Winter cover crops	4,411	6,461	46%	28%	42%	-	-	-
2. Windbreaks and shelterbelts	7,370	6,703	-9%	38%	37%	-	-	-
3. No-till or zero-till seeding	6,333	6,539	3%	40%	43%	1,097,455	1,001,965	-9%
4. Tillage methods that retain crop residue at the surface	4,993	5,710	14%	31%	37%	790,881	1,144,545	45%
5. Tillage methods that incorporate crop residue in the soil	10,555	8,454	-20%	67%	55%	1,294,325	1,265,613	-2%
6. Injection of liquid manure	1,723	1,521	-12%	19%	21%	202,625	215,287	6%
7. Non-incorporation of liquid manure	1,167	1,243	7%	13%	17%	96,667	125,707	30%
8. Incorporation of solid manure	5,910	4,384	-26%	65%	61%	266,917	259,357	-3%
9. Non-incorporation of solid manure	3,354	2,345	-30%	37%	33%	115,118	93,973	-18%
10. Use of commercial fertilizer	13,741	12,505	-9%	87%	82%	2,596,527	2,746,406	6%
11. Plowing down green crops	4,540	3,638	-20%	29%	24%	-	-	-
12. Irrigation	1,577	1,095	-31%	8%	6%	94,010	69,549	-26%

1. Percentages for this column were calculated using the census criteria below.

.

Farm Totals by Land Use Practice – Lake Erie basin	Land Use Practice from Table 8	Number of Farms	
		2006	**2016**
Total number of farms that applied manure in the calendar year prior to the census	6,7,8,9	9,087	7,213
Total number of farms that prepared land for seeding	1,3,4,5,10,11	15,852	15,241
Total number of farms	2,12	19,551	18,150

Table 13: Census Land Use Practices, Ontario

SOURCE: Statistics Canada, Agricultural Census (2006, 2011) and OMAFRA (2016).

Land Use Practice	Number of Farms that Reported Land Use Practice		Percent Change in the Number of Farms	Percentage of Total Farms that Reported Land Use Practice[1]		Number of Acres Impacted by the Land Use Practice		Percent Change in the Number of Acres
Description	**2006**	**2016**	**2006-2016**	**2006**	**2016**	**2006**	**2016**	**2006-2016**
1. Winter cover crops	8,562	12,451	45%	22%	35%	-	-	-
2. Windbreaks and shelterbelts	18,963	12,451	-34%	33%	35%	-	-	-
3. No-till or zero-till seeding	12,624	14,332	14%	33%	40%	2,071,178	2,125,427	3%
4. Tillage methods that retain crop residue at the surface	11,314	12,568	11%	29%	35%	1,626,710	2,536,946	56%
5. Tillage methods that incorporate crop residue in the soil	26,796	20,747	-23%	70%	58%	2,901,160	2,864,914	-1%
6. Injection of liquid manure	3,523	3,274	-7%	11%	15%	429,299	473,947	10%
7. Non-incorporation of liquid manure	2,544	2,582	1%	8%	12%	229,528	285,986	25%
8. Incorporation of solid manure	19,777	12,333	-38%	63%	56%	826,714	685,686	-17%
9. Non-incorporation of solid manure	14,486	9,469	-35%	46%	43%	510,287	358,625	-30%
10. Use of commercial fertilizer	32,481	28,379	-13%	84%	79%	5,844,252	6,317,820	8%
11. Plowing down green crops	11,526	8,626	-25%	30%	24%	-	-	-
12. Irrigation	2,968	2,487	-16%	5%	5%	154,154	114,999	-25%

1. Percentages for this column were calculated using the census criteria below.

.

Farm Totals by Land Use Practice - Ontario	Land Use Practice from Table 8	Number of Farms	
		2006	**2016**
Total number of farms that applied manure in the calendar year prior to the census	6,7,8,9	31,541	22,215
Total number of farms that prepared land for seeding	1,3,4,5,10,11	38,550	35,949
Total number of farms	2,12	56,960	49,600

Table 14: Summary of Census Land Use Practices, Lake Erie Basin and Ontario
SOURCE: Statistics Canada, Agricultural Census (2006, 2011) and OMAFRA (2016).

Summary of Land Use Practices	
Winter cover crops	The number of farms in the Lake Erie basin that practice winter cover cropping increased 46% between 2006 and 2016. As of 2016, 42% of farms in the basin that prepare land for seeding practice cover cropping (n=6,461). This compares to Ontario where only 35% of farms practice cover cropping. Acres for this land use practice were not collected in the census.
Windbreaks and shelterbelts	There was a slight decrease in the number of farms that reported the presence of windbreaks and shelterbelts between 2006 and 2016. As of 2016, 37% of farms in the basin identified windbreaks and shelterbelts as a land use practice on their farm (n=6,703). In comparison, Ontario reported a steeper decline in the number of farms that use windbreaks and shelterbelts as a land use practice. Acres for this land use practice were not collected in the census.
No-till or zero-till seeding	While there was a slight increase in the number of farms that practice no-till (3%), there was a 9% decrease in the total number of no-till acres in the Lake Erie basin. In Ontario there was a 14% increase in the number of farms practicing no-till, and a 3% increase in the number of no-till acres. As of 2016, 43% of farms in the Lake Erie basin practice no-till, in comparison to 40% for Ontario.
Retain crop residue at soil surface	The number of farms that use tillage methods that retain crop residues at the soil surface increased 14%, and the number of acres increased 45% from 790,881 to 1,144,545 acres. As of 2016, 37% of farms in the Lake Erie basin use practices that retain crop residue at the soil surface, this compares to 35% of farms in Ontario.
Incorporate crop residue at soil surface	The number of farms that incorporate crop residue at the soil surface decreased by 20%, however this only led to a small decrease in the number of acres that use crop residue incorporation (2%). As of 2016, 55% of farms in the Lake Erie basin use residue incorporation, this compares to 58% for Ontario.
Liquid manure application	Between 2006 and 2016 there was a 12% decrease in the number of farms that incorporated liquid manure in the Lake Erie basin. Conversely, there was a 7% increase in the number farms using non-incorporation to apply liquid manure. The number of acres impacted through incorporation increased 6% while the number of acres impacted by non-incorporation increased 30%. In 2016, 17% of farms did not use incorporation to apply liquid manure; this compares to 12% for Ontario.

Summary of Land Use Practices	
Solid manure application	Between 2006 and 2016, the number of farms in the Lake Erie basin that incorporated solid manure declined 26%; there was also a 3% decline in the number of acres for this practice. More farms in the Lake Erie basin (61%) use incorporation methods compared to Ontario (56%). In the Lake Erie basin, there was an 18% decline in the number of acres impacted by non-incorporation compared to Ontario, which saw a 30% decline.
Commercial fertilizer	There was a 9% decrease in the number of farms that used commercial fertilizers in the Lake Erie basin, but there was a 6% increase in the number of acres fertilized. This was a smaller increase compared to Ontario, which saw an 8% increase in the number of fertilized acres between 2006 and 2016. In 2016, 82% of farms (n=12,505) that prepared land for seeding in the Lake Erie basin applied commercial fertilizers. This compares to 79% of farms for Ontario.
Green manure	There was a 20% decrease in the number of farms that plow down green crops in the Lake Erie basin; and as of 2016, 24% use this practice. This percentage was identical for Ontario. Acres for this land use practice were not collected in the census.
Irrigation	There are fewer farms that irrigate and fewer irrigated acres in both the Lake Erie basin and Ontario. There was a 31% decrease in the number of farms that use irrigation in the Lake Erie basin, and a 26% decrease in the number of irrigated acres between 2006 and 2016. In Ontario, there was a 16% decrease in the number of farms that use irrigation, and a 25% decrease in the number of irrigated acres.

Land Use Practices by Tertiary Watershed

There is also considerable variation in use land use practices within the Lake Erie basin itself. These trends can be further sub-divided on a tertiary watershed level. Tables 15 through 21 summarize a select number of land use practices by tertiary watershed; these include the number of farms and acres, as well as the percent change for both metrics for select practices in the Lake Erie basin. These characteristics highlight the prevalence of distinct agricultural areas within the Canadian side of the Lake Erie basin. These areas are influenced by a range of agricultural characteristics; such as the density of major agricultural industries, conservation approaches, soil types, topography and field conditions, weather, type of crops grown, livestock numbers, proximity to natural areas, among many other considerations.

Spatial trends can help to inform the development of future cost-share programs, particularly in areas where the adoption of certain land use practices may be lagging. Spatial analysis on an aggregated level may help to identify where and why specific land use practices are more prevalent in certain areas over others, and where enhanced education, outreach and engagement may be useful to bring more farmers into the fold.

Winter cover crops

As shown in Table 15, 42% of farms in the Lake Erie basin practice winter cover cropping; this is an increase of 14% from 2006. Sydenham (20%) and Upper Grand (18%) saw the largest increase cover cropping over this period by number of farms. The watershed of Big (+5%) reported a smaller increase, however this is because more farms in this watershed were already using winter cover crops. The percentage of total farms that practiced cover cropping in the watershed of Big is 48%, the highest use in the Lake Erie basin. This compares to 37% of farms in Cedar and Rondeau, both of which had the lowest self-reported use of winter cover crops in 2016.

Table 15: Census Land Use Practice: Winter Cover Crops, Lake Erie Basin
SOURCE: Statistics Canada, Agricultural Census (2006, 2011) and OMAFRA (2016).

Tertiary Watershed	Number of Farms	Percent of Total Farms[1]	Number of Farms	Percent of Total Farms[1]	Percent Change: Number of Farms
Name	**2006**		**2016**		**2006-2016**
Upper Grand	859	26%	1,375	43%	18%
Lower Grand	309	31%	459	43%	12%
Big	1,177	42%	1,214	48%	5%
Upper Thames	617	25%	998	43%	17%
Lower Thames	506	25%	767	39%	14%
Rondeau	133	26%	186	37%	12%
Sydenham	536	22%	977	42%	20%
Cedar	272	20%	487	37%	17%
Total	**4,411**	**28%[2]**	**6,461**	**42%[2]**	**15%[2]**

1. As a percentage of the total number of farms that prepared land for seeding in the census year.
2. Average (not total) percent change.

Windbreaks and shelterbelts

Windbreaks and shelterbelts are often found along the edge of fields or buildings. They reduce wind erosion, enhance soil productivity and water conservation, and provide habitat for wildlife. All watersheds, except for Upper Grand, reported a decrease in the number of farms that have windbreaks or shelterbelts (natural or planted). As shown in Table 16, these areas are more prevalent on farms in the watersheds of Upper Grand (50%) and Big (49%); in comparison to the more southerly watersheds of Cedar (34%) and Sydenham (37%).

Table 16: Census Land Use Practice: Windbreaks and Shelterbelts, Lake Erie Basin

SOURCE: Statistics Canada, Agricultural Census (2006, 2011) and OMAFRA (2016).

Tertiary Watershed	Number of Farms	Percent of Total Farms[1]	Number of Farms	Percent of Total Farms[1]	Percent Change: Number of Farms
Name	**2006**		**2016**		**2006-2016**
Upper Grand	1,579	47%	1,599	50%	3%
Lower Grand	459	46%	455	43%	-3%
Big	1,490	54%	1,253	49%	-4%
Upper Thames	1,112	46%	976	42%	-4%
Lower Thames	969	48%	877	45%	-4%
Rondeau	258	50%	225	45%	-5%
Sydenham	985	41%	871	37%	-3%
Cedar	517	39%	445	34%	-5%
Total	**7,370**	**46%[2]**	**6,703**	**44%[2]**	**-3%[2]**

1. As a percentage of the total number of farms that prepared land for seeding in the census year.
2. Average (not total) percent change.

No-till or zero-till seeding

No-till planting was practiced by 43% of farms in the Lake Erie basin in 2016 (Statistics Canada, 2016). While there was a 3% increase in the number of farms that practiced no-till over this period, this ranged from a 48% increase in Upper Grand to a 13% decrease in Rondeau. Cedar was the only southerly watershed that reported an increase in the number of farms that practiced no-till methods over this period.

The number of no-till acres decreased 9% on average for the entire Lake Erie basin (Table 17), this ranged from a 13% increase in Upper Grand to a 30% decrease in Rondeau. Changes in major crop rotation explain some of these trends. For example, in Rondeau there was a 50% increase in the number of acres planted with corn and a 48% decrease in the number of winter wheat acres planted over this period. Conversely, in Upper Grand, where no-till acres increased the most, there was a 31% increase in the number of winter wheat acres planted, the largest increase in the Lake Erie basin over this period. Most winter wheat is grown using a no-till production system (OMAFRA, 2021).

In 2016, over one million acres of croplands were planted using no-till methods in the Lake Erie basin. This represents 13% of Ontario's total farmland area that is prepared for seeding.

Table 17: Census Land Use Practice: No-Till or Zero-Till Seeding, Lake Erie Basin

SOURCE: Statistics Canada, Agricultural Census (2006, 2011) and OMAFRA (2016).

Tertiary Watershed	Number of Farms		Percent Change: Number of Farms	Number of Acres		Percent Change: Number of Acres
Name	**2006**	**2016**	**2006-2016**	**2006**	**2016**	**2006-2016**
Upper Grand	819	1,210	48%	114,294	129,598	13%
Lower Grand	409	463	13%	78,761	82,192	4%
Big	855	795	-7%	143,801	114,573	-20%
Upper Thames	974	891	-9%	127,062	119,045	-6%
Lower Thames	1,009	935	-7%	194,216	159,873	-18%
Rondeau	249	216	-13%	50,692	35,291	-30%
Sydenham	1,347	1,292	-4%	251,813	233,216	-7%
Cedar	672	735	9%	136,817	128,178	-6%
Total	**6,333**	**6,539**	**3%[2]**	**1,097,455**	**1,001,965**	**-9%[2]**

1. As a percentage of the total number of farms that prepared land for seeding in the census year.
2. Average (not total) percent change.

Crop residue management

In the Lake Erie basin, a majority of farms incorporate crop residues instead of retaining it on the soil surface. In 2016, 5,710 farms retained most crop residue on the soil surface; this compares to 8,454 farms that incorporated crop residue. Crop residues on the soil surface help to sustain soil productivity through enhanced nutrient cycling; and conservation tillage systems help to maintain residues at the soil surface (OMAFRA, 2021). The loss of surface crop residues can increase the risk of water and wind erosion.

Between 2006 and 2016, there was a 45% increase in the number of farms that retained crop residue on the soil surface; this compares to a 20% decrease in the number of farms that incorporated most residue into the soil. Increases were highest in the watersheds of Lower Grand and Upper Thames.

All watersheds within the Lake Erie basin reported increases in the number of acres impacted by retaining crop residue at the soil surface. In 2016, 1,144,545 acres retained most crop residue at the soil surface, this compared to 1,265,613 acres that incorporated crop residue. Between 2006 and 2016, there was a 2% decrease in the number of acres in the Lake Erie basin that incorporated crop residues. However, the number of acres impacted by incorporation increased in Cedar (22%), Rondeau (12%) and Lower Thames (6%) over this period.

Table 18: Census Land Use Practice: Surface Crop Residue Retained, Lake Erie Basin

SOURCE: Statistics Canada, Agricultural Census (2006, 2011) and OMAFRA (2016).

Tertiary Watershed	Number of Farms		Percent Change: Number of Farms	Number of Acres		Percent Change: Number of Acres
Name	**2006**	**2016**	**2006-2016**	**2006**	**2016**	**2006-2016**
Upper Grand	917	1,048	35%	127,953	173,346	14%
Lower Grand	298	372	89%	40,577	76,830	25%
Big	885	964	45%	141,725	206,014	9%
Upper Thames	726	884	60%	103,521	165,185	22%
Lower Thames	748	841	41%	133,755	188,264	12%
Rondeau	200	225	49%	38,801	57,801	12%
Sydenham	816	927	40%	136,362	190,525	14%
Cedar	403	450	27%	68,189	86,580	12%
Total	**4,993**	**5,710**	**45%**[2]	**790,881**	**1,144,545**	**14%**[2]

1. As a percentage of the total number of farms that prepared land for seeding in the census year.
2. Average (not total) percent change.

Liquid manure application

Incorporation of manure includes direct injection (for liquid) or tillage to mix nutrient materials into the soil surface; this reduces surface runoff, improves nutrient retention, and reduces pathogen transport (OMAFRA, 2021). Non-incorporation leaves material on the soil surface and increases the risk of runoff. In 2016, 1,521 farms used incorporation methods to apply liquid manure; this compared to 1,243 farms that used non-incorporation. Between 2006 and 2016, there was a 12% decrease in the number of farms that used incorporation; this compares to a 7% increase in the number of farms that used non-incorporation.

Several watersheds within the Lake Erie basin reported increases in the number of acres impacted by liquid manure incorporation. In the watershed of Big, there was a 21% increase in the number of acres impacted by liquid manure incorporation. This compares to Cedar where there was a 72% decrease in the number of acres impacted by incorporation. Note that liquid manure is most often applied in the watersheds of Upper Grand, Upper Thames, Big and Sydenham. In 2016, there were 215,287 acres impacted by incorporation of liquid manure, this compares to 125,707 acres impacted by non-incorporation.

Between 2006 and 2016, there was a 30% increase in the number of acres impacted by non-incorporation of liquid manure (Statistics Canada, 2016). This increase occurred in the northern half of the Lake Erie basin, specifically the watersheds of Upper and Lower Grand, Big and Upper Thames. All other watersheds saw decreases in the number of acres impacted by non-incorporation. The Agricultural Census does not collect information on the timing or soil conditions when non-incorporation was most often used.

Table 19: Census Land Use Practice: Liquid Manure Incorporated, Lake Erie Basin

SOURCE: Statistics Canada, Agricultural Census (2006, 2011) and OMAFRA (2016).

Tertiary Watershed	Number of Farms		Percent Change: Number of Farms	Number of Acres		Percent Change: Number of Acres
Name	**2006**	**2016**	**2006-2016**	**2006**	**2016**	**2006-2016**
Upper Grand	516	471	-9%	49,465	54,111	9%
Lower Grand	91	96	6%	11,586	12,853	11%
Big	222	207	-7%	26,191	31,740	21%
Upper Thames	511	482	-6%	70,616	79,360	12%
Lower Thames	126	87	-31%	14,082	12,342	-12%
Rondeau	34	23	-32%	4,068	3,133	-23%
Sydenham	197	141	-29%	24,620	21,195	-14%
Cedar	25	14	-46%	1,998	554	-72%
Total	**1,723**	**1,521**	**-12%[2]**	**202,625**	**215,287**	**6%[2]**

1. As a percentage of the total number of farms that prepared land for seeding in the census year.
2. Average (not total) percent change.

Solid manure application

As shown in Table 20, 4,384 farms used incorporation methods to apply solid manure nutrients on agricultural lands in 2016; this compares to 2,345 farms that used non-incorporation (Statistics Canada, 2016). Between 2006 and 2016, there was a 26% decrease in the number of farms that used incorporation methods; this compares to a 30% decrease in the number of farms that used non-incorporation. Note that solid manure nutrients are more often applied to agricultural lands in the watersheds of Upper Grand, Upper Thames, and Big.

Several watersheds within the Lake Erie basin reported increases in the number of acres impacted by solid manure incorporation. In the watershed of Upper Thames, there was a 13% increase in the number of acres impacted by solid manure incorporation. This compares to Sydenham where the number of acres decreased 22%. In 2016, 259,257 acres were impacted by solid manure incorporation; which is nearly three times higher than the number of acres impacted by non-incorporation (n=93,973 acres).

Between 2006 and 2016, there was an 18% decrease in the number of acres impacted by solid manure non-incorporation (Statistics Canada, 2016). All watersheds reported a decrease in acres for non-incorporation; the largest decreases occurred Lower Thames, Rondeau, Sydenham and Cedar (Statistics Canada, 2016).

Table 20: Census Land Use Practice: Solid Manure Incorporated, Lake Erie Basin

SOURCE: Statistics Canada, Agricultural Census (2006, 2011) and OMAFRA (2016).

Tertiary Watershed	Number of Farms		Percent Change: Number of Farms	Number of Acres		Percent Change: Number of Acres
Name	**2006**	**2016**	**2006-2016**	**2006**	**2016**	**2006-2016**
Upper Grand	2,122	1,657	-22%	99,298	96,440	-3%
Lower Grand	445	351	-21%	18,110	20,325	12%
Big	963	750	-22%	42,555	41,125	-3%
Upper Thames	1,055	790	-25%	44,912	50,967	13%
Lower Thames	399	279	-30%	20,130	16,139	-20%
Rondeau	118	83	-30%	5,500	5,061	-8%
Sydenham	631	358	-43%	31,283	24,276	-22%
Cedar	176	117	-34%	5,129	5,025	-2%
Total	**5,910**	**4,384**	**-26%**[2]	**266,917**	**259,357**	**-3%**[2]

1. As a percentage of the total number of farms that prepared land for seeding in the census year.
2. Average (not total) percent change.

Commercial fertilizer application

Commercial fertilizers are applied to agricultural fields to supplement essential plant nutrients that are found naturally in soils (OMAFRA, 2021). As shown in Table 21, 12,505 farms applied fertilizers to croplands in 2016, a decrease of 9% from 2006. All watersheds, except for Lower Grand, reported a decrease in the number of farms applying commercial fertilizers. On average, 82% of farms in the Lake Erie basin use commercial fertilizers, a decrease from 87% of farms in 2006.

Big was the only watershed in the Lake Erie basin that reported a decrease in the number of acres impacted by commercial fertilizers; all other watersheds reported increases, ranging from a 2% increase in Upper Grand to a 19% increase in Lower Grand. As of 2016, Sydenham had the most cropland acres that were commercially fertilized, at 472,414 acres. In total, 2.7 million cropland acres were commercially fertilized in the Lake Erie basin 2016.

Table 21: Census Land Use Practice: Commercial Fertilizer, Lake Erie Basin
SOURCE: Statistics Canada, Agricultural Census (2006, 2011) and OMAFRA (2016).

Tertiary Watershed	Number of Farms		Percent Change: Number of Farms	Number of Acres		Percent Change: Number of Acres
Name	**2006**	**2016**	**2006-2016**	**2006**	**2016**	**2006-2016**
Upper Grand	2,764	2,511	-9%	439,451	447,670	2%
Lower Grand	821	836	2%	159,685	189,727	19%
Big	2,413	2,104	-13%	452,402	442,652	-2%
Upper Thames	2,120	1,951	-8%	407,987	426,736	5%
Lower Thames	1,804	1,706	-5%	388,995	424,389	9%
Rondeau	469	439	-6%	107,699	119,814	11%
Sydenham	2,176	1,958	-10%	442,659	472,414	7%
Cedar	1,175	1,001	-15%	197,649	223,005	13%
Total	**13,741**	**12,505**	**-9%**[2]	**2,596,527**	**2,746,406**	**6%**[2]

1. As a percentage of the total number of farms that prepared land for seeding in the census year.
2. Average (not total) percent change.

Commercial fertilizer application often requires the use of technology, such as GPS technology and GIS mapping (i.e., for soil sampling). In the 2016 Agricultural Census, farms were asked to self-report whether they use certain technology practices which included: automated steering (auto-steer), GPS and GIS mapping (Statistics Canada, 2016).

Of these three practices, GPS was most commonly used by 50% of farms in the Lake Erie basin. This compared to 25% of farms using auto-steer technology, and 21% of farms using GIS technology for soil mapping. GPS for soil mapping was self-reported most often by farms in the watersheds of Rondeau and Lower Thames.

Cost-Share Programs

Cost-share opportunities are voluntary, incentive-based programs that provide financial resources to support implementation of Best Management Practices (BMPs). Environmental cost-share programs were developed to reduce environmental risks and encourage the adoption of practices that protect farm ecosystem services like soil health, water quality and biodiversity. These services benefit the farm, the surrounding landscape and the health of Lake Erie; and they are the focus of many project categories that were supported across multiple program designs. Cost-share programs have also addressed regulatory concerns, including health and safety risks for farms and the surrounding community (e.g., protection of drinking water). These actions to address regulatory concerns were not mandated nor enforced, and completion of projects to address these environmental risks were voluntary actions on the part of farmers. Nevertheless, some of these regulatory concerns afforded programs with more financial resources during certain years, and they were able to support more environmental projects, impacting participation levels.

Environmental cost-share programs can be divided into two main formats: conventional and merit-based. Both approaches require completion of the Environmental Farm Plan (EFP).

Environmental Farm Plan

To access most environmental cost-share funding, farmers need to complete an EFP. This voluntary assessment is self-administered by farmers and is typically completed over a two-day educational workshop. The EFP is a risk assessment tool that identifies environmental strengths and areas of environmental concern (Smith et al., 2016). The resulting EFP Action Plan indicates how and when a farm will change a practice to reduce environmental risk (Smith et al., 2020). It is an educational opportunity that is often used in conjunction with cost-share programs as farmers begin to implement their Action Plan. Many cost-share programs use the EFP risk ratings to estimate the environmental impact of a proposed project for select BMPs. Therefore, for some programs, the EFP is a qualifier for funding. As a self-administered assessment, EFP data is not used by OSCIA. However, limited data is submitted with a project application package to demonstrate merit for cost-share programs associated with the EFP.

The EFP was a grassroots response to increasing environmental pressures in the early 1990s, and OSCIA has been the delivery agent for the EFP since its inception in 1992.

Conventional Program Design

Some of the earliest cost-share programs considered in this analysis were conventionally structured. In this format, and for many BMPs, projects were treated the equally, regardless of environmental benefit. In some cases, priority was allocated to applicants with proposed projects that were new to the farm property in addressing a risk identified in the EFP Action Plan. Applicants would submit an application for a project that they felt was most important to their needs, and they also received assistance to complete the application package from OSCIA program representatives. Cost-share payments were fairly predicable and straightforward, and applicants generally had a good idea about the amount of funding they would qualify for and receive. Applicants were also more likely to be certain that their application would be approved for funding; particularly if the program was continuously open to receive applications over a longer time period.

As government priorities for use of public funding changed, a new merit-based design was introduced to direct more limited funding towards actions with the greatest environmental impact. However, not all programs that were delivered after this point were merit-based. Some continued to be delivered with a conventional format, where support was still offered to applicants when submitting an application package (i.e., the Species at Risk Farm Incentive Program).

Merit-based Program Design

Within this format, merit assessment prioritizes funding towards projects that result in the greatest environmental benefit. This was different to conventional formats as the process required more information to determine the proposed environmental benefit. This allowed the program to compare projects within the same category. For some programs, applications were collected and assessed together in an application intake period, instead of being approved one at a time throughout a program season. Due to the competitive nature of merit across some programs, applicants had to complete the application package themselves. As funding was more limited, the approval process became more stringent to identify and rank projects that were most competitive. Applicants had to demonstrate how the project would address an identified EFP risk, such that the proposed practice would improve the EFP rating for a specific environmental risk area. For many programs, the selection and ranking of projects were based on scores and other environmental indicators provided in the application package. Merit was structured in such a way as to motivate farms and make it easier for them to try a new practice on the farm. For many categories, funding was not available to repeat a practice that had already been adopted by the farm.

Merit-based programs continued to evolve, giving rise to formats that paired financial incentives with the provision of technical and educational support. In his format, funding decisions were based on the independent recommendations of technical specialists, such as Certified Crop Advisors (CCA) or Professional Agrologists (P. Ag), as part of the Farmland Health Check Up (FHCU). The Check-Up collected information about current field conditions and identified highest risk areas through automated scoring systems. The technical specialist worked with the farmer to develop specific BMPs that would most effectively address these risks. The farmer would receive technical support and education in addition to the financial support (if the project was successful). This hybrid approach was used as the primary funding qualifier for a sliding scale of funding levels that were based on risks identified by the technical specialists.

Table 22 summarizes some of the major differences between these program designs.

Other Sources of Funding

Some of the earliest conventional programs were designed as “top-up” initiatives; where successful applicants could access up to 100% cost-share utilizing a single project application. As a result, a single project could receive funding from multiple sources (e.g., a provincial and a federal contribution.) This streamlining helped funding partners to accelerate the adoption of key actions based on shared priorities in a single cost-share delivery system.

Many programs also allowed the stacking of funding towards a single project from two or more delivery agents (e.g., OSCIA contributes 50% and a Conservation Authority contributes 20% for a total rate of 70% towards a single tree planting project); provided that funding did not exceed 100% of a project’s total cost. Tree planting and habitat creation BMPs were more likely to have opportunities for stackable funding, given the number of environmental delivery agents operating in the Lake Erie basin over this period.

Geography also played a role in stackable funding, given the many regional environmental initiatives and grants delivered in this region (e.g., rural water quality initiatives, clean water grants etc.). In the analysis, project costs and averages only include the contribution provided by OSCIA programs, and does not include data from other partner agencies.

Table 22: Major Program Design Differences, OSCIA Programs

SOURCE: Alternative Funding Models for Agricultural Stewardship Programs in Ontario (OSCIA, 2014).

Conventional Program Design	Merit-based Program Design
• Farm applicants receive assistance to complete the application and claim forms • Eligible projects were not always assessed by environmental priority, and were mostly treated equal • For many conventional program designs, less time was required to prepare a proposed project application because the assessment process was more straightforward so less information was required • Funding rates were predictable and fixed and the farm knew exactly what amount they would receive as long as funding was still available • While the EFP was the primary source of education for these programs, there was limited technical support and fewer opportunities for knowledge transfer • Limited need for additional project metrics to be collected on the application and claim forms	• While some of the earliest merit-based programs provided some assistance in filling out the application and claim forms, current merit-based programs no longer provide this assistance to farmers • Projects are assessed together in a pool of proposed applications, instead of being approved one at a time • More time may be required to prepare a detailed application that asks for more information compared to conventional application forms • Some merit-based programs used sliding scale funding rates, so the farm does not initially know how much they would qualify for (this impacts project planning) • Greater need to collect more detailed information about the project and its expected impacts, creating more robust opportunities for program evaluation and tracking • Farm businesses in effect, were competing against one another for the limited dollars

Table 23 lists the names of cost-share programs that were delivered by OSCIA during the 2005-2018 period. The oldest programs were conventionally structured, while those delivered more recently were mostly merit-based. The assessment column identifies the primary sources of information in addition to the application, that were used in the project approval process.

Table 23: Cost-Share Programs, Program Design and Assessment, 2005-2018

Program	Acronym	Timeframe	Model	Assessment
Canada-Ontario Farm Stewardship Program	COFSP	2005-2013	Conventional	EFP
Greencover Canada	GC	2005-2009	Conventional	EFP
Ontario Drinking Water Stewardship Program	ODWSP	2006-2012	Conventional	EFP
Species at Risk Farm Incentive Program	SARFIP	2008-2018	Conventional	EFP
Growing Forward 2	GF2	2013-2018	Merit-based	EFP / Score
Farmland Health Incentive Program	FHIP	2015-2018	Merit-based	EFP / FHCU
Priority Sub-watershed Project	PSP	2015-2018	Merit-based	Other – CA[1]

1. Participants of PSP partnered with their local Conservation Authority (CA).

Cost-Share Programs

Canada-Ontario Farm Stewardship Program (COFSP), 2005-2013

COFSP was a voluntary cost-share program that encouraged farmers to improve the management of agricultural land through the adoption of BMPs to reduce the risk of water and air quality, soil productivity and wildlife habitat. Cost-share for specific COFSP categories varied between 30 to 50%, up to the category caps. Stackable funding for a single project application was permitted, allowing a project application to receive up to 100% cost-share funding (i.e., drinking water initiatives). Stackable funding was permitted for all categories, but it was not always available from other sources for all categories. All funds were available on a first-come, first-serve basis up to the available annual funds for each year of the program. COFSP launched under the Agricultural Policy Framework (APF) and was continued through the Growing Forward (GF).

Greencover Canada (GC), 2005-2009

GC was an initiative that was also concurrently delivered with COFSP. GC helped producers to improve land management practices, promote sustainable land use, protect water quality, reduce greenhouse gas emissions, enhance biodiversity and wildlife habitat, and expand the land base covered with perennial forage and trees. Elements of GC included: critical area management (i.e., enhancing riparian areas), shelterbelts, and technical assistance. The cost-share for GC was set at 50%, up to the category caps. For the purposes of this analysis, GC and COFSP projects were categorized as COFSP due to program naming conventions used in the database.

Ontario Drinking Water Stewardship Program (ODWSP), 2006-2012

ODWSP cost-share was available to farmers for select environmental projects that were implemented on a parcel of agricultural land that was within, or extended into a wellhead protection area or intake protection zone. Up to 100 percent combined cost-share was available to support three components: early actions within intake and wellhead protection areas, education and outreach, and complementing special projects. Projects funded under ODWSP and COFSP include nutrient management planning, stream crossings, buffer establishment, fencing, manure storage improvements, equipment to improve manure application, and septic system improvements. For the purposes of this analysis, ODWSP projects were categorized as COFSP due to program naming conventions used in the database.

Species at Risk Farm Incentive Program (SARFIP), 2008-2018

SARFIP was an annual cost-share program supported by the federal and provincial governments, depending on the program year. Funding was provided initially by the Ministry of Natural Resources and Forestry (MNRF) and then later both the MNRF and Environment and Climate Change Canada (ECCC) provided funding to assist with the recovery of species at risk (SAR) on agricultural land. SARFIP provided funding to agricultural and rural landowners interested in creating, enhancing or protecting habitat BMPs that support species at risk. Cost-share funding was available for beneficial practices that directly or indirectly benefit SAR. While the focus is on habitat, the BMP categories also support the creation and protection of natural areas that improve terrestrial and aquatic systems.

Growing Forward 2 (GF2), 2013-2018

GF2 was a five-year commitment by Canada's federal, provincial and territorial governments to encourage innovation, competitiveness and industry sustainability in Canada's agriculture, agri-food and agri-based sectors. GF2 built on the success of the COFSP under the Growing Forward and Agricultural Policy Frameworks. As a merit-based program, it was intended to drive positive change and support only the most impactful projects with funding. Under the Environment and Climate Change Adaptation Focus Area, farmers accessed funding to improve their overall environmental performance related to air and soil quality, water quality and quantity and biodiversity. Farmers accessed up to 50 percent cost-share funding for environmental plans, and 35 percent for the remaining project categories.

Farmland Health Incentive Program (FHIP), 2015-2018

As part of the Great Lakes Agricultural Stewardship Initiative (GLASI), FHIP offered funding to improve soil health and reduce edge of field phosphorus loss. Farmers worked with a Certified Crop Advisor (CCA) or Professional Agrologist (P. Ag) free of charge, to complete an assessment of on-farm soil health, and develop a list of BMPs that were specifically targeted to the farm operation. The Farmland Health Check-Up (FHCU) workbook assessed baseline farm health levels and identified target levels that farms could work towards through implementation of recommended BMPs. By implementing recommended BMPs in the FHCU, farmers received cost-share funding to address the independently assessed environmental challenges. FHIP used a sliding scale of funding, which was determined based on the BMP recommendations in the FHCU. Farmers could also apply for additional bonus funding if the project demonstrated synergy through implementation of two or more BMPs, such as supporting pollinator habitat or implemented novel practices that were not yet being used in the target area.

Priority Sub-watershed Project (PSP), 2015-2018

As part of the Great Lakes Agricultural Stewardship Initiative (GLASI), PSP was delivered within a defined priority subwatershed area in partnership with local Conservation Authorities. PSP was different from FHIP in that it relied on a focused stewardship approach with the aim of achieving measurable improvements in water quality and soil health. Projects were implemented within highly targeted and defined subwatersheds, with a focus on reducing edge-of-field phosphorus loss. PSP's primary focus was applied water quality research in highly targeted study areas. Extensive water quality and quantify monitoring was part of this project that aimed to quantify the cost of P reductions. Three of four participating Conservation Authorities were located within the Lake Erie Basin; they include Essex Region Conservation Authority (ERCA), Lower Thames Valley Conservation Authority (LTVCA) and Upper Thames River Conservation Authority (UTRCA).

Methodology

Cost-share project data is collected to process applications for funding. A methodology to collate different program datasets that used different data management procedures was developed to ensure consistency in merging program records into a single database.

List of Programs for Analysis

A list of program opportunities delivered in the Lake Erie basin was developed in consultation with OSCIA staff and OMAFRA specialists. Not all programs delivered during the specified timeframe were included in the analysis because either: no projects were implemented in the Lake Erie basin from those programs, the programs did not fund defined water quality actions on the farm landscape, the data was not available[8], or because the program was not delivered in partnership with OMAFRA.

Table 24: Cost-Share Programs Included in the Analysis, 2005-2018

Program	Acronym	Framework	Timeframe
Canada-Ontario Farm Stewardship Program	COFSP	APF/GFF	2004 - 2013
Greencover Canada	GC	APF	2005 - 2009
Ontario Drinking Water Stewardship Program	ODWSP	APF/GFF	2006 - 2012
Species at Risk Farm Incentive Program	SARFIP	GFF/GF2	2008 - 2018
Growing Forward 2	GF2	GF2	2013 - 2018
Farmland Health Incentive Program	FHIP	GLASI (GF2)	2015 - 2018
Priority Sub-watershed Project	PSP	GLASI (GF2)	2015 - 2018

Internal Data Sources

OSCIA has a robust data management system that efficiently tracks project records dating back to 2013. For program records prior to 2013, a custom data report was provided by OSCIA for records administered between 2004 and 2013. Copies of program brochures and select application forms were also reviewed as part of the analysis.

External Data Sources

Agricultural census data is not collected on a watershed basis. To use it for this purpose it must first be deconstructed at its lowest level and rebuilt based on watershed boundaries. Statistics Canada provided agricultural census datasets for the 2006 and 2011 census years, while OMAFRA provided the dataset for 2016. These datasets enable the use of filtering to select Lake Erie basin tertiary watersheds and municipalities. These datasets do not include other delineated regions for spatial analysis, such as county or the administrative Conservation Authority boundary. ArcGIS shapefiles were also used to validate project locations within these boundaries.

Shapefile	Data Source
Ontario Watershed Boundaries	Land Information Ontario
Lake Erie and Lake St. Clair Watersheds Boundary	OSCIA
Census Boundary Files, 2016	Statistics Canada
Conservation Authority Admin Area	Land Information Ontario

[8] The Nutrient Management Financial Assistance Program (NMFAP) was delivered between 2005 and 2008, however data for this program was not available in the database files provided. The Manure and Biosolids Management Program under GLASI for custom operators did not have adequate spatial information in the database to be included.

Data Verification

As data management processes were developed, improved data entry and validation procedures were implemented to capture project and claim information. Procedures did not always consider other uses for the data besides the administrative processing at the time of use; so, for many older records, some data was not available to the analysis. This includes detailed cost information, which was not consistently entered across all years of program delivery. For example, costs data entered as “invoice from equipment dealer,” or “erosion control costs” simply do not allow for deeper analyses.

Table 25: List of Data Fields

Data fields	Description of data field
Framework	The name of the assigned funding framework
Program Name and Acronym	The name and acronym of the cost-share program
Application Number	Unique identifier that references a single project application
Unique Project Identifier	Number that references a single BMP project
BMP Code	The code referencing a specific BMP
BMP Category	Category of the BMP
Project Date	The date the project was implemented
Fiscal Year	The fiscal year the project was funded
Status	The final status of the project (approved or declined)
Operation Identifier	Unique identifier that references a unique farm operation
Address	Physical address of the project or farm
City	Physical address of the project or farm
Province	Ontario
Postal Code	Physical address of the project or farm
Project Description	Description of the proposed project
Total Eligible Proposed Costs	Total of all eligible anticipated costs (includes in-kind)
Total Eligible Claim Costs	Total of actual costs (includes in-kind)
Total Eligible Claim Costs (Normalized)	Total actual costs normalized to today’s dollars
Payment Amount	Final cheque amount
Payment Amount (Normalized)	Final cheque amount normalized into today’s dollars
Funding Rate	Funding level percentage
Conservation Authority	Location by administrative conservation authority boundary
Tertiary Watershed	Location by tertiary watershed
Tertiary Watershed Code	Location by tertiary code
County	Location by census county
Township	Location by census township
Primary Commodity	Commodity that contributes to the majority of gross income
Secondary Commodity	Commodity that contributes to at least 25% of gross income
Livestock Quantity: Beef	The number of beef cattle
Livestock Quantity: Dairy	The number of dairy cattle
Livestock Quantity: Hogs	The number of hogs
Livestock Quantity: Poultry	The number of poultry
Livestock Quantity: Sheep	The number of sheep
Irrigated Acreage	Number of acres that are irrigated on the farm
Owned Crop Pasture Acres	Number of acres in pasture or crop production
Owned Non-Crop Pasture Acres	Number of acres not in pasture or crop production
Rented Crop Pasture Acres	Number of rented acres
Project Metric Description	Project metric criteria (e.g., number of acres)

Note: italicized data fields were created to facilitate the analysis.

BMP Selection

A list of related water quality BMPs was developed in consultation with OSCIA staff and OMAFRA specialists. An environmental BMP was included in the analysis if it directly or indirectly improved water quality by: (1) managing phosphorus at the source (e.g., nutrient planning, manure storage, etc.), (2) field treatment that reduced phosphorus (e.g., conservation tillage, variable rate, etc.), or (3) acted as a last line of defense for edge of field phosphorus loss (e.g., wetlands, etc.). A complete list of BMPs considered and the final selections with updated naming conventions are included in Table 54.

BMP Reclassification

With each new iteration of a program (or intake), the naming conventions of environmental project categories often changed. Sometimes these changes were just the result of rewording for clarity; other times sub-categories were amalgamated into a smaller number of grouped project categories; or they were split apart because new separate funding levels had been developed and there was interest in capturing this information more distinctly.

BMPs required reclassification to allow for general comparison across the six programs. Wherever possible, the lowest level of information was used to classify a project in the Lake Erie database. For example, a buffer strip project accidentally classified as a windbreak in the original database was re-classified to the windbreak and shelterbelt project category for this analysis. As a result, there may be a very slight difference between the final numbers used in this analysis when compared to annual reports that were submitted during delivery of these programs (2005-2018).

Other reclassifications included assigning an individual BMP to an overarching BMP focus group to allow for more general comparisons in water quality focus areas (Table 53). For example, banding and variable rate-controlled application equipment projects were grouped under conservation tillage, so that this activity could be compared to other fertility and tillage practices, but also remain distinct from other conservation tillage equipment.

Another example of BMP reclassification involves the amalgamation of multiple BMP names into one, as was the case with erosion control structures. This BMP included the following names in the original databases: (1) constructed works in non-riparian areas, (2) constructed works in riparian areas, (3) riparian erosion control structures, (4) erosion control structures, (5) in-field erosion control structures, and (6) structural erosion control. Reclassification ensures consistency in activities between BMPs and between programs. There were no situations where a category name was unable to be assigned to a single BMP or BMP group, and the naming conventions used for the most recent programs became the default, where applicable.

Sometimes BMP eligibility requirements changed between different years and across programs; and these nuances were not always tracked within a project description or database. Because this information was not readily available in the original database, this consideration was not factored into the analysis. It is generally not expected that these variations would have had a significant impact on the final selection of BMPs; however, the lack of this data prevents a more fulsome analysis of participation trends because the reason many BMPs may have increased or declined was because the eligibility criteria changed, and not because the land use became more or less popular on the farm landscape.

Spatial Classification

After the BMP data were compiled and reclassified, they were assessed spatially. These data fields were used to identify whether the project or farm address was located in the Lake Erie basin. It should be noted that OSCIA classified project and farm locations by the administrative Conservation Authority boundary, not by watershed (Table 26). A watershed is a catchment basin that includes all of the land that is drained by a watercourse and its tributaries (OMNRF, 2020). Tertiary watersheds are based on the federal framework originally known as the Water Resources Index Inventory Filing System (OMNRF, 2020). Projects were assigned to a tertiary watershed to align with the approach used in the census analysis.

1. Data fields were filtered to exclude administrative boundaries that were not located in the Lake Erie basin. Projects that were assigned to St. Clair Region Conservation Authority and Niagara Peninsula Conservation Authority were validated to ensure they were located within the Lake Erie Basin; as only a portion of these administrative boundaries falls within the Lake Erie basin. Projects that were located outside of the tertiary boundary in these administrative layers were removed from the analysis.
2. Projects that were assigned to Grand River Conservation Authority and Lower Thames Valley Conservation Authority required a tertiary reclassification; because these boundary layers do not overlap with the delineated catchment basins. In Grand River Conservation Authority, a project can either be located in Upper or Lower Grand; while in Lower Thames Valley Conservation, a project could be located in either Upper Thames, Lower Thames or Rondeau. All three shapefiles were overlayed in ArcGIS, and the tertiary watershed was assigned based on the lowest level of physical address provided with the application.

Not all projects provided a street level address, so the Township or postal code had to be used when this information was missing.

Examples:

1. ### Street Address, City, Township, Postal Code – MORE DETAIL
2. RR # City, Postal Code – LESS DETAIL
3. Project lot and concession – MORE DETAIL

Table 26: List of Administrative Conservation Authority Boundaries and Tertiary Watershed Boundaries

Conservation Authority Boundary	Tertiary Watershed Boundary	Lake Erie Boundary
Catfish Creek	Big	Full extent within basin
Essex Region	Cedar	Full extent within basin
Grand River	Upper Grand / Lower Grand	Full extent within basin
Kettle Creek	Big	Full extent within basin
Long Point	Big	Full extent within basin
Lower Thames Valley	Lower Thames / Rondeau	Full extent within basin
Niagara Peninsula	Big	Partial overlap
St. Clair Region	Sydenham	Partial overlap
Upper Thames River	Upper Thames	Full extent within basin

Spatial Validation

At the time it was initially collected, spatial data was not always verified prior to entry into the program database. This was more apparent for records retrieved from the older database (prior to 2013); as these records required more corrections. More recent programs provided criteria dependent drop-down lists to encode spatial information to a project at the time of application, or in the claims processing stages. For example, today you cannot assign the township of Amaranth to a project that has already been assigned to the county of Brant. These types of checks and balances were not always in place for each fiscal year of program delivery, particularly when processing involved manual paperwork so this had to be rechecked. Occasionally, an incorrect township was assigned to a project application with a different county. PivotTables were used to ensure that classification between county and township fields were accurate, ensuring they aligned to the address assigned with the cost-share payment.

Townships also had to be validated to ensure alignment with the naming conventions and boundaries used by the census. For those projects which were assigned to a Township that has since been amalgamated, the most up-to-date naming convention was applied. For example, projects previously assigned to Guelph or Eramosa were reclassified to Guelph/Eramosa to align with the current census classification system.

After these issues were corrected, all four spatial data fields (conservation authority, tertiary watershed, county, and township) were cross-examined one final time to ensure accuracy across all spatial information assigned to a BMP project address.

For some programs, the project location and the farm location were not always identified clearly in the original database, and in some cases one or the other was collected and assigned to a project record. This is was more apparent for projects digitized prior to 2011, when the location of the home farm (or mailing address) was added to the database for financial processing, instead of the project address. Mass data entry procedures previously required entering the information exactly as it appeared on the application form, without spatial validation of an address. Therefore, some addresses may refer to the home farm, instead of the specific project location. This was more apparent for those applicants that have more than one farm business location.

The most recently delivered programs required the collection of specific project address information, including premise identification numbers to ensure the precise location of the project was retained digitally. It is not known how many project records prior to 2011 may have interchanged the project location or the farm mailing address in the database; so, this may or may not have introduced some data integrity issues in terms of the precise project locations. However, this is not expected to significantly impact the analysis or the spatial analysis presented in the Annex, because of the sample size involved and the scale of aggregation.

Project Status

There can be up to 22 unique project statuses in use at any given time that can be assigned to a project application before it is deemed complete and reconciled. Since the data for this analysis was sourced from programs that were closed and audited, the datasets were filtered to exclude any project application that was not issued a cost-share payment.

Duplication

For those projects that received more than one funding source, the project record may have been duplicated in the original program database; this occurred when a project received a provincial and a federal contribution. In this case, the project is considered one distinct project.

Duplication also occurred when a single project application number funded more than one BMP on the same application. For example: a manure storage project and nutrient management plan have the same application number. For the purposes of this analysis, this project was counted as two unique projects to distinguish the unique BMP activities and funding. There were 315 project records that fell into this category of duplication. Duplicate records were identified by conditionally formatting the dataset to identify duplicate application numbers, and then merging appropriate data fields using the PivotTable. This prevented double counting of measures in grouped analyses (i.e., the number of crop pasture acres is counted once for a single farm operation per project).

Data Cleaning

Multiple data fields had to be cleaned to ensure consistency of project metrics across all program years. For example, the primary commodity information was standardized based on the conventions used in the current program enrolment form (e.g., beef feeders and beef cow calf were reclassified as beef, including feedlots, etc.).

Project descriptions were also reviewed for the equipment project categories given the large number of those projects in the Lake Erie basin database. The cost items, project descriptions, project summaries and outcomes were all reviewed to classify the equipment as either:

- Managing and planting cover crops
- Modifications to improve manure application
- Modifications to reduce soil compaction
- No-till planting units or components
- Planting in high-residue situations
- Strip-till units or components
- Equipment or components to enable banding, variable rate or controlled applications
- Vertical tillage planting units or components

This follows the approach used for review of FHIP equipment projects when it became necessary to classify specific equipment projects into sub-categories to allow for more meaningful analyses (e.g., tillage, residue management or fertility).

Normalization of Costs

To allow for comparison of costs and averages across the 13-year period, two additional columns were created to calculate the normalized eligible claim costs and final cost-share payment. The consumer price index was used to calculate yearly inflation across all fiscal years.

Project Metrics

For most project records, it was voluntary for a farm to provide information about specific outcome related metrics on the final claim form. This included metrics beyond those required to validate costs, as they were not required to be provided based on the program design. This information may have included the number of acres planted, the number of livestock, or even the number of trees planted, etc. Since not all applications provided this information consistently, project averages were used based on the applications that did provide this information (sometimes it was mandatory to provide metrics, per select program rules). For equipment projects, FHIP collected the most detail about impact acreages, and these metrics were used to calculate averages for specific equipment categories (e.g., the number of acres impacted by a no-till implement). However, a number of project categories did not collect any project metrics at all, such as nutrient recovery systems, and irrigation equipment, among others.

There is a fine line in requesting this information from a farmer, given that participation is voluntary and the program does not want to be seen as cumbersome or data intrusive. By aggregating this information across different spatial scales, farmers can have confidence that their information is only being used to understand and improve upon programs to better suit their needs.

Final Comments

Extensive time and resources went into the development of this database, particularly in ensuring the records were accurate and detailed enough to provide a meaningful analysis. The Lake Erie basin database may be a useful tool for ongoing research in this region.

It must be emphasized that this analysis only focused on projects that improved water quality. Care should be taken to remember that these results do not reflect the entire environmental 'footprint' of actions implemented by farmers in the Lake Erie basin supported by these programs. There were many additional environmental projects completed by farmers during this period that did not fit into the water quality lens of this analysis. Some of those environmental actions included energy conservation, habitat structures for species-at-risk, pest management, and management of invasive species, among others. As well, only projects that were successful in receiving a cost-share allocation were included. Many additional applications were submitted during this period but were unsuccessful in receiving a cost-share allocation.

OSCIA-delivered programs are only a selection of the opportunities for farmers to receive financial support in the Lake Erie basin. There are other delivery agents doing similar work delivering incentive-based educational programs, so this is not a "snap shot" of the entire Lake Erie basin; merely the story from one delivery agent and the farmers that were successful in receiving a funding allocation from those programs. It is the cumulative effort of all farmers and delivery agents that will accelerate the adoption of practices in reducing phosphorus inputs to Lake Erie. The benefits in implementing multiple BMPs are not explored in this analysis. For every adopted BMP, benefits extend beyond just water quality issues. For example, a riparian buffer along a stream will reduce erosion along the banks, act as a trap for phosphorus, provide habitat for species at risk, and support the soil during climate-driven changes in precipitation, among other benefits. Therefore, a single project touches many ecosystem services, from water quality to soil health, to biodiversity and climate change resiliency.

Finally, the results do not reflect the actions that farmers have already taken – and continue to take - without cost-share support. These trends do not reflect farmer willingness to address water quality issues or environmental risk, but a willingness to participate in the cost-share program opportunities that OSCIA delivered over this period.

Cost-Share Program Participation

Number of Projects

Since 2005, there have been 6,696 water quality improvement projects completed by 3,079 unique farms in the Lake Erie Basin. This represents an average of 2.2 water quality projects per farm over a 13-year period. The highest participation occurred during the final years of the Agricultural Policy Framework (2007-2008) and the first two years of Growing Forward (2008-2010). The number of projects completed between 2007 and 2009 represent 47% of total water quality improvement projects completed. Coinciding with a decline in available funding and the transition from conventional to merit-based programs; participation levelled off in 2013 and then began to modestly increase again during Growing Forward 2 and GLASI where the number of projects completed annually returned to levels previously seen in 2011.

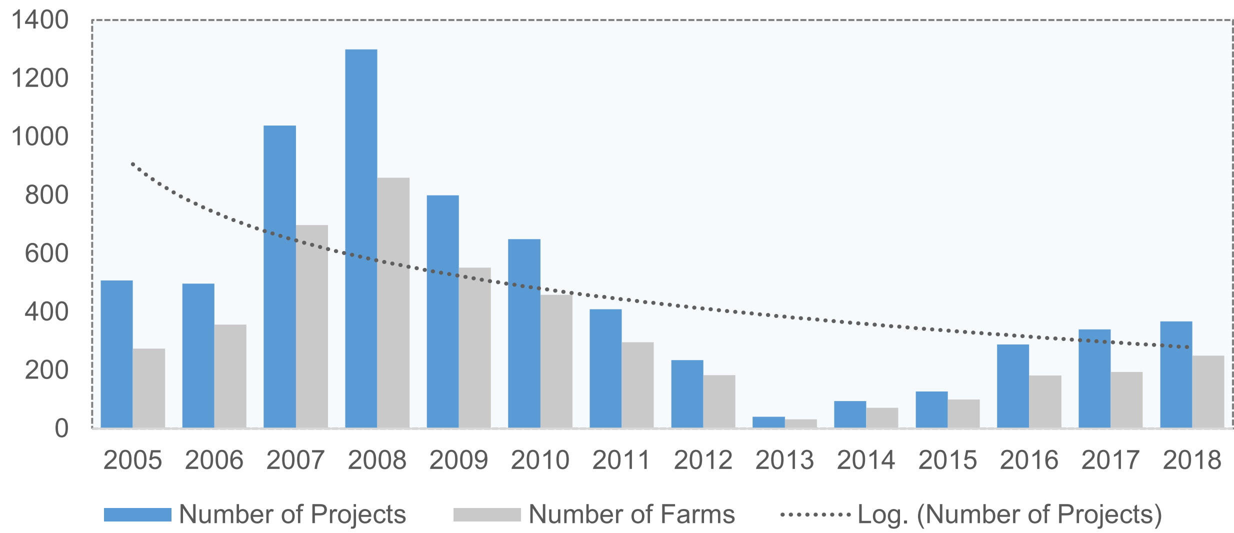


Figure 7: Total Number of Water Quality Improvement Projects in the Lake Erie Basin, 2005-2018

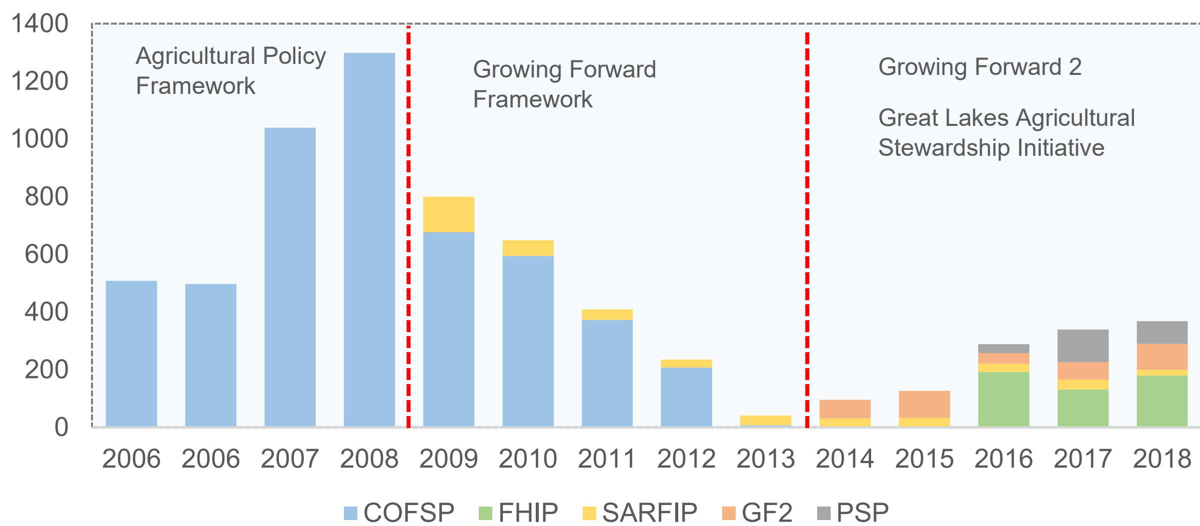


Figure 8: Number of Water Quality Improvement Projects by Major Funding Source

The average number of farms that completed a project declined 70% from 547 during APF to around 159 per year in GF2. The number of census reported farms in the Lake Erie basin declined 7% during this same period; however, there were several other forces impacting program participation and project completion to these water quality BMP categories.

Firstly, the decline in overall program funding limited the number of applicants that could participate in any given year. This means that declining participation is correlated to the decline in available funding. In fact, programs that were previously open for months at a time to receive a steady stream of applications (e.g., COFSP), were replaced with programs structured as application intake periods; where funding was sometimes fully allocated only a few days or weeks after an intake opened to receive applications.

Secondly, there was an adjustment period as farmers had to become familiar with new application procedures of the merit-based format. For many years, farmers had grown to expect support in filling out application and claim forms. This approach was discontinued for most programs when applications were assessed competitively against one another because of limited funding. As well, some farmers may have been somewhat hesitant to invest the time to apply because of the uncertainty of a successful outcome. Time constraints between applying, getting approval and completing a project in a single funding cycle challenged the completion of certain BMPs.

Thirdly, the approval process for many programs relied upon scoring thresholds and other BMP specific evaluation criteria that ensured program funds were allocated to the projects that best met the objectives of the program. Other reasons a project may not have qualified for funding was because the application did not demonstrate the environmental impact as effectively, or the application may have been incomplete, or perhaps the project was “out ranked” by another project that better met the program criteria.

Finally, these numbers also reflect a change in priority funding, as attention shifted to crop production activities and non-point sources of pollution. For example, project categories like manure storage improvements now have more stringent and specific eligibility requirements compared to prior years to allow targeting of funds to specific project objectives. In more recent years, funding caps are smaller and this has also impacted program participation to some BMPs. As mentioned, regional water quality initiatives in the region - such as those delivered by Conservation Authorities and other delivery agents - provide alternatives to the cost-share programs delivered by OSCIA. It is unknown how community delivery of these programs, in the context of cost-share competition may have influenced participation to OSCIA-delivered opportunities over this period.

The majority of programs included in the analysis were delivered province-wide, with the exception of GLASI. Under this framework, FHIP re-introduced funding for conservation tillage equipment, which had not been available in the preceding three years; so, there was a pent-up demand for this type of funding. It is difficult to say whether the new format - using a combination of financial incentives and technical support - was more successful in driving participation to water quality actions because the equipment focus was largely soil-health based, and it was promoted as such.

Estimated Participation Rate

To get a better understanding of how many farms in the basin actually participated in these programs, requires the use of census data. Program eligibility typically[9] requires a farm to have a

[9] An exception to this is SARFIP, which requires payment of farm taxes or a minimum acreage, and/or and FBRN.

Farm Business Registration Number (FBRN) or equivalent, demonstrating that the farm earns at least $7,000 in gross farm income.

Not all of the reported farms in the census would be eligible to participate in an OSCIA-delivered cost-share program, so a qualifier has to be applied to normalize these values. In this case, the closest census indicator is total gross farm receipts; specifically, farms earning less than $10,000. While it is not the same as the FBRN, it does provide a general proxy from which to estimate the number of "likely eligible" census reported farms that could have participated over this period.

After reviewing revenue data collected in GLASI and GF2 from program enrolment information, it was determined that 86% of farms that completed a water quality project reported between $50,000 and $3,000,000 in gross revenue. In GLASI, less than 4% of farms reported revenues between $7,000 and $9,000; while in GF2 less than 1% of farms reported less than $10,000. In the census, 14% of total farms in the Lake Erie basin report less than $10,000 in gross farm receipts. The number of census farms (excluding those reporting less than $10,000) was compared to cost-share program participation numbers in Table 27 to allow for a general, but not equivalent, comparison.

Table 27: Estimated Program Participation Rate, Lake Erie Basin (2006-2016)
SOURCE: OSCIA Program Records (2005-2018).

Tertiary Watershed	Census Farms[1]	Farms with < $10,000 Gross Farm Receipts[1]	Estimated Eligible Farms *(FBRN Proxy)*	OSCIA Participating Farms	Estimated Participation Rate
Name	**Number**	**Number**	**Number**	**Number**	**Percent**
Upper Grand	4,229	648	3,581	693	19%
Lower Grand	1,395	267	1,128	130	12%
Big	3,242	512	2,730	367	13%
Upper Thames	2,777	278	2,499	631	25%
Lower Thames	2,187	270	1,917	335	18%
Rondeau	570	73	497	130	26%
Sydenham	2,651	309	2,342	488	21%
Cedar	1,547	272	1,275	305	24%
Total / Average	**18,598**	**2,628**	**15,970**	**3,079**	**20%**

1. Number of census farms was calculated by averaging the total number of farms in each census reporting period: 2006, 2011 and 2016. This was also done for the number of farms reporting less than $10,000 in total gross farm receipts. This average allows for comparison against the total number of farms that have participated over the same period in OSCIA-delivered programs.

As shown above, an estimated 20% of farms in the Lake Erie basin have completed a water quality improvement project with the assistance from OSCIA-delivered cost-share programs. This rate varies between watersheds, ranging from as low as 12% in Lower Grand, to as much as 26% of farms in Rondeau.

The same comparison was also done for townships (that have geographic areas that fall within the Lake Erie basin); and participation rates ranged from as low as 5% to as much as 75% (Table 52). Townships with estimated participation rates higher than the average of 20%, and that are fully located within the boundary of the Lake Erie basin, included Grand Valley, Essex, Chatham-Kent, Wellesley, and the area in and around London.

It was estimated that six percent of total eligible farms in the Lake Erie basin completed at least one water quality project in 2006. This dropped to three percent in 2011 and was two percent by 2016. This decrease doesn't necessarily indicate disinterest with these programs; it instead potentially reflects the challenge in successfully securing a cost-share allocation. Competition associated with the merit-based format, combined with significantly fewer dollars and lower funding caps to support environmental activities, have all contributed to a drop in the number of farms securing a cost-share allocation. While it has become more challenging to secure funding, there is greater confidence that these programs have supported projects that best met the program objectives at the time. It is not known what percentage of farmers in the Lake Erie basin are taking actions to address water quality without the support of cost-share funding assistance.

Primary Commodity Trends

Program data allowed for select industry group participation to be analyzed. As shown in Figure 8, there was a notable increase in participation from oilseed and grain producers in 2016. One may assume this was related to the re-introduction of equipment funding in GLASI and concurrent intakes of GF2. However, when equipment categories were excluded from the analysis, the trend was still very similar. This signal may instead reflect an increase in engagement with crop producers that are completing projects to address non-point sources of phosphorus.

Greenhouse participation has been relatively stable throughout the period. In Figure 9, this industry group includes vegetable and melon producers because it was not collected as a separate category prior to 2013 in OSCIA-delivered cost-share programs.

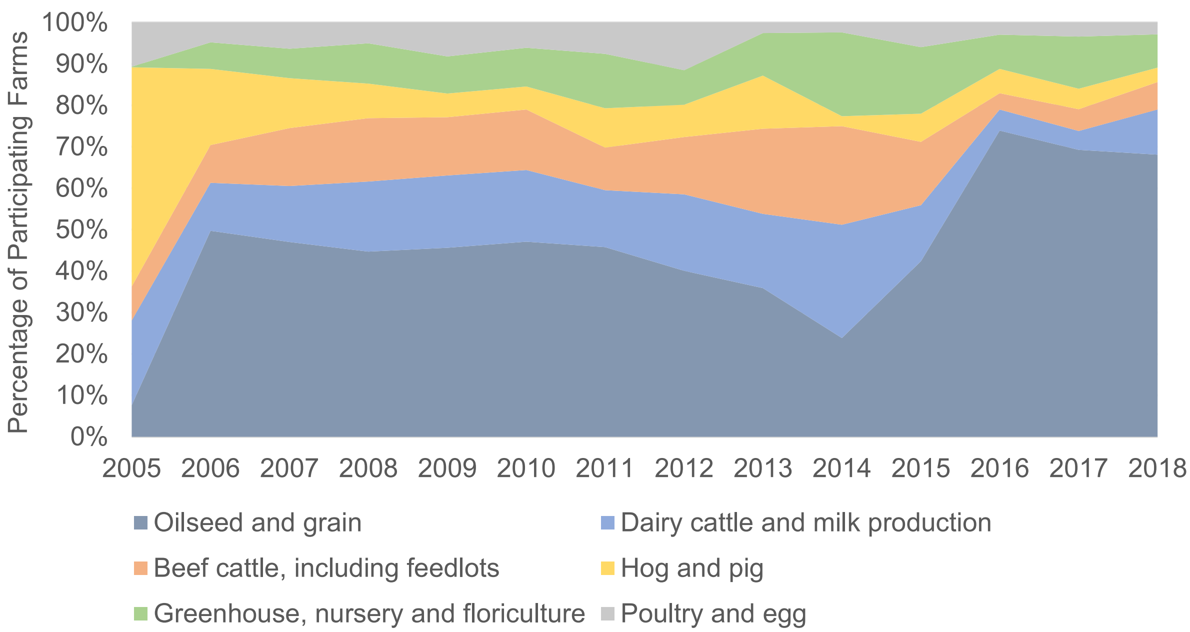


Figure 9: Participation by Industry Group, All BMP Project Categories, Lake Erie Basin

Numerous non-environmental BMP categories were offered in GF2. These focus areas included biosecurity, assurance systems, labour productivity, animal welfare, and market development, among other actions. These areas are also considered pillars of sustainability. This greater selection of categories, provided competition to the water quality improvement projects; as farms only had a limited amount of funding to commit to a select number of projects in any given year. It is not known if the availability of funding to these other categories, or the different eligibility criteria that apply to them, may have impacted a farm's priority in addressing environmental risks identified in the EFP. It is important to mention that merit-based programs would often limit the number of applications, restricting investment to a smaller number of project categories in each funding year.

It is not known how these additional offerings may have impacted the priority in addressing water quality in the Lake Erie basin. Each industry faces unique challenges and opportunities in supporting water quality; and regulation and market pressures in the food system continue to impact the adoption of environmental practices.

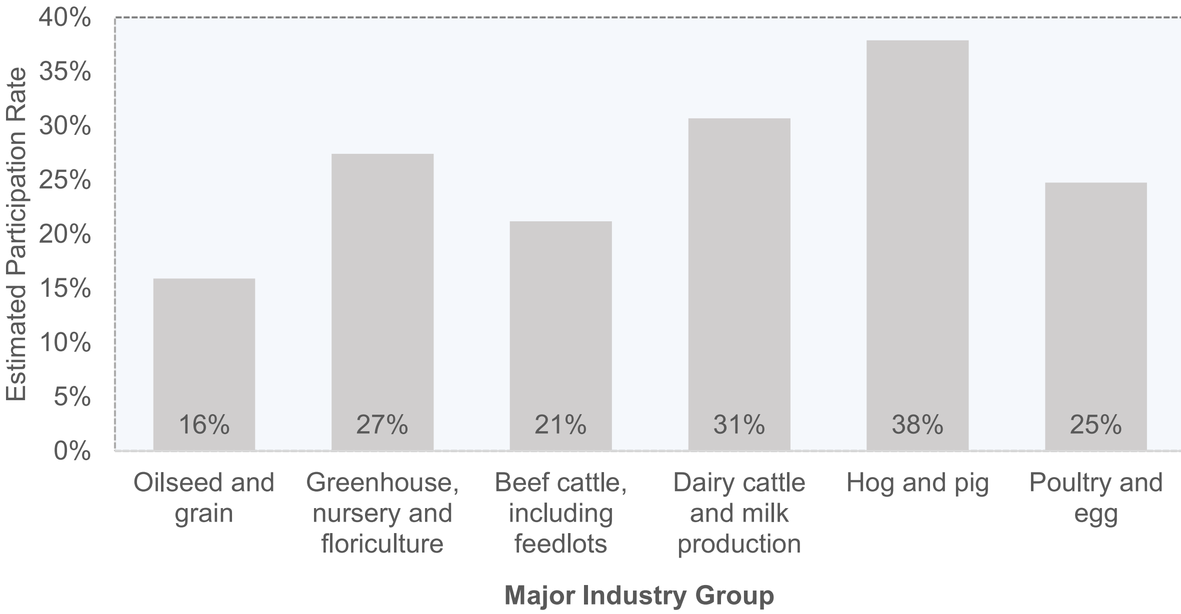


Figure 10: Estimated Average Cumulative Participation Rate of Estimated Eligible Farms (2006-2016)

It is estimated that the highest participation in OSCIA-delivered programs supporting water quality, came from hog and pig farms (38%); this was followed by dairy farms (31%), and then greenhouses (27%). The increase in oilseed and grain producers in recent years, could be the result of fewer of these farms having previously participated in cost-share programs before; as compared to the other industry groups where regulation has played a factor in addressing on-farm environmental risks in the livestock sector. It is also important to consider how the design of certain programs reached different farm audiences. FHIP intentionally targeted crop producers and required farmers to partner with their CCA or P. Ag; so, it may have been the technical specialist that introduced the farmer to cost-share, instead of through the traditional gateway, such as the EFP workshops.

This trend may also reflect issues with the data itself, as a farm is only required to submit one program enrolment form upon initial participation. If that farm later switches to a new industry after subsequent project applications, that information may or may not have been updated in the original program database. While participation trends can reveal general trends about water quality cost-share program participation; it is through closer examination of BMP groups and individual BMPs that the impact of water quality actions can be more fully understood in this region.

BMP Project Trends

Many factors have influenced BMP adoption across the Lake Erie basin. Each year of program delivery saw a different mix of BMP category offerings, and cost-share funding rates and caps. Cost-share funding has played a role in these trends, but there are many other factors that contribute to the ebb and flow of cost-share program participation. These factors include: risks identified in the EFP Action Plan, education, cost-share program awareness, farm resources, alignment of application and project timelines between the farm and the program, regulatory and market pressures, extension agents, technical support, the application review outcome, expected benefits, and confidentiality concerns (PRA, 2011).

In the Lake Erie basin, some BMPs have cycled back and forth between periods of higher and lower uptake; while others have seen more consistent uptake (Figure 11). For example, manure management activities and runoff prevention and recovery actions, have declined in more recent years of program delivery. These BMP categories have seen more stringent and targeted eligibility criteria introduced in more recent years. Plans and assessments, which include crop nutrient planning and nutrient management planning activities have seen a slightly higher proportion of projects completed in more recent years. This growth has been accelerated by crop nutrient planning, which is now promoted as a standalone BMP to crop producers in the Lake Erie basin.

In 2013, many BMP categories offered limited funding as cost-share programs like COFSP were winding down. During this period, SARFIP BMPs such as the protection or restoration of natural areas through livestock exclusion fencing and tree planting actions, made up a greater proportion of total projects. The absence of funding for conservation tillage implements between 2013 and 2015 can also be seen in Figure 11; and this trend highlights the impact that cost-share funding availability plays on the adoption of priority BMPs in any given year.

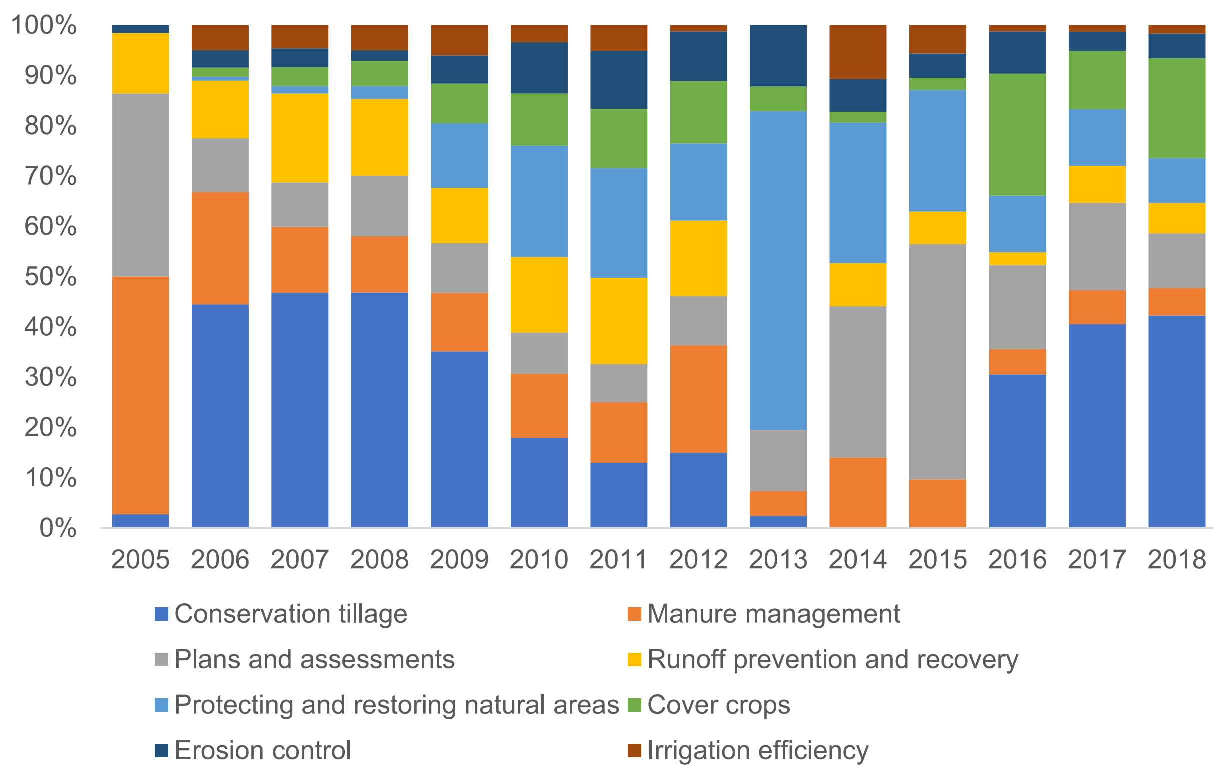


Figure 11: Proportion of Total Projects by Major BMP Group, Lake Erie Basin, 2005-2008

As shown in Figure 12, conservation tillage and cover cropping have been more popular as a percentage of total projects in the Conservation Authorities of Lower Thames Valley, St. Clair Region and Kettle Creek. In areas with greater livestock production, such as in Grand River and Upper Thames River, there is a greater proportion of manure management activities.

Grand River also saw a higher a proportion of projects focused on protecting or restoring sensitive on-farm environmental areas (i.e., streams, forests, grasslands etc.). These projects made up a much smaller percentage of total projects St. Clair Region, Essex Region and Kettle Creek. Catfish Creek had a larger proportion of projects addressing erosion, while irrigation efficiencies were more prevalent in Essex and Long Point where there is a larger presence of greenhouses. Spatial trends by township and Conservation Authority (Figure 70) are presented on page 102.

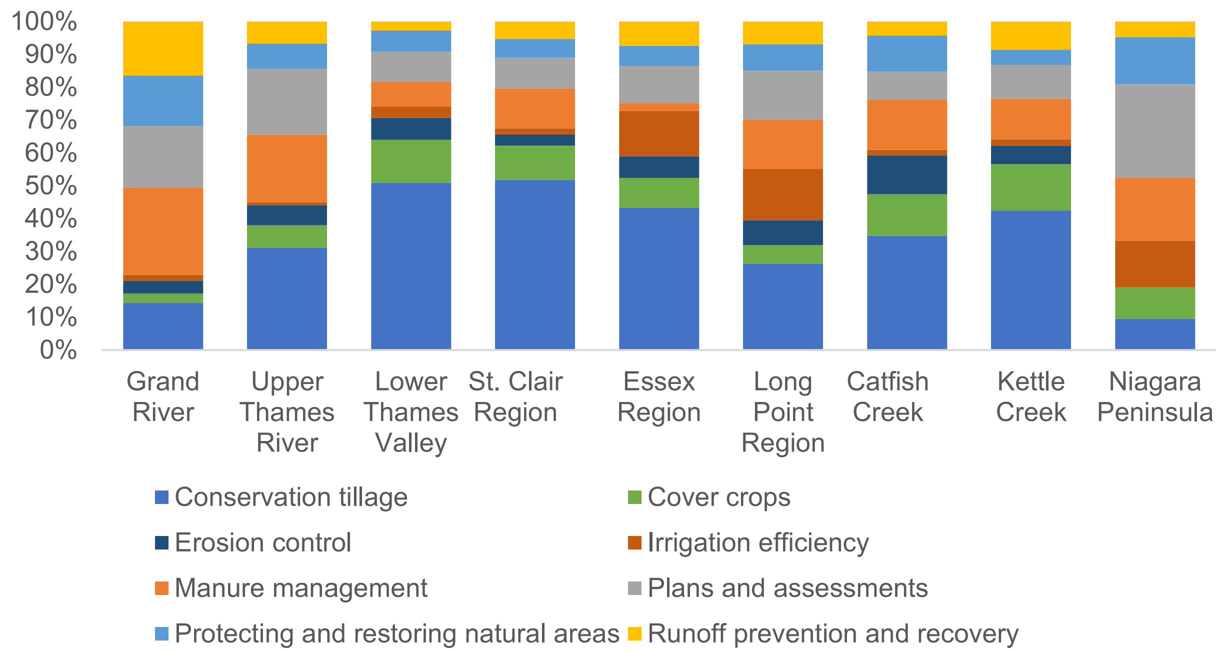


Figure 12: Proportion of Total Projects by Tertiary Watershed, 2005-2008

As shown in Table 28, conservation tillage had the largest number of projects compared to all other major BMP groups. These projects (n=2,161) represent 32% of total projects completed in the Lake Erie basin with support from OSCIA-delivered cost-share programs. This was followed by manure management, with 15% of total projects, and planning activities, with 13% of total projects. Together, these three BMP groups represent 60% of total projects completed.

In terms of the investment contributed to these water quality focus areas, manure management accounted for 38% of total project costs. This was followed by conservation tillage, with 26% of total project costs, and runoff prevention and recovery actions with 20% of total project costs. Together, these three BMP groups represent nearly 84% of total project costs.

In terms of project numbers, about 60% of total projects addressed non-point sources of phosphorus runoff, while about 30% focused specifically on point-sources. However, in terms of total investment this ratio is reversed, with 60% of total project costs contributing to point sources of phosphorus pollution. This ratio changes depending upon which program years are evaluated.

Table 28: Number of Projects and Total Investment by Major BMP Group (2005-2018)
SOURCE: OSCIA Program Records (2005-2018).

BMP Group	Total Projects	Percent of Total Projects	Total Project Cost	Percent of Project Cost	Total Payment Amount	Percent of Payment Amount
Conservation tillage	2,161	32%	$42,860,118	26%	$12,984,610	26%
Manure management	986	15%	$61,776,167	38%	$16,775,140	34%
Plans and assessments	895	13%	$3,394,917	2%	$1,541,104	3%
Runoff prevention and recovery	856	13%	$33,335,563	20%	$9,560,082	19%
Protecting and restoring natural areas	598	9%	$5,399,968	3%	$2,311,536	5%
Cover crops	491	7%	$1,960,333	1%	$658,219	1%
Erosion control	338	5%	$5,700,019	3%	$2,350,480	5%
Irrigation efficiency	262	4%	$8,497,865	5%	$2,264,141	5%
Organic amendments	104	2%	$1,450,759	1%	$575,212	1%
Septic systems	5	<1%	$78,559	<1%	$49,894	<1%
Total	**6,696**	**100%**	**$164,454,267**	**100%**	**$49,070,418**	**100%**

A complete summary of individual BMP projects can be found in Tables 29-31. While evaluating the impact of major BMP groups can be a useful way to assess the general preference for certain water quality themes, individual BMPs provide the most fulsome opportunity for analysis.

As previously mentioned, conservation tillage encompasses several equipment categories; and banding, variable rate or controlled application equipment saw the most projects out of all conservation tillage types. In fact, this BMP also had the largest number of projects out of all other BMPs (n=1,022) in the Lake Erie basin, accounting for 15% of total projects. This was followed closely by no-till equipment projects (n=827) to enable no-till or zero-till seeding, improved manure storage (n=756), and nutrient management planning (n=730). Together these four BMPs represent 50% of total water quality improvement projects implemented in the Lake Erie basin between 2005 and 2018 with support from OSCIA-delivered cost-share.

Manure storage accounted for 34% of total project costs; this was followed by no-till equipment with 13% of total project costs, and nutrient recovery from wastewater with 10% of total project costs. Together, these three BMPs represent nearly 60% of total project costs.

BMPs with comparatively lower project numbers do not necessarily indicate less interest by farmers in the Lake Erie basin, as some BMP activities were more widely promoted and funded than others. However, they certainly do warrant more examination to determine if any program barriers may be impacting a farm's willingness or motivation to try these BMPs on their farmland. A more in-depth timeseries analysis, showing participation rates for individual BMPs on an annual basis can be found on page 62.

Table 29: Number of Projects and Total Project Costs, Ranked by Number of Projects (2005-2018)
SOURCE: OSCIA Program Records (2005-2018).

Best Management Practice	Number	Percent of Total Number	Total Project Cost[1]	Percent of Project Costs
Conservation tillage equipment: to enable banding, variable or controlled applications	1,022	15%	$14,821,216	9%
Conservation tillage equipment: no-till planting units or components	827	12%	$22,098,479	13%
Improved manure storage	756	11%	$56,237,432	34%
Nutrient management planning	730	11%	$2,578,305	2%
Cover crops	491	7%	$1,960,333	1%
Livestock and facility runoff control	432	6%	$14,511,372	9%
Nutrient recovery from wastewater	343	5%	$16,914,964	10%
Erosion control structures	339	5%	$5,715,220	3%
Improved irrigation efficiency	262	4%	$8,497,865	5%
Conservation tillage equipment: Modifications to improve manure application	230	3%	$5,538,735	3%
Windbreak and shelterbelts	212	3%	$1,372,415	1%
Livestock exclusion fencing	155	2%	$1,266,776	1%
Conservation tillage equipment: combine collectors and spreaders to manage chaff	136	2%	$802,924	<1%
Adding organic amendments	104	2%	$1,450,759	1%
Crop nutrient planning	97	1%	$360,551	<1%
Product and waste management	80	1%	$1,894,025	1%
Conservation tillage equipment: planting in high-residue situations	75	1%	$1,319,760	1%
Buffer strips	69	1%	$550,254	<1%
Other plans and assessments	68	1%	$456,062	<1%
Conservation tillage equipment: strip-till units or components	60	1%	$2,728,756	2%
Wetland restoration	42	1%	$999,459	1%
Alternative watering systems	41	1%	$209,333	<1%
Reforestation	32	<1%	$276,874	<1%
Improved stream crossings	23	<1%	$477,527	<1%
Conservation tillage equipment: managing and planting cover crops	22	<1%	$481,355	<1%
Grassland restoration	21	<1%	$162,505	<1%
Conservation tillage equipment: modifications to reduce soil compaction	11	<1%	$292,954	<1%
Conservation tillage equipment: vertical tillage planting units or components	8	<1%	$314,674	<1%
Septic systems	5	<1%	$78,559	<1%
Fragile land retirement	3	<1%	$84,825	<1%
Total	**6,696**	**100%**	**$164,454,267**	**100%**

1. Dollars have been normalized using inflation rates based on the consumer price index (CPI).

Table 30: Number of Projects and Average Investment, Ranked by Number of Projects (2005-2018)
SOURCE: OSCIA Program Records (2005-2018).

Best Management Practice	Number	Percent of Total Number	Average Project Cost[1]	Average Payment[1]
Conservation tillage equipment: to enable banding, variable or controlled applications	1,022	15%	$14,502	$4,546
Conservation tillage equipment: no-till planting units or components	827	12%	$26,721	$7,414
Improved manure storage	756	11%	$74,388	$20,221
Nutrient management planning	730	11%	$3,532	$1,615
Cover crops	491	7%	$3,993	$1,341
Livestock and facility runoff control	432	6%	$33,591	$11,169
Nutrient recovery from wastewater	343	5%	$49,315	$12,422
Erosion control structures	339	5%	$16,859	$6,963
Improved irrigation efficiency	262	4%	$32,435	$8,642
Conservation tillage equipment: Modifications to improve manure application	230	3%	$24,081	$6,469
Windbreak and shelterbelts	212	3%	$6,474	$2,233
Livestock exclusion fencing	155	2%	$8,173	$3,913
Conservation tillage equipment: combine collectors and spreaders to manage chaff	136	2%	$5,904	$1,714
Adding organic amendments	104	2%	$13,950	$5,531
Crop nutrient planning	97	1%	$3,717	$1,846
Product and waste management	80	1%	$23,675	$5,809
Conservation tillage equipment: planting in high-residue situations	75	1%	$17,597	$5,921
Buffer strips	69	1%	$7,975	$2,869
Other plans and assessments	68	1%	$6,707	$2,694
Conservation tillage equipment: strip-till units or components	60	1%	$45,479	$17,001
Wetland restoration	42	1%	$23,797	$11,483
Alternative watering systems	41	1%	$5,106	$2,588
Reforestation	32	<1%	$8,652	$3,911
Improved stream crossings	23	<1%	$20,762	$8,249
Conservation tillage equipment: managing and planting cover crops	22	<1%	$21,880	$9,935
Grassland restoration	21	<1%	$7,738	$4,278
Conservation tillage equipment: modifications to reduce soil compaction	11	<1%	$26,632	$12,823
Conservation tillage equipment: vertical tillage planting units or components	8	<1%	$39,334	$18,811
Septic systems	5	<1%	$15,712	$9,979
Fragile land retirement	3	<1%	$28,275	$13,497
Total	**6,696**	**100%**	**$24,560**	**$7,328**

1. Dollars have been normalized using inflation rates based on the consumer price index (CPI).
2. Average (not total)

Table 31: Number of Projects, Total Source Investment and Average Total Cost-Share Rate (2005-2018)
SOURCE: OSCIA Program Records (2005-2018).

Best Management Practice	Total Project Cost	Total Farm Contribution	Total Payment	Rate[2]
Conservation tillage equipment: to enable banding, variable or controlled applications	$14,821,216	$10,175,707	$4,645,509	31%
Conservation tillage equipment: no-till planting units or components	$22,098,479	$15,966,818	$6,131,661	28%
Improved manure storage	$56,237,432	$40,950,144	$15,287,288	27%
Nutrient management planning	$2,578,305	$1,399,462	$1,178,843	46%
Cover crops	$1,960,333	$1,302,114	$658,219	34%
Livestock and facility runoff control	$14,511,372	$9,686,468	$4,824,904	33%
Nutrient recovery from wastewater	$16,914,964	$12,654,373	$4,260,591	25%
Erosion control structures	$5,715,220	$3,354,859	$2,360,362	41%
Improved irrigation efficiency	$8,497,865	$6,233,724	$2,264,141	27%
Conservation tillage equipment: Modifications to improve manure application	$5,538,735	$4,050,883	$1,487,852	27%
Windbreak and shelterbelts	$1,372,415	$898,980	$473,435	34%
Livestock exclusion fencing	$1,266,776	$660,226	$606,550	48%
Conservation tillage equipment: combine collectors and spreaders to manage chaff	$802,924	$569,777	$233,148	29%
Adding organic amendments	$1,450,759	$875,547	$575,212	40%
Crop nutrient planning	$360,551	$181,516	$179,035	50%
Product and waste management	$1,894,025	$1,429,318	$464,707	25%
Conservation tillage equipment: planting in high-residue situations	$1,319,760	$875,658	$444,103	34%
Buffer strips	$550,254	$352,292	$197,962	36%
Other plans and assessments	$456,062	$272,836	$183,226	40%
Conservation tillage equipment: strip-till units or components	$2,728,756	$1,708,682	$1,020,074	37%
Wetland restoration	$999,459	$517,181	$482,277	48%
Alternative watering systems	$209,333	$103,229	$106,104	51%
Reforestation	$276,874	$151,710	$125,164	45%
Improved stream crossings	$477,527	$287,806	$189,721	40%
Conservation tillage equipment: managing and planting cover crops	$481,355	$262,778	$218,577	45%
Grassland restoration	$162,505	$72,675	$89,830	55%
Conservation tillage equipment: modifications to reduce soil compaction	$292,954	$151,903	$141,051	48%
Conservation tillage equipment: vertical tillage planting units or components	$314,674	$164,187	$150,488	48%
Septic systems	$78,559	$28,664	$49,894	64%
Fragile land retirement	$84,825	$44,334	$40,492	48%
Total	**$164,454,267**	**$115,383,849**	**$49,070,418**	**30%**

1. Dollars have been normalized using inflation rates based on the consumer price index (CPI).
2. Average cost-share funding rate.

Investment Summary

Between 2005 and 2018, 3,079 unique farm operations invested $115,383,846 to implement 6,696 water quality improvement projects in the Lake Erie basin. This represents an average farm investment of $37,474 per farm, with an average farm contribution of $17,232 per project. When considering all investment sources (farm and government contribution), the average project cost was $24,560, while the average cost-share payment was $7,328. However, this ranges across individual BMPs. Tables 32 and 33 summarize the average, minimum, maximum and median project costs and cost-share payments for all individual BMPs. An average of 2.2 water quality projects per farm were completed in the Lake Erie basin over this period.

The total cost of these water quality improvement projects from all sources (farm and government cost-share contribution) was $164,454,267. Across all BMPs, the average rate or percent contribution from cost-share funding was around 30%. This means that on average, for each $100 investment a farm made to address water quality risks over this period, a farm received about $30 in cost-share to support the project. However, on average, this ranged from as high as 64% for septic systems to as low as 25% for nutrient recovery from wastewater projects. BMPs that have average cost-share rates lower than 30%, often exceeded the funding cap. In Table 31, the average cost-share rate considers all eligible project costs and the funding cap. The program database did not always collect information about the funding cap, as they often changed from year to year, or intake to intake.

While the average project cost was $24,560 across all BMPs and all years, individual project costs ranged from as low as $43 (for a crop nutrient plan) to a maximum cost of $499,334 (for a covered yard). The earlier years of program delivery (2005-2012) generally saw higher funding caps, and provided higher levels of cost-share funding which enabled the programs to support a larger portion of total project costs. Because of this, the project average can change significantly depending upon which program years are evaluated. Project and payment costs presented in this analysis only include those costs deemed eligible in the final claim submission. Across all years, the average cost-share payment was $7,328 per project, with $26 being the lowest payment issued and $112,000 being the highest payment issued.

While each farm completed 2.2 water quality projects on average; this ranged from as low as 1.9 projects per farm in Long Point Region Conservation Authority to as high as 2.5 projects per farm in Lower Thames River Conservation Authority. The BMP adoption rate also ranges when individual BMPs are compared. As some BMPs were more likely to be repeated by the same unique farm business at multiple unique locations, such as: livestock exclusion fencing, cover crops, crop nutrient planning and erosion control structures.

When reviewing maximum project and payment costs in Tables 32-33, a few outliers were observed. In the other plans and assessments BMP category (which includes planning not related to crop nutrient or nutrient management planning, such as irrigation or erosion control planning), a project with a maximum project cost of $71,946 was identified. At first glance, this would seem unlikely for a planning project; however, in this particular record, the project description indicated contractor costs for surveying, grid sampling and the development of an irrigation plan for a large facility. No other details in the project record can explain the high cost for this project. Another such example was the maximum project cost identified for windbreaks and shelterbelts ($79,409). This also seemed unusual, but no other cost information was provided in the record. Current programs now track detailed expenditures more consistently in the database.

Table 32: BMP Project Summary: Minimum, Maximum, Median Project Costs, Lake Erie Basin (2005-2018)
SOURCE: OSCIA Program Records (2005-2018).

Best Management Practice	Number of Projects	Total Project Cost[2]	Average Project Cost	Minimum Project Cost	Maximum Project Cost	Median Project Cost
Conservation tillage equipment: to enable banding, variable or controlled applications	1,022	$14,821,216	$14,502	$106	$296,551	$5,796
Conservation tillage equipment: no-till planting units or components	827	$22,098,479	$26,721	$441	$175,107	$21,222
Improved manure storage	756	$56,237,432	$74,388	$391	$405,879	$66,519
Nutrient management planning	730	$2,578,305	$3,532	$191	$77,889	$2,384
Cover crops	491	$1,960,333	$3,993	$199	$33,085	$2,910
Livestock and facility runoff control	432	$14,511,372	$33,591	$335	$449,344	$18,041
Nutrient recovery from wastewater	343	$16,914,964	$49,315	$227	$378,468	$26,213
Erosion control structures	339	$5,715,220	$16,859	$288	$242,540	$10,036
Improved irrigation efficiency	262	$8,497,865	$32,435	$502	$196,388	$23,971
Conservation tillage equipment: Modifications to improve manure application	230	$5,538,735	$24,081	$1,227	$179,466	$16,213
Windbreak and shelterbelts	212	$1,372,415	$6,474	$240	$79,409	$3,467
Livestock exclusion fencing	155	$1,266,776	$8,173	$848	$43,383	$6,177
Conservation tillage equipment: combine collectors and spreaders to manage chaff	136	$802,924	$5,904	$848	$63,083	$3,342
Adding organic amendments	104	$1,450,759	$13,950	$1,260	$68,544	$11,521
Crop nutrient planning	97	$360,551	$3,717	$43	$32,072	$2,227
Product and waste management	80	$1,894,025	$23,675	$546	$346,345	$12,372

Best Management Practice	Number of Projects	Total Project Cost[2]	Average Project Cost	Minimum Project Cost	Maximum Project Cost	Median Project Cost
Conservation tillage equipment: planting in high-residue situations	75	$1,319,760	$17,597	$715	$76,074	$9,497
Buffer strips	69	$550,254	$7,975	$481	$56,937	$4,303
Other plans and assessments	68	$456,062	$6,707	$249	$71,946	$4,425
Conservation tillage equipment: strip-till units or components	60	$2,728,756	$45,479	$2,014	$181,721	$39,620
Wetland restoration	42	$999,459	$23,797	$1,848	$183,081	$15,601
Alternative watering systems	41	$209,333	$5,106	$181	$30,656	$2,902
Reforestation	32	$276,874	$8,652	$412	$55,792	$6,562
Improved stream crossings	23	$477,527	$20,762	$649	$109,166	$14,548
Conservation tillage equipment: managing and planting cover crops	22	$481,355	$21,880	$679	$74,109	$17,106
Grassland restoration	21	$162,505	$7,738	$834	$29,666	$5,252
Conservation tillage equipment: modifications to reduce soil compaction	11	$292,954	$26,632	$15,450	$63,348	$23,109
Conservation tillage equipment: vertical tillage planting units or components	8	$314,674	$39,334	$4,244	$67,465	$45,341
Septic systems	5	$78,559	$15,712	$9,217	$25,137	$14,016
Fragile land retirement	3	$84,825	$28,275	$12,631	$37,520	$34,674
Grand Total	**6,696**	**$164,454,267**	**$24,560[1]**	**$1,910[1]**	**$137,672[1]**	**$15,646[1]**

1. Average (not total).
2. Costs have been normalized using inflation rates based on the consumer price index (CPI).

Table 33: BMP Project Summary: Minimum, Maximum, Median Payments, Lake Erie Basin (2005-2018)
SOURCE: OSCIA Program Records (2005-2018).

Best Management Practice	Number of Projects	Total Payment[2]	Average Payment	Minimum Payment	Maximum Payment	Median Payment
Conservation tillage equipment: to enable banding, variable or controlled applications	1,022	$4,645,509	$4,546	$85	$78,781	$2,019
Conservation tillage equipment: no-till planting units or components	827	$6,131,661	$7,414	$155	$63,344	$5,853
Improved manure storage	756	$15,287,288	$20,221	$196	$110,613	$19,202
Nutrient management planning	730	$1,178,843	$1,615	$112	$12,576	$1,179
Cover crops	491	$658,219	$1,341	$60	$15,780	$947
Livestock and facility runoff control	432	$4,824,904	$11,169	$168	$112,000	$7,936
Nutrient recovery from wastewater	343	$4,260,591	$12,422	$68	$112,000	$6,773
Erosion control structures	339	$2,360,362	$6,963	$113	$77,250	$4,768
Improved irrigation efficiency	262	$2,264,141	$8,642	$151	$53,865	$6,963
Conservation tillage equipment: Modifications to improve manure application	230	$1,487,852	$6,469	$368	$35,975	$4,812
Windbreak and shelterbelts	212	$473,435	$2,233	$113	$22,103	$1,310
Livestock exclusion fencing	155	$606,550	$3,913	$170	$19,477	$2,656
Conservation tillage equipment: combine collectors and spreaders to manage chaff	136	$233,148	$1,714	$254	$18,925	$991
Adding organic amendments	104	$575,212	$5,531	$469	$23,518	$4,237
Crop nutrient planning	97	$179,035	$1,846	$26	$20,806	$1,150
Product and waste management	80	$464,707	$5,809	$164	$18,405	$3,664

Best Management Practice	Number of Projects	Total Payment[2]	Average Payment	Minimum Payment	Maximum Payment	Median Payment
Conservation tillage equipment: planting in high-residue situations	75	$444,103	$5,921	$207	$26,260	$3,294
Buffer strips	69	$197,962	$2,869	$102	$15,506	$1,553
Other plans and assessments	68	$183,226	$2,694	$200	$10,300	$2,179
Conservation tillage equipment: strip-till units or components	60	$1,020,074	$17,001	$604	$75,635	$15,488
Wetland restoration	42	$482,277	$11,483	$1,042	$57,155	$8,769
Alternative watering systems	41	$106,104	$2,588	$91	$15,439	$1,292
Reforestation	32	$125,164	$3,911	$309	$16,758	$2,269
Improved stream crossings	23	$189,721	$8,249	$324	$22,862	$7,688
Conservation tillage equipment: managing and planting cover crops	22	$218,577	$9,935	$238	$26,260	$9,589
Grassland restoration	21	$89,830	$4,278	$417	$22,862	$2,397
Conservation tillage equipment: modifications to reduce soil compaction	11	$141,051	$12,823	$6,180	$22,470	$12,132
Conservation tillage equipment: vertical tillage planting units or components	8	$150,488	$18,811	$1,273	$42,681	$10,500
Septic systems	5	$49,894	$9,979	$7,374	$17,955	$8,185
Fragile land retirement	3	$40,492	$13,497	$5,053	$18,512	$16,928
Total	**6,696**	**$49,070,418**	**$7,328[1]**	**$869[1]**	**$39,536[1]**	**$5,891[1]**

1. Average (not total).
2. Costs have been normalized using inflation rates based on the consumer price index (CPI).

Average Project Costs and Payments

As shown in Figure 13, average project costs were higher in 2005 and 2014 compared to the other years included in this study. This was the result of additional manure storage; nutrient recovery and irrigation efficiency projects being supported in those years, which are more expensive projects to implement. Across all years of program delivery, average project costs remained fairly consistent; however, they do vary significantly across different industry groups. In more recent years of program delivery, there have been a greater proportion of non-point source projects completed.

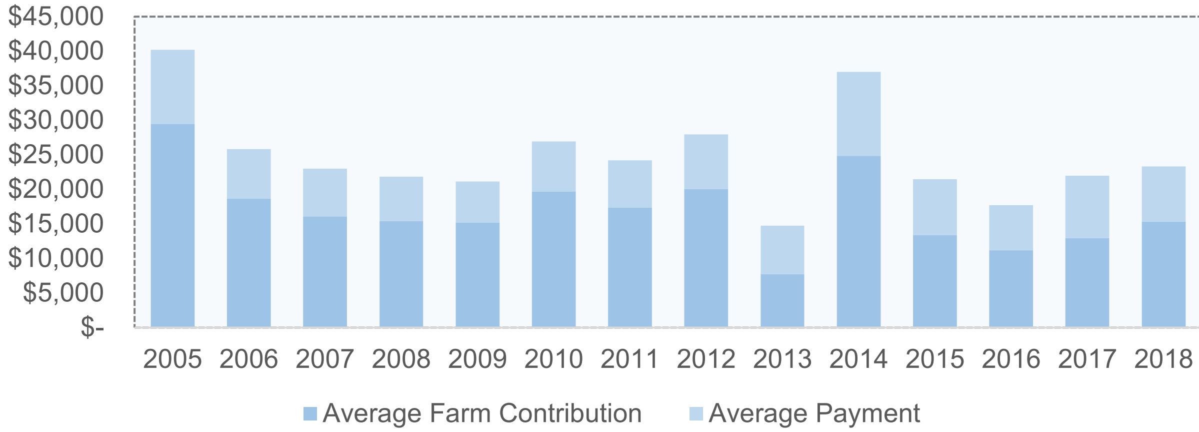


Figure 13: Average Project Cost, Lake Erie Basin

The investment required for greenhouses and dairy farms to complete a water quality project was higher on average compared to other industry groups. As shown in Figure 14, the average project cost for a greenhouse was $42,697, compared to $16,228 for an oilseed and grain operation. While cost-share rates and caps often consider different requirements for certain industry groups, they do not always consider variability between industries for the same BMP project category. For example, an oilseed and grain operation will typically invest $19,786 for a conservation tillage implement; but a vegetable and melon farm with different crop needs might invest $32,448.

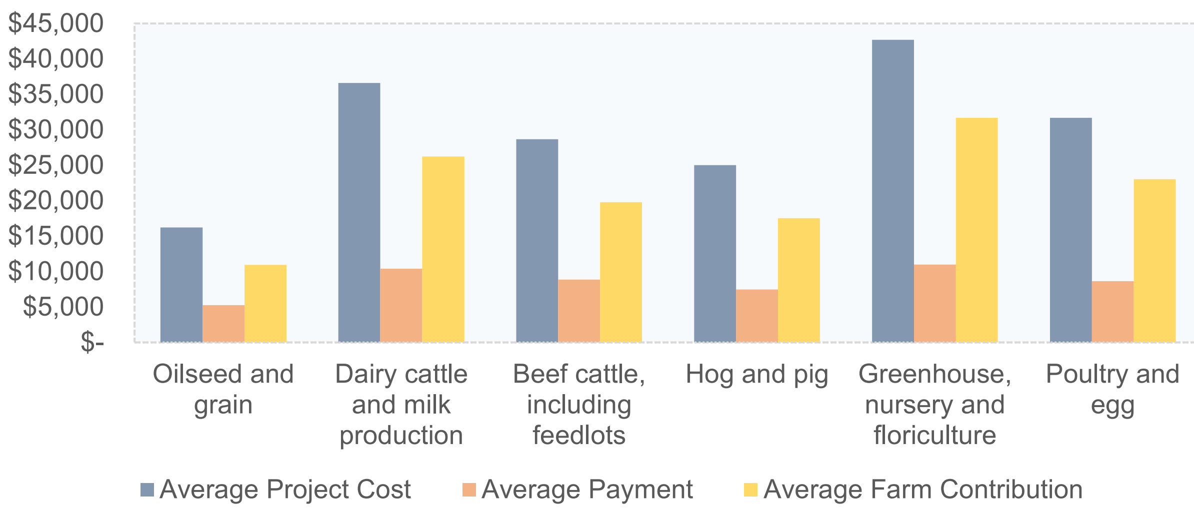


Figure 14: Average Project Cost and Farm Contribution, Lake Erie Basin

BMP Time Series Analysis

Winter cover cropping

337 unique farm operations completed 491 cover crop projects in the Lake Erie basin. Approximately 91 farms (27%) completed more than one cover crop project. The average project cost was $3,993, while the average cost-share contribution was $1,341 (34% of project costs).

It is estimated that on average, 140 acres were planted per project; this ranged from as low as 8 acres to as much as 5,200 acres. The average number of cover crop acres planted per project decreased from an average of 184 acres in 2011 to 104 acres in 2018. It is estimated that 68,740 acres were planted as the result of these projects in the first-year alone. As shown in Figure 15, the highest number of projects were completed in 2018.

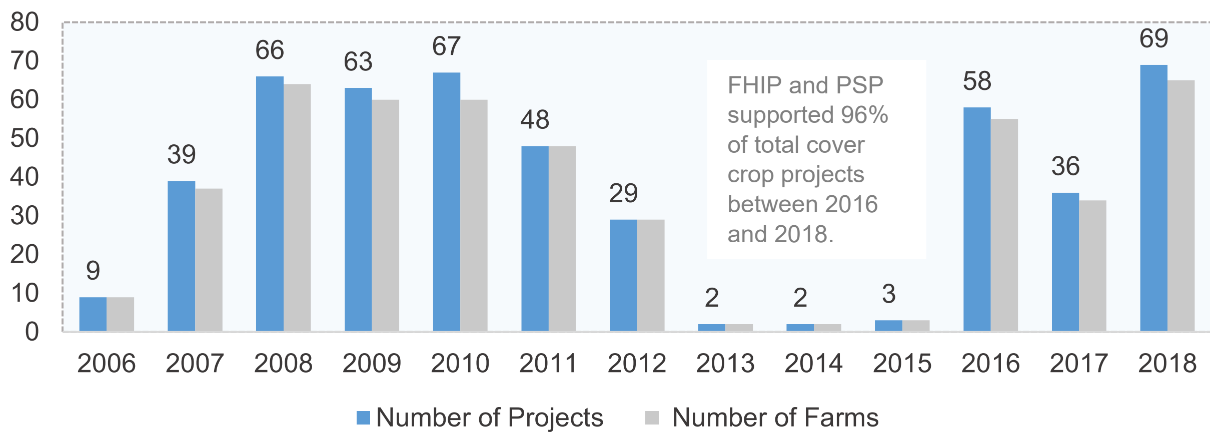


Figure 15: Total Number of Cover Crop Projects in the Lake Erie Basin

In terms of project numbers, FHIP (n=132) and PSP (n=25) were more successful in driving adoption of cover cropping compared to GF2 (n=11). Together, FHIP and PSP supported 96% of total cover crop projects completed between 2006 and 2018. GF2 was the only funding available for cover crops between 2013 and 2015 in OSCIA-delivered programs, and motivation for completing these projects was based on the EFP risks[10], however, this program design saw low uptake for this practice.

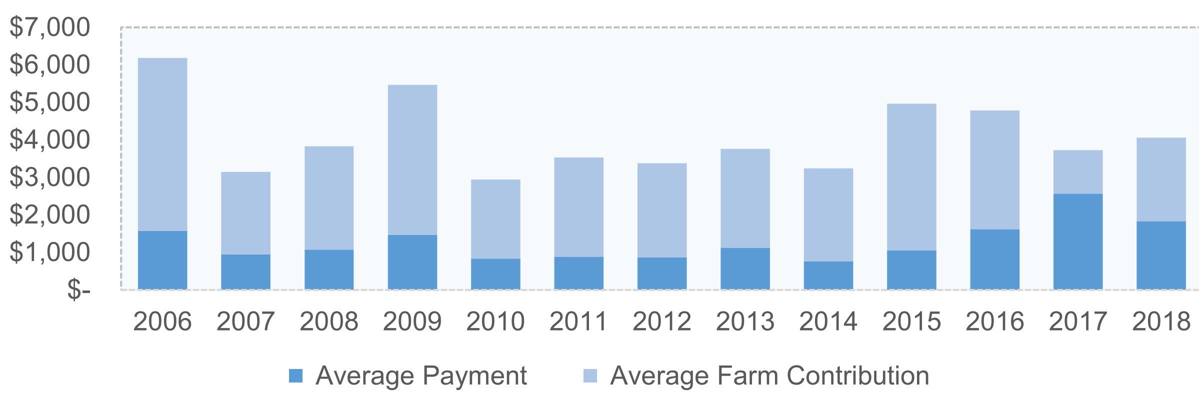


Figure 16: Average Project Cost by Year, Cover Crops

[10] This compares to FHIP, where a farm may have been motivated to complete a cover crop project after receiving technical support and recommendations from a CCA or P.Ag through completion of the Farmland Health Check-Up.

No-till or zero-till seeding

749 unique farm operations completed 827 no-till projects in the Lake Erie basin. Approximately 59 farms (8%) completed more than one project. The average project cost was $26,721, while the average cost-share contribution was $7,414 (28% of project costs).

It is estimated that on average, 525 acres were impacted per project. As a result of these projects, 434,175 acres were impacted, or up to 1,302,525 acres when all years following completion of the project are considered. As shown in Figure 19, the highest number of no-till projects was completed in 2008, when there were more cost-share dollars available to support a greater number of projects in this category. Note the increase in average payments between 2016 and 2018, when a farmer could secure a higher cost-share funding level if it was recommended as a priority action in the Farmland Health Check-Up assessment tool (Figure 18).

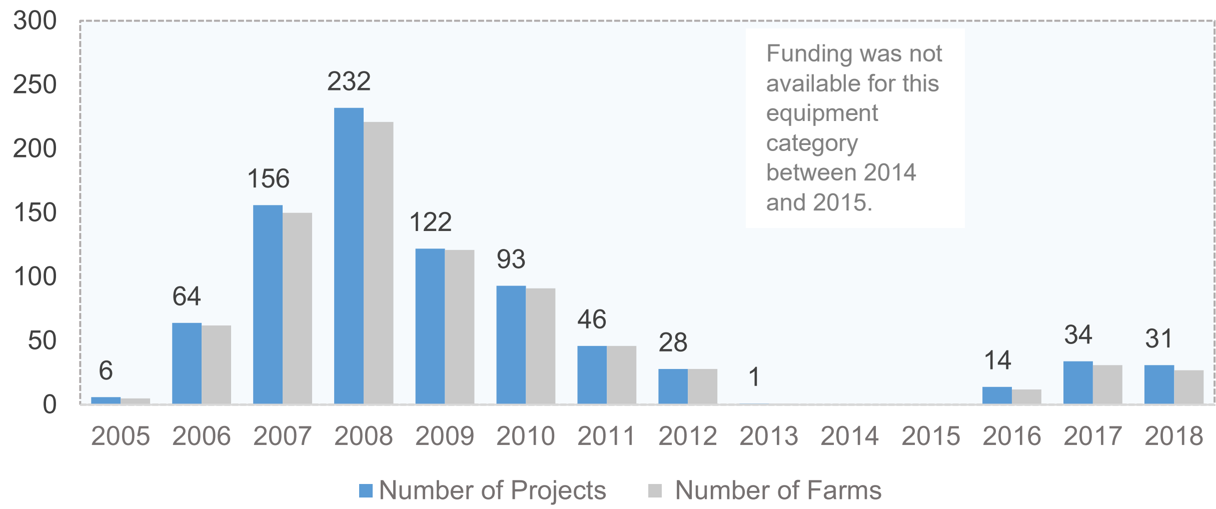


Figure 18: Total Number of No-Till Projects in the Lake Erie Basin.

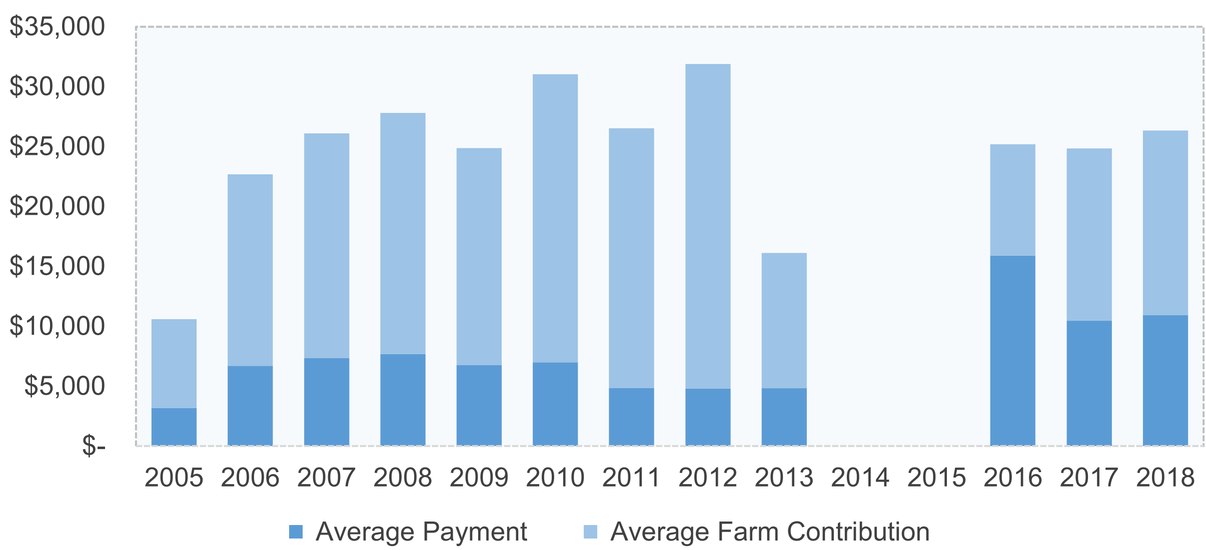


Figure 17: Average Project Cost by Year, No-Till Equipment

Banding, variable rate or controlled application

820 unique farm operations completed 1,022 equipment projects to enable banding, variable rate or controlled applications. Approximately 130 farms (16%) completed more than one project. The average project cost was $14,502, while the average cost-share contribution was $4,546 (31% of project costs).

It is estimated that on average, 974 acres were impacted per project. As a result of these projects, 995,428 acres were impacted, and up to 1,930,468 acres when all subsequent years following completion of the project are considered. As shown in Figure 19, 2008 saw the highest number of projects completed. Higher average costs in 2016 may have been the result of fertilizer carts being supported on some project applications (Figure 20).

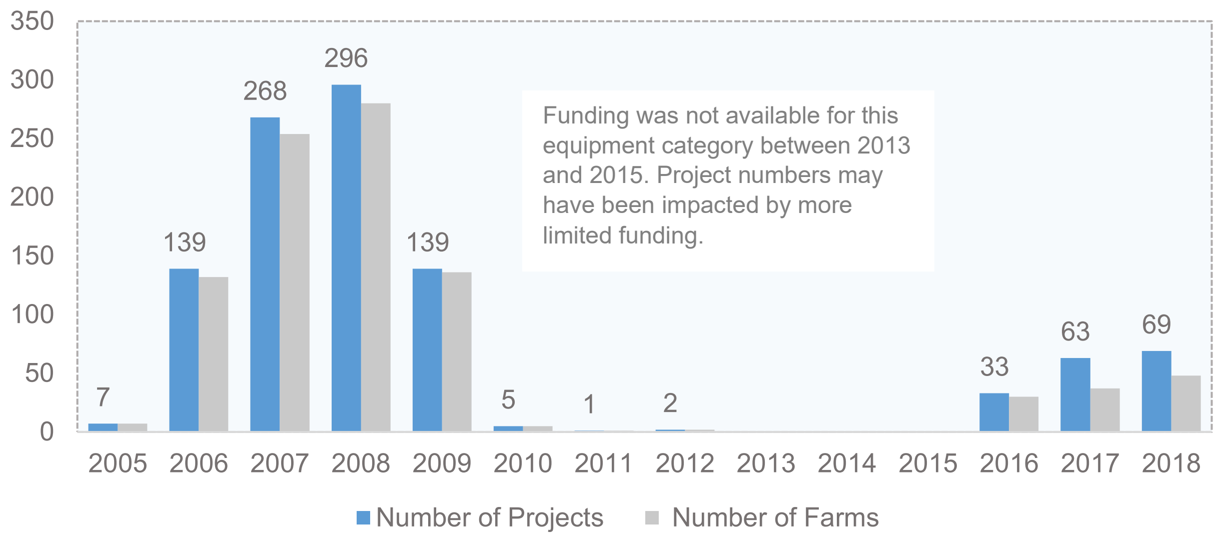


Figure 19: Total Number of Precision Fertilizer Equipment Projects in the Lake Erie Basin.

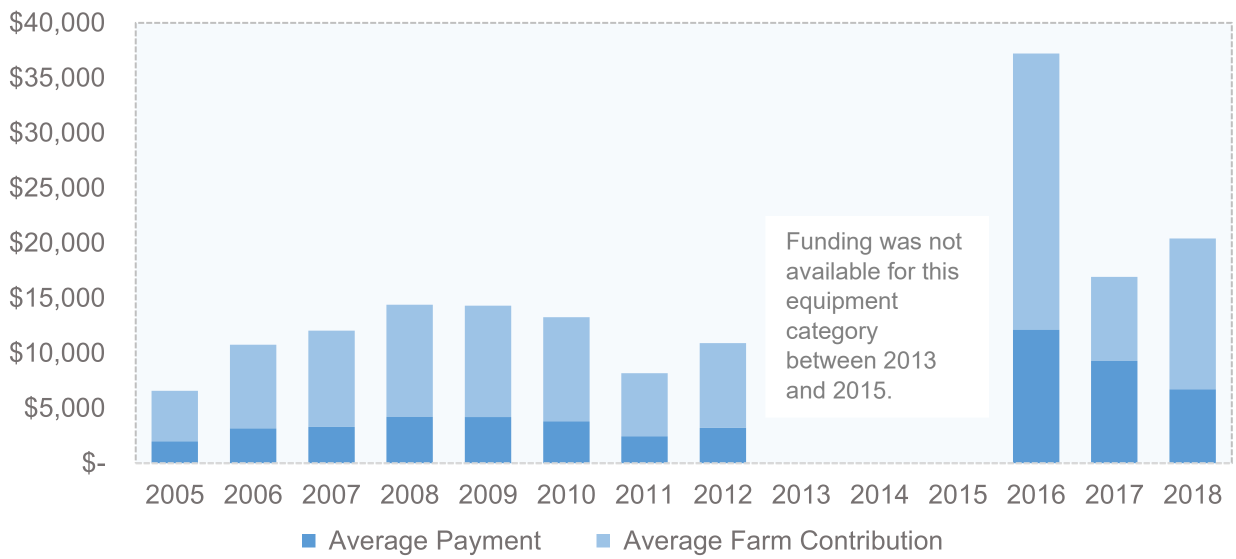


Figure 20: Average Project Costs by Year, Precision Fertilizer Equipment

Manure storage improvement

676 unique farm operations completed 756 manure storage improvement projects. Approximately 73 farms (11%) completed more than one project. The average project cost was $74,388, while the average cost-share contribution was $20,221 (27% of project costs). Average cost differed between industry groups, ranging from as high as $85,146 for dairy farms, to as low as $36,362 for sheep and goat farms[11].

Projects were most often completed by farms that identified dairy (37%), beef (24%), hog and pig (17%) and poultry (13%) as a primary commodity. Farms that completed a project to improve manure storage, reported the following average livestock numbers: beef (n=227), dairy (n=222), poultry (n=460,630), hogs (n=2,281) and sheep or goat (n=256).

As shown in Figure 21, the number of projects completed annually has declined 87% since 2005.

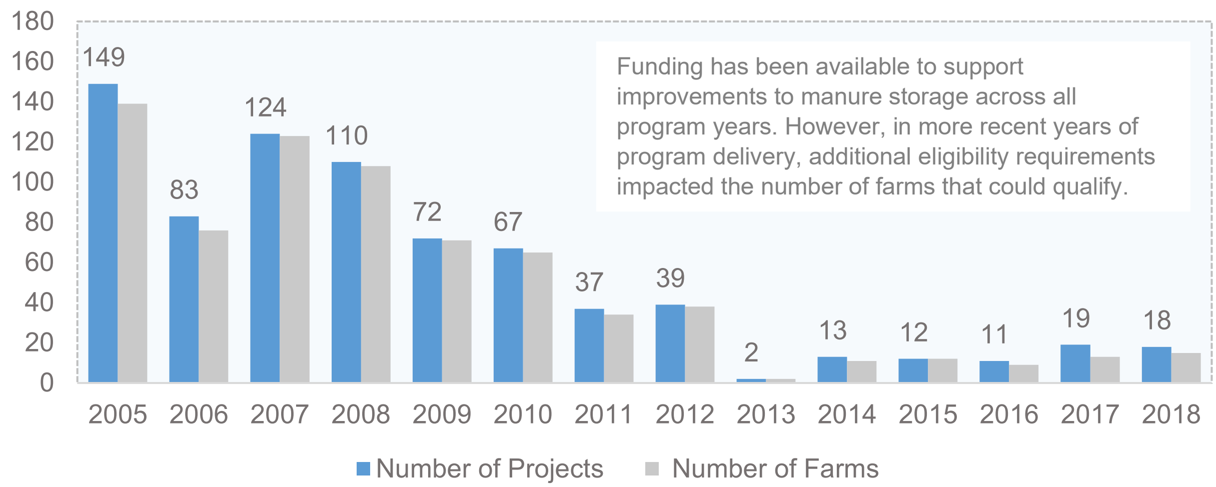


Figure 21:Total Number of Manure Storage Projects in the Lake Erie Basin.

.

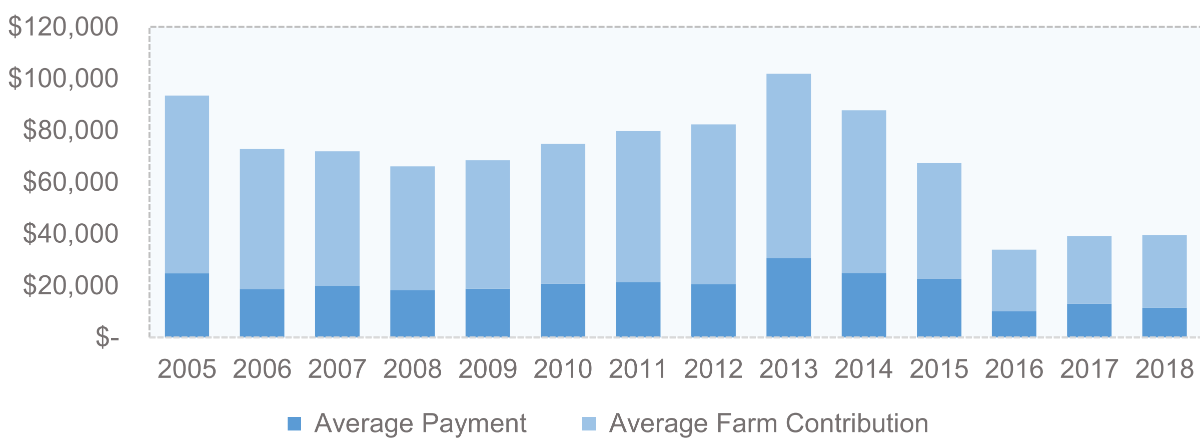


Figure 22: Average Project Costs by Year, Improved Manure Storage

[11] The average project cost per industry group: beef ($63,763), dairy ($85,146), poultry ($79,776), hog and pig ($71,993), and sheep and goat ($36,362)

Nutrient management planning

676 unique farm operations completed 730 nutrient management plans. Approximately 38 farms (6%) completed more than one project. The average project cost was $3,532, while the average cost-share contribution was $1,615 (46% of project costs).

It is estimated that on average, 284 acres were impacted per project. As a result of these projects, 191,984 acres were impacted and up to 414,640 acres when all subsequent years following completion of the project are considered. Projects were most often completed by farms that identified dairy (31%), hog and pig (26%), beef (15%), poultry (11%), and sheep and goat (3%) as a primary commodity. In total, 96% of projects were classified as nutrient management plans, while 4% were classified as nutrient management strategies[12].

As shown in Figure 23, the number of nutrient management planning projects completed annually has declined 92% since 2008.

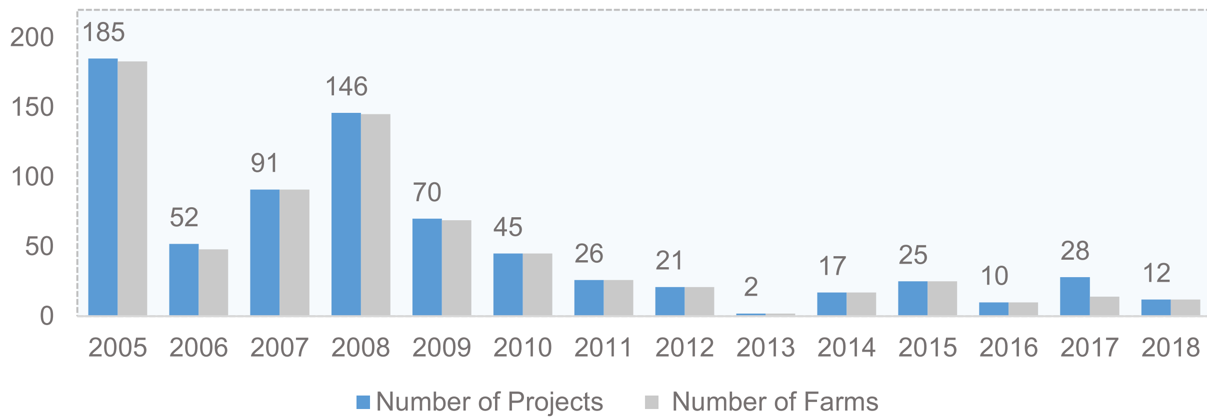


Figure 23: Total Number of Nutrient Management Plans in the Lake Erie Basin.

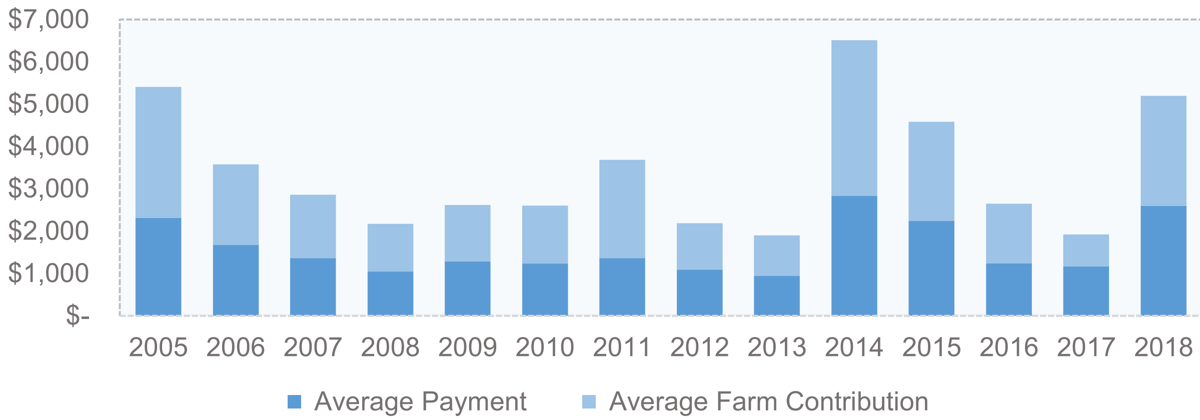


Figure 24: Average Project Costs by Contribution in the Lake Erie Basin.

[12] Nutrient management strategies outline storage and destination plans for manure, while nutrient management plans detail how the manure is going to be applied to the field. The Nutrient Management Act (NMA) requires only certain agricultural operations to have an NMS or NMP. These participating farms were not subject to the NMA, and were voluntary projects self-identified on the EFP.

Crop nutrient planning

71 unique farm operations completed 97 plans to address crop nutrient inputs. Approximately 18 farms (25%) completed more than one project. The average project cost was $3,717, while the average cost-share contribution was $1,846 (50% of project costs).

It is estimated that on average, 450 acres were impacted per project. As a result of these projects, 43,650 acres were impacted and up to 78,750 acres when all subsequent years following completion of the project are considered. The majority of projects were completed by farms that identified oilseed and grain (82%) and greenhouses (7%) as a primary commodity. As shown in Figure 26, the number of plans completed annually increased 74% between 2010 and 2018.

Beginning in 2015, crop nutrient planning was promoted as a distinct project category in FHIP; it was previously funded more broadly under grouped planning activities that included nutrient management, water planning and soil erosion planning. While funding was available across all years, there were no plans completed between 2005-2009 or 2012-2013.

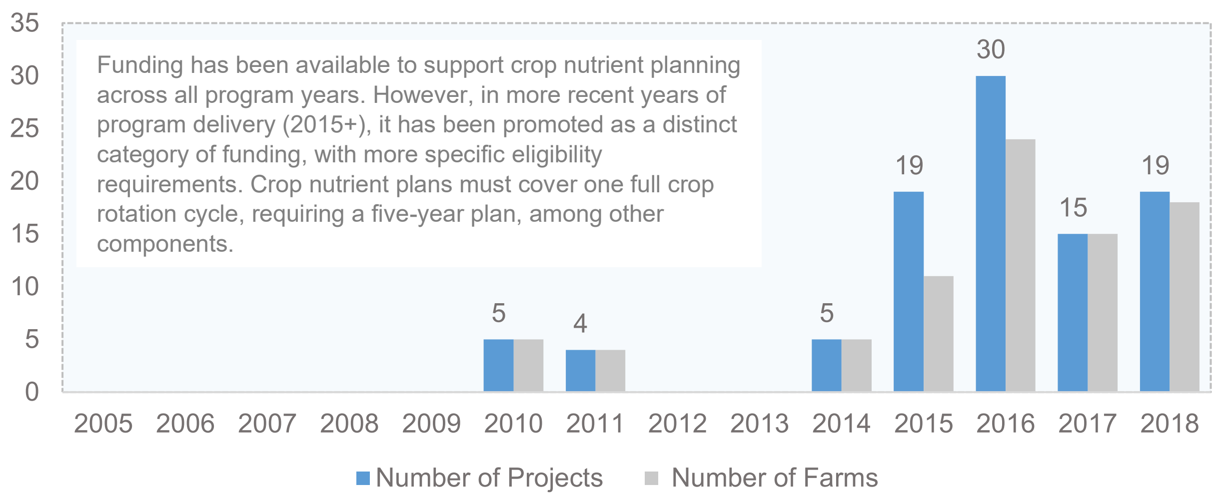


Figure 25: Total Number of Crop Nutrient Plan Projects in the Lake Erie Basin.

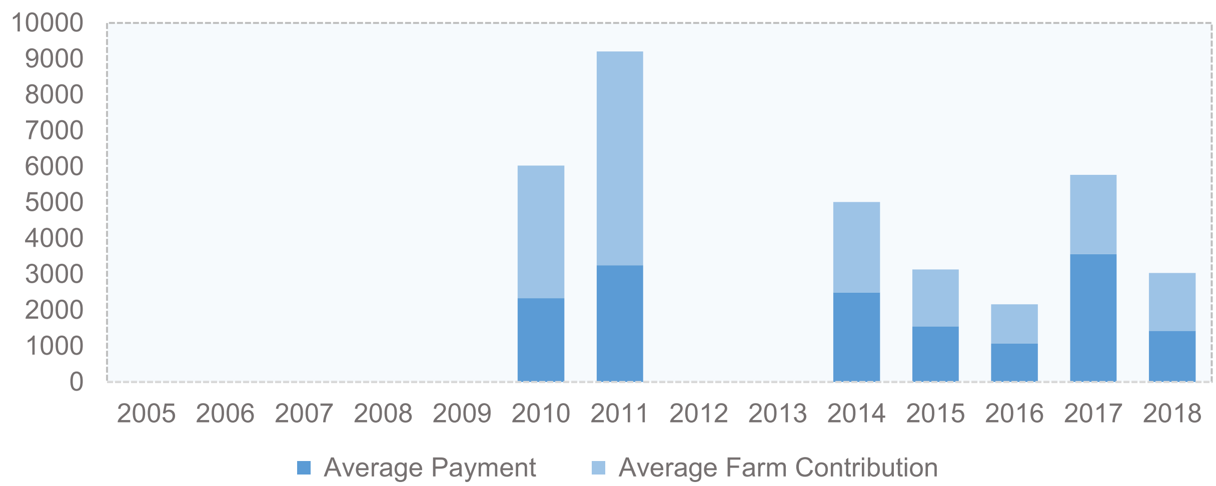


Figure 26: Average Project Cost by Year, Crop Nutrient Plans

Livestock and facility runoff control

375 unique farm operations completed 432 livestock and facility runoff control projects in the Lake Erie basin. Approximately 42 farms (11%) completed more than one project. The average project cost was $33,591, while the average cost-share contribution was $11,169 (33% of project costs). Average cost-share differed between industry groups, ranging from as high as $39,062 for beef farms, to as low as $20,711 for poultry farms[13].

The majority of projects were completed by farms that identified beef (41%) and dairy (24%) as a primary commodity. As shown in Figure 27, the number of projects completed per year has declined 89% since 2008. There wasn't enough information in the project records to explain the increased average costs shown in 2014, 2016 and 2018; most participation in these years came from cattle farms (Figure 28).

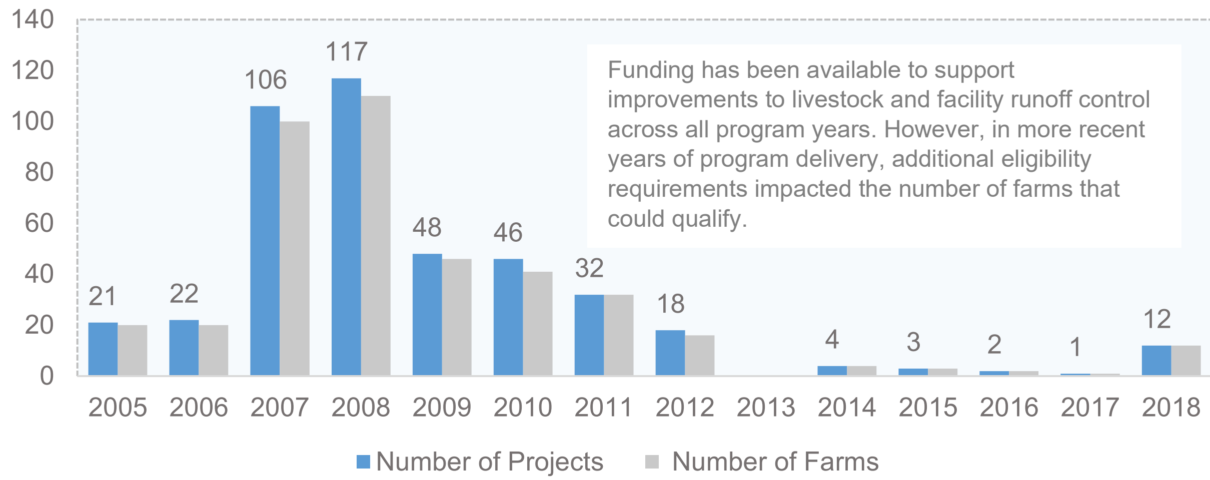


Figure 27: Total Number of Livestock Facility Runoff Control Projects in the Lake Erie Basin.

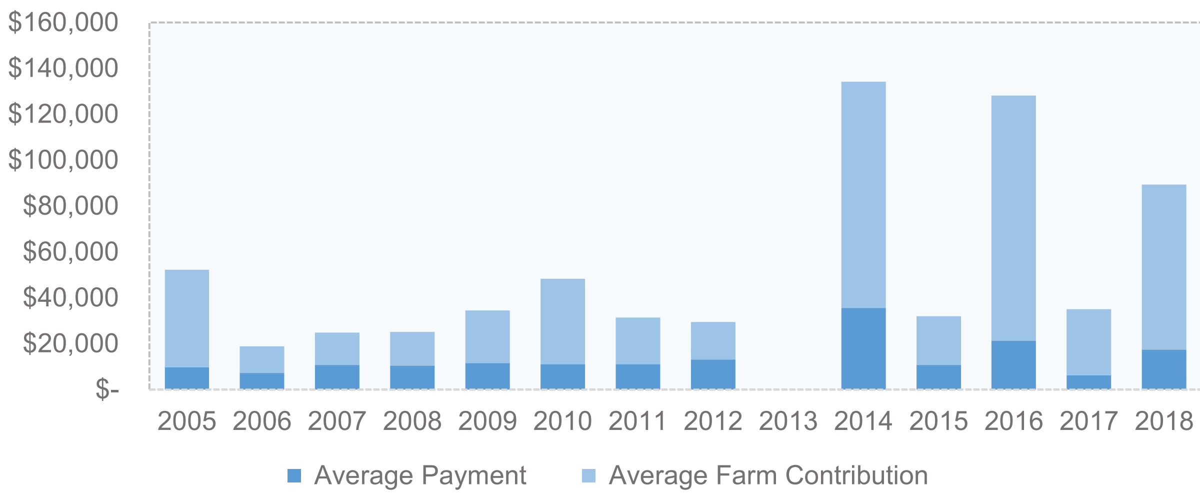


Figure 28: Average Project Costs by Year, Livestock Facility Runoff Control

[13] The average project cost per industry group: beef ($39,062), dairy ($36,416), hog and pig ($25,794), oilseed and grain ($24,099), greenhouse ($34,715), and poultry ($20,722).

Nutrient recovery systems

269 unique farm operations completed 343 nutrient recovery projects in the Lake Erie basin. Approximately 54 farms (20%) completed more than one project. The average project cost was $49,315 while the average cost-share contribution was $12,422 (25% of project costs). Average cost-share differed between industry groups, ranging from as high as $95,747 for greenhouses, to as low as $20,480 for hog and pig operations[14].

The majority of projects were completed by farms that identified greenhouses (33%), hog and pig (22%), dairy (15%), oilseed and grain (10%) and poultry (10%) as a primary commodity. As shown in Figure 29, the number of projects completed annually has declined 84% since 2007. Higher greenhouse participation in 2014 may have led to an increase in average project costs (Figure 30). Between 2014 and 2018, 74% of projects were completed by greenhouses.

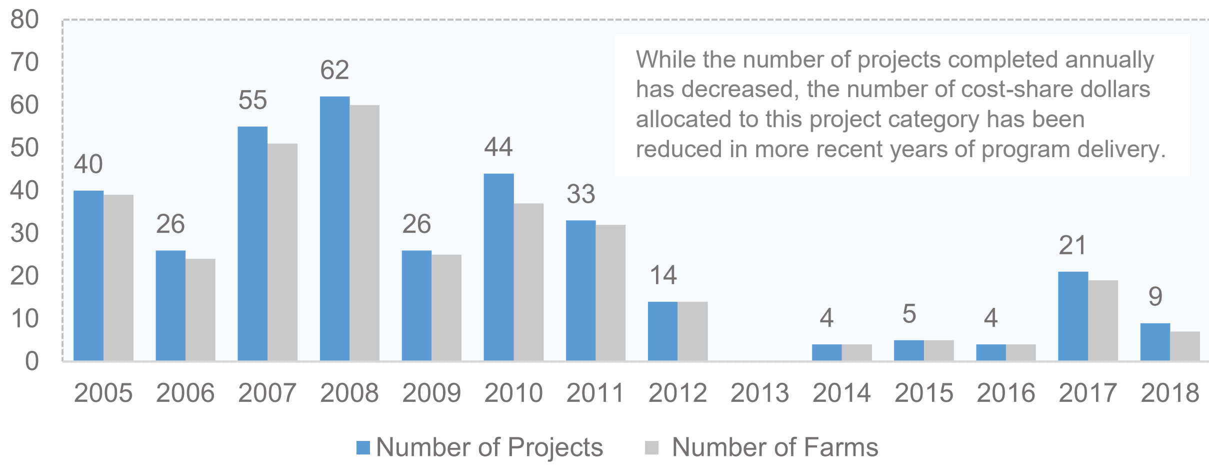


Figure 29: Total Number of Nutrient Recovery System Projects in the Lake Erie Basin

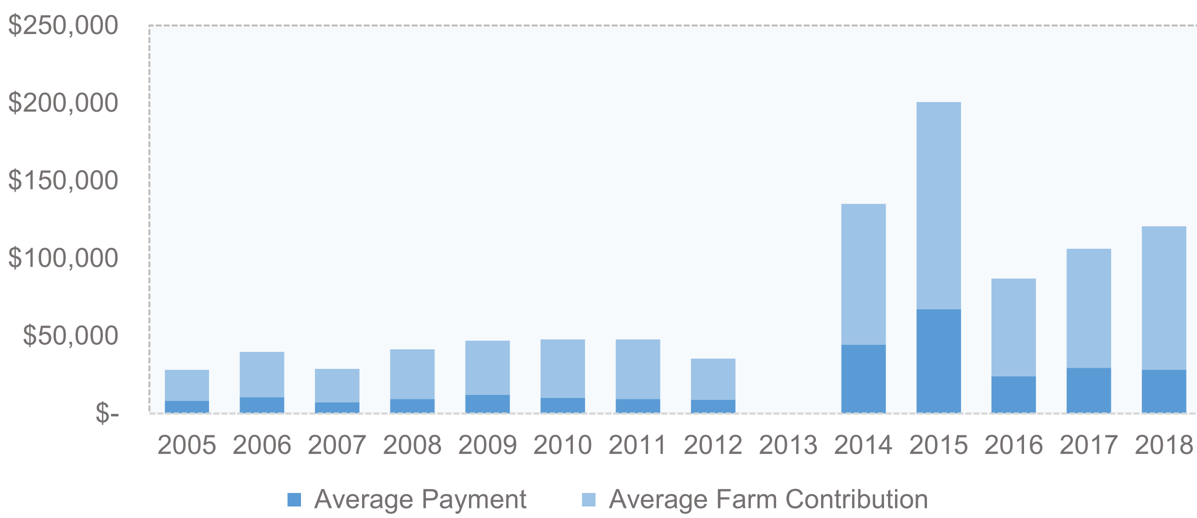


Figure 30: Average Project Costs by Year, Nutrient Recovery Systems

[14] The average project cost per industry group: greenhouse ($95,747), hog and pig ($20,480), dairy ($28,856), oilseed and grain ($25,331) and poultry ($30,007).

Improved irrigation efficiency

214 unique farm operations completed 262 projects to improve efficiency of existing irrigation systems. Approximately 40 farms (19%) completed more than one project. The average project cost was $32,435, while the average cost-share contribution was $8,642 (26% of project costs).

The majority of projects were completed by farms that identified greenhouses (74%) and oilseed and grain (18%) as a primary commodity. On average, each project may have impacted 105 acres. As shown in Figure 31, the number of projects completed annually with cost-share funding assistance decreased 91% between 2008 and 2018.

The number of census reported farms in the Lake Erie basin that reported using irrigation decreased 31% between 2006 and 2016. The number of acres under irrigation decreased 26% from 94,010 acres in 2006 to 69,548 acres in 2016.

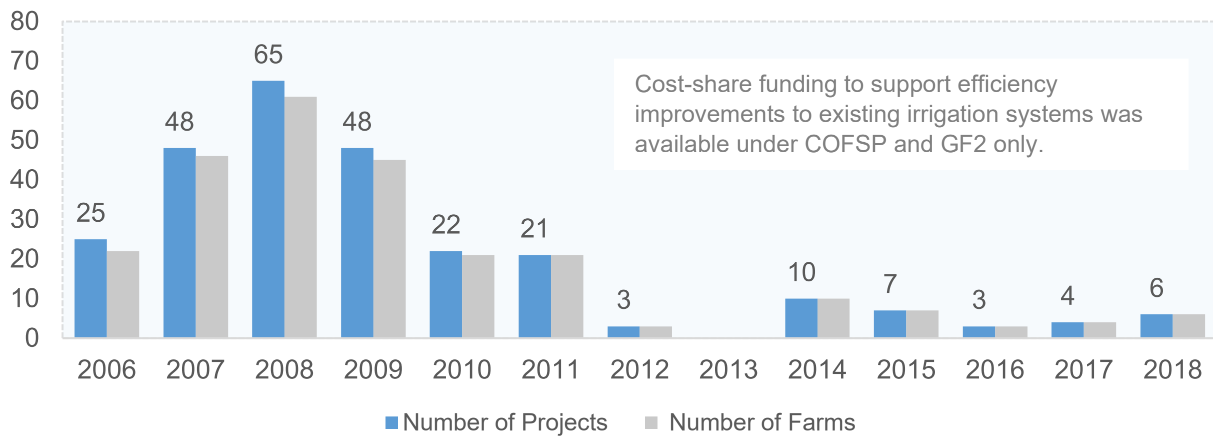


Figure 31: Total Number of Irrigation Efficiency Projects Completed in the Lake Erie Basin

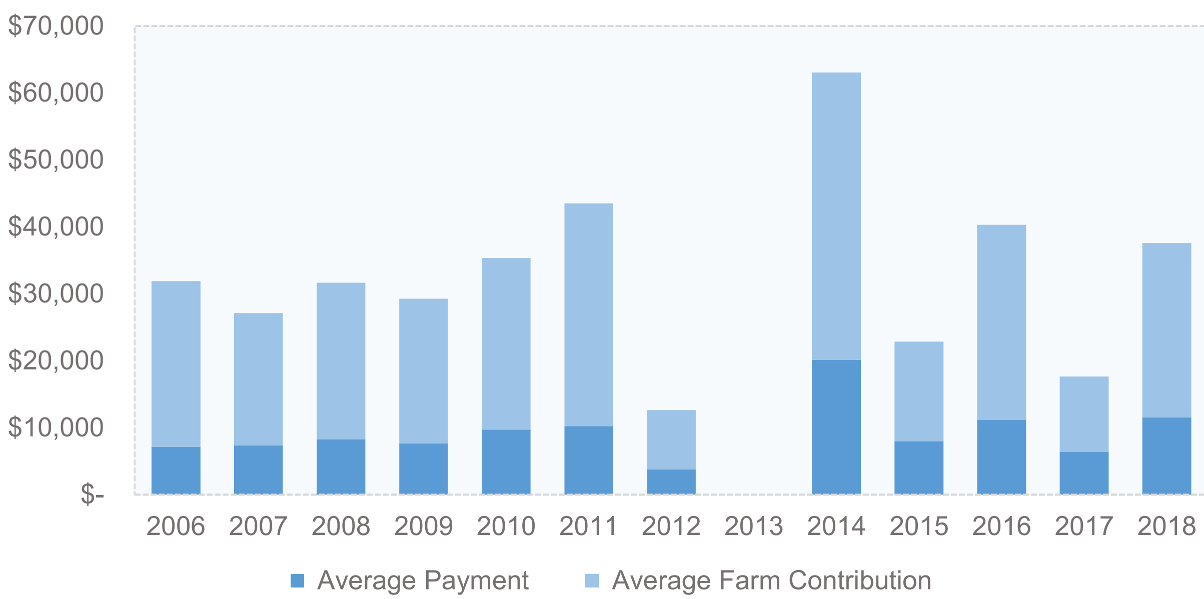


Figure 32: Average Project Costs by Year, Irrigation Efficiency Improvements

Erosion control structures

264 unique farm operations completed 339 projects to address erosion issues. Approximately 51 farms (19%) completed more than one erosion control project. The average project cost was $16,859 while the average cost-share contribution was $6,963 (41% of project costs).

The majority of projects were completed by farms that identified oilseed and grain (63%), hog and pig (12%), beef (8%), dairy (7%) and greenhouses (4%) as a primary commodity. In terms of the type of erosion, it is estimated that 63% of projects addressed primarily non-riparian erosion issues, through contour terraces, drop inlets, gully stabilization and retention ponds. The remaining 36% of projects addressed riparian erosion through ditch bank stabilization, shoreline stabilization, grade control and WASCoBs[15]. As shown in Figure 33, the number of erosion control projects completed annually with cost-share funding assistance declined 74% from highs in 2010.

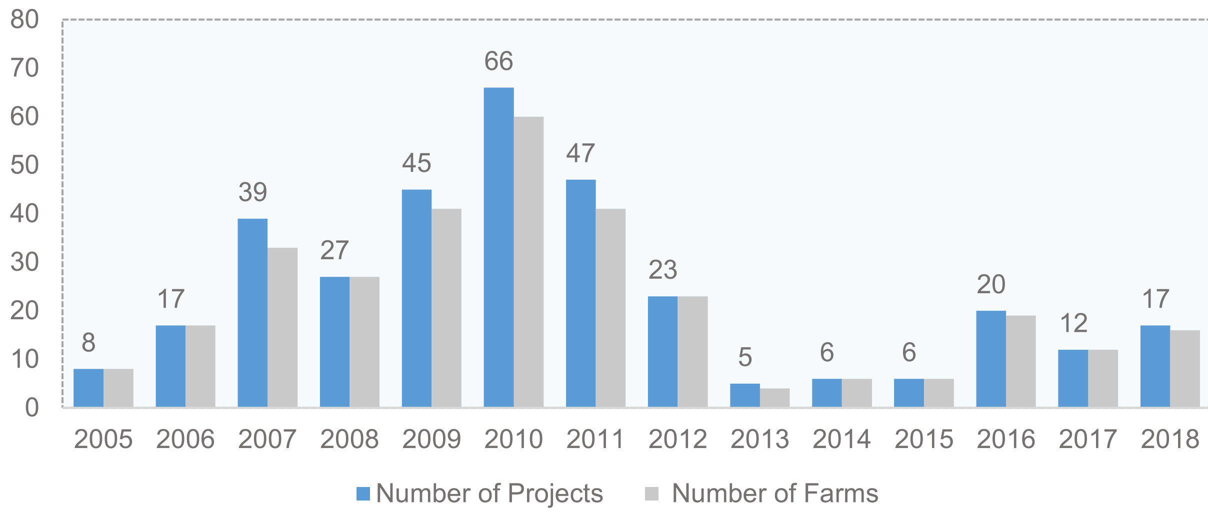


Figure 33: Total Number of Erosion Control Projects in the Lake Erie Basin

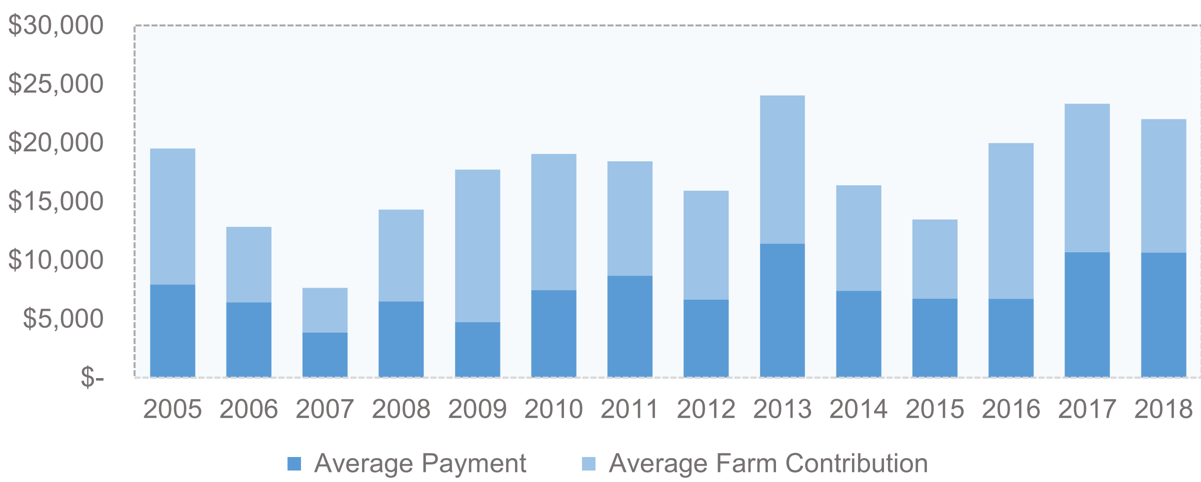


Figure 34: Average Project Cost by Year, Erosion Control Structures

[15] This was based on project descriptions which may not have included all project details.

Improved manure application equipment

218 unique farm operations completed 230 projects to improve land application of manure through direct injection, below canopy, or incorporation equipment. Approximately 12 farms (5%) completed more than one project. The average project cost was $24,081, while the average cost-share contribution was $6,469 (27% of project costs).

Since 2005, there has been a 95% decrease in the number of projects completed annually. The number of census reported farms in the Lake Erie basin that reported manure application decreased 21% between 2006 and 2016; however, the number of acres impacted by manure application increased 3% from 681,327 acres to 694,324 acres

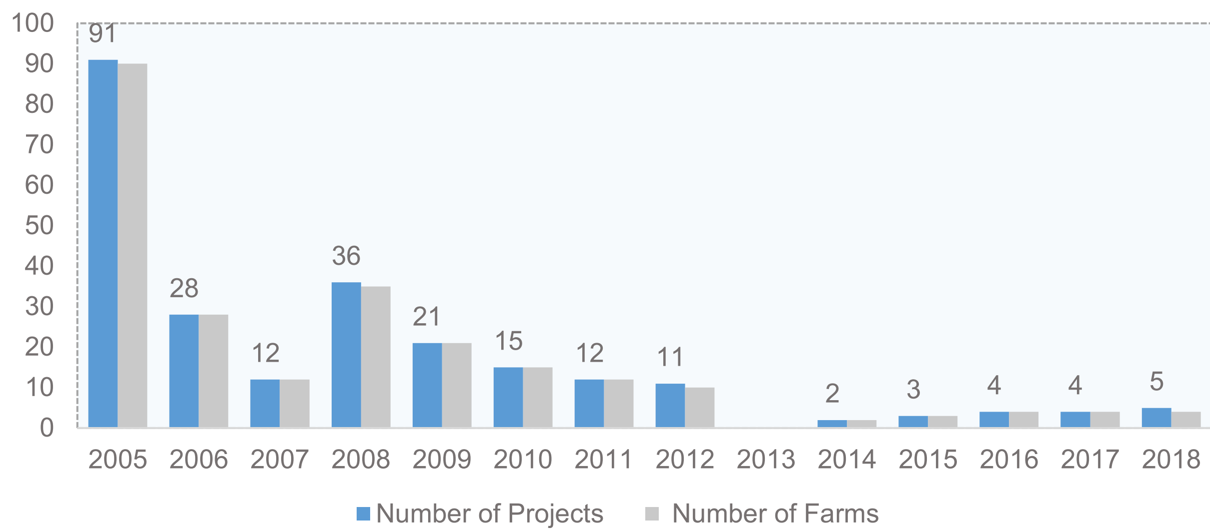


Figure 35: Total Number of Manure Application Equipment in the Lake Erie Basin.

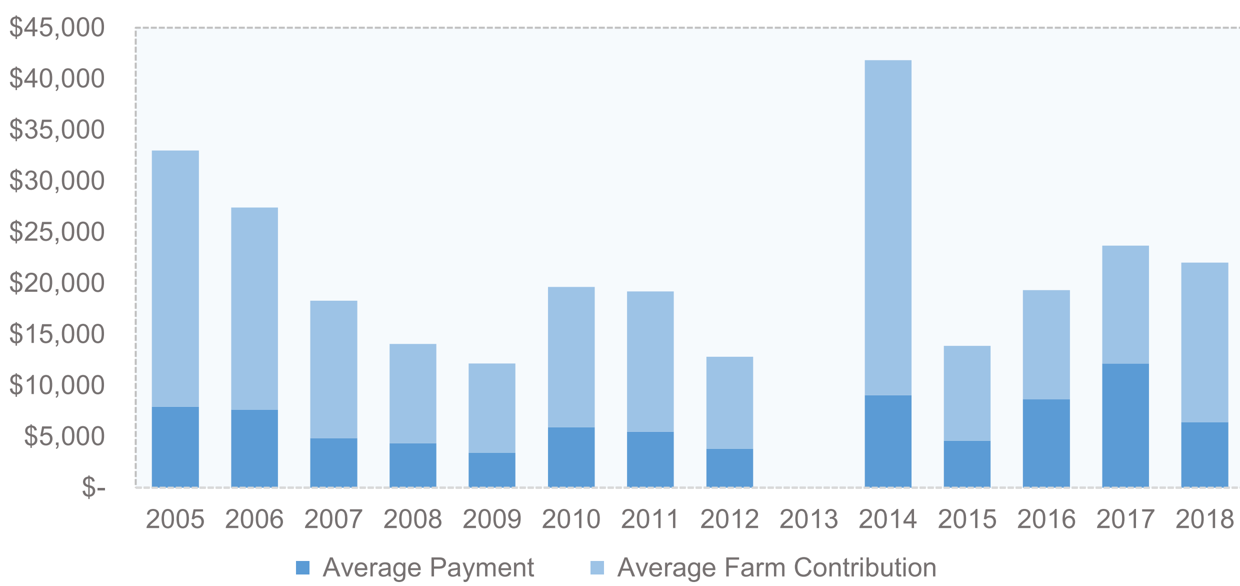


Figure 36: Average Project Costs by Year, Manure Application Equipment.

Protecting and restoring natural areas – tree planting and habitat creation

313 unique farm operations completed 363 projects to protect or restore sensitive environmental areas by planting trees, grasses or by creating habitat. Approximately 69 farms (22%) completed more than one project. The average project cost was $9,613, while the average cost-share contribution was $3,924 (41% of project costs).

Projects were completed by farms that identified oilseed and grain (50%), beef (12%), dairy (9%), greenhouses (7%), poultry (6%), and hog and pig (4%) as a primary commodity. Windbreaks and shelterbelts made up the majority of projects (56%), followed by buffer strips (18%), restoring wetlands (11%), block tree planting (8%), restoring grasslands (6%), and retiring marginal/fragile farmland (<1%). It is estimated that these projects created 211 acres of on-farm habitat (riparian, woodlands or grasslands areas, etc.). As shown in Figure 35, since 2010, the number of naturalization projects completed annually with cost-share funding assistance declined 79%.

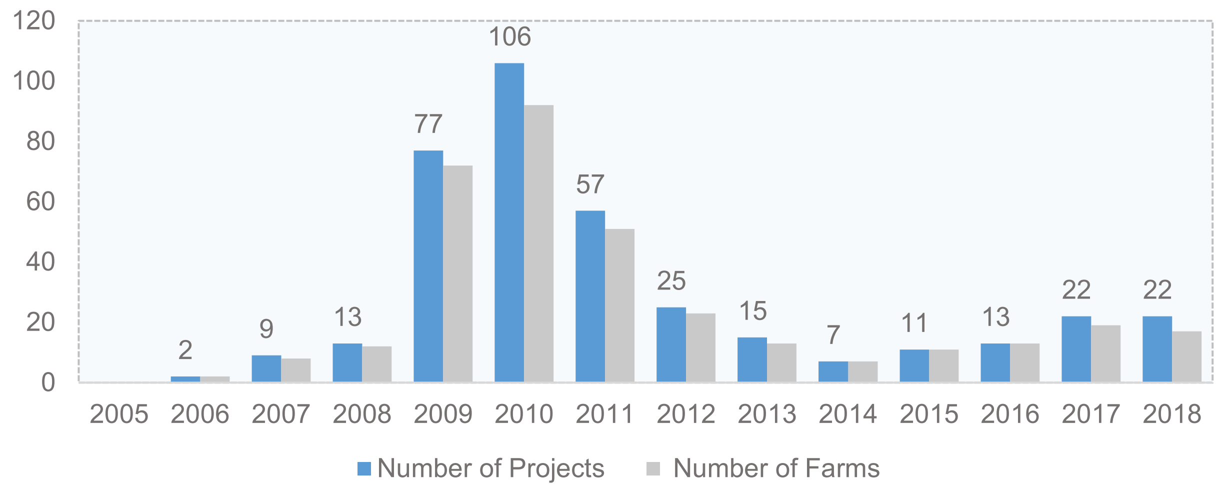


Figure 37: Total Number of Tree Planting Projects in the Lake Erie Basin.

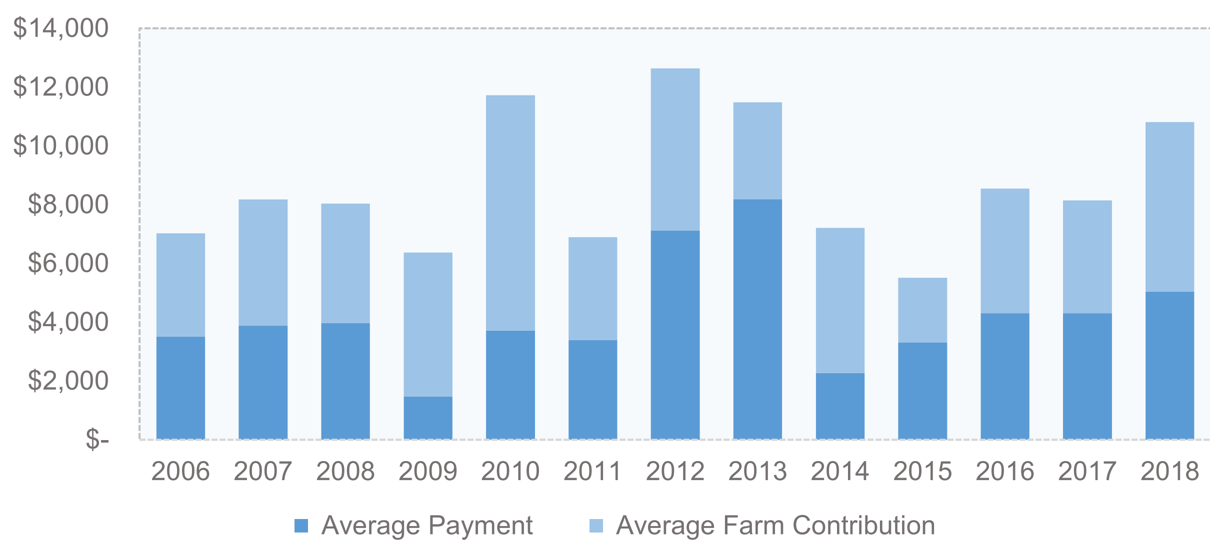


Figure 38: Average Project Costs by Year, Naturalization.

Protecting and restoring natural areas – exclusion fencing

117 unique farm operations completed 196 projects to protect or restore environmental areas through livestock exclusion fencing (80% of projects) and alternative watering systems for livestock (20% of projects). Approximately 39 farms (33%) completed more than one project.

Livestock exclusion fencing keeps livestock out of forests and streams, and protects grasslands and pasturelands from overgrazing. Cross-fencing is used to for pasture management in rotational grazing systems. Approximately 60% of projects established permanent fencing to keep livestock away from streams, ponds or woodlands; while the remaining fencing projects addressed rotational grazing issues through temporary cross-fencing.

Projects were completed by farms that identified beef (49%), oilseed and grain (21%), dairy (11%), sheep and goat (6%) and poultry (4%) as a primary commodity.

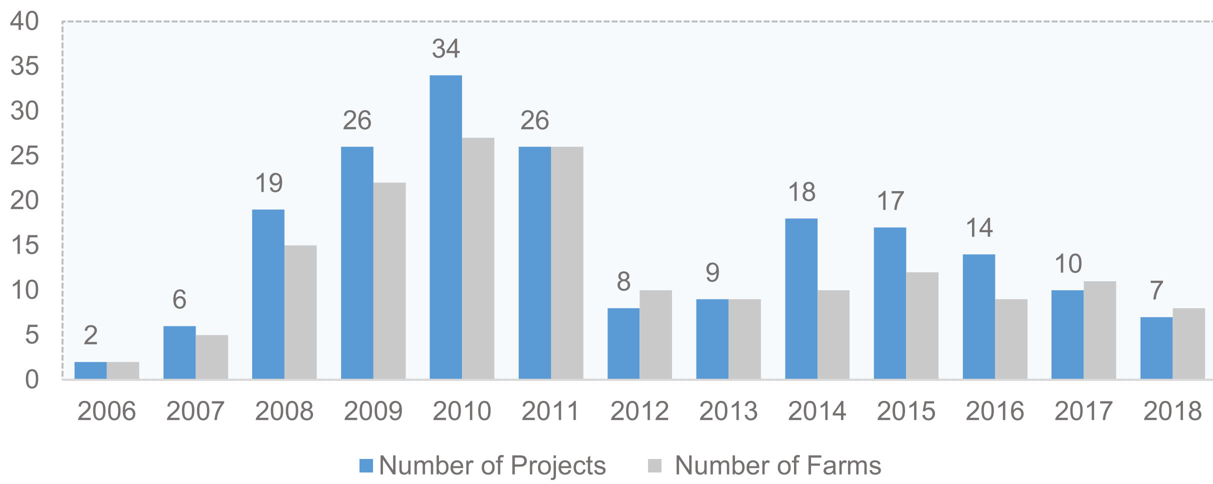


Figure 39: Number of Livestock Exclusion Fencing Projects in the Lake Erie Basin.

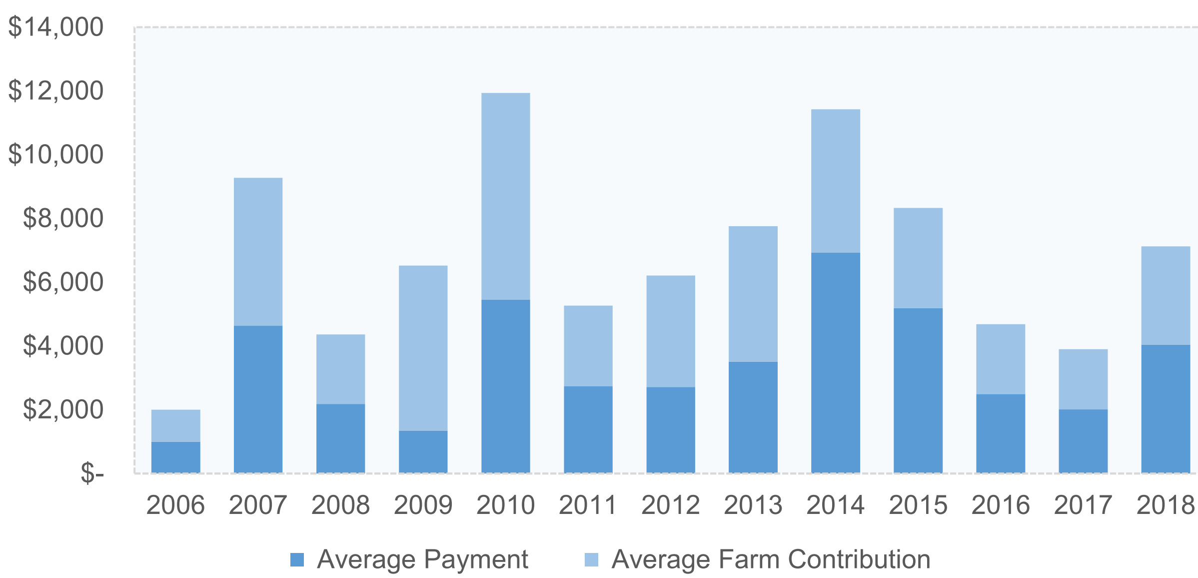


Figure 40: Average Project Costs by Year, Livestock Exclusion Fencing

General Overview of BMP Trends

Lake Erie farmers have made considerable progress in addressing water quality improvements that contribute to the health of Lake Erie. Cost-share programs must continue to anticipate the needs of farmers to better understand and support the acceleration of environmental action across the Lake Erie basin. The following may be helpful in informing the needs of agri-environmental education and cost-share programming in the region.

Cover crops

Winter cover cropping was the only BMP that experienced an increase in the number of projects supported by OSCIA-delivered cost-share funding over this period. The census also reported an increase in the number of farms using cover crops in the Lake Erie basin, with up to 42% of total farms using this practice in 2016. It is estimated that up to 6% of farms that self-reported cover crops as a land use practice in the census, may have accessed cost-share funding from OSCIA-delivered programs to complete a cover crop project. Cover cropping as a BMP was the third least expensive water quality project to complete in the Lake Erie basin over this period, and on average, cost-share funding contributed 34% to total project costs.

Across all years of program delivery, it was estimated that on average, 140 acres were planted per project for winter cover cropping; however, this ranged from as low as 8 acres per project to as much as 5,200 acres, with a median of 88 acres. FHIP collected cover crop acres more reliably, so it is recommended that FHIP's average be considered for more recently delivered programs. The average number of cover crop acres supported per FHIP project was 104 acres; however, this ranged from as low as 8 acres to as much as 200 acres, with a median of 77 acres. It should also be mentioned that applications submitted as part of the Farmland Health Checkup program were restricted to three fields only. This, in combination with the 200-acre limit, may have impacted the number of acres on a single project application. Between 2011 and 2018, the average number of acres supported on a single cover crop project application declined. The average number of cropped acres per farm in the Lake Erie basin is around 200 acres; however, this ranged from as low as 156 acres in Lower Grand to as much as 255 acres in Rondeau. These limits may be a barrier for larger farms that have more acres available to be cover cropped.

Spatially, cover cropping projects were mostly concentrated in the southern portion of the Lake Erie basin, where 36% of total projects were completed in Chatham-Kent (Figure 42).

Conservation tillage

No-till or zero-till seeding

If it is assumed that all farms that practice no-till or zero-till seeding in the Lake Erie basin are eligible for cost-share funding assistance (i.e., in meeting the FBRN qualifier); it is estimated that 12% may have accessed OSCIA-delivered cost-share funding to complete a no-till equipment project. The number of farms in the Lake Erie basin that use no-till methods increased 3% to 43% of total of farms in 2016. However, in the Lake Erie basin, the number of acres under no-till production decreased from 1,097,455 acres to 1,001,965 acres. This represents a 9% decline in no-till acres across the Lake Erie basin; and it coincides with an increase in the number of grain corn and soybean acres, and a decline in the number of winter wheat acres over this period.

On average, cost-share funding contributed 28% towards total project costs for this BMP; however, this would typically only consider equipment or components that were deemed eligible for cost-share funding. For many equipment programs, only the cost of the components to enable no-till, or the difference between the conventional planter (trade in) and the proposed no-till planter would have been eligible for cost-share. This approach is no longer used given the impact of funding caps. This ensured that funding was directed towards the BMP improvement, as equipment costs can vary widely between implements.

Note the increase in average payments between 2016 and 2018 when a farmer could secure a higher cost-share funding level if it was recommended as a priority in the Farmland Health Check-Up (Figure 18).

Spatially, no-till equipment projects were primarily concentrated in townships adjacent to Lake St Clair and Lake Erie (Figure 45). Chatham-Kent had the most no-till projects; this was followed by Lakeshore, Essex, St. Clair, Kingsville, Perth East and Perth South. Together, these seven townships account for 50% of total no-till projects completed over this period.

Banding, variable rate or controlled application

If it is assumed that all farms that apply commercial fertilizer in the Lake Erie basin are eligible for cost-share funding assistance (i.e., in meeting the FBRN qualifier); it is estimated that 7% of these farms may have accessed OSCIA-delivered cost-share funding to purchase banding, variable rate or controlled application equipment or components. According to the census, the number of farms that used commercial fertilizer decreased 9% between 2006 and 2016, while the number of acres impacted by commercial fertilizer increased 6%.

On average, cost-share funding contributed 31% to total eligible project costs; however, this only considers the equipment or components that were deemed eligible for cost-share funding. For many programs, only the cost of the precision fertilizer components would have been eligible for cost-share, especially if they were included as part of a complete implement. This ensured that funding was directed towards the BMP improvement, as equipment costs can vary widely between implements.

Over 28% of total banding, variable rate and controlled applications were located in the township of Chatham-Kent (Figure 46).

Planning

Crop nutrient planning

Few farms in the Lake Erie basin have accessed cost-share funding from OSCIA-delivered programs to develop a crop nutrient plan. It is estimated that less than 1% of total farms in the basin that prepare land for seeding may have accessed cost-share funding to develop a plan, or complete activities related to the completion of a crop nutrient plan, such as soil sampling or mapping. Interestingly, the census reported that 21% of farms in the Lake Erie basin have used GIS technology for soil mapping in 2016. Most projects were completed by oilseed and grain producers (82%) and greenhouses (7%).

There was a notable increase in participation after the category was promoted as a standalone BMP category in FHIP, as more than half of all crop nutrient planning projects were funded by FHIP through completion of a FHCU; as recommended by the farm's Certified Crop Advisor (CCA) or Professional Agrologist (P. Ag). On average, cost-share funding contributed 50% to total project costs for this BMP. Across all years of program delivery, the average number acres impacted by a crop nutrient planning project was 450 acres; however, this ranged from as low as 40 acres to as much as 1,400 acres, with a median of 298 acres.

Spatially, crop nutrient planning projects were concentrated in the southern portion of the Lake Erie basin, primarily in and around Lakes St. Clair and Erie. Nearly 50% of total projects were completed in Chatham-Kent and Kingsville (Figure 43).

Nutrient management planning

The number of nutrient management planning projects completed annually has declined 92% from 2005 to 2018. The majority of projects were completed by dairy and hog and pig farms. In more recent years of program delivery, dairy farms and oilseed and grain producers with livestock as a secondary commodity have completed more nutrient management planning projects with support from OSCIA-delivered cost-share. Although livestock production in terms of livestock numbers has declined in the Lake Erie basin (except for poultry production), the number of acres impacted by liquid manure nutrients has increased. While participation to this BMP may have been influenced by regulatory concerns pertaining to the Nutrient Management Act (NMA); these projects were not subject to the NMA and were voluntary projects self-identified on the EFP.

Across all years of program delivery, the number acres impacted by a nutrient management planning project was 284 acres; however, this ranged from as low as 32 acres to as much as 900 acres, with a median of 142 acres. On average, cost-share funding contributed 46% to total project costs. It is estimated that up to 7% of total beef farms, 14% of total dairy farms, 25% of total hog and pig farms, and 9% of total poultry farms in the Lake Erie basin may have accessed cost-share funding to develop a nutrient management plan, or complete activities related to the completion of a nutrient management plan or strategy over this period.

Spatially, nutrient management planning projects were concentrated in areas with higher livestock densities. The top three townships with the most nutrient management planning projects were Wellesley, Perth East, and Zorra (Figure 44).

Irrigation efficiency improvements

The number of census reported farms that use irrigation decreased 31% between 2006 and 2016, while the number of census reported irrigated croplands decreased 26% from 94,010 to 69,549 acres. The number of farms accessing cost-share funding from OSCIA-delivered programs to improve irrigation efficiency decreased 91% between 2005 and 2018. It is estimated that 19% of farms that use irrigation may have accessed OSCIA-delivered cost-share funding to improve the efficiency of existing irrigation systems. The average number of irrigated acres per farm that accessed cost-share funding to improve irrigation efficiency was 118 acres; this ranged from as low as 0.7 acres to as much as 1,000 acres, with a median of 60 acres. On average, cost-share funding for this BMP category contributed 27% to total project costs. Programs that provided funding to support irrigation efficiency improvements did not collect project metrics (i.e., water volume) on the application and claim forms, so this information was not available to the analysis. Projects were primarily concentrated in Norfolk, Leamington, Chatham-Kent, and Kingsville (Figure 53).

Erosion control structures

The number of farms accessing cost-share funding from OSCIA delivered programs to address erosion issues in the Lake Erie basin decreased 74% between 2005 and 2018. Between 2008 and 2012, an average of 37 erosion control projects were completed annually, but this declined to an average of 12 projects annually between 2013 and 2018.

Only 7% of total erosion control projects were completed under FHIP, and 2% in GF2. SARFIP has funded more erosion control projects than FHIP, PSP and GF2 combined, despite being marketed as a species-at-risk program, and one of the few conventionally delivered programs in more recent years of program delivery. On average, cost-share funding contributed 41% towards the total costs of erosion control in the Lake Erie basin. Spatially, projects were concentrated in Chatham-Kent, Norfolk, Zorra, and Essex (Figure 50).

Protecting and restoring natural areas

Tree planting projects

Tree planting and habitat creation BMPs generally saw lower participation from Lake Erie farmers compared to other water quality BMPs; this was more apparent in more recent years of program delivery. Project types included windbreaks and shelterbelts, reforestation, wetland restoration, grassland restoration, buffer strips and marginal/fragile land retirement. SARFIP (50% of projects) and COFSP (44% of projects) were more successful in driving adoption to these BMPs. Both of these programs were delivered without assignment of merit; and provided farmers with some general assistance in filling out the application forms. GF2 and FHIP have seen lower uptake, which may emphasize the competition from other BMP funding and the fact these program frameworks promoted production BMPs. Another consideration, is that some tree planting activities may also qualify for stackable funding (when it is available), such as from cost-share programs delivered by Conservation Authorities; this can significantly enhance the total rate of cost-share a project could qualify for. It is not known if opportunities to stack funding towards the same project have declined over this period, or how many of these naturalization projects may have received other source funding in addition to an OSCIA cost-share allocation.

Windbreaks and shelterbelts resulted in the most projects (56%), followed by buffer strips (18%) and wetland restoration (11%). Given the decline in the number farms in the Lake Erie basin that report using windbreaks and shelterbelts as a land use practice, naturalization BMPs supported by cost-share could be further examined. On average, cost-share funding contributed 34% to windbreaks and shelterbelts, 36% to buffer strips, 48% to wetland restoration activities, 45% to reforestation, 55% to grassland restoration and 48% to fragile land retirement.

Spatially, planting and naturalization projects were most often completed in Chatham-Kent, Mapleton, Perth East, St. Clair and Wellesley (Figure 51).

Livestock exclusion fencing, stream crossings and alternative watering systems

In addition to tree planting and other on-farm habitat creation actions, livestock producers must manage livestock in the field to protect vulnerable habitats. Protecting and restoring natural areas often requires the installation of livestock exclusion fencing to prevent livestock from accessing streams, ponds and woodland areas. While COFSP and SARFIP have provided funding to support cross-fencing for rotational grazing and alternative watering systems for livestock, SARFIP is only one of two OSCIA-delivered programs that have provided funding for livestock exclusion fencing over this period (the other being SARPAL, which was not included in this analysis because it was not delivered in partnership with OMAFRA). More than 60% of fencing projects were established to keep livestock away from sensitive environmental areas, while the remainder supported cross-fencing for rotational grazing. Spatially, projects were most often completed in Amaranth, Chatham-Kent, Perth East, Norfolk and Wellington North (Figure 52).

Runoff prevention and recovery

Nutrient recovery systems

The number of nutrient recovery projects completed annually has decreased 84% between 2005 and 2018. Average costs for these projects are typically three times higher for greenhouses compared to other industry groups for the same project category. In more recent years of program delivery, there has been significantly higher participation from greenhouses, which has increased average project costs. Approximately 87% of total projects were funded under the COFSP, compared to just 13% for GF2. On average, cost-share funding contributed 25% to total project costs for nutrient recovery systems, as many projects exceeded the funding cap for this category. None of the projects provided any metrics about the rate or volume of feedwater that was recovered. Spatially, projects were most often located in Leamington, Kingsville, and Chatham-Kent (Figure 53).

Livestock and facility runoff control

The number of projects addressing livestock and facility runoff control, decreased 89% between 2005 and 2018. More projects in this category were completed by farms that identified beef and dairy as a primary commodity (61% of projects). Since 2013, only dairy, beef and oilseed and grain producers with cattle as a secondary commodity, have completed projects to address runoff from livestock facilities. In 2014, average project costs nearly doubled, but it is unknown what led to this increase as there was limited information in the project records to identify a specific cause. Projects completed in more recent years of program delivery addressed cattle facility runoff, which had a higher average project cost compared to other industry group participation in this BMP category. On average, cost-share funding contributed 33% to total eligible project costs. Spatially, projects were most often located in Wellesley and Perth East (Figure 48).

Manure management

Improved manure storage

The number of manure storage improvement projects decreased 87% between 2005 and 2018. More projects in this category were completed by farms that identified dairy (37%), beef (24%), hog and pig (17%) and poultry (13%) as a primary commodity. It is estimated that up to 10% of total beef farms, 20% of total dairy farms, 18% of total hog and pig farms, and 13% of total poultry farms in the Lake Erie basin may have accessed cost-share funding from OSCIA-delivered programs to improve manure storage facilities. The average project cost between livestock industry groups varied, ranging from as high as $85,146 for dairy farms to as low as $36,362 for a sheep and goat farm.

Spatially, almost 20% of total manure storage improvement projects were located in Wellesley. Overall, project concentrations coincided with areas of higher livestock densities, such as Mapleton, Perth East, Southwest Oxford, Zorra and Chatham-Kent.

Manure application equipment

It is estimated that 3% of farms that apply manure in the Lake Erie basin may have accessed cost-share funding from OSCIA-delivered programs to upgrade or modify existing manure application equipment. Between 2005 and 2018 there was a 95% decrease in the number of projects completed annually, however funding for this BMP has not been available across all years of program delivery[16]. The Manure and Biosolids Management Program (MBMP) under GLASI was available to custom operator, but this data was included in the study. It is estimated that up to 75 projects may have been funded in the Lake Erie basin through this initiative.

The census reported an 18% decrease in the number of acres impacted by solid manure non-incorporation, but a 30% increase in the number of acres impacted by liquid manure non-incorporation. In 2016, the census reported 1,167 farms using non-incorporation for liquid nutrient materials, and 4,384 farms using non-incorporation for solid nutrient materials in the Lake Erie basin. More that 56% of manure application projects supported through OSCIA-delivered cost-share addressed modifications to existing manure application equipment to enable direct injection.

Spatially, most projects were completed in Chatham-Kent, Perth East, Zorra, Warwick and Southwest Oxford (Figure 49). However, because not all cost-share data for this BMP was able to be included, the spatial analysis results for this BMP should be interpreted with caution.

Limitations, Caveats and Opportunities

This analysis has provided a high-level overview of general participation and BMP trends across the Lake Erie basin, through participation in OSCIA-delivered cost-share programs. While many of the trends presented here have been influenced by the availability of funding and data; the story presented is lacking a few important considerations.

Declined Projects and the “Lost” BMP Signal

This analysis only evaluated projects that were successful in receiving a cost-share allocation; as declined projects were excluded from the analysis. However, examining the number and type of farms that attempted to participate in a water quality BMP, could provide a more fulsome signal of water quality BMP interest in the Lake Erie basin. It may also be useful to evaluate how many

[16] Not all cost-share program data that provided funding for this BMP was available to the analysis.

unique farms have been willing to re-apply to a subsequent intake, and whether it was for the same water quality BMP activity. Also important is understanding the reasons for BMP project declines in the water quality focus area. This may identify trends in reported water quality issues which prompted the initial BMP project proposal, as well as any barriers that may exist at the cost-share program interface. It is not known how many farms in the Lake Erie basin are addressing water quality issues without support from cost-share funding.

There has been an increase in the number of applicants that are not successful in securing a cost-share allocation. Merit-based programs have more limited funding, and are designed to support projects that best demonstrate the program objectives. There may be useful information buried within these “attempts” at participation. Unfortunately, this type of analysis was beyond the scope of this particular report. So, the value of declined cost-share project data should not be discounted in future analyses. Recall, that an estimated 20% of farmers in the Lake Erie basin have been successful in receiving a cost-share allocation to address water quality issues through OSCIA-delivered programs. To accurately measure reach and engagement, it may be necessary to consider all types of farm participation, including general trends about those participants who were not successful in receiving cost-share.

BMP Competition

There are many BMP funding opportunities that support environmental and non-environmental sustainability issues. Many factors influence a farm’s willingness to implement different BMPs; but what impact does “BMP over choice” have on prioritizing water quality in the Lake Erie basin? Conservation tillage equipment has been a popular BMP choice for farmers in this region, and the benefits to soil health are unquestionable. However, when reviewing water quality BMPs that were not as well subscribed, it does warrant further examination. It may be important to understand how multiple BMP offerings are impacting the collective resources of farms in addressing various water quality issues, particularly issues that may not be seen as high risk.

Cost-Share Program Data Quality

Analyzing 13-years of BMP projects has provided an opportunity to evaluate the quality of cost-share data across different program designs. Cost-share programs provide a unique opportunity to collect important information about the type, scale and impact of water quality actions, and other focus areas of importance. While the application and claim forms are often viewed as a barrier; this information is necessary to effectively review a proposed project for eligibility. This analysis was limited by the available data from earlier program years, when less project information was required on the application and claim forms.

What was lacking in this analysis was more specific and frequently collected project metrics that can provide insight into the impact of a completed project. While there are often large sample sizes across many BMP categories (over a 13-year period); project averages can be less reliable for categories with fewer projects. Project descriptions and expected outcomes were often collected as large open text fields, limiting the analysis of this information. Cost item analysis should be encouraged for future analyses; as detailed expenditures can provide a better understanding of specific costs that are required for common water quality issues in this region.

While the collection of mandatory impact information has been introduced into presently delivered cost-share programs; there is further opportunity to evaluate the collection of this data, to see how it can better contribute to future analyses like this one.

Phosphorus-Loss Reductions

Capturing project metrics through cost-share program delivery has provided an opportunity to estimate the quantity of phosphorus-loss reduced for different BMP activities. Phosphorus-loading equations can be used to estimate the number of kilograms of phosphorus loss reduced by a particular BMP project. These values can also be calculated over specific timeframes, as many BMPs provide ongoing phosphorus-loss reductions when used repeatedly (e.g., conservation tillage equipment is used for many years after the initial purchase).

Not all of the projects analyzed in this report have captured enough data to estimate quantifiable phosphorus impacts in the Lake Erie basin. Additionally, not all BMPs have a phosphorus loading equation because of the high variability among individual practices and site conditions (i.e., slope, soil texture, soil moisture, technology etc.). Some of the large-scale engineering and construction categories that were funded by OSCIA-delivered cost-share programs - such as nutrient recovery systems or irrigation equipment - require specific technology and equipment to reduce risk of phosphorus inputs and other nutrients from entering drainage areas. There is wide variation in the scale of some projects and without knowing specifics, such as recycled volume of water, it is difficult to make general assumptions required to calculate P-loss reductions.

Additionally, variable rate-controlled nutrient application may not always lead to a decrease in the total amount of fertilizer applied; even though it helps to ensure more effective and efficient application (OMAFRA, 2021). It relies on grid sampling or management zones to calibrate application rates within a field; rates are higher in field areas that have a high potential to respond to nutrients and are lower (or nil) in field areas that have sufficient levels (OMAFRA, 2017). There was not enough information in the project records for this BMP to make an accurate assessment about the changes in rate or the total P applied that could result in P-loss reductions.

These equations are often used alongside phosphorus offsetting programs in Ontario, such as rural water quality programs (RWQPs) that are administered by Conservation Authorities. Grants are provided to support environmental actions that control phosphorus at non-point sources to offset the loadings allowed by point sources by municipalities. Projects are supported if phosphorus impacts are reduced through controls at various non-point sources throughout the watershed (IISD, 2019). As mentioned earlier, many of the cost-share programs delivered by OSCIA use merit-assessment to identify environmental benefits; and the capture of these project metrics – such as the number of acres or number of livestock – can be inputted into the equations to estimate the load of phosphorus reduced or “offset” by a BMP.

Phosphorus equations can be used to estimate the quantity of phosphorus-loss reduced through various water quality projects supported by OSCIA-delivered cost-share programs. The values in Table 24 were developed for RWQPs delivered by Conservation Authority cost-share programs in Ontario who have done literature reviews. The Grand River Conservation Authority (in the Lake Erie basin) and the South Nation Conservation Authority (in eastern Ontario) have used these equations to calculate the amount of phosphorus that is kept out of watercourses by various BMPs in those regions (Allaway, 2013; Sinclair, D., & Roumeliotis, 2017).

Similar equations have also been used to develop phosphorus budgeting tools in the Lake Simcoe watershed. Phosphorus equations help to assess the impact of BMPs before and after project implementation; and these accounting methodologies consider nutrient flow pathways and are based on data sourced from regional studies (MECP, 2012; Environment Canada, 2012).

Phosphorus equations can be used as reasonable estimates for RWQP analysis and other phosphorus offsetting opportunities; but they are presented here as an example of how cost-share data can be used to support phosphorus-loss reduction (Sinclair, D., & Roumeliotis, 2017; Environment Canada, 2012; O'Grady, 2008). Because the calculations rely on averages derived from incomplete cost-share program data; these estimations should be treated as hypothetical. It demonstrates the need for collecting consistent impact data alongside BMP projects that were completed with cost-share funding assistance.

Table 34: Phosphorus-Loading Equations for Select Cost-Shared BMPs

SOURCE: Grand River Conservation Authority (1999), South Nation Conservation Authority (2003).

Baseline	Best Management Practice	Phosphorus Equation
What farmstead or field condition is leading to increased risk of phosphorus runoff?	Which BMP can be implemented to reduce risk of phosphorus runoff?	What would the estimated phosphorus load savings be after BMP implementation?
Conventional tillage, such as moldboard plowing, disturbs the soil over multiple passes, leaving the soil bare with limited residue.	Conservation (or reduced) tillage, such as no-till, leaves the soil undisturbed from planting to harvest.	Hectares * 0.75 kg P/ha
Manure is stacked in piles, berms or is processed in a solid-liquid settling basin, leading to increased risk of phosphorus runoff	Construct improved manure storage structures to replace stacked manure piles or berms.	Animal phosphorus factor[1] * total head of livestock * days of manure production * 0.04
Infrequent soil sampling, with nutrient application based on maintenance regimens instead of landscape-scale efficiency	Crop and nutrient management planning	Hectares * 25 kg P/ha* 0.1
Limited crop residues, bare soil conditions, particularly during the non-growing season	Planting of cover crops to cover the soil and protect from erosion	Hectares * 0.4 kg P/ha
Nutrient runoff from livestock and/or facilities is not prevented nor recovered at the source	Avoid and control livestock facility runoff at the source (e.g., covered livestock yard).	Number livestock * animal phosphorus factor[1] * days * 0.02
With unrestricted access to a stream, livestock may generate up to 200 kg of manure per animal per year into a watercourse (Allaway, 2003).	Livestock exclusion fencing and structures installed to protect sensitive environmental areas	Number livestock * days * animal phosphorus factor[1] * 0.03 * 0.5 (half day access)
Lack of planted or naturally occurring vegetation that can help to filter nutrients and sediments from agricultural runoff	Establishment of buffer strips and other plantings (grasses, shrubs, trees) that do not experience concentrated flow	0.7 kg/P * hectares

1. Animal phosphorus factor is the measure of phosphorus produced (excreted) per day for various livestock per day per animal. These factors were determined by the United States Department of Agriculture (USDA, 1992) and the American Society of Agricultural Engineers (ASAE, 2001).

Source: Phosphorus Loading Algorithms for the South Nation River: Updated Phosphorus Source Accounting Methodology for the Rural Water Quality Program (Allaway, 2003).

Phosphorus-Loss Methodology

Number of Acres

For each BMP with an available phosphorus equation, cost-share data was filtered to identify matching projects in each program delivery year. Because not all of the projects provided detailed project metrics, such as number of acres, averages had to be used. For example, in Table 36, conservation tillage includes only those projects that identified any sort of reduced tillage outcome. But only FHIP (2015-2018) collected the number of acres impacted by this type of equipment, so an average for this program was applied to all conservation tillage projects (2005-2018) to estimate the total land acres impacted.

Livestock Type and Numbers

When a farm business enrols in an OSCIA-delivered cost-share program, they submit a program enrolment form that identifies the number and type of livestock on their farm, and the primary commodity of their farm business. Many BMP project records for improved manure storage, livestock exclusion fencing and livestock facility runoff control did not indicate the type of livestock associated with the project. It was assumed for this analysis that the BMP project addressed the livestock that was associated with a farm's self-reported primary commodity. For example, if a farm that completed a manure storage project, identified beef cattle as their primary commodity and they reported 125 beef cattle and 350 hogs on their farm; it was assumed the manure storage project addressed the manure generated by the 125 beef cattle only. So, for this project example, only the number of beef cattle was factored into the phosphorus equation for that project. Also, to ensure consistency and to allow for comparison across the different livestock BMPs, it was assumed that cattle had access to pasture for one quarter of the year (91.25 days).

Animal Phosphorus Factors

Animal phosphorus factors measure the quantity of phosphorus (excreted) per day for various types of livestock; and these values have been obtained from South Nation Conservation Authority's Updated Phosphorus Source Accounting Methodology for the Rural Water Quality Program (Allaway, 2003). Poultry was determined by averaging the values for layers, pullets and broilers; while values for beef, dairy and hogs were used as directly from Table 35.

Table 35: Kilograms of Phosphorus Produced Per Day Per Livestock Animal
SOURCE: USDA (1992), ASAE (2001), Allaway (2003).

Type of Animal	Average weight per animal	Kg of Phosphorus produced per day per 454 kg (1,000 lb) of body weight	Kg of Phosphorus produced per day per animal (average weight x P factor/454 kg)
Dairy	640	0.043	0.061
Beef	360	0.042	0.033
Swine	61	0.082	0.011
Layer	1.8	0.136	0.00054
Pullet	0.68	0.109	0.00016
Broiler	0.9	0.136	0.00026

Modified Table 6 from the Updated Phosphorus Source Accounting Methodology for the Rural Water Quality Program by South Nation Conservation Authority (Allaway, 2003).

Naturalization

The phosphorus equation that was used for naturalization projects is typically used for buffer strips (Allaway, 2003). Given the small sample size of projects in this category, and because many naturalization projects did not collect specific metrics or details about the total area of planting or the overall project purpose; it was assumed for this analysis, that planting projects that resulted in a newly established natural area would be included in this equation. Buffers may be permanent or temporary and can include windbreaks and shelterbelts, riparian forest buffers, wetlands, grassed waterways, among many other in-field or edge of field designs (Hoekstra and Hannam, 2017). There are many buffer types, and it can be difficult to classify a cost-share project because many of these projects can fit into multiple categories. Because some of the project descriptions indicated that the purpose of the project was to create a buffer to address erosion, it seemed reasonable to include naturalization projects devoted to planting in this calculation.

It is also important to mention that the effectiveness of buffers in trapping sediments can vary dramatically due to variability in planting characteristics, soil type, tillage, topography and rainfall characteristics (Yuan et al., 2009). It is generally understood that if well developed buffers are appropriately designed, sized and placed, they can be effective in filtering agricultural runoff; so, it is assumed here that all naturalization projects have the appropriate characteristics and size to provide adequate water quality functioning (Yuan et al., 2009; Hickey and Doran, 2004).

Because many of the projects did not include total planting area, averages were calculated by reviewing all planting projects by type that were supported by OSCIA-delivered cost-share programs in the Lake Erie basin (most of these values were collected in SARFIP).

First-Year and Cumulative Impact Considerations

For Tables 36 through 46, the phosphorus loading equations were used to calculate the first-year impact and the cumulative impact which considers all years following completion of the project, up to and including the year of 2018. For many BMPs, the phosphorus-loss reduction continues in subsequent years; and for these equations, it was assumed that the first-year impact continues at the same rate. For example, the average number of acres impacted by a cover crop project was estimated to be 140 acres based on OSCA-delivered project records. For this BMP, it was assumed that the initial project resulted in a permanent land-use change, so the same number of acres continued to be cover cropped in subsequent years. In reality this is unlikely, as some farms may choose to implement cover crops on fewer acres or more acres in subsequent years, of which crop rotation will play an important consideration. So, this assumption is more problematic for land use based-projects, such as cover cropping; as opposed to a manure storage project where the impact is more clearly defined in subsequent years (assuming the rate of livestock stays the same).

As mentioned earlier, these calculations are provided as estimates only. Because they rely on averages, they should be interpreted with caution. They are provided here as an example of how agri-environmental cost-share programs can be valuable resources for data collection when BMP project metrics are collected regularly and are standardized. These calculations have been used to estimate the total quantity of phosphorus that has been reduced cumulatively by these projects over the 2005-2018 program delivery period.

Table 36: Estimated Phosphorus Loss Reductions: Conservation Tillage

Year	Total Projects[1]	Estimated Land Area Impacted (acres) [1]	Estimated Land Area Impacted (hectares)	First Year Estimated Phosphorus Loss Reduction (Kg P)	Cumulative Estimated Phosphorus Loss Reduction (Kg P)	Total Claim Cost	Estimated Cost Per Kg of P First Year	Estimated Cumulative Cost Per Kg of P / Cumulative Land Area
2005	7	3,675	1,487	1,115	1,115	$ 65,593	$ 59	$ 59
2006	82	43,050	17,422	13,066	14,182	$ 1,715,512	$ 131	$ 126
2007	218	114,450	46,316	34,737	48,919	$ 4,737,380	$ 136	$ 133
2008	312	163,800	66,288	49,716	98,635	$ 7,163,312	$ 144	$ 139
2009	142	74,550	30,169	22,627	121,262	$ 3,152,533	$ 139	$ 139
2010	111	58,275	23,583	17,687	138,949	$ 3,147,994	$ 178	$ 144
2011	52	27,300	11,048	8,286	147,235	$ 1,273,762	$ 154	$ 144
2012	33	17,325	7,011	5,258	152,493	$ 972,937	$ 185	$ 146
2013	1	525	212	159	152,653	$ 16,108	$ 101	$ 146
2014	0	-	-	-	152,653	-	-	$ 146
2015	0	-	-	-	152,653	-	-	$ 146
2016	37	19,425	7,861	5,896	158,548	$ 1,151,532	$ 195	$ 148
2017	63	33,075	13,385	10,039	168,587	$ 1,951,332	$ 194	$ 150
2018	73	38,325	15,510	11,632	180,219	$ 2,479,107	$ 213	$ 154
Total	**1,131**	**593,775**	**240,292**	**180,219**	**180,219**	**$ 27,827,103**	**$ 154**	**$ 154**

1. Includes all conservation tillage and high-residue management equipment projects; but excludes all banding, variable controlled rate application equipment. It was estimated the average number of acres impacted by conservation tillage equipment in the first year of use was 525 acres per project. The first-year rate of use is assumed to continue for all subsequent years.

Table 37: Estimated Phosphorus Loss Reductions: Cover Cropping

Year	Total Projects	Estimated Land Area Impacted (acres) [1]	Estimated Land Area Impacted (hectares)	First Year Estimated Phosphorus Loss Reduction (Kg P)	Cumulative Estimated Phosphorus Loss Reduction (Kg P)[2]	Total Claim Cost	Estimated Cost Per Kg of P First Year	Estimated Cumulative Cost Per Kg of P / Cumulative Land Area
2005	0	-	-	-	-	-	-	-
2006	9	1,260	510	204	204	$55,647	$ 273	$ 273
2007	39	5,460	2,210	884	1,088	$122,715	$ 139	$ 164
2008	66	9,240	3,739	1,496	2,584	$252,506	$ 169	$ 167
2009	63	8,820	3,569	1,428	4,011	$344,387	$ 241	$ 193
2010	67	9,380	3,796	1,518	5,530	$196,927	$ 130	$ 176
2011	48	6,720	2,719	1,088	6,617	$169,427	$ 156	$ 173
2012	29	4,060	1,643	657	7,275	$97,899	$ 149	$ 170
2013	2	280	113	45	7,320	$7,521	$ 166	$ 170
2014	2	280	113	45	7,365	$6,483	$ 143	$ 170
2015	3	420	170	68	7,433	$14,905	$ 219	$ 171
2016	58	8,120	3,286	1,314	8,748	$277,431	$ 211	$ 177
2017	36	5,040	2,040	816	9,564	$134,326	$ 165	$ 176
2018	69	9,660	3,909	1,564	11,127	$280,158	$ 179	$ 176
Total	**491**	**68,740**	**27,818**	**11,127**	**11,127**	**$1,960,333**	**$ 176**	**$ 176**

1. It was estimated the average number of acres planted per project across all years of program delivery is 140 acres per cover crop project.
2. Assumes the project led to a behavior change, and that cover cropping continues across all subsequent years at the same rate as the first-year.

Table 38: Estimated Phosphorus Loss Reductions: Nutrient Management Planning

Year	Total Farms	Estimated Land Area Impacted (acres) [1]	Estimated Land Area Impacted (hectares)	First Year Estimated Phosphorus Loss Reduction (Kg P)	Cumulative Estimated Phosphorus Loss Reduction (Kg P)[2]	Total Claim Cost	Estimated Cost Per Kg of P First Year	Estimated Cumulative Cost Per Kg of P / Cumulative Land Area
2005	183	51,972	21,262	53,156	53,156	$1,000,197	$19	$19
2006	48	13,632	5,976	14,941	68,097	$186,178	$12	$17
2007	91	25,844	10,459	26,147	94,243	$260,614	$10	$15
2008	145	41,180	16,780	41,950	136,193	$317,350	$8	$13
2009	69	19,596	8,045	20,113	156,306	$183,270	$9	$12
2010	45	12,780	5,172	12,930	169,236	$117,179	$9	$12
2011	26	7,384	2,988	7,471	176,706	$95,796	$13	$12
2012	21	5,964	2,414	6,034	182,740	$45,978	$8	$12
2013	2	568	230	575	183,315	$3,798	$7	$12
2014	17	4,828	1,954	4,885	188,199	$110,639	$23	$12
2015	25	7,100	2,873	7,183	195,382	$114,671	$16	$12
2016	10	2,840	1,149	2,873	198,256	$26,460	$9	$12
2017	14	3,976	3,218	8,045	206,301	$53,787	$7	$12
2018	12	3,408	1,379	3,448	209,749	$62,388	$18	$12
Total	**676**	**191,984**	**83,900**	**209,749**	**209,749**	**$2,578,305**	**$12**	**$12**

1. It was estimated the average number of acres impacted per nutrient management planning project/farm is 284 acres across all years of program delivery.
2. Assumes the impact of the plan continues in all subsequent years at the same rate as the initial plan (284 acres).

Table 39: Estimated Phosphorus Loss Reductions: Crop Nutrient Planning

Year	Total Farms	Estimated Land Area Impacted (acres) [1]	Estimated Land Area Impacted (hectares)	First Year Estimated Phosphorus Loss Reduction (Kg P)	Cumulative Estimated Phosphorus Loss Reduction (Kg P)[2]	Total Claim Cost	Estimated Cost Per Kg of P First Year	Estimated Cumulative Cost Per Kg of P / Cumulative Land Area
2005	0	-	-	-	-	-	-	-
2006	0	-	-	-	-	-	-	-
2007	0	-	-	-	-	-	-	-
2008	0	-	-	-	-	-	-	-
2009	0	-	-	-	-	-	-	-
2010	5	2,250	911	2,276	2,276	$30,140	$13	$13
2011	4	1,800	728	1,821	4,097	$36,808	$20	$16
2012	0	-	-	-	4,097	-	-	$16
2013	0	-	-	-	4,097	-	-	$16
2014	5	2,250	911	2,276	6,374	$25,079	$11	$14
2015	11	8,550	3,460	8,650	15,024	$59,467	$7	$10
2016	24	13,500	5,463	13,658	28,682	$64,900	$5	$8
2017	15	6,750	2,732	6,829	35,511	$86,527	$13	$9
2018	18	8,550	3,460	8,650	44,161	$57,628	$7	$8
Total	**71**	**43,650**	**17,665**	**44,161**	**44,161**	**$360,551**	**$8**	**$8**

1. It was estimated the average number of acres impacted per crop nutrient planning project is 450 acres across all years of program delivery.
2. Assumes the impact of the plan continues in all subsequent years at the same rate as the initial plan (450 acres).

Table 40: Estimated Phosphorus Loss Reductions: Naturalization

Year	Total Farms	Estimated Land Area Impacted (acres) [1]	Estimated Land Area Impacted (hectares)	First Year Estimated Phosphorus Loss Reduction (Kg P)	Cumulative Estimated Phosphorus Loss Reduction (Kg P)[2]	Total Claim Cost	Estimated Cost Per Kg of P First Year	Estimated Cumulative Cost Per Kg of P / Cumulative Land Area
2005	-	-	-	-	-	-	-	-
2006	2	8.05	3.26	2.28	2.28	$7,023	$3,080	$3,080
2007	9	13.50	5.46	3.82	6.10	$34,945	$9,138	$6,875
2008	13	54.15	21.91	15.34	21.44	$51,500	$3,357	$4,359
2009	77	60.25	24.38	17.07	38.51	$113,898	$6,673	$5,384
2010	106	90.08	36.45	25.52	64.03	$394,045	$15,442	$9,393
2011	57	46.39	18.77	13.14	77.17	$193,018	$14,688	$10,294
2012	25	32.98	13.35	9.34	86.51	$178,066	$19,060	$11,241
2013	15	24.00	9.71	6.80	93.31	$122,817	$18,065	$11,738
2014	7	6.75	2.73	1.91	95.22	$15,904	$8,317	$11,669
2015	11	13.83	5.60	3.92	99.14	$36,411	$9,294	$11,576
2016	13	17.62	7.13	4.99	104.13	$56,011	$11,222	$11,559
2017	25	97.66	39.52	27.67	131.80	$94,585	$3,419	$9,850
2018	19	50.62	20.49	14.34	146.14	$110,935	$7,736	$9,643
Total	**379**	**515.88**	**208.77**	**146.14**	**146.14**	**$1,409,160**	**$9,643**	**$9,643**

1. The average number of acres planted per project is based on the estimates below, which relied upon averages from OSCIA records.
2. Assumes the impact of the project continues in all subsequent years at the same area of planting.

Estimated Average Planting Area for Naturalization Projects (OSCIA records)

Type of Project	Planting Area (Acres)	Number of Projects	Total Planting Area (Hectares)
Windbreaks and shelterbelts	0.65	212	56
Buffer strips	0.45	69	13
Wetland restoration	1.75	42	30
Reforestation	2.44	32	32
Grassland restoration	7.60	21	65
Fragile land retirement	11.95	3	15

Table 41: Estimated Phosphorus Loss Reductions: Manure Storage Improvements

Year	Total Farms	Estimated Livestock Impacted[17]	First Year Estimated Phosphorus Loss Reduction (Kg P)	Cumulative Estimated Phosphorus Loss Reduction (Kg P)[2]	Total Claim Cost	Estimated Cost Per Kg of P First Year	Estimated Cumulative Cost Per Kg of P / Cumulative Livestock
2005	139	7,851,174	68,537	68,537	$13,930,996	$203	$203
2006	76	28,925,349	144,218	212,755	$6,044,909	$42	$94
2007	123	845,160	9,667	222,422	$8,916,539	$922	$130
2008	108	1,169,602	7,862	230,283	$7,270,036	$925	$157
2009	71	137,418	2,773	233,056	$4,927,064	$1,777	$176
2010	65	1,107,737	7,545	240,601	$5,006,734	$664	$192
2011	34	850,010	6,677	247,278	$2,948,421	$442	$198
2012	38	28,145	596	247,874	$3,211,546	$5,388	$211
2013	2	100	22	247,896	$203,860	$9,156	$212
2014	11	92,244	787	248,683	$1,141,189	$1,450	$216
2015	12	26,035	280	248,964	$808,832	$2,884	$219
2016	9	3,999	696	249,660	$373,606	$537	$219
2017	13	108,195	970	250,630	$743,291	$766	$222
2018	15	3,018	497	251,126	$710,410	$1,430	$224
Total	**675**	**41,148,186**	**251,126**	**251,126**	**$56,237,432**	**$224**	**$224**

Livestock numbers were provided by the farm business on the program enrolment form; and included all livestock types for that operation at the time of enrolment. It was assumed that the manure storage project correlated to the primary commodity identified by the farm. If the farm identified beef cattle as the primary commodity, then only the number of beef cattle from the program enrolment form was factored into the calculation for that project.

Table 42: Total Number of Livestock and Manure P Generated: Manure Storage

Year	Number of Livestock				Kilograms of Phosphorus			
	Beef	Dairy	Poultry	Hogs	Beef	Dairy	Poultry	Hogs
2005	17,630	18,884	7,644,200	170,460	2,124	4,205	34,833	27,376
2006	5,889	9,467	28,848,063	61,930	709	2,108	131,455	9,946
2007	5,779	6,527	809,000	23,854	696	1,453	3,686	3,831
2008	2,330	7,352	1,155,700	4,220	281	1,637	5,266	678
2009	1,162	6,006	125,750	4,500	140	1,337	573	723
2010	940	7,158	1,094,339	5,300	113	1,594	4,987	851
2011	1,105	3,236	833,048	12,621	133	720	3,796	2,027
2012	0	2,145	26,000	0	0	478	118	0
2013	0	100	0	0	0	22	0	0
2014	1,200	1,044	90,000	0	145	232	410	0
2015	625	410	25,000	0	75	91	114	0
2016	620	1,273	0	2,106	75	283	0	338
2017	1,120	375	105,000	1,700	135	83	478	273
2018	1,715	1,303	0	0	207	290	0	0
Total	**40,115**	**65,280**	**40,756,100**	**286,691**	**4,832**	**14,535**	**185,717**	**46,043**

[17] Animal phosphorus factors: beef (0.033), dairy (0.061), poultry (0.00032) and hog and pig (0.011). Days of manure production collected: cattle (91.25 days), hogs and poultry (365 days).

Table 43: Estimated Phosphorus Loss Reductions: Livestock Facility Runoff Control

Year	Total Farms	Estimated Livestock Impacted[18]	First Year Estimated Phosphorus Loss Reduction (Kg P)	Cumulative Estimated Phosphorus Loss Reduction (Kg P)[2]	Total Claim Cost	Estimated Cost Per Kg of P First Year	Estimated Cumulative Cost Per Kg of P / Cumulative Livestock
2005	20	136,820	2,252	2,252	$1,096,201	$487	$487
2006	20	10,870	330	2,582	$413,592	$1,253	$585
2007	100	104,300	2,291	4,873	$2,639,894	$1,152	$851
2008	110	255,309	2,589	7,462	$2,948,020	$1,139	$951
2009	46	60,597	1,334	8,796	$1,658,065	$1,243	$995
2010	41	2,691,390	7,847	16,643	$2,223,906	$283	$660
2011	32	62,603	671	17,314	$1,003,760	$1,495	$692
2012	16	266,762	979	18,293	$530,903	$542	$684
2013	0	-	-	18,293	-	-	-
2014	4	2,745	216	18,509	$536,832	$2,483	$705
2015	3	670	71	18,580	$96,058	$1,353	$708
2016	2	475	29	18,609	$256,188	$8,955	$720
2017	1	80	5	18,614	$35,052	$7,275	$722
2018	12	9,994	252	18,866	$1,072,900	$4,260	$769
Total	**375**	**3,602,615**	**18,866**	**18,866**	**$14,511,372**	**$769**	**$769**

Livestock numbers were provided by the farm business on the program enrolment form; and included all livestock types for that operation at the time of enrolment. It was assumed that the manure storage project correlated to the primary commodity identified by the farm. If the farm identified beef cattle as the primary commodity, then only the number of beef cattle from the program enrolment form was factored into the calculation for that project.

Table 44: Total Number of Livestock and Manure P Generated: Livestock Facility Runoff Control

Year	Number of Livestock				Kilograms of Phosphorus			
	Beef	Dairy	Poultry	Hogs	Beef	Dairy	Poultry	Hogs
2005	10,424	1,846	110,000	14,550	628	206	251	1,168
2006	1,148	1,703	7,339	680	69	190	17	55
2007	6,983	3,226	77,467	16,624	421	359	177	1,335
2008	10,713	5,619	229,064	9,913	645	626	522	796
2009	1,878	2,639	45,833	10,247	113	294	104	823
2010	2,801	3,313	2,670,010	15,266	169	369	6,083	1,226
2011	4,427	966	55,072	2,138	267	108	125	172
2012	1,868	1,194	262,000	1,700	113	133	597	137
2013					0	0	0	0
2014	1,640	925		180	99	103	0	14
2015	70	600			4	67	0	0
2016	475				29	0	0	0
2017	80				5	0	0	0
2018	1,878	316	6,700	1,100	113	35	15	88
Total	**44,385**	**22,347**	**3,463,485**	**72,398**	**2,673**	**2,488**	**7,891**	**5,814**

[18] Animal phosphorus factors used: beef (0.033), dairy (0.061), poultry (0.00032) and hog and pig (0.011). Days of manure production collected: cattle (91.25 days), hogs and poultry (365 days).

Table 45: Estimated Phosphorus Loss Reductions: Livestock Exclusion Fencing

Year	Total Farms	Estimated Livestock Impacted[19]	First Year Estimated Phosphorus Loss Reduction (Kg P)	Cumulative Estimated Phosphorus Loss Reduction (Kg P)[2]	Total Claim Cost	Estimated Cost Per Kg of P First Year	Estimated Cumulative Cost Per Kg of P / Cumulative Livestock
2005	0	-	-	-	-	-	-
2006	2	220	10	10	$4,009	$403	$403
2007	5	667	36	46	$55,647	$1,551	$1,663
2008	14	2,745	132	177	$82,955	$630	$1,083
2009	22	3,367	198	376	$169,543	$855	$1,575
2010	24	3,401	177	553	$405,852	$2,291	$4,054
2011	23	1,355	81	634	$136,875	$1,687	$10,537
2012	7	548	25	659	$49,730	$2,009	$36,546
2013	7	276	16	675	$69,832	$4,284	$59,785
2014	9	972	50	725	$205,588	$4,078	$23,404
2015	10	3,765	176	901	$141,551	$806	$7,529
2016	9	942	43	943	$65,558	$1,541	$32,601
2017	8	510	27	970	$39,056	$1,449	$52,930
2018	6	230	10	981	$49,912	$4,804	$142,086
Total	**117**	**18,998**	**981**	**981**	**$1,476,109**	**$1,505**	**$1,505**

Livestock numbers were provided by the farm business on the program enrolment form; and included all livestock types for that operation at the time of enrolment. It was assumed that the manure storage project correlated to the primary commodity identified by the farm. If the farm identified beef cattle as the primary commodity, then only the number of beef cattle from the program enrolment form was factored into the calculation for that project.

Table 46: Total Number of Livestock and Manure P Generated: Livestock Exclusion Fencing

Year	Number of Livestock				Kilograms of Phosphorus			
	Beef	Dairy	Poultry	Hogs	Beef	Dairy	Poultry	Hogs
2005	-	-	-	-	-	-	-	-
2006	220	0	0	0	10	0	-	-
2007	517	150	0	0	23	13	-	-
2008	2,545	200	0	0	115	17	-	-
2009	2,163	1,204	0	0	98	101	-	-
2010	2,788	613	0	0	126	51	-	-
2011	835	520	0	0	38	43	-	-
2012	548	0	0	0	25	0	-	-
2013	176	100	0	0	8	8	-	-
2014	802	170	0	0	36	14	-	-
2015	3,622	143	0	0	164	12	-	-
2016	942	0	0	0	43	0	-	-
2017	408	102	0	0	18	9	-	-
2018	230	0	0	0	10	0	-	-
Total	**15,796**	**3,202**	**0**	**0**	**713**	**267**	**-**	**-**

[19] Animal phosphorus factors used: beef (0.033), dairy (0.061), poultry (0.00032) and hog and pig (0.011). Days of manure production collected: cattle (91.25 days), hogs and poultry (365 days).

Summary of Estimated Reductions

According to Environment and Climate Change Canada, total Canadian sources of phosphorus contributed 17,724 tonnes to Lake Erie between 2008 and 2018. This represents an average contribution of 1,611 tonnes of phosphorus per year from Canadian sources (ECCC, 2020). The contribution from Canadian non-point sources was 11,469 tonnes, or about 65% of Canada's total phosphorus loadings to Lake Erie over this period. While non-point sources include both agriculture and urban stormwater runoff, the majority of non-point sources is attributed to be from excessive fertilizers and manure runoff (ECCC, 2020). These values can be compared to the estimated quantities of phosphorus-loss reduced by OSCIA-delivered projects. As shown in Table 47, 3,540 projects reduced an estimated 716,375 kilograms of phosphorus in the Lake Erie basin between 2005 and 2018. This is equivalent to 716 tonnes of phosphorus, or about 170 kilograms per project over a 13-year period.

Table 47: Estimated Phosphorus-Loss Reduced, Lake Erie Basin, 2005-2018

BMP	Number of Projects	Total Claim Costs	Estimated Kg P Reduced	Average Cost Per Kg P Reduced
Crop nutrient planning	71	$360,551	44,161	$8
Nutrient management planning	676	$2,578,305	209,749	$12
Conservation tillage equipment	1,131	$27,827,103	180,219	$154
Cover crops	491	$1,960,333	11,127	$176
Improved manure storage	675	$56,237,432	251,126	$224
Livestock facility runoff control	375	$14,511,372	18,866	$769
Livestock exclusion fencing	117	$1,476,109	981	$1,505
Naturalization	379	$1,409,160	146	$9,643
Total	**3,540**	**$106,360,365**	**716,375**	**$1,539**[1]

1. Average (not total)

Table 48 compares the estimated phosphorus-loss reduced for OSCIA projects that were completed between 2008 and 2018. It was estimated that projects completed between this period may have contributed to a reduction of 3.39% of total non-point phosphorus loadings to Lake Erie; or a 2.19% reduction of total Canadian phosphorus loadings over this period. This fluctuated year to year based on the total number, type and scale of projects completed.

The potential investment required to achieve these estimated phosphorus-loss reductions was an average of $1,539 per one kilogram of phosphorus. However, this ranged from as low as $8 per kilogram P for crop nutrient planning to as much $9,643 per kilogram of P for a naturalization project. This average has been impacted by the much higher estimated cost per kilogram for naturalization projects; for which the calculations only consider the total planting area, not the total area of farmland that may have benefited. These calculations do not reflect any other ecosystem services that are provided by natural areas and which are not quantified in this estimation. For this BMP especially, it signals an opportunity to more accurately capture the total land area impacted by these actions.

When excluding naturalization projects, the average cost to reduce one kilogram of phosphorus across the remaining water quality BMPs in the Lake Erie basin was $380. This reinforces the importance of collecting project metrics; because the averages and methodology used to prepare the data for these equations may have impacted the estimated phosphorus-loss values.

Table 48: Estimated Phosphorus-Loss Reduced by Year, Lake Erie Basin, 2008-2018

SOURCE: Environment Canada and Climate Change Canada, 2020.

Year	Total Canadian phosphorus loading (tonnes per year)	Total Canadian non-point sources (tonnes per year)	Number of Water Quality Projects (OSCIA-delivered programs)	Conservation tillage (kg of P)	Cover cropping kg of P)	Nutrient management planning kg of P)	Crop nutrient planning kg of P)	Naturalization kg of P)	Improved manure storage kg of P)	Livestock facility runoff control kg of P)	Livestock exclusion fencing kg of P)	Estimated Phosphorus-loss reduced (kg P)	Estimated Phosphorus-loss reduced (tonnes per year)	Estimated Phosphorus-loss reduced (as a % of Canadian non-point sources)
2008	1,591	799	658	66,288	1,496	41,950	-	15	7,862	2,589	132	120,332	120	15%
2009	1,829	1,184	444	30,169	1,428	20,113	-	17	2,773	1,334	198	56,032	56	5%
2010	842	342	423	23,583	1,518	12,930	2,276	26	7,545	7,847	177	55,902	56	16%
2011	2,349	1,767	244	11,048	1,088	7,471	1,821	13	6,677	671	81	28,870	29	2%
2012	1,088	644	153	7,011	657	6,034	-	9	596	979	25	15,311	15	2%
2013	1,744	1,165	29	212	45	575	-	7	22	-	16	877	1	<1%
2014	2,230	1,751	51	-	45	4,885	2,276	2	787	216	50	8,261	8	<1%
2015	1,345	842	72	-	68	7,183	8,650	4	280	71	176	16,432	16	2%
2016	1,053	550	160	7,861	1,314	2,873	13,658	5	696	29	43	26,479	26	5%
2017	1,690	1,043	174	13,385	816	8,045	6,829	28	970	5	27	30,105	30	3%
2018	1,963	1,382	212	15,510	1,564	3,448	8,650	14	497	252	10	29,945	30	2%
Total	**17,724**	**11,469**	**2,620**	**175,067**	**10,039**	**115,507**	**44,160**	**140**	**28,705**	**13,993**	**935**	**388,546**	**389**	**3%**

Conclusion

This analysis has provided a detailed overview of voluntary water quality actions by farmers in the Lake Erie basin. Together with the help of cost-share funding assistance, over 3,000 farmers have invested $160 million to implement over 6,600 water quality improvement projects over a 13-year period. Cost-share programs have been an important companion in driving BMP adoption across the farm landscape in this region. But there are signals that participation rates for many water quality BMPs supported by OSCIA-delivered cost-share programs have declined. While many trends presented in this analysis have been impacted by the availability of funding, BMPs with comparatively lower subscription should be examined further to rule out any barriers at the cost-share program interface. It is also important to consider how changing land use practices and land acres impacted, such as those quantified by the Census of Agriculture, may be impacting participation to these program opportunities.

As each iteration of a program tries to respond to the needs of farmers, the story of water quality is one of continual change. Many farmers have already taken the initiative to address water quality issues on their farmland; and it remains unknown how many have done so without cost-share support, or with support from other program opportunities not delivered by OSCIA. Across the entire period of program delivery, it was estimated that about 20% of farmers in the Lake Erie basin have received a cost-share allocation from OSCIA-delivered programs to address water quality issues. In order to accelerate and sustain water quality improvement on the Canadian side of the Lake Erie basin, the number of BMP projects should be increased. As the results of the estimated phosphorus-loss reductions have revealed, the greater the number of acres that are sustainability managed, the greater the benefits to Lake Erie in terms of excessive phosphorus reduced. Lake Erie is particularly vulnerable to nutrients, and as the pressures of land use and climate change continue to impact the production of algal blooms, increased engagement should be strived for. It is also important to consider how the availability of program data has impacted this analysis. The lack of project metrics across many BMP project categories makes it difficult to quantify the total land area impacted by these actions.

This analysis also highlights an opportunity to review how these program offerings are being marketed to different agricultural industry groups in the Lake Erie basin. It is important to consider the impact in specifically communicating water quality issues in future cost-share program communications, particularly program formats that rely upon extension agents. One such example is the Farmland Health Check-Up which is currently in use in the region. It is not known how many Check-Ups are recommending BMPs like windbreaks or shelterbelts, or buffer strips to address the decreasing number of farms that report these natural areas as a land use practice. In comparison to the widely understood soil health benefits of conservation tillage equipment; the water quality benefits of naturalization actions through tree planting and other habitat creation projects may not be as well understood; this presents an opportunity for increased education and awareness regarding the benefits of non production focused BMPs that help to improve water quality. It was also observable from the data, that BMPs with more distinct profiles get more attention than BMPs that are grouped together among dozens of other BMP choices. The competition of water quality BMP project categories and other non-environmental BMP actions must be considered in the context of farm resources and priorities.

Addressing water quality issues can sometimes require significant resources, depending upon the type of project being completed. The average farm invested $37,474 to complete an average of

2.2 water quality projects over this 13-year period. Understanding the specific costs that contribute to a complete water quality project may help to reveal if cost-share rates and caps for certain BMP activities are as effective; particularly for those actions that have lower participation rates. Given the limits to funding in water quality focus areas, merit-based program designs provide an effective means to allocate funding to projects that demonstrate the best benefit. However, data collection should be enhanced and standardized so that meaningful metrics can be effectively tracked. Cost-share programs can be important data sources for improving our understanding of BMP adoption. The lack of consistent data collection and tracking for some BMPs impacted the reliability of phosphorus-loss equations, which are useful in estimating or quantifying the total impact of projects at different time and spatial scales.

The voluntary actions of farmers in addressing farm-specific water quality BMPs in this region should be acknowledged, particularly in relation to the Lake Erie Action Plan (LEAP). Their cumulative participation has helped to accelerate environmental action in support of Lake Erie's ecological health and resiliency. While these numbers reflect a great accomplishment for Lake Erie, the trends also indicate that more work needs to be done to maintain and evaluate phosphorus-loss through BMP adoption supported by cost-share on agricultural lands in the Lake Erie basin.

Recommendations

The following recommendations may be helpful as program designers and delivery personal plan for the next iteration of water quality focused cost-share programs in the Lake Erie Basin.

- Water quality BMPs that had comparatively lower participation over this period included: soil compaction equipment, tree planting and habitat restoration actions (reforestation, wetland restoration, windbreaks and shelterbelts and buffer strips, etc.), conservation tillage equipment for planting in high-residue situations (row cleaners, trash whippers, etc.), and improved stream crossings, among others. Comparing adoption rates in these programs to currently delivered programs may help to identify if these trends have seen a recent reversal, or if they remain low for other reasons.
- To more effectively track and measure interest and/or willingness to address water quality issues with cost-share funding support, declined projects could be analyzed to determine if cost-share program barriers may be a contributing factor given the impact of merit-based evaluation criteria and the more limited funding. Declined water quality BMP projects provide an important signal in terms of BMP interest; data collection for these projects should be standardized to track and evaluate trends on attempted participation.
- The Farmland Health Check-Up is an important behavior change tool in the Lake Erie basin. The aggregated data collected in the workbook may provide region specific evidence about what water quality BMPs may or may not be recommended as often, and under what field conditions and geographies those might be occurring in. While the intent of the program was to engage with crop producers and production BMPs; it is not known how those recommendations and funding levels may have impacted the type of BMPs that ultimately were successful in receiving a cost-share allocation as reviewed in this analysis.
- It is recommended that cost-share programs aim to collect standardized and consistent project metrics within a single program framework, as this allows the data to be compared

within a five-year period similar to the process used by the Census of Agriculture. Within some of the programs evaluated in this analysis, project metrics changed intake to intake, and this impacted the ability to examine trends within certain water quality BMP groups. As well some programs collected metrics as a range instead of as a distinct measure, which impacted the quantification of total project impacts.

- While it may be cumbersome to digitize all cost description items listed on a project claim form; this data could be collected in a standardized format to allow for comparison within the same BMP. For example, application forms collect large open text fields; but other structured approaches could be considered. This includes the use of drop-down dependent lists, check lists, or BMP project "keywords" to allow for filtering of cost items and project impact information.
- In 2013, Growing Forward 2 (GF2) introduced a range of non-environmental BMP categories under numerous farm sustainability focus areas. It is unknown how these additional offerings may have impacted a farm operations willingness to address water quality as a priority. A BMP competition analysis could reveal trends on water quality participation across different industry groups and geographies.
- Consider the impact mandatory project information may have on program participation itself. This considers farmer concerns about confidentiality, the quality of self-reported data, and time constraints in providing and validating the data. This should also consider the resources necessary for the development of data and information management infrastructure to support delivery and ongoing evaluation of these cost-share programs in real time, so that programs can respond and adapt more easily. Without consistent and reliable data on project impacts, it may difficult to accurately estimate the phosphorus-loss reductions of BMP projects in this region as demonstrated through this analysis.
- It is advised that estimated program participation rates be examined in further, as this may indicate gaps in terms of outreach and engagement, such as in the way programs are being delivered, communicated and/or promoted to local regions.
- To get a more accurate sense of water quality trends in the Lake Erie basin, it would be helpful to compare the results of OSCIA-delivered cost-share programs with other delivery agents in the region who may also be providing similar cost-share.

References

Allaway, Chris. (2003). *Phosphorus Loading Algorithms for the South Nation River. Updated Phosphorus Source Accounting Methodology for the Rural Water Quality Program*. South Nation Conservation Authority. Retrieved from: http://www.envtn.org/water-quality-trading/programs-outside-us/FinalPhosphAlgorithmReportPIIJan03.pdf

Environment Canada (2012, October). *Data Sources and Methods for Reducing Phosphorus Loads to Lake Simcoe Indicator.* Retrieved from: https://publications.gc.ca/site/eng/9.696678/publication.html

Environment and Climate Change Canada. (2017). *Canadian Environmental Sustainability Indicators: Reducing phosphorus loads to Lake Simcoe and southeastern Georgian Bay.* https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/reducing-phosporus-lake-simcoe-georgian-bay.html

Environment and Climate Change Canada (2018, March 13) *Partnering on Achieving Phosphorus Loading Reductions to Lake Erie from Canadian Sources: Canada-Ontario Lake Erie Action Plan.* Retrieved from: https://www.canada.ca/en/environment-climate-change/services/great-lakes-protection/action-plan-reduce-phosphorus-lake-erie.html

Environment and Climate Change Canada (2020, October 15) *Phosphorus loading to Lake Erie.* Canadian Environmental Sustainability Indicators. Retrieved from: https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/phosphorus-loading-lake-erie.html

Environment Canada & the United States Environmental Protection Agency. (2014). *State of the Great Lakes 2011*: *Indicators to assess the status and trends of the Great Lakes ecosystem.* Catalogue No. En161-3/1-2011E-PDF. ISSN 2292-1222. https://binational.net/wp-content/uploads/2014/11/sogl-2011-technical-report-en.pdf

Hickey, B., & Doran, B. (2004). A Review of the Efficiency of Buffer Strips for the Maintenance and Enhancement of Riparian Ecosystems. *Water Quality Research Journal of Canada*, 39 (3), 311-317. https://doi.org/10.2166/wqrj.2004.042

Hoekstra, P., & Hannam, C. (2017). *White Paper on Vegetative Buffers.* A Report to the Agriculture and Agri-Food Canada Multi-Stakeholder Forum. Retrieved from: https://seedinnovation.ca/wp-content/uploads/2017/11/Vegetative-Buffers-Whitepaper.pdf

International Joint Commission (2014). *A Balanced Diet for Lake Erie: Reducing Phosphorus Loadings and Harmful Algal Blooms. Report of the Lake Erie Ecosystem Priority.* Retrieved from: https://www.ijc.org/en/balanced-diet-lake-erie-reducing-phosphorus-loadings-and-harmful-algal-blooms

International Joint Commission (IJC) (2018). *Fertilizer Application Patterns and Trends and Their Implications for Water Quality in the Western Lake Erie Basin*. (Cat. No.: 978-0-660-24731-1). Retrieved from: https://ijc.org/en/fertilizer-application-patterns-and-trends-and-their-implications-water-quality-western-lake-erie

Maguire, T., Wellen, C., Stammler, K and Mundle, Scott. (2018). Increased nutrient concentrations in Lake Erie tributaries influenced by greenhouse agriculture. *The Science of the total environment.* 633. 433-440. 10.1016/j.scitotenv.2018.03.188.

Michalak, A., Anderson, E., Beletsky, D., Boland, S., Bosch, N., Bridgeman, T., Chaffin, J., Cho, K., Confesor, R., Daloğlu, I., DePinto, J., Evans, M., Fahnenstiel, G., He, G., Ho, J., Jenkins, L., Johengen, T., Kuo, K., LaPorte, E., Liu, X., McWilliams, M., Moore, M., Posselt, D., Richards, P., Scavia, D., Steiner, A., Verhamme, E., Wright, D and Zagorski, M. (2013). Record-setting algal bloom in Lake Erie caused by agricultural and meteorological trends consistent with expected future conditions*. Proceedings of the National Academy of Sciences of the United States of America, 110 (16), 6448-6452. https://doi.org/10.1073/pnas.1216006110*

O'Grady, D. (2008). Point to non-point phosphorus trading in the South Nation River watershed. *WIT Transactions on Ecology and the Environment*, 108, 189-195. https://www.witpress.com/Secure/elibrary/papers/EEIA08/EEIA08019FU1.pdf

Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA). (2021, February 12). *Fact Sheet: Determining the Phosphorus Index for a Field*. Retrieved from: http://www.omafra.gov.on.ca/english/engineer/facts/05-067.htm#4

Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA). (2021, February 12). *Fact Sheet: Lease Agreements: Crop Share Leases.* Retrieved from: http://www.omafra.gov.on.ca/english/busdev/facts/13-047.htm

Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA). (2021, February 12). *Porcine Epidemic Diarrhea (PED).* Retrieved from: http://www.omafra.gov.on.ca/english/food/inspection/ahw/PED-advisory.html

Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA). (2021). *Soil Fertility Handbook: Publication 611.* Retrieved from: http://www.omafra.gov.on.ca/english/crops/pub611/pub611.pdf

Ontario Ministry of Natural Resources and Forestry (ONMRF). (2020). *User Guide for Ontario Watershed Boundaries (OWB).* Retrieved from: https://mnrf.maps.arcgis.com/home/item.html?id=53a1c537b320404087c54ef09700a7db

Ontario Soil and Crop Improvement Association (OSCIA). (2014). *Alternative Funding Models for Agricultural Stewardship Programs in Ontario.* Retrieved from: https://www.ontariosoilcrop.org/research-resources/publications-resources/

Ontario Soil and Crop Improvement Association (OSCIA). (2018). *Lake Erie Retrospective Analysis.* Retrieved from: https://www.ontariosoilcrop.org/research-resources/lakesimcoe/

Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA). (2021, February 12). *Cover Crops: Adaptation and Use of Cover Crops*. Retrieved from: http://www.omafra.gov.on.ca/english/crops/facts/cover_crops01/cover.htm#cover%20crop%20functions

Prepas, E & Charette, T. (2003). Worldwide Eutrophication of Water Bodies: Causes, Concerns, Controls. *Treatise On Geochemistry*. 9, 311-331. https://doi.org/10.1016/B0-08-043751-6/09169-6

Puzyreva, M., Roy, D., & Stanley, M. (2019). *Case Study Research on Offsets for Water Quality Management.* International Institute for Water Quality Management (IISD). Retrieved from: https://www.iisd.org/system/files/publications/offsets-water-quality-management.pdf

Reutter, J. & Maurice, P. (2019). Lake Erie: Past, Present, and Future. *Encyclopedia of Water: Science, Technology, and Society*. https://doi.org/10.1002/9781119300762.wsts0085

Sinclair, D., & Roumeliotis, T. (2017). *Phosphorus Offsetting: Review of Existing Ontario Programs and Opportunities.* Region of Waterloo. Retrieved from: https://www.regionofwaterloo.ca/en/living-here/resources/Documents/water/projects/wastewater/plan/WS2018V5-Tech_Memo_9A_WWTMP-Phosphorus_Offsetting_2017.PDF

Paul Smith, Carrie Bibik, Jon Lazarus, David Armitage, Cindy Bradley-Macmillan, Maxine Kingston, Andrew Graham, Ryan Plummer & Robert Summers. (2020). Canada's

Environmental Farm Plan: Evaluating Implementation, Use of Services, and the Influence of Social Factors. *Sustainable Agriculture Research*, 9, 4. doi:10.5539/sar.v9n4p1.

Smith, P & Bibik, C & Lazarus, J & Armitage, David & Bradley-Macmillan, Cindy & Kingston, Maxine & Cherny, Nancy & Graham, Andrew & Plummer, Ryan & Summers, Robert. (2016). Ontario's Environmental Farm Plan: Measuring Performance, Improving Effectiveness, and Increasing Participation.

Smith, P., Kingston, M., and Begin, M. (2008). Successful Partnerships in On-Farm Environmental Action in Ontario: The Environmental Farm Plan and Related Initiatives.

Smith, P. (2012). Water Stewardship Actions under Environmental Farm Plans.

Smith, P, Bradley-Macmillan, C., Kingston, M., Graham, A., and Armitage, D. (2008). Progress in Adoption of Beneficial Management Practices and Environmental Farm Plans under the Agricultural Policy Framework 2005-2008.

Smith, P & Graham, A. (2006). Progress on Environmental Farm Plan and On-Farm Action.

Prairie Resource Associates (PRA). (2011). *Environmental Farm Plans: Measuring Performance, Improving Effectiveness, and Increasing Participation.* Retrieved from: https://www.ontariosoilcrop.org/wp-content/uploads/2015/08/Final-Report-EFPs-Measuring-Performance-Improving-Effectiveness-and-Increasing-Participation.pdf

Statistics Canada. (2017, May 10). *2016 Census of Agriculture*: *The Daily*. Retrieved from: https://www150.statcan.gc.ca/n1/daily-quotidien/170510/dq170510a-eng.htm

Statistics Canada. (2020, November 23). *Census of Agriculture FAQs.* Retrieved from: https://www.statcan.gc.ca/eng/statistical-programs/document/3438_D4_T9_V2

Statistics Canada. (2006, June 28). *Canada's beef industry and BSE.* Retrieved from: https://www150.statcan.gc.ca/n1/pub/11-402-x/2006/0920/ceb0920_001-eng.htm

Statistics Canada. (2018, March 23). *Farm and Farm Operator Data: Cropland in Ontario grows despite fewer farms.* Retrieved from: https://www150.statcan.gc.ca/n1/pub/95-640-x/2016001/article/14805-eng.htm

Woyzbun, E. (2015). *Spatial Analysis of the Adoption of Nutrient Related BMPs in Ontario*. Retrieved from: https://www.ontariosoilcrop.org/wp-content/uploads/2015/08/final_report_spatial_analysis_nm_bmp_ontario.pdf

United States Environmental Protection Agency (USEPA) (2020, July 23). *The Great Lakes: Lake Erie*. Retrieved from: https://www.epa.gov/greatlakes/lake-erie

Annex

Maps

Select BMP maps by township and the administrative Conservation Authority (CA) boundary have been created. Spatially evaluating the reach and impact of water quality BMPs at both scales may be important for program developers and partnerships. Where a geographic area shows no data, it does not necessarily mean that no projects were completed in this parcel over this period; as some projects were established very close to the delineated boundary. The entire area of some townships and CAs does not fall within the extent of Lake Erie basin. The data is derived from OSCIA program records and is provided "as is". Unless otherwise stated, map data has been classified using Natural Breaks (Jenks).

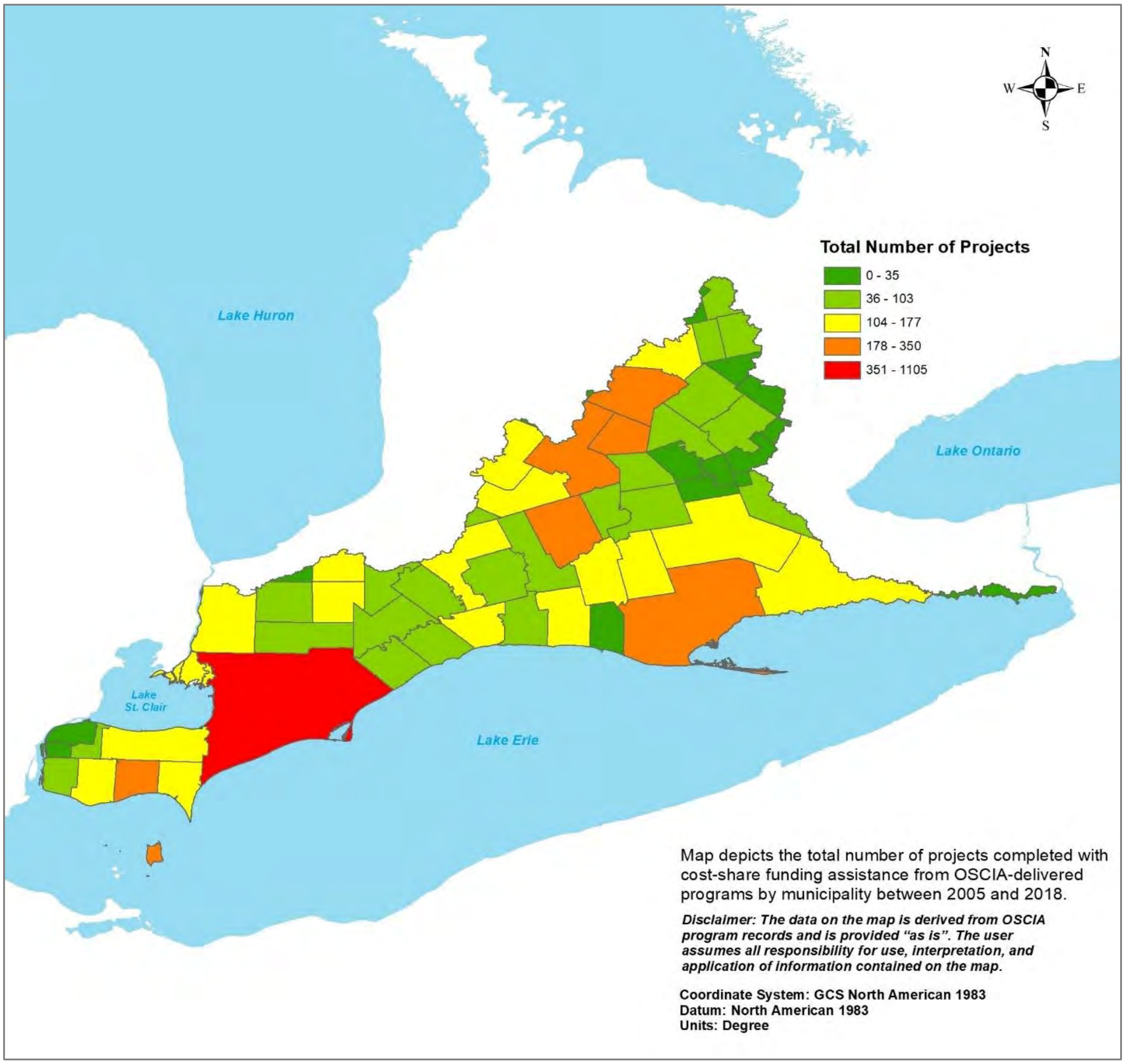


Figure 41: Total Number of Water Quality Projects by Township

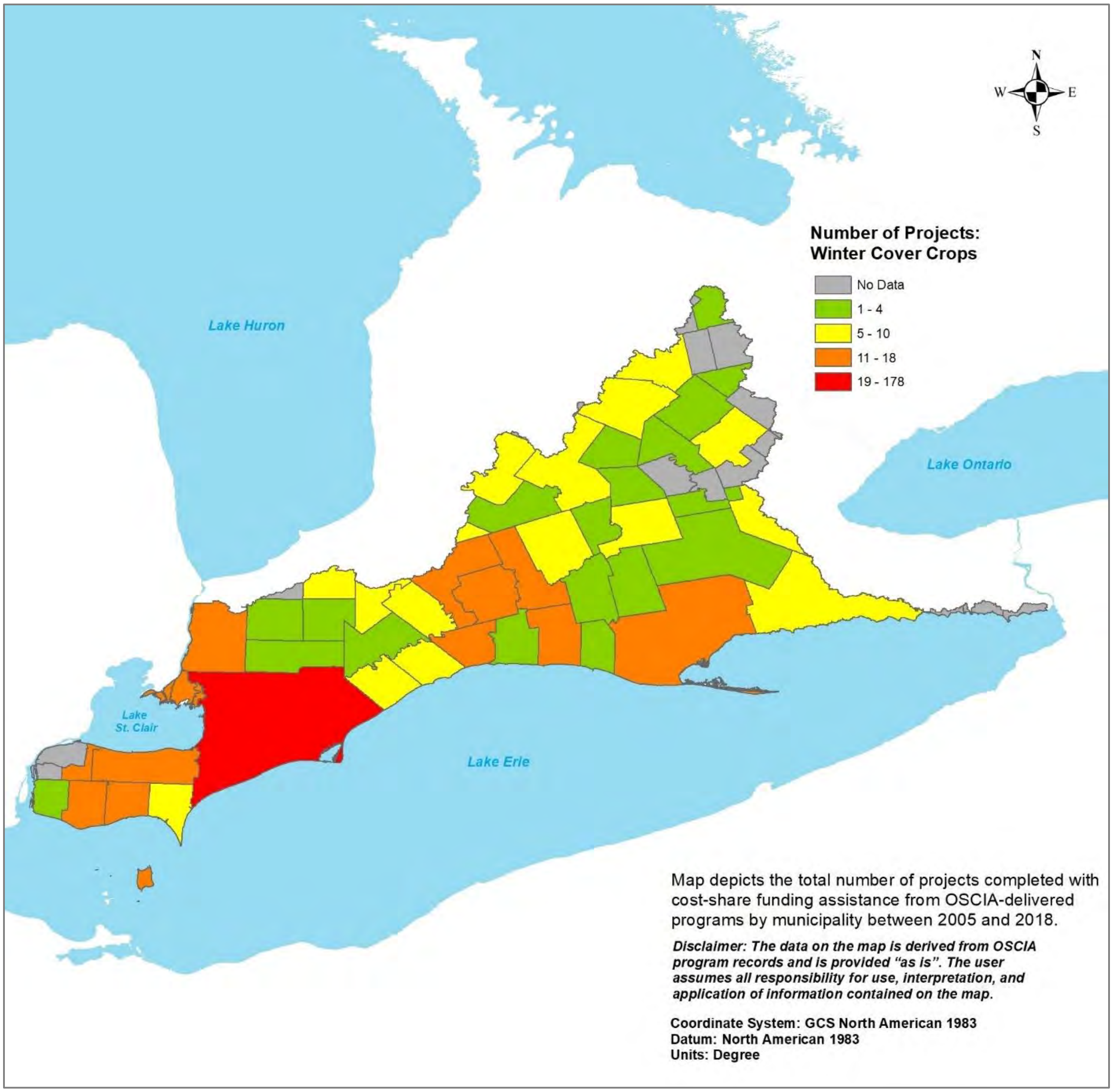


Figure 42: Total Number of Cover Crop Projects by Township

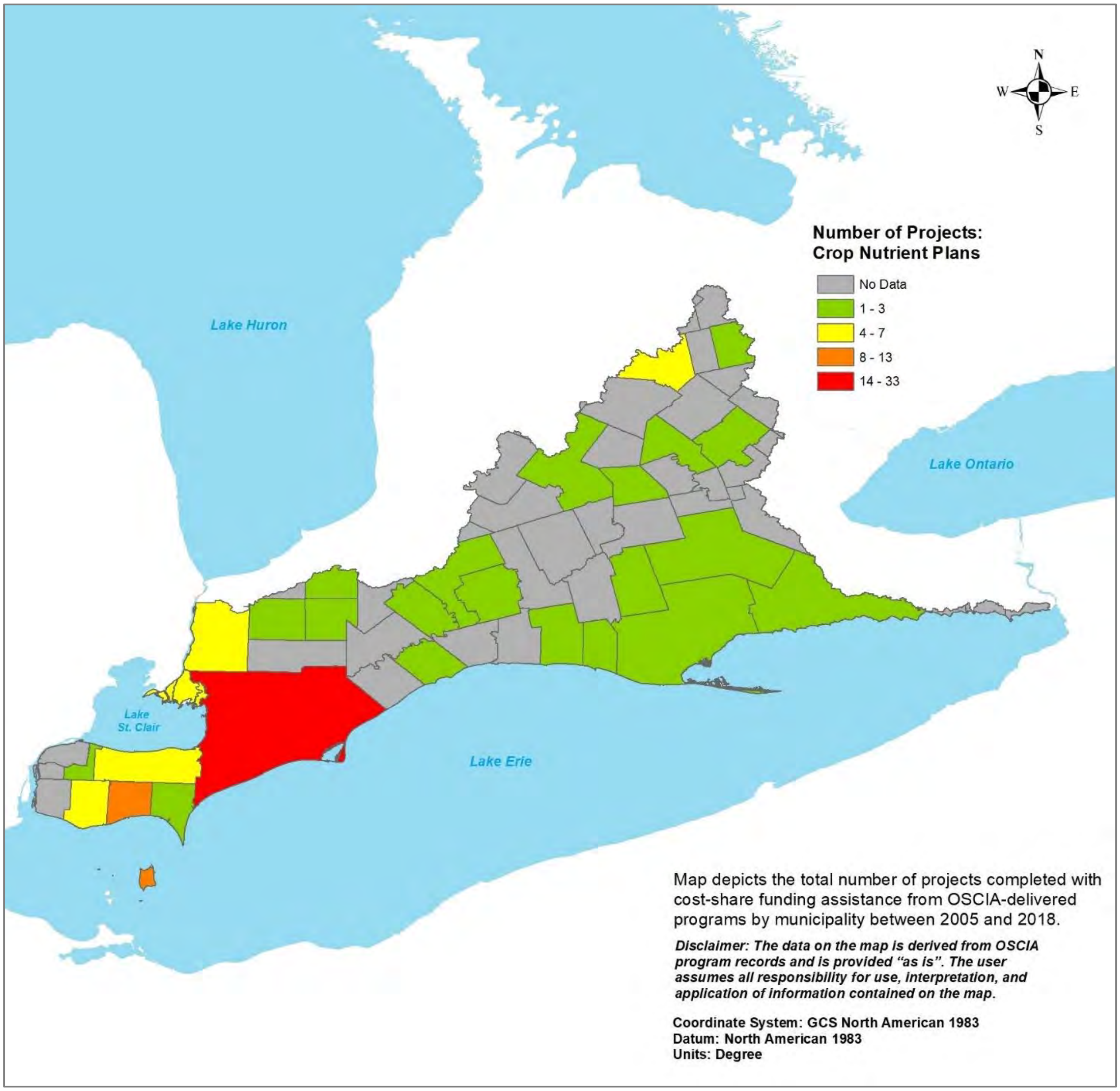


Figure 43: Total Number of Crop Nutrient Plan Projects by Township

.

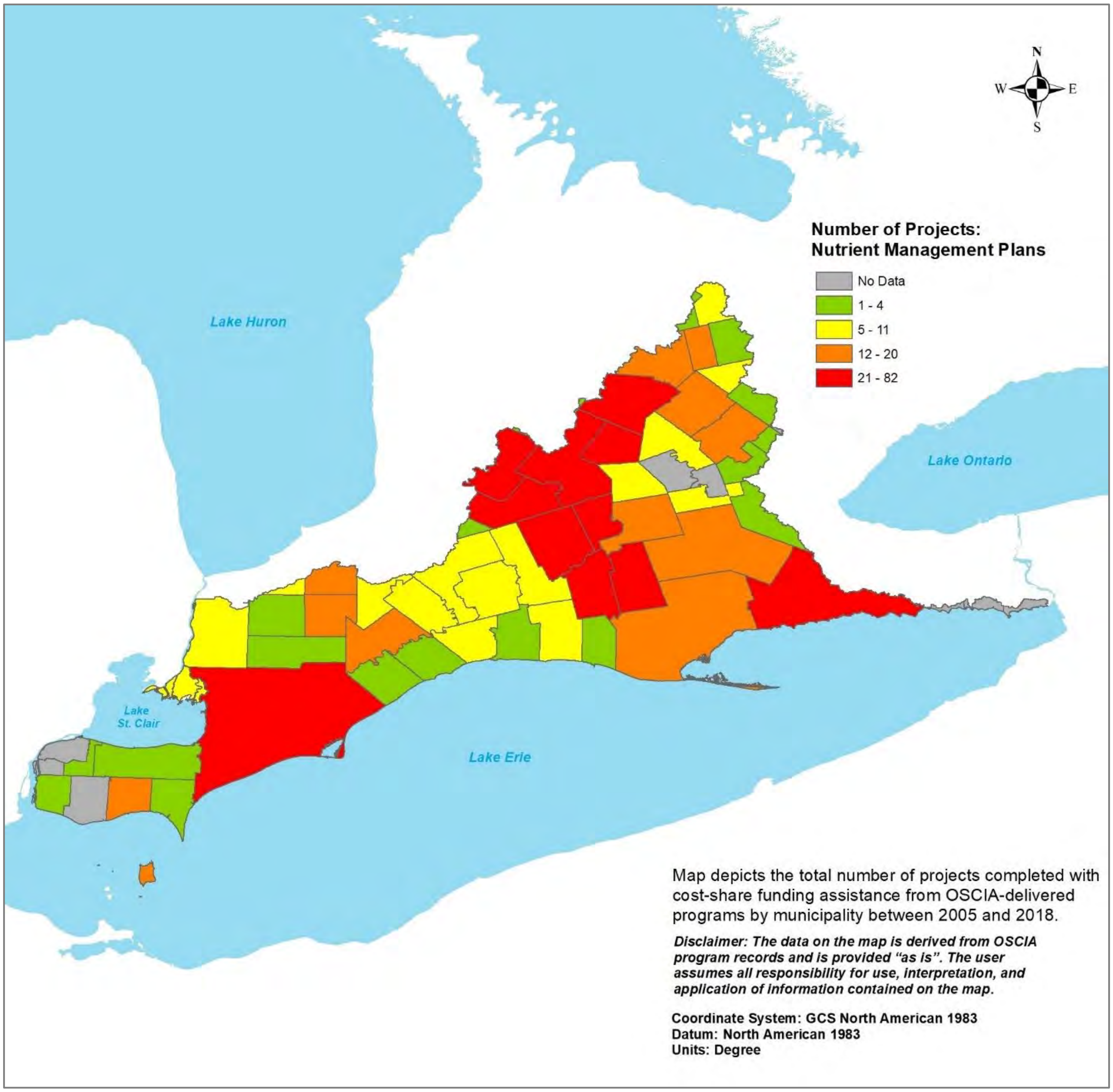


Figure 44: The Total Number of Nutrient Management Planning Projects by Township

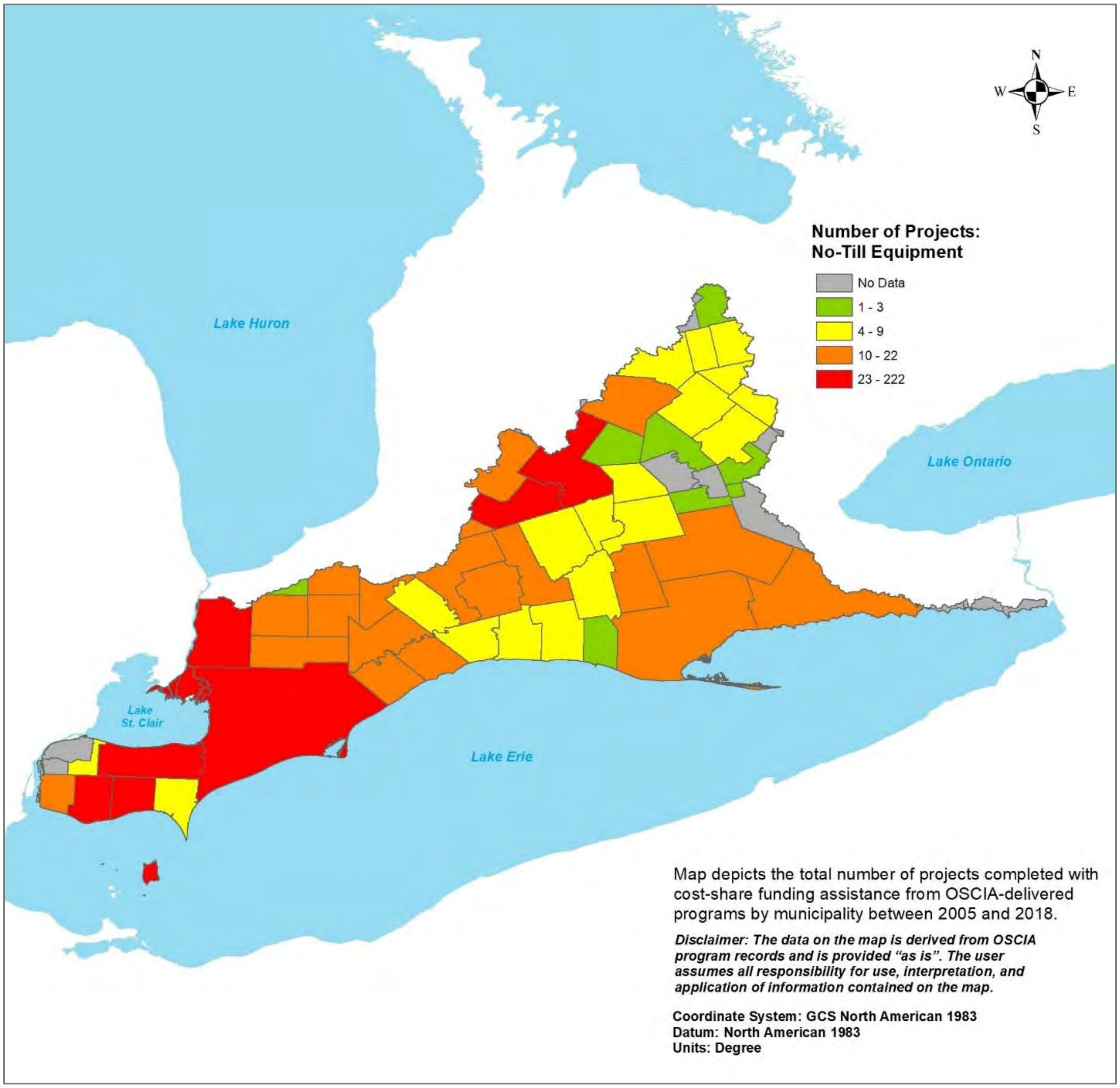


Figure 45: Total Number of No-Till Projects by Township

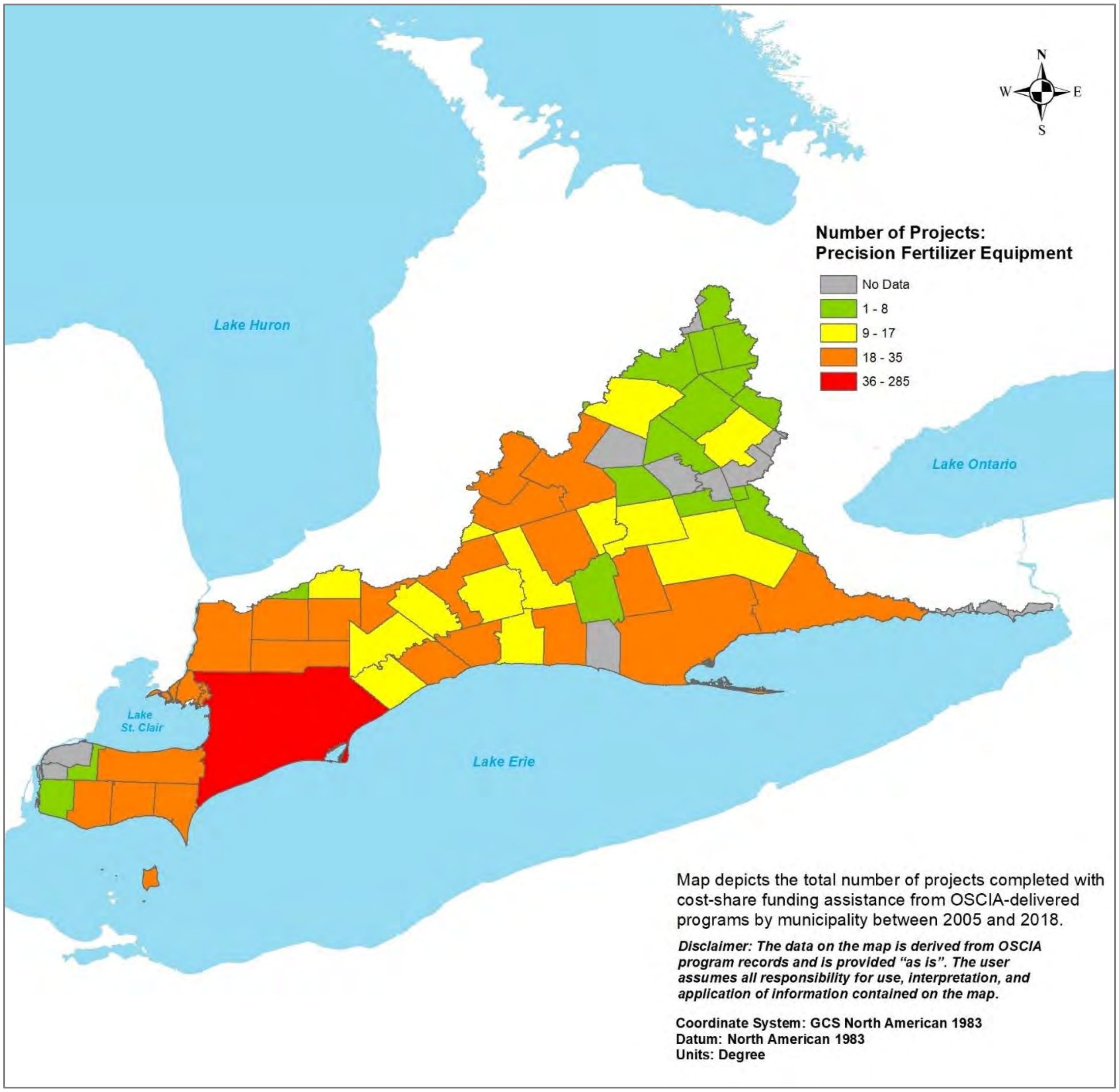


Figure 46: Total Number of Precision Fertilizer Equipment by Township

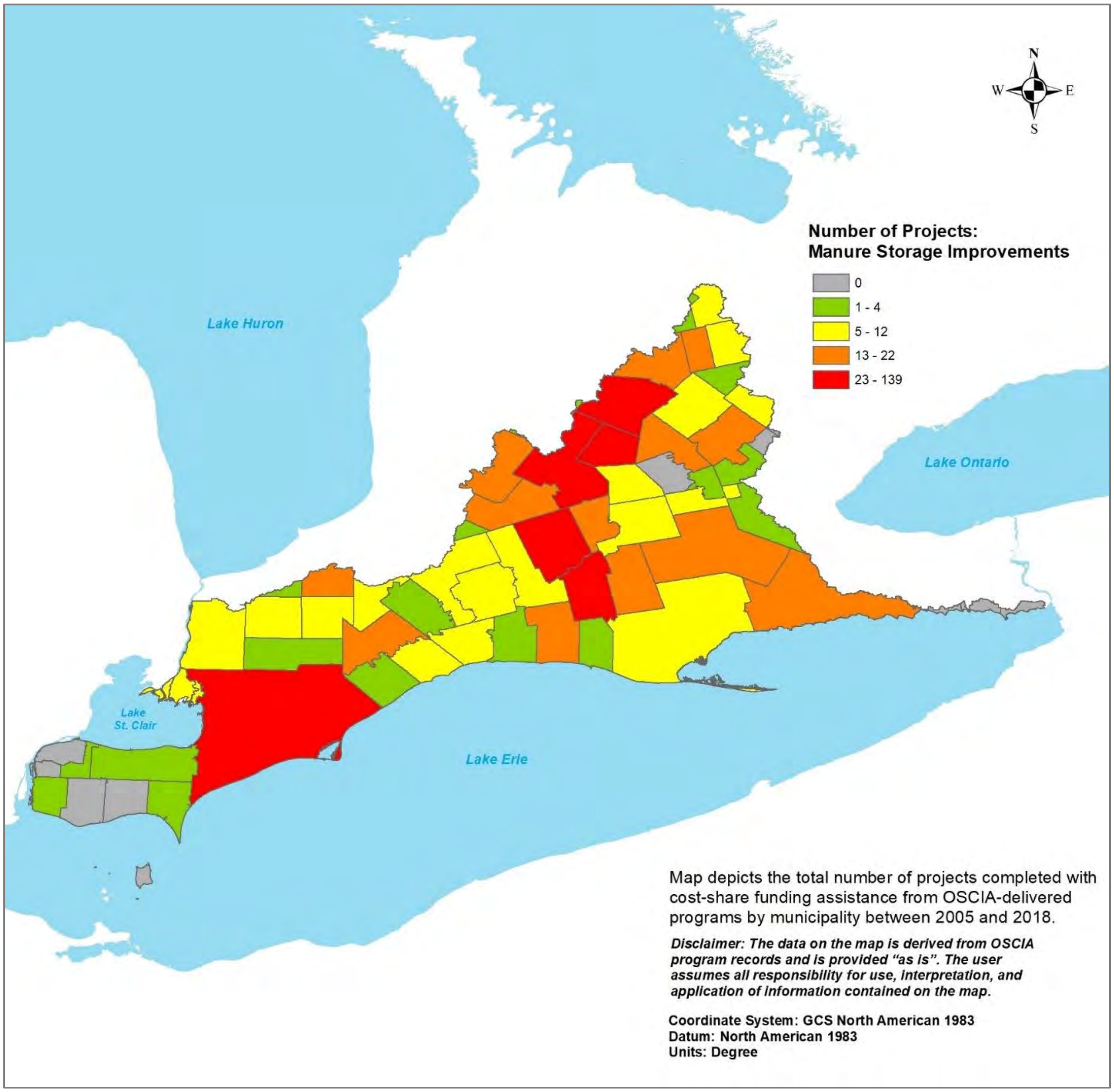


Figure 47: Total Number of Manure Storage Improvement Projects by Township

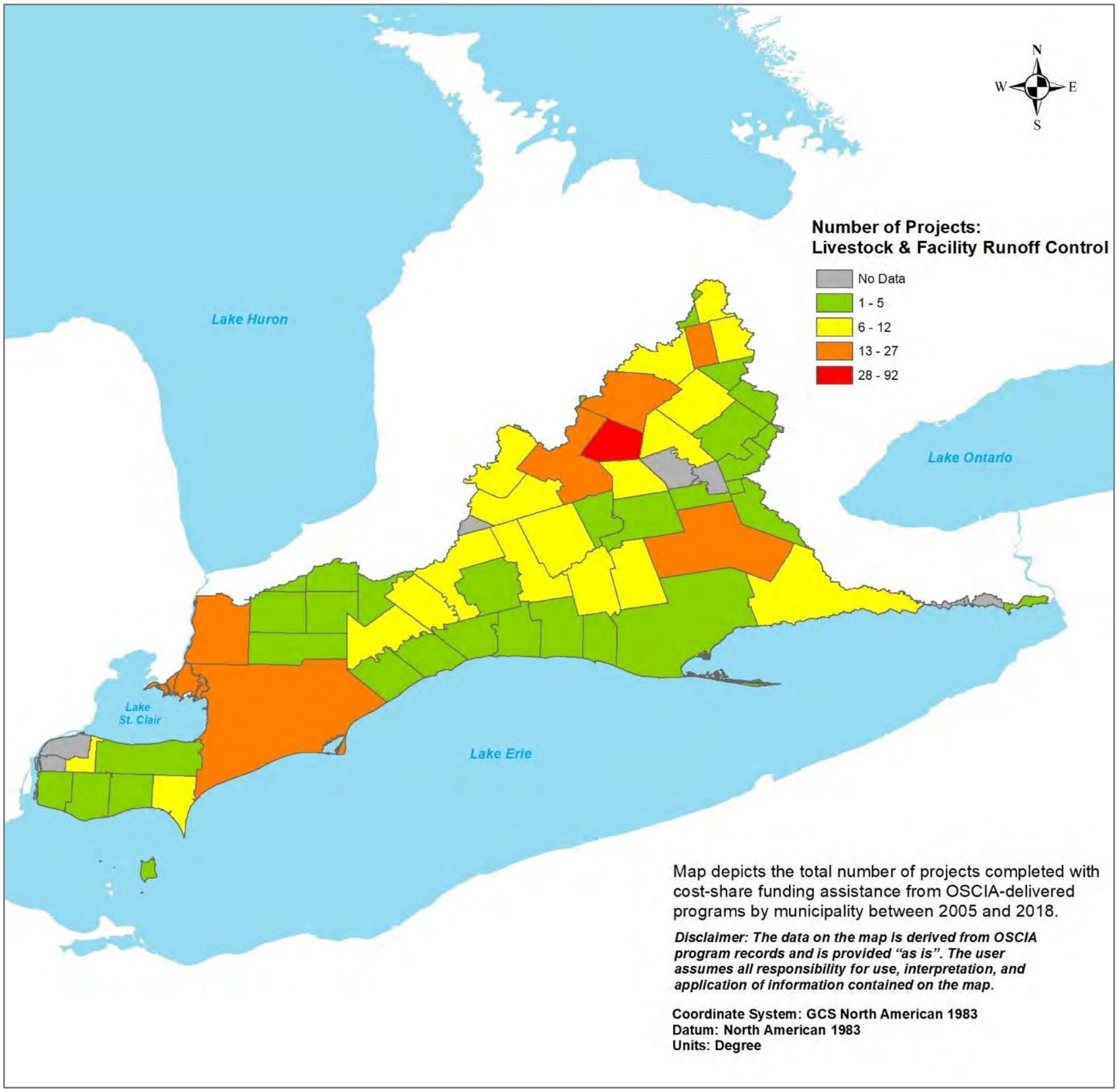


Figure 48: Total Number of Livestock and Facility Runoff Control Projects by Township

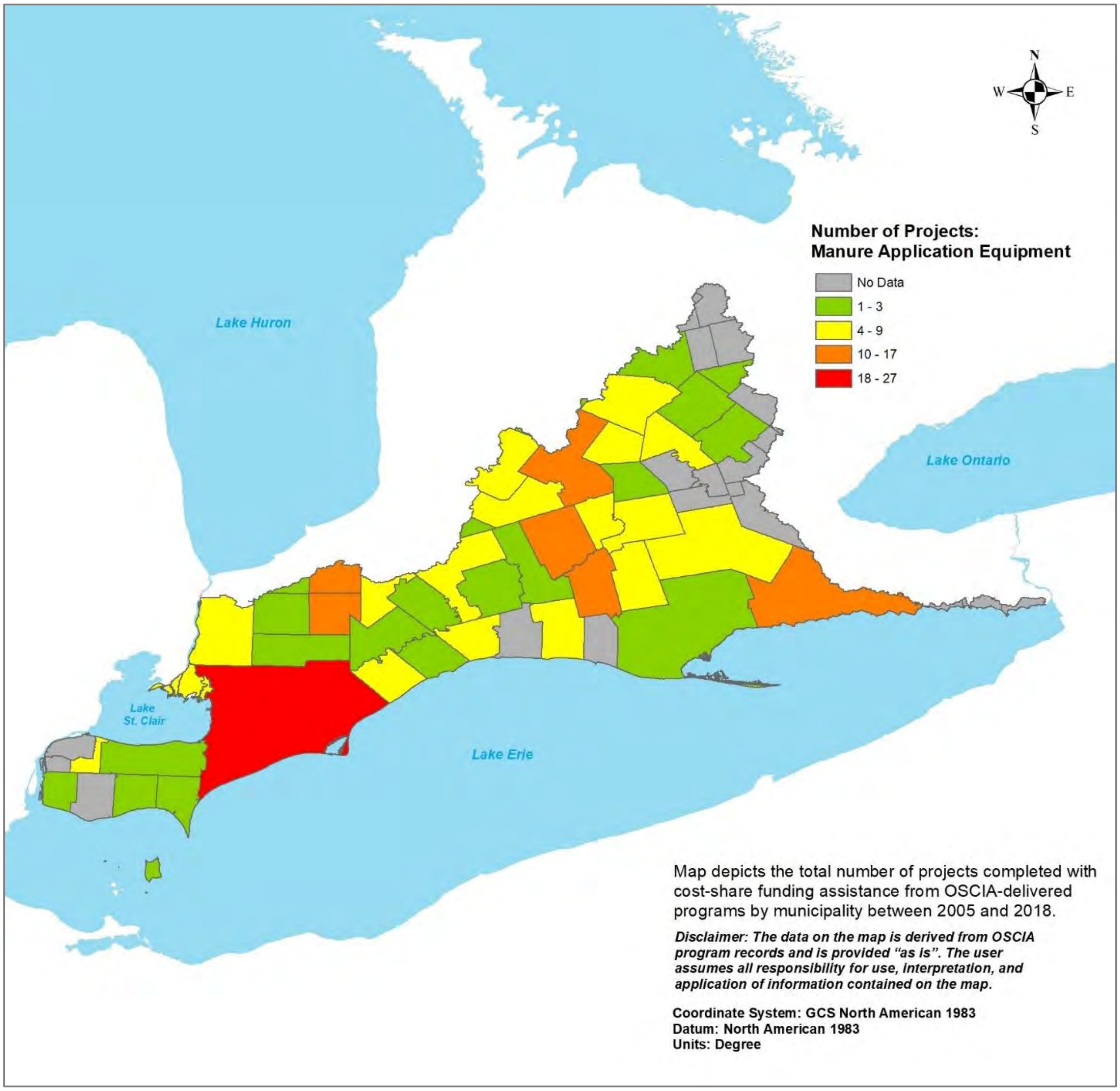


Figure 49: Total Number of Manure Application Equipment Projects by Township

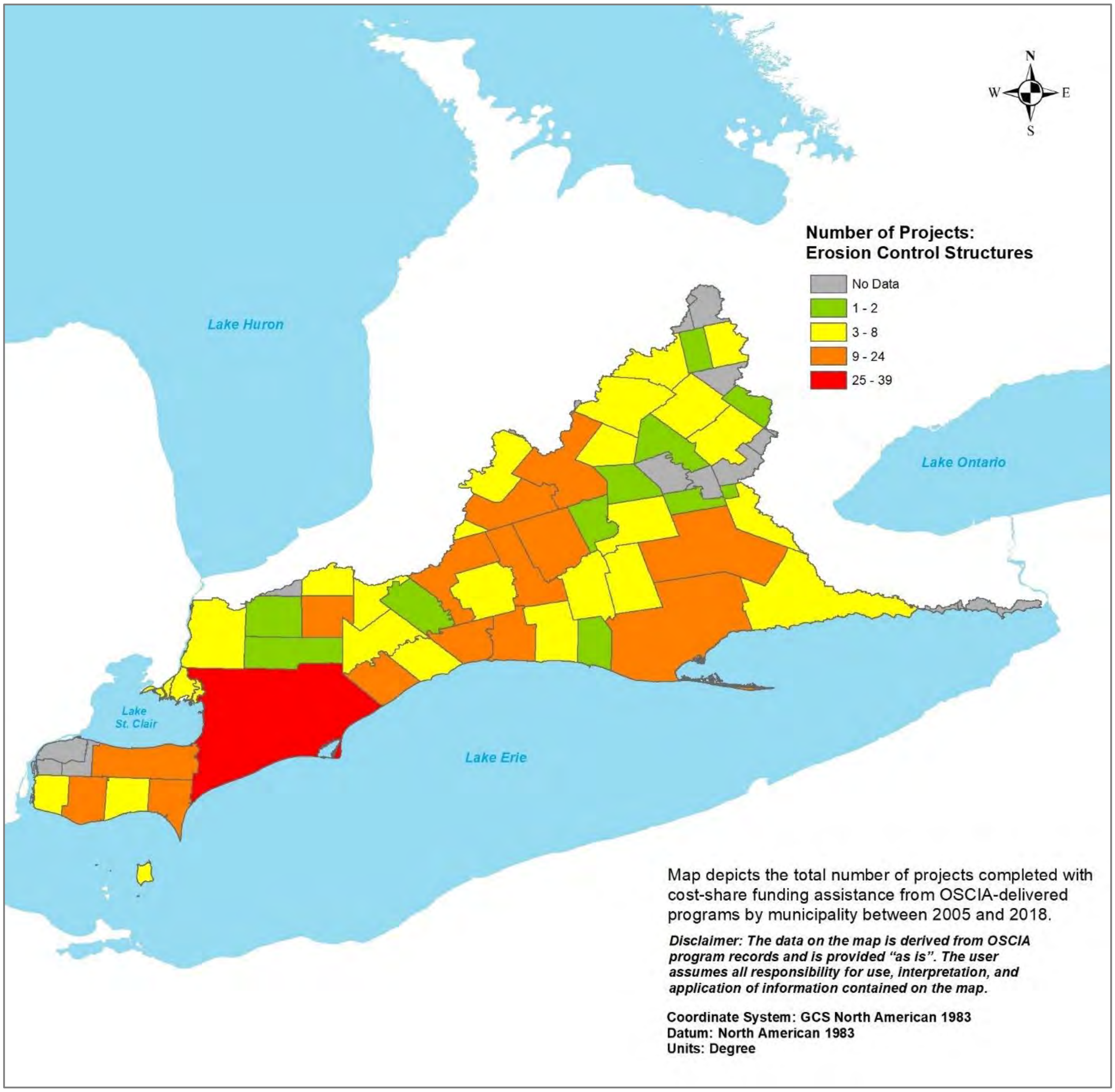


Figure 50: Total Number of Erosion Control Projects by Township

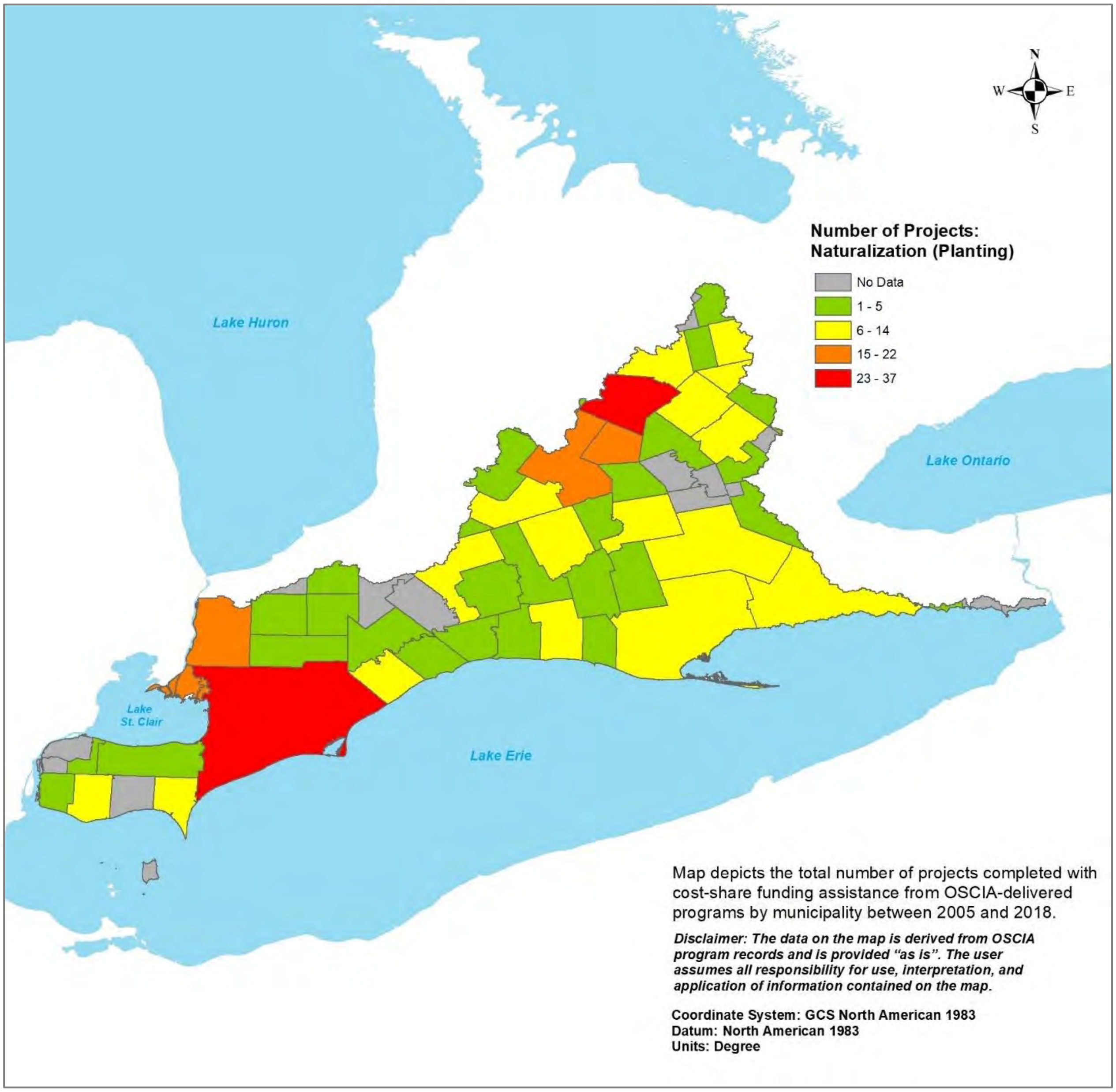


Figure 51: Total Number of Planting Projects by Township

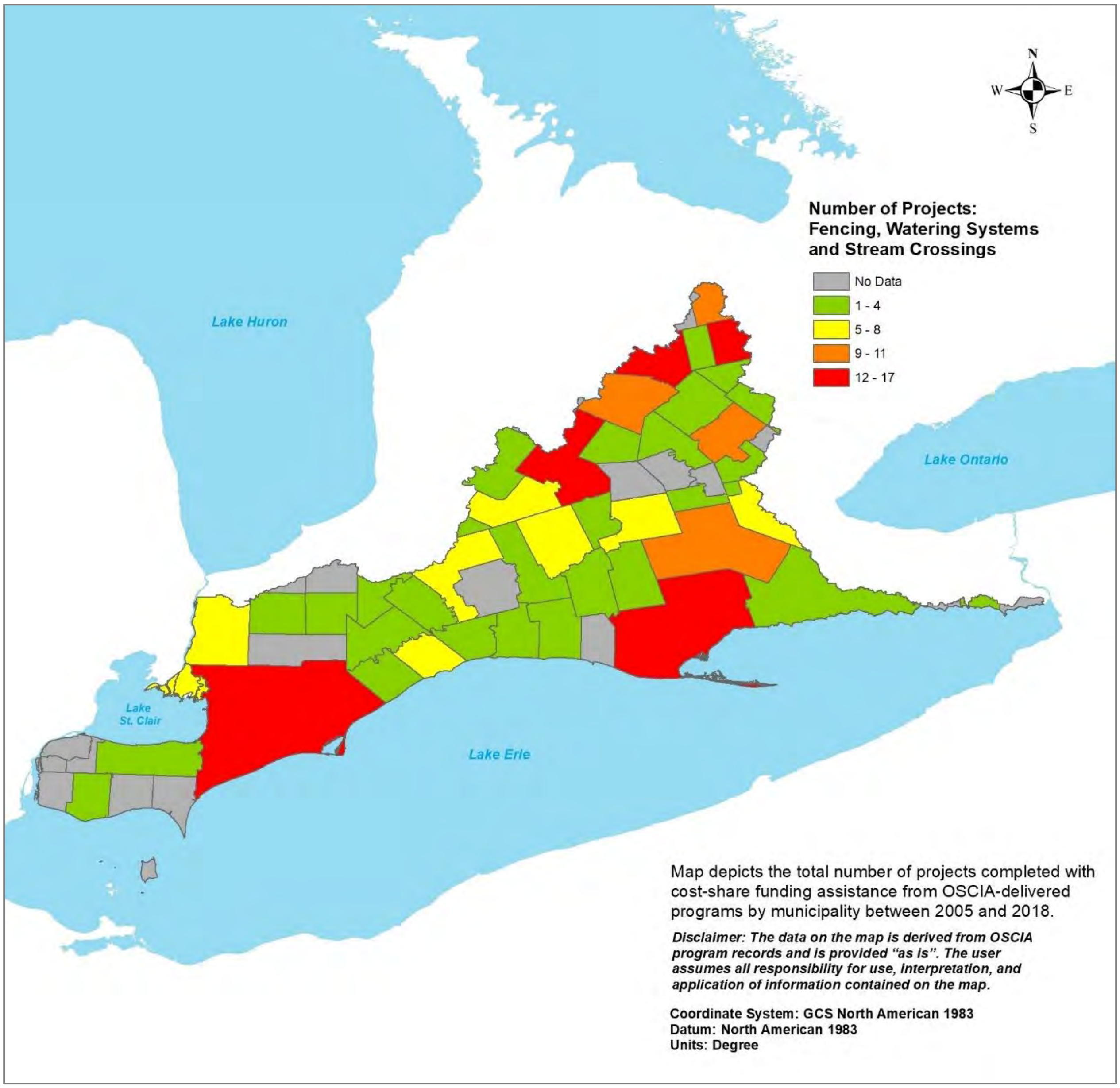


Figure 52: Total Number of Livestock Exclusion Fencing and Stream Crossing Projects by Township

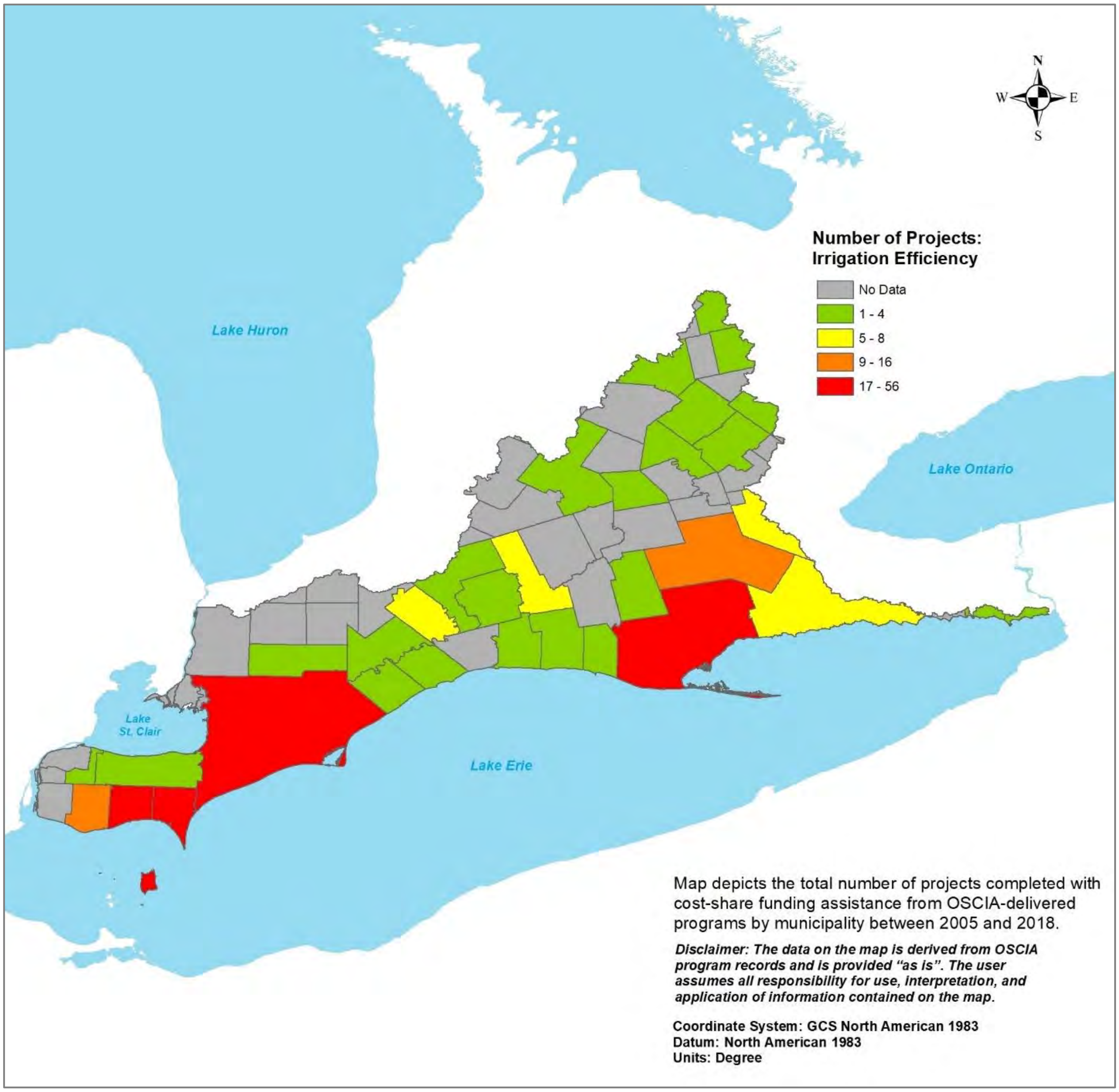


Figure 53: Total Number of Irrigation Efficiency Projects by Township

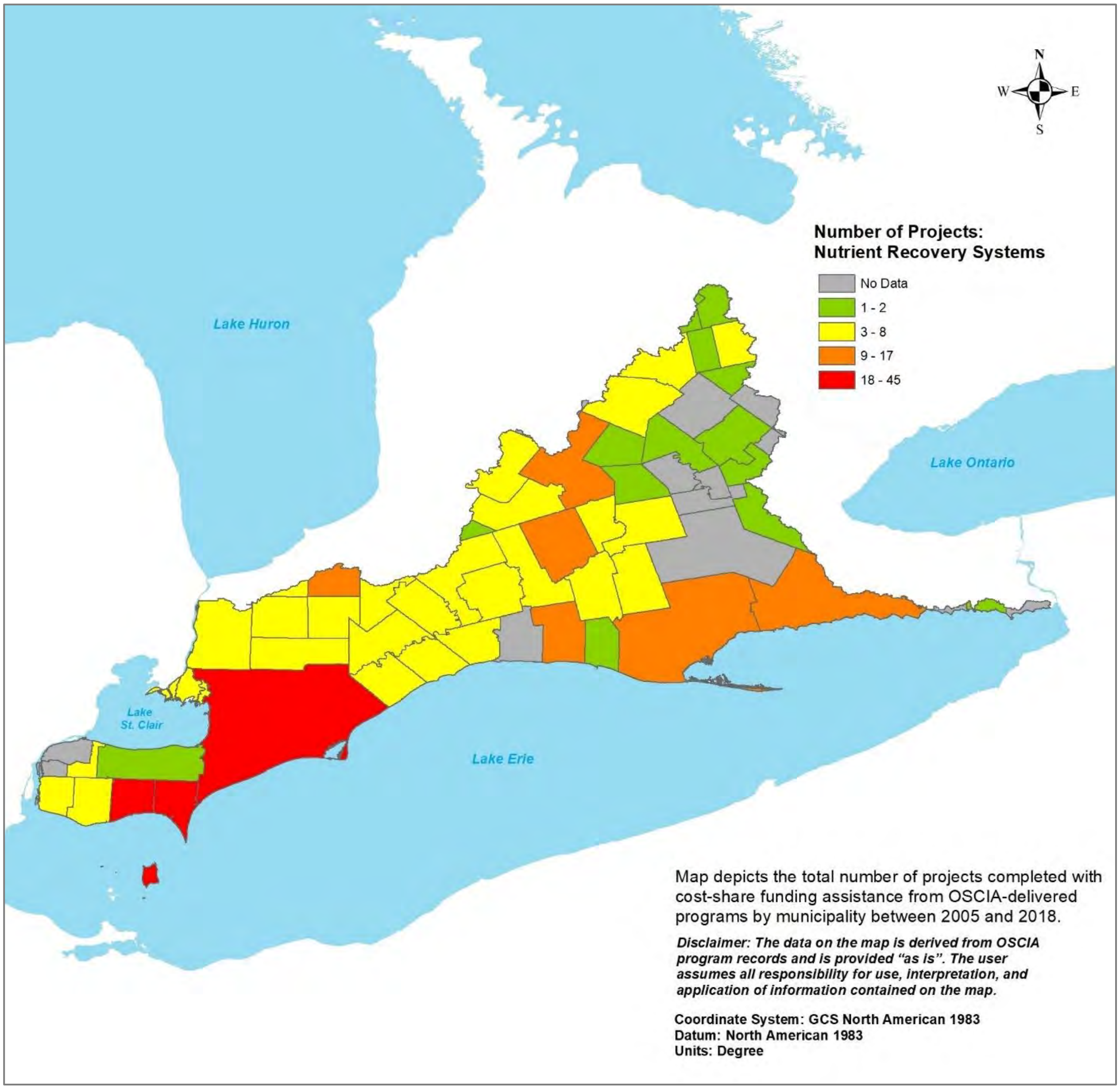


Figure 54: Total Number of Nutrient Recovery System Projects by Township

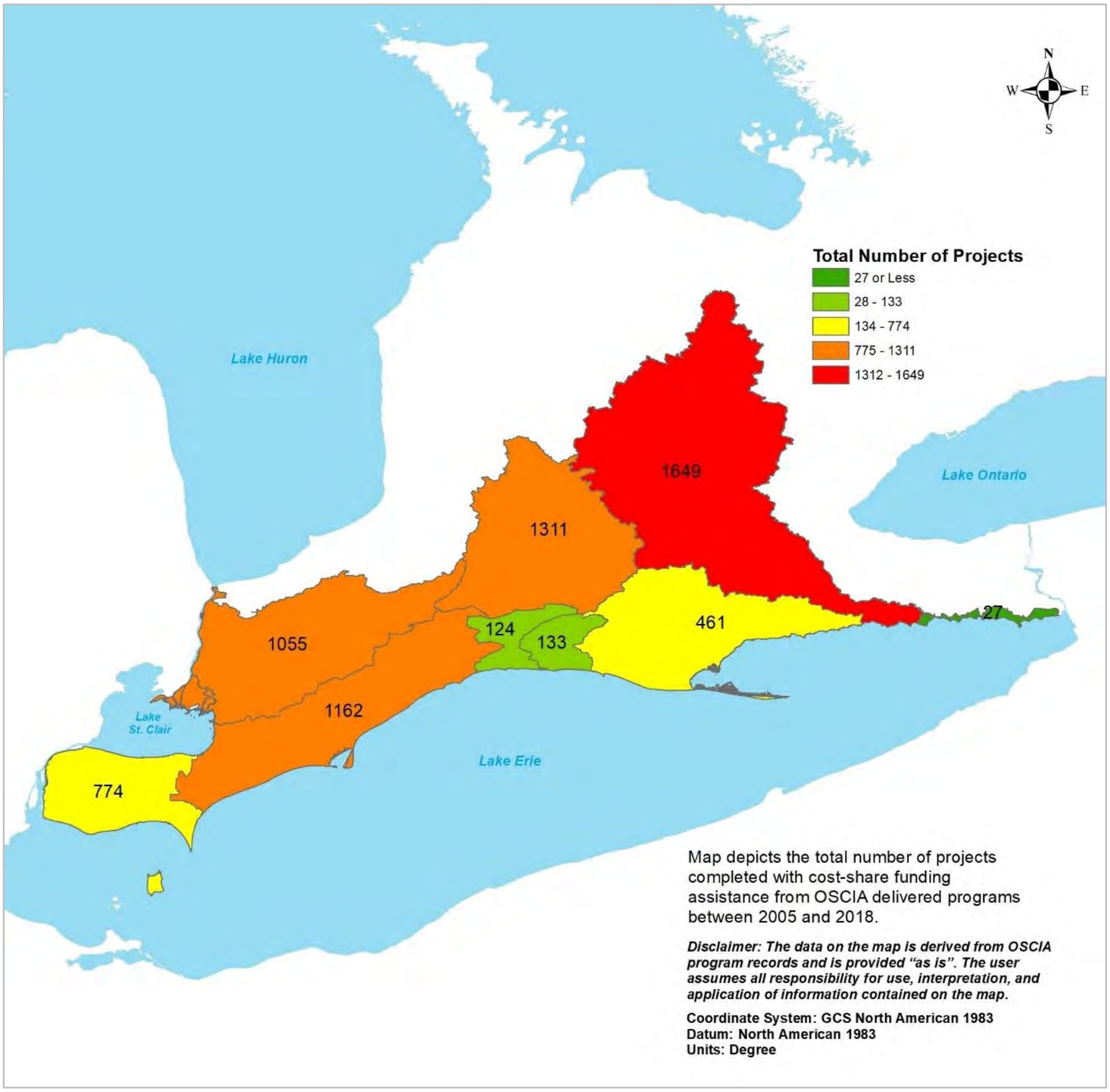


Figure 55: Total Number of Water Quality Projects by Conservation Authority

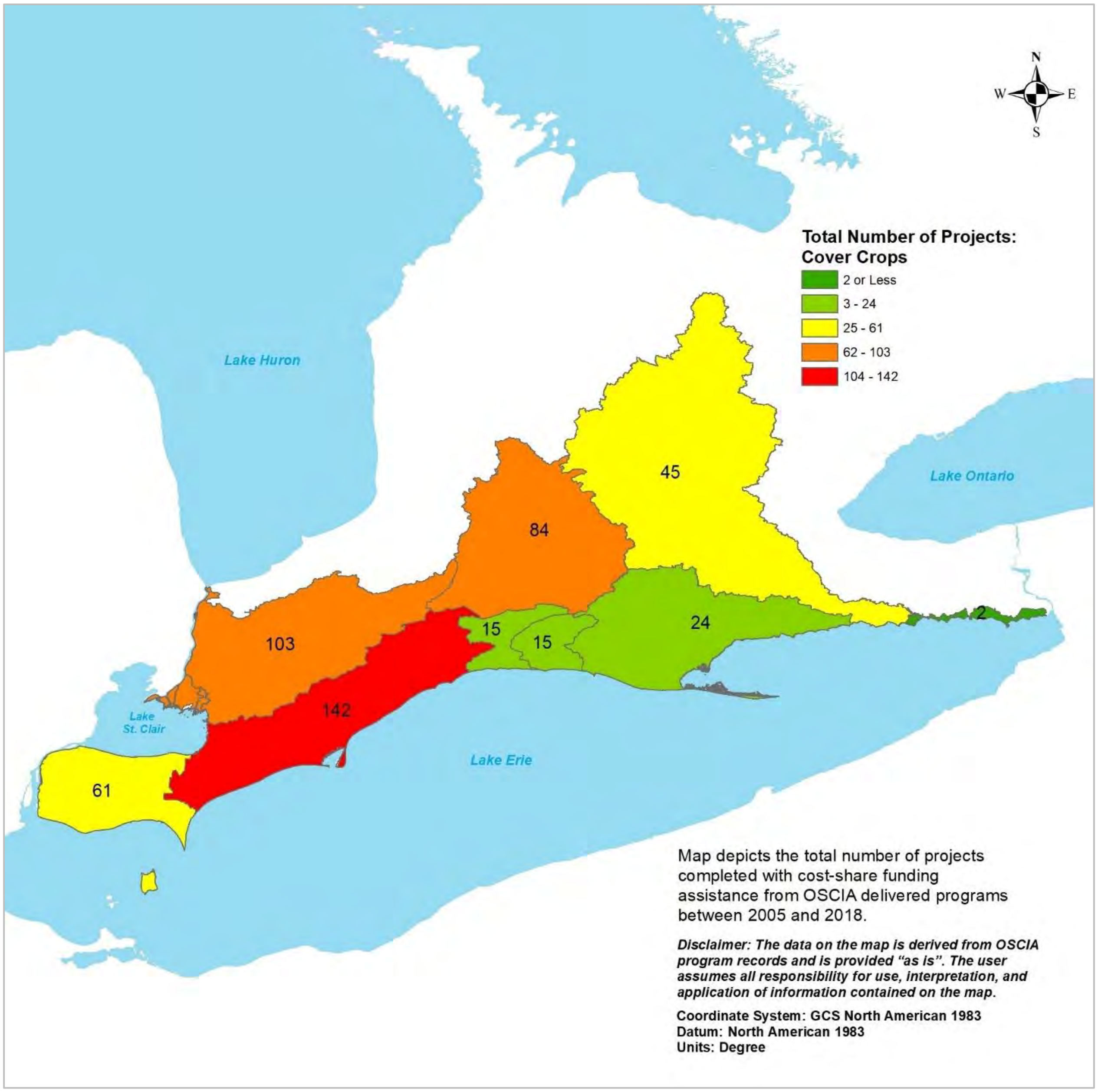


Figure 56: Total Number of Cover Crop Projects by Conservation Authority

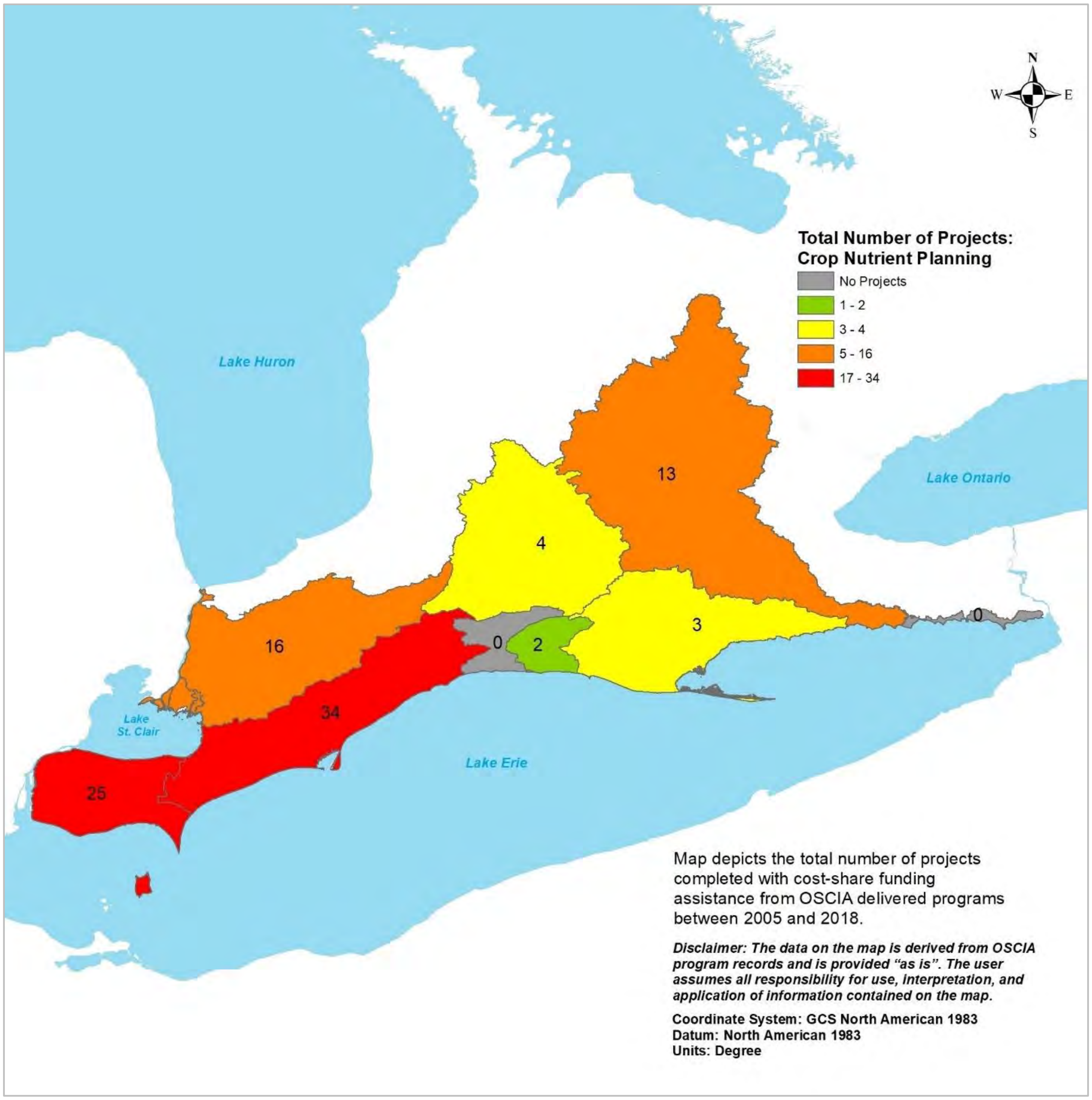


Figure 57: Total Number of Crop Nutrient Planning Projects by Conservation Authority

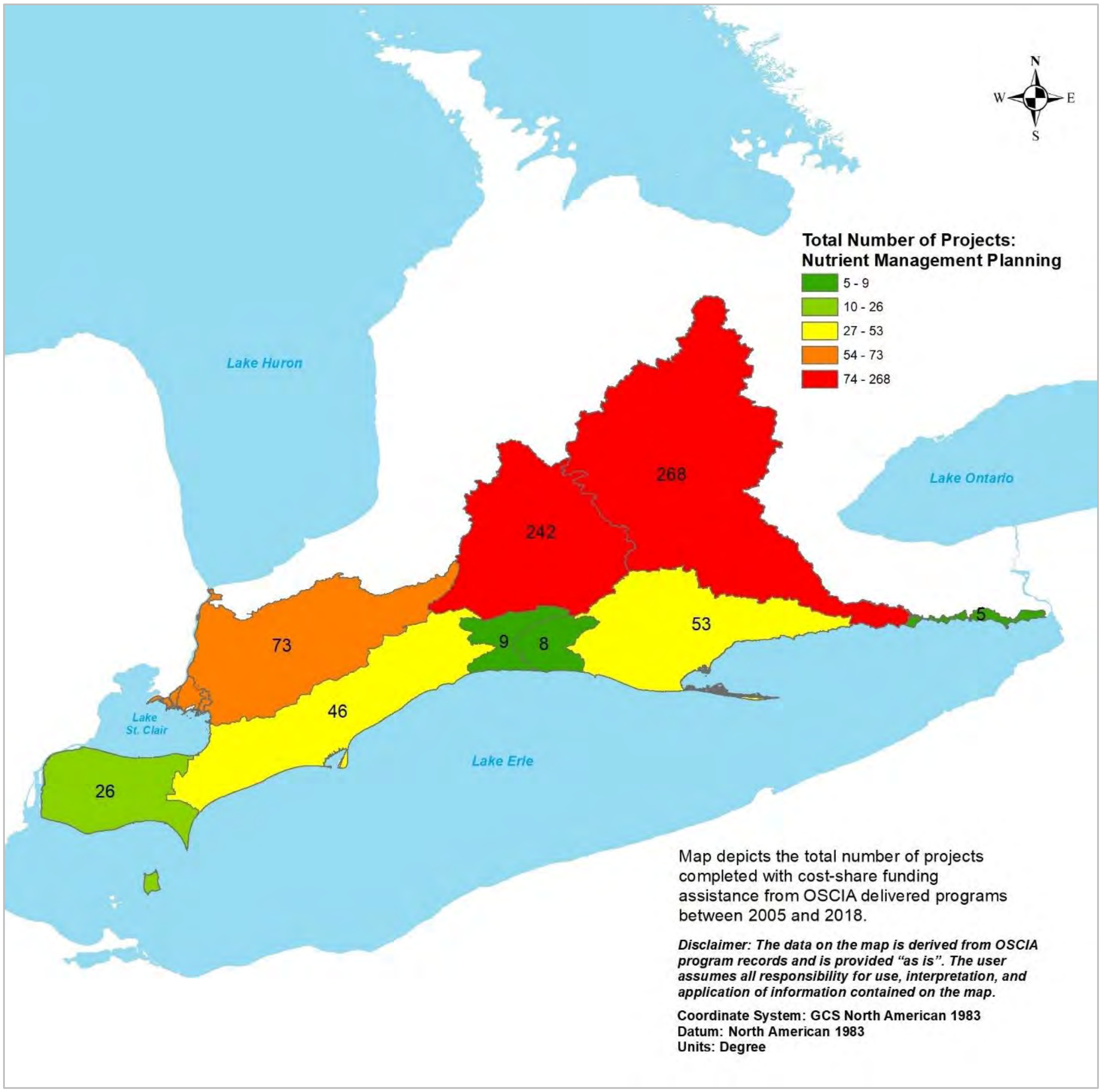


Figure 58: Total Number of Nutrient Management Planning Projects by Conservation Authority

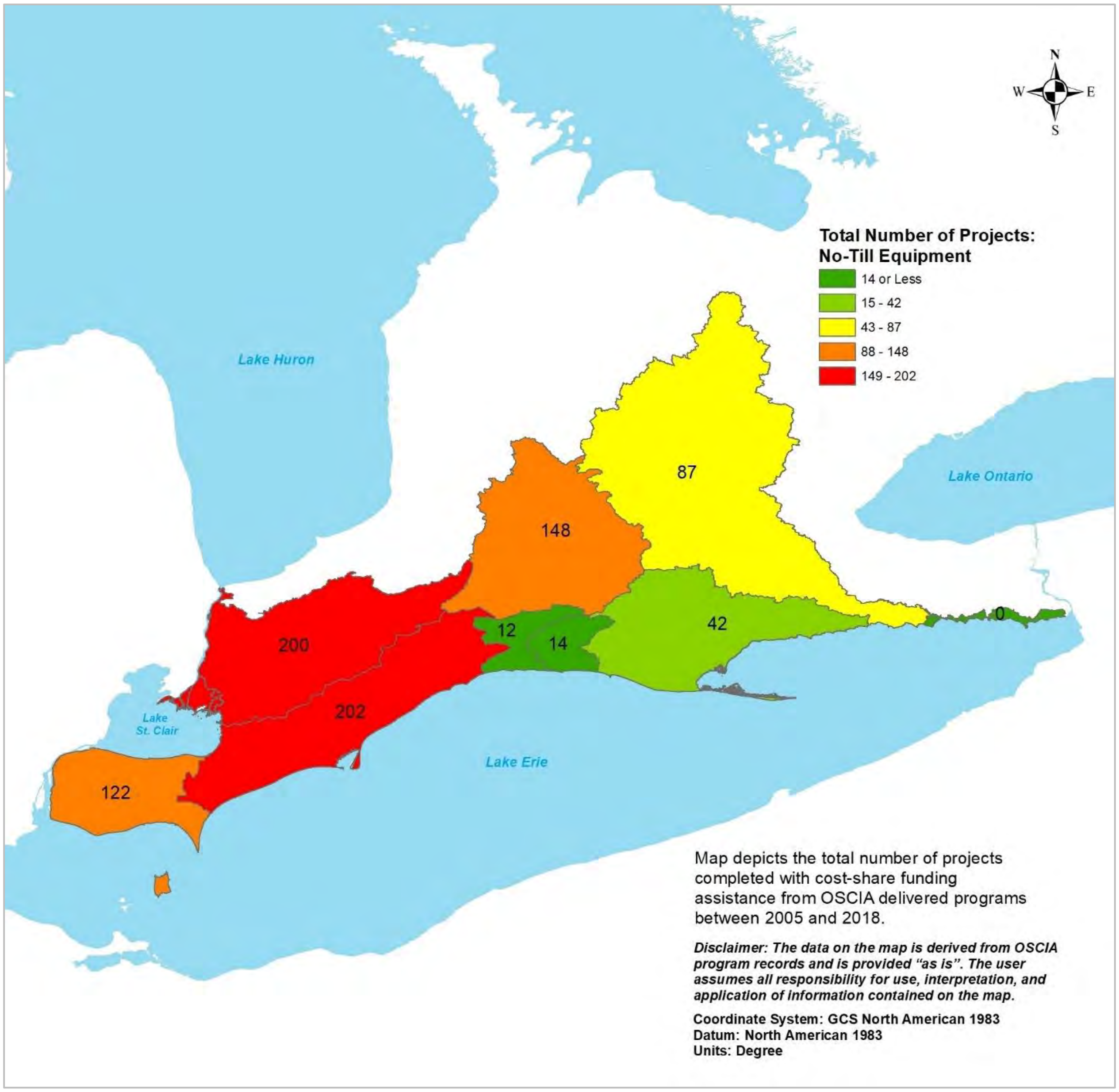


Figure 59: Total Number of No-Till Equipment Projects by Conservation Authority

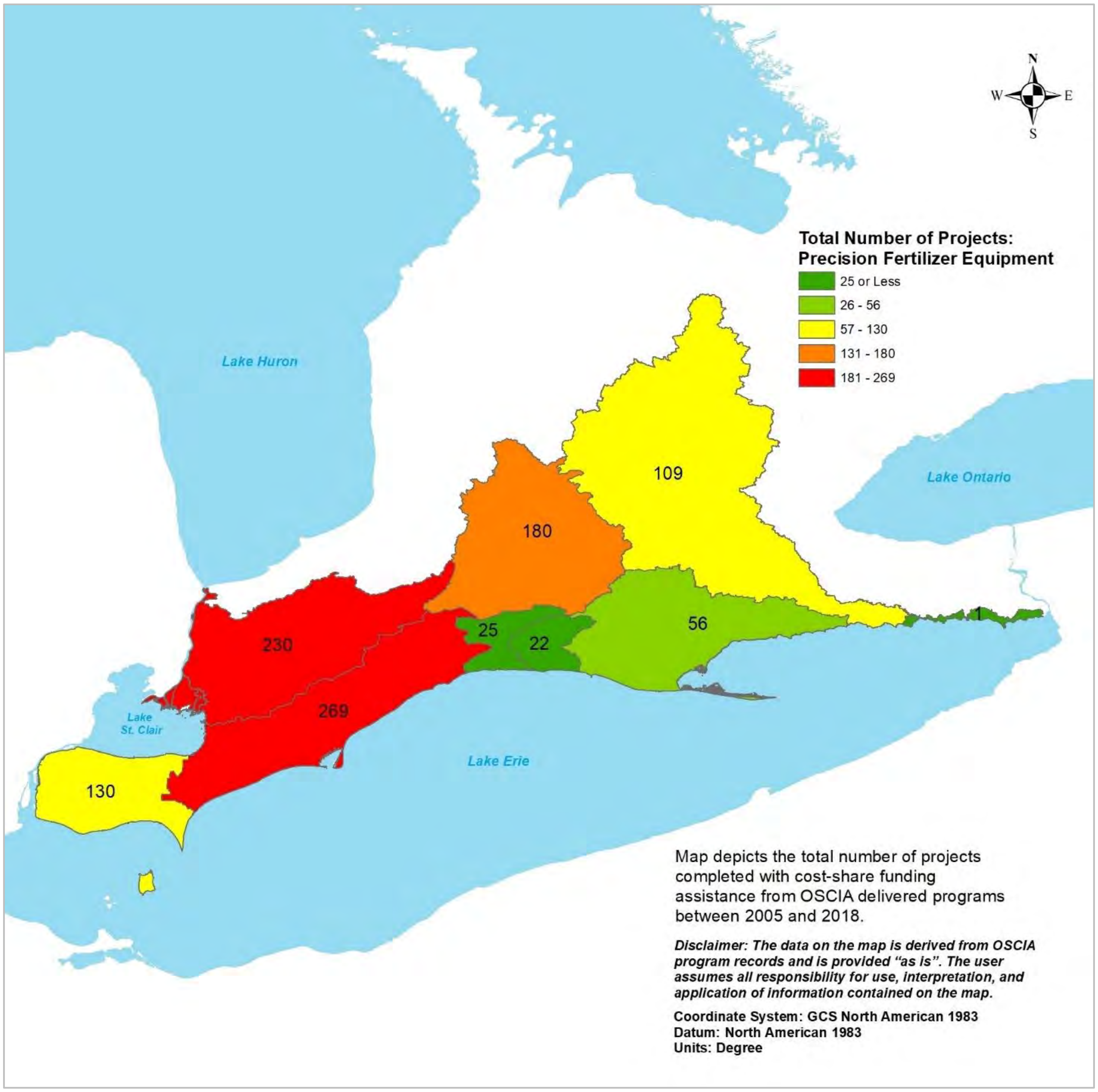


Figure 60: Total Number of Precision Fertilizer Equipment Projects by Conservation Authority

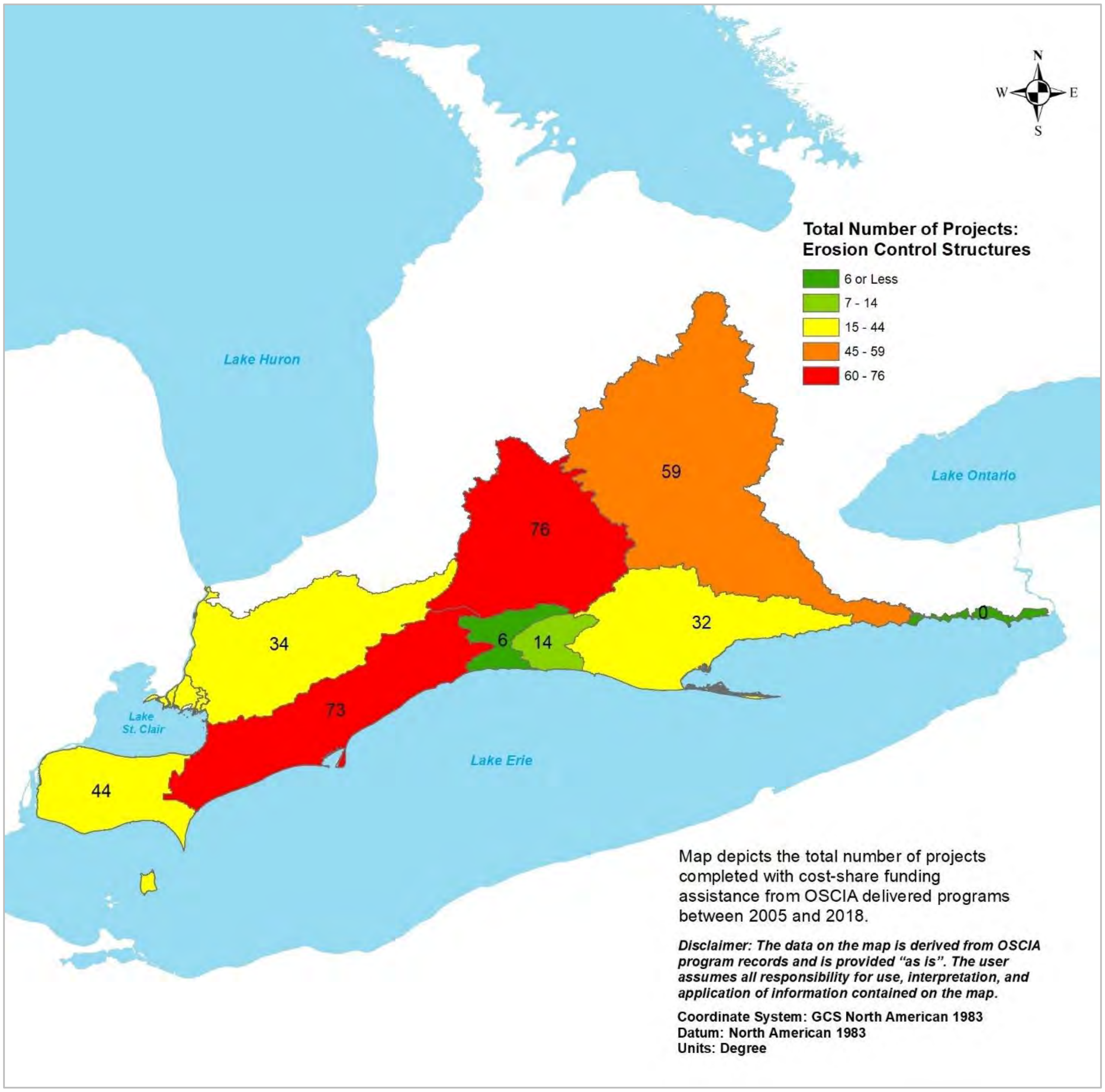


Figure 61: Total Number of Erosion Control Projects by Conservation Authority

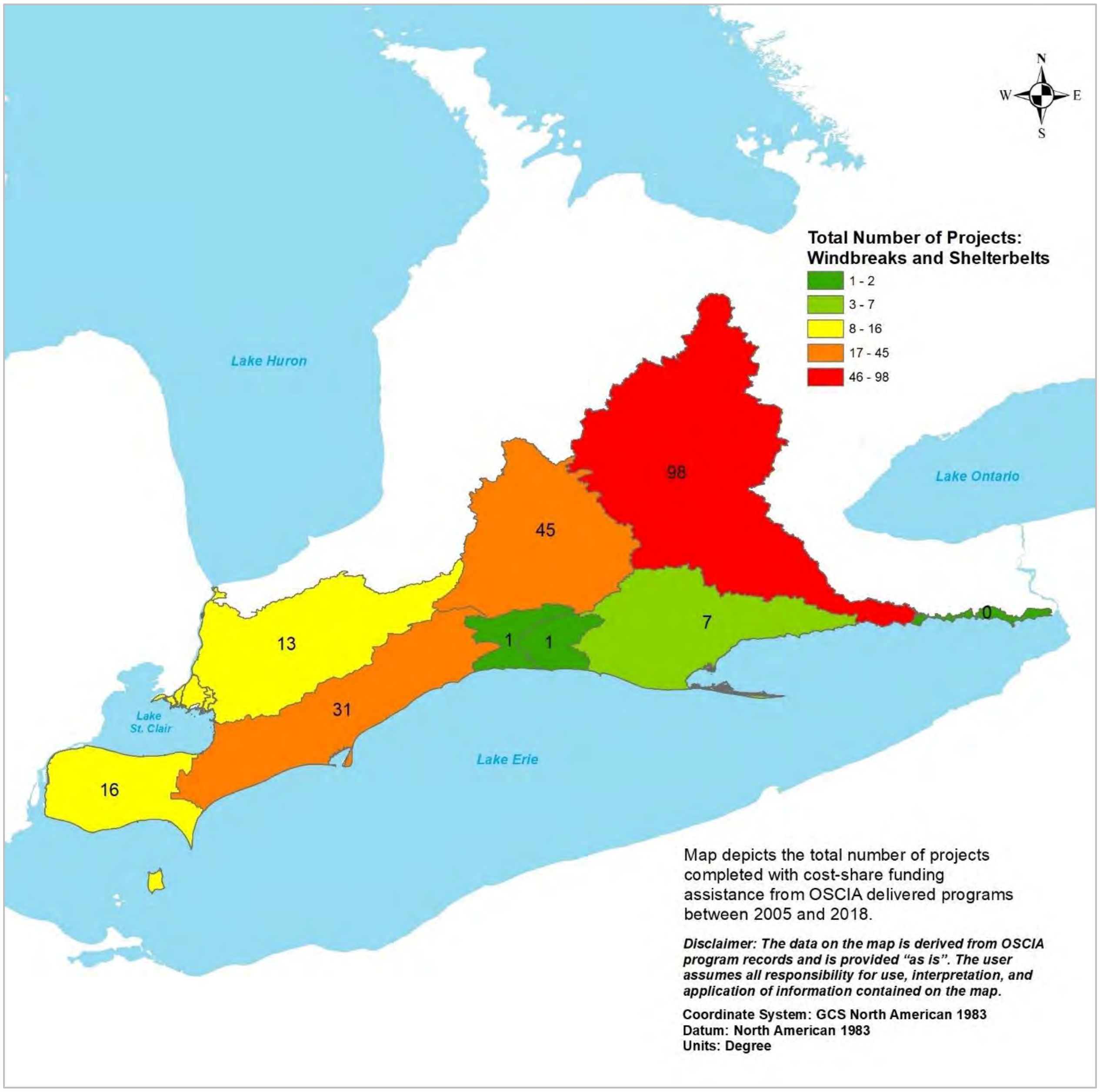


Figure 62: Total Number of Windbreak and Shelterbelt Projects by Conservation Authority

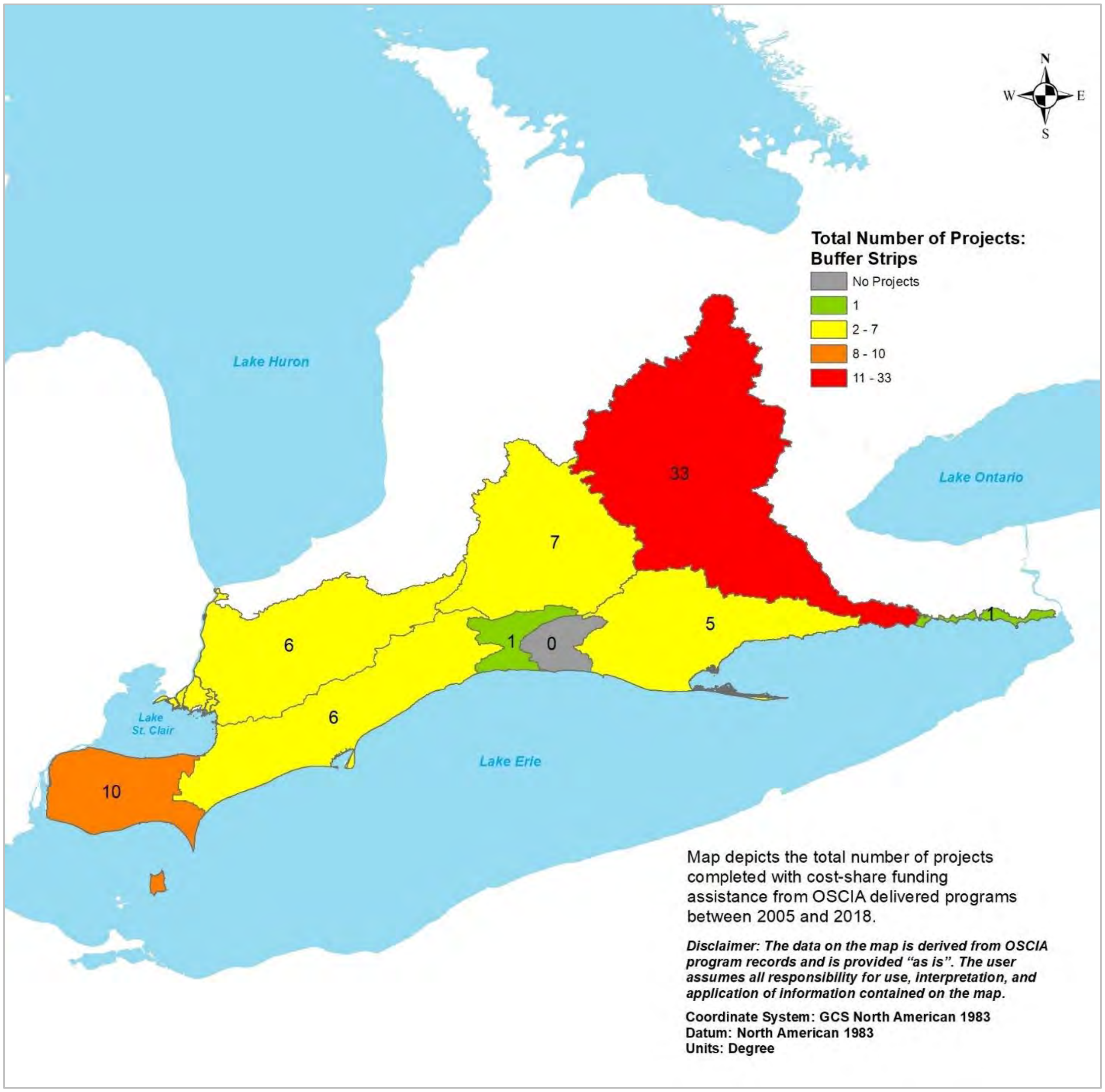


Figure 63: Total Number of Buffer Strip Projects by Conservation Authority

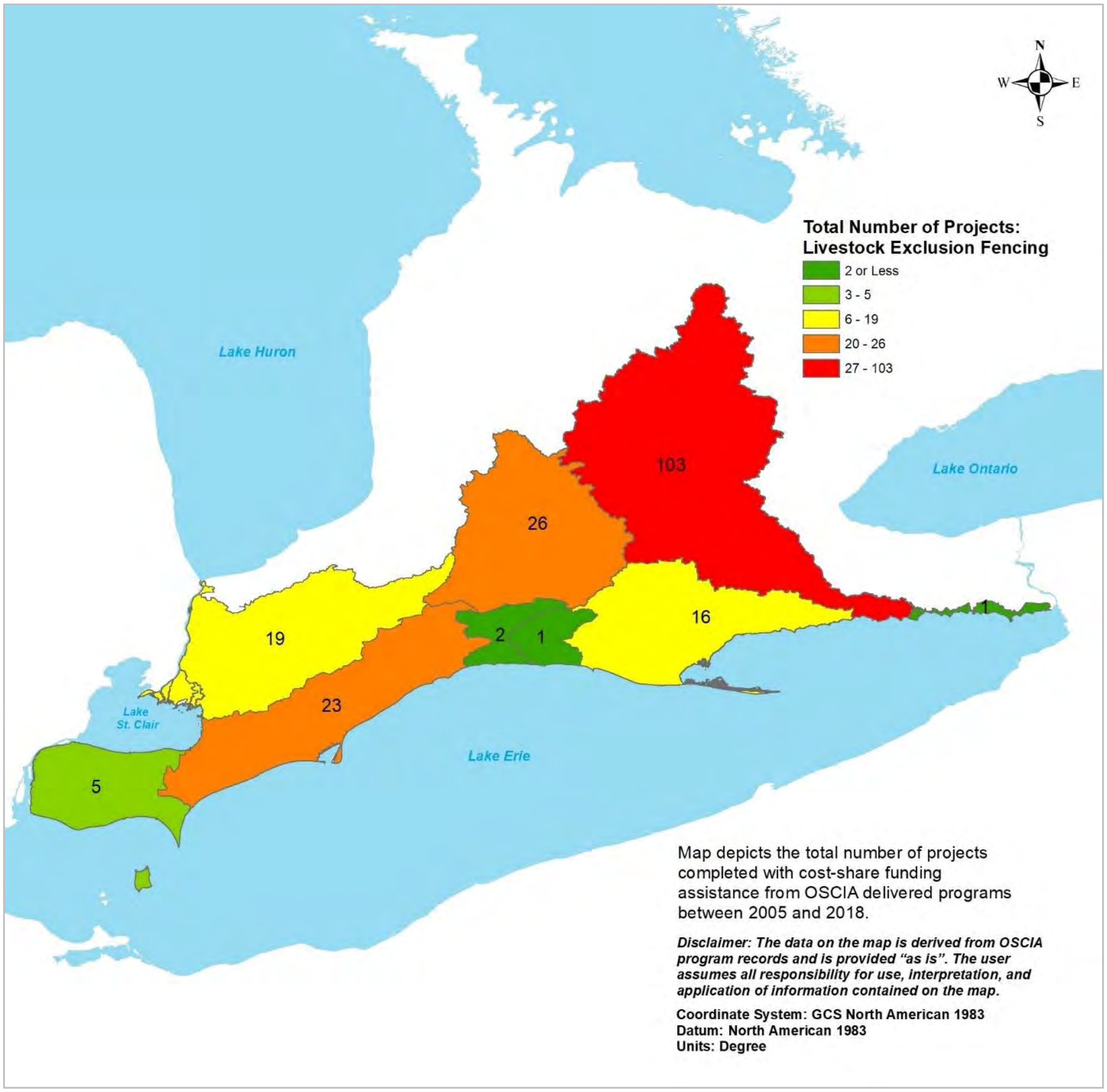


Figure 64: Total Number of Livestock Exclusion Fencing Projects by Conservation Authority

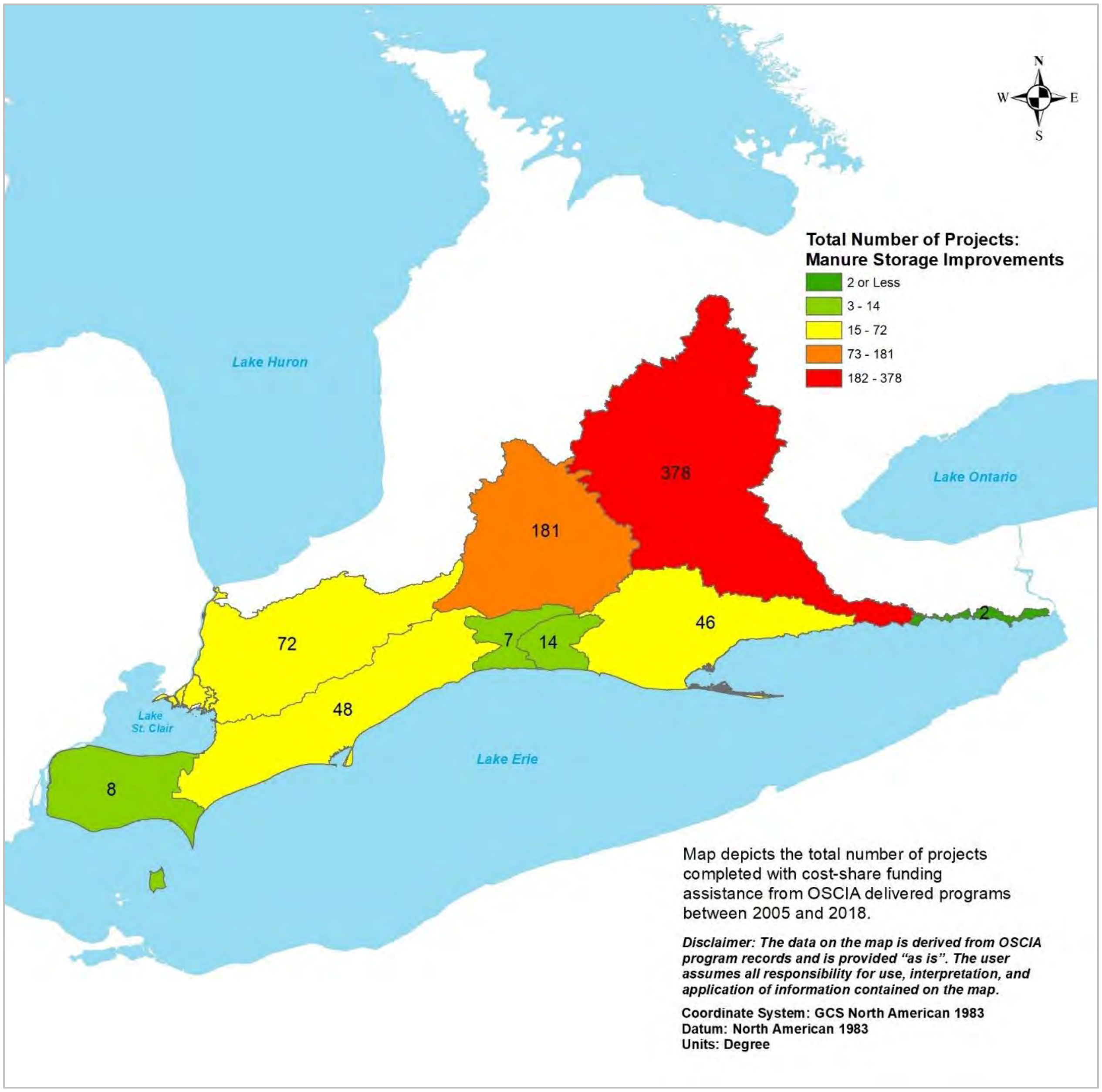


Figure 65: Total Number of Improved Manure Storage Projects by Conservation Authority

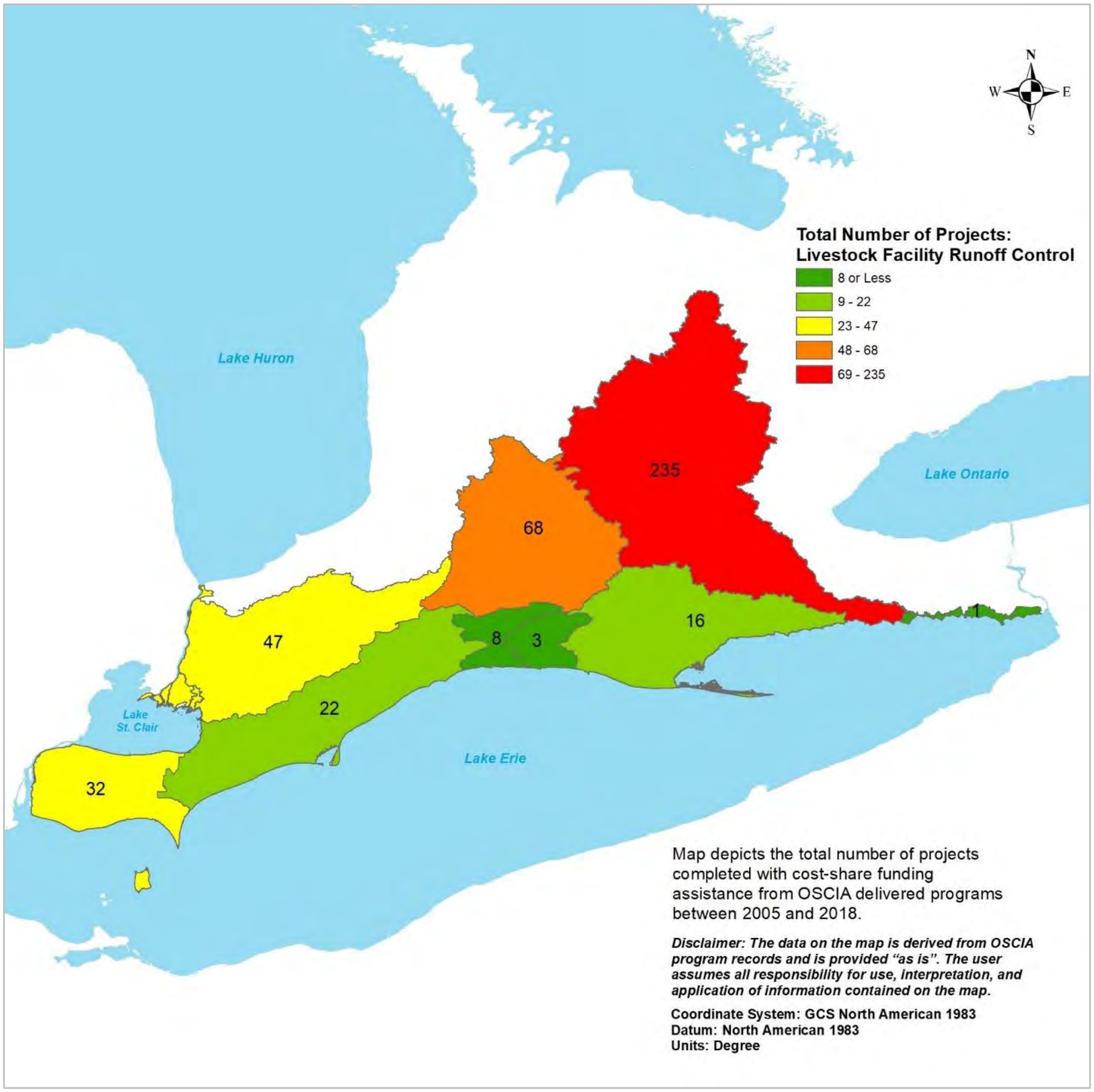


Figure 66: Total Number of Livestock Facility Runoff Control Projects by Conservation Authority

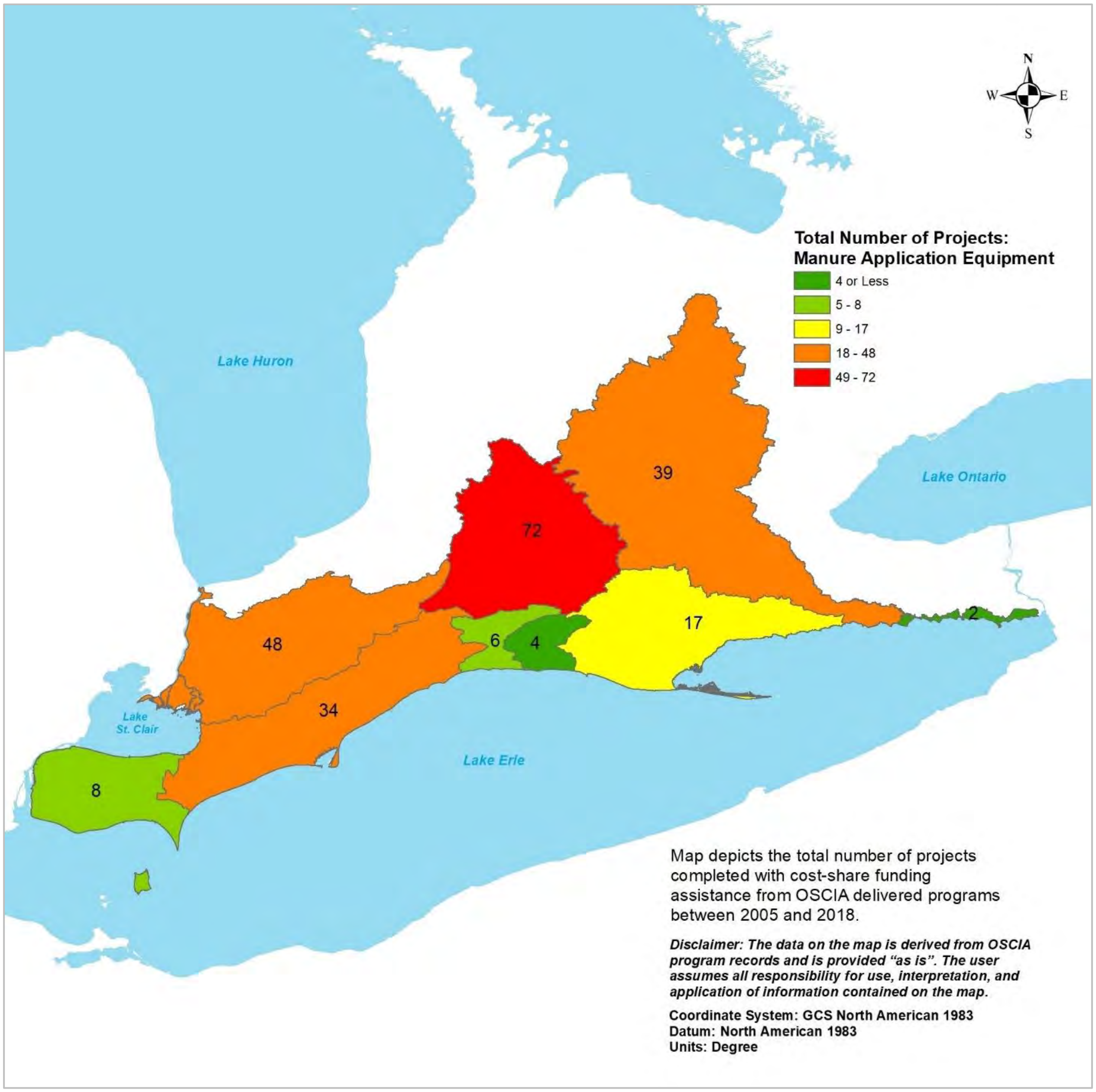


Figure 67: Total Number of Manure Application Equipment Projects by Conservation Authority

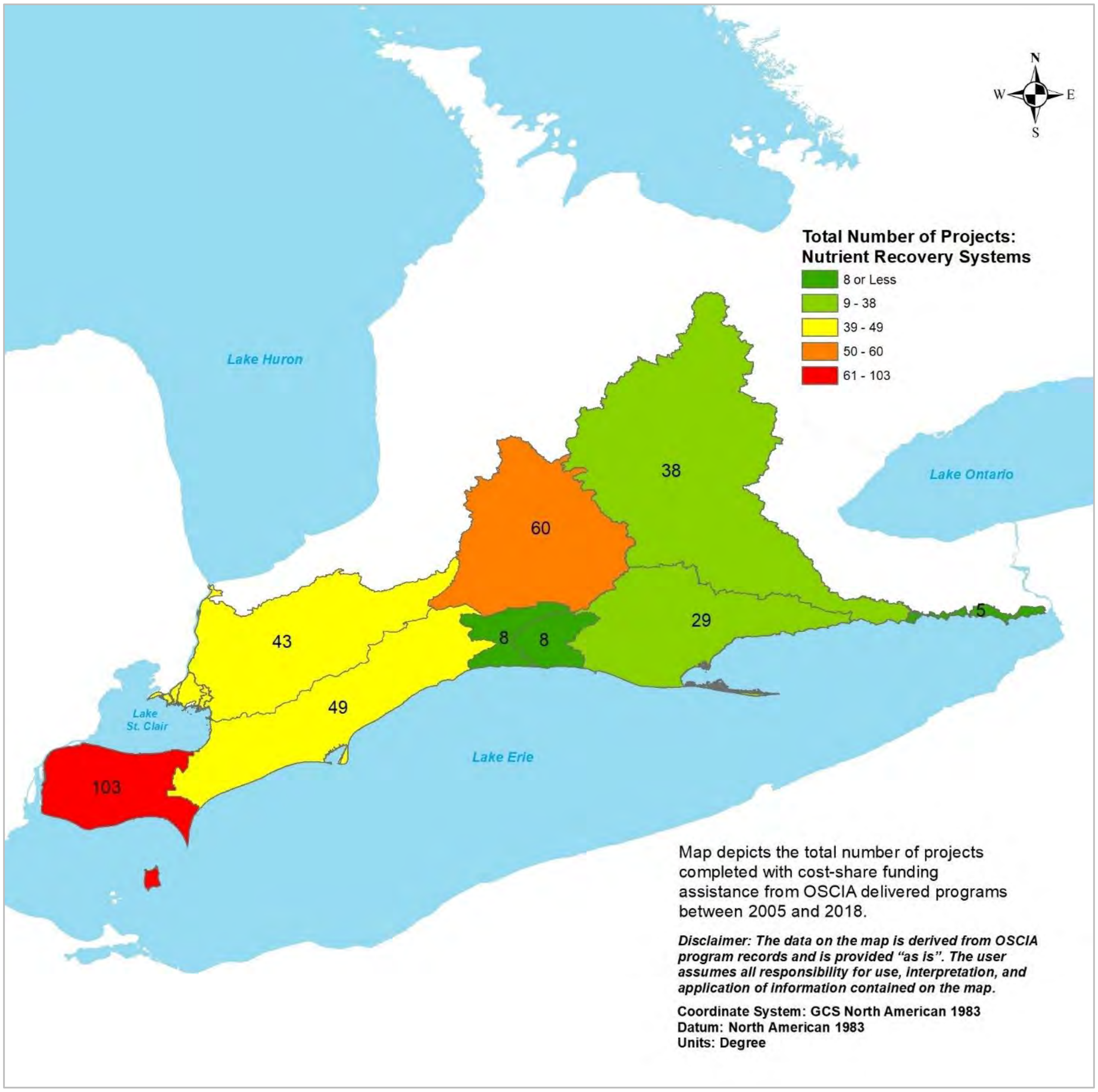


Figure 68: Total Number of Nutrient Recovery Projects by Conservation Authority

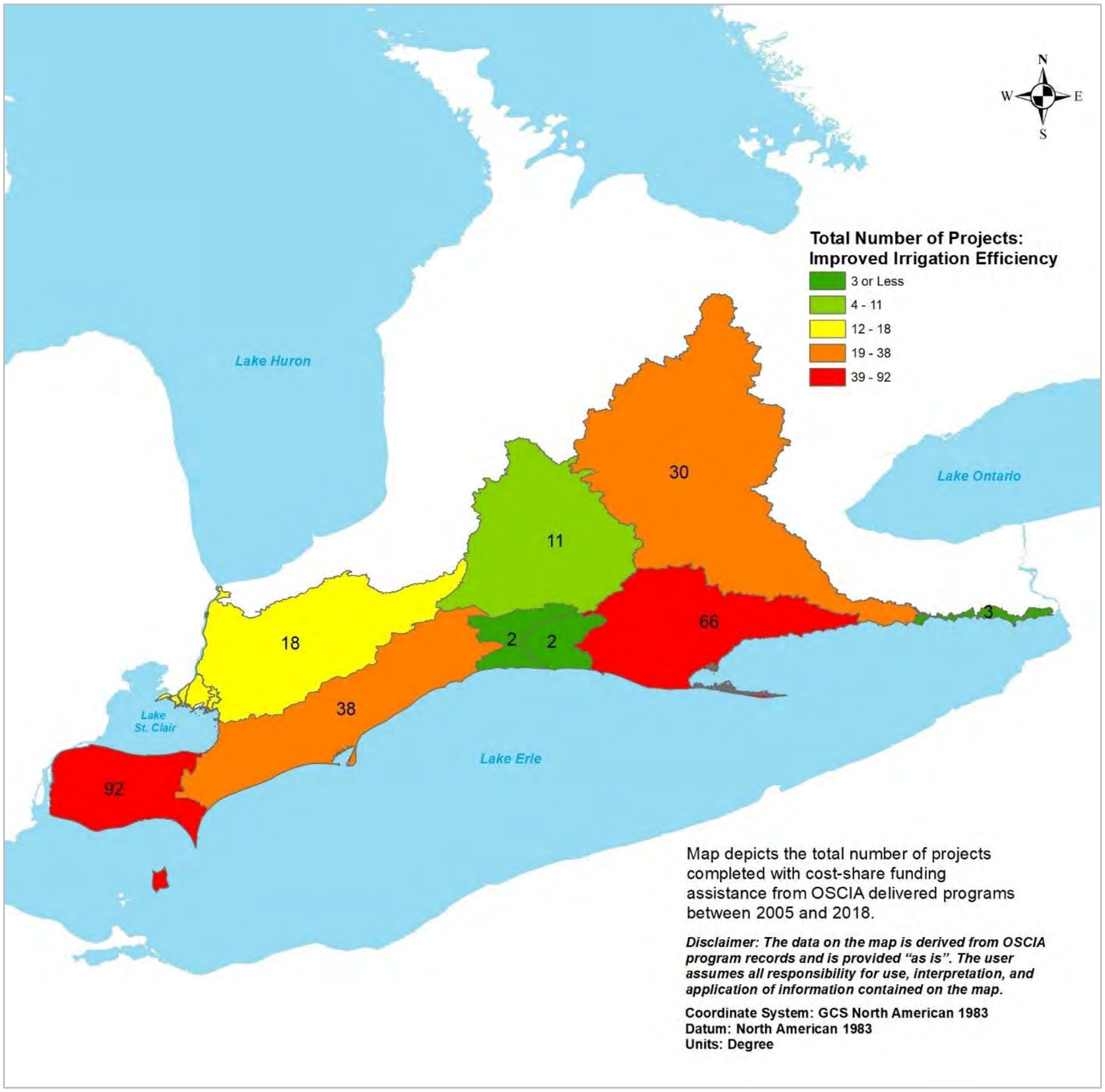


Figure 69: Total Number of Improved Irrigation Efficiency Projects by Conservation Authority

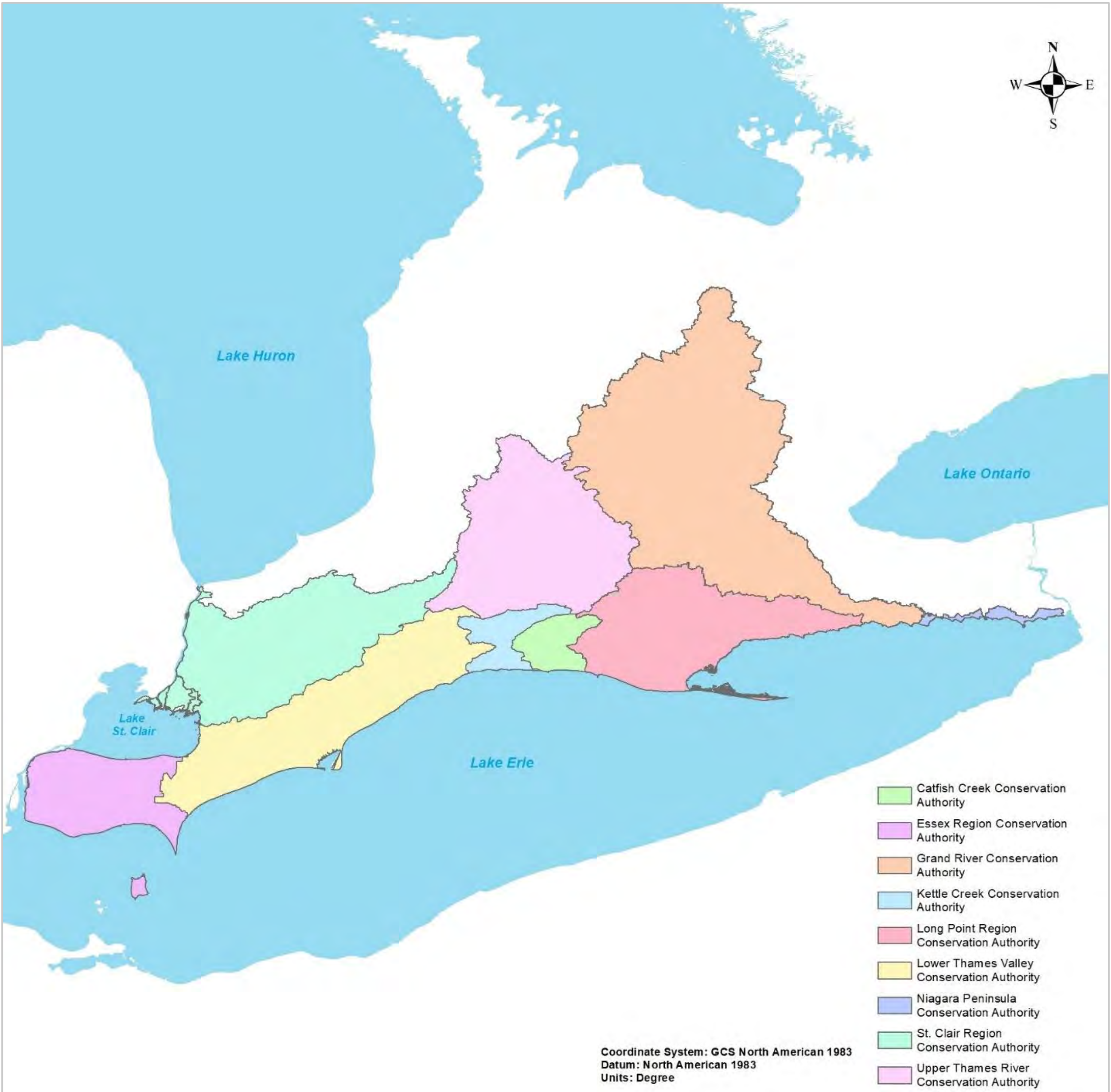


Figure 70: Conservation Authority Watersheds in the Lake Erie Basin

List of Data Tables

To protect farmer confidentially attributed to smaller sample sizes of partial census delineated regions; suppression of data may have been applied if the number of projects was 5 or less. Recall, that some geographic areas are only partially included in the Lake Erie basin.

Table 49: Number of Water Quality Improvement Projects by County (2005-2018)
SOURCE: OSCIA Program Records (2005-2018).

County	Number of Projects	Percentage of Projects	Project Costs	Payment
Brant	130	1.94%	$2,212,571	$734,707
Chatham-Kent	1,105	16.50%	$18,870,286	$5,461,440
Dufferin	213	3.18%	$4,576,414	$1,305,384
Elgin	498	7.44%	$10,652,445	$3,153,453
Essex	781	11.66%	$22,498,550	$6,473,671
Grey	<5	0.07%	$297,503	$57,280
Haldimand-Norfolk	394	5.88%	$11,365,824	$3,165,821
Halton	<5	0.07%	$30,755	$15,378
Hamilton	50	0.75%	$920,076	$302,879
Lambton	580	8.66%	$12,534,937	$3,649,428
Middlesex	661	9.87%	$14,357,742	$4,791,678
Niagara	8	0.12%	$127,874	$45,733
Oxford	644	9.62%	$16,659,132	$4,988,974
Perth	601	8.98%	$16,347,931	$4,933,395
Waterloo	490	7.32%	$16,877,444	$5,393,643
Wellington	531	7.93%	$16,124,782	$4,597,553
Total	**6,696**	**100.00%**	**$164,454,267**	**$49,070,418**

Table 50: Number of Water Quality Improvement Projects by Township (2005-2018)
SOURCE: OSCIA Program Records (2005-2018).

Township	Number of Projects	Percentage of Projects	Project Costs	Payment
Adelaide-Metcalfe	100	1.49%	$2,064,827	$589,402
Amaranth	66	0.99%	$1,193,475	$395,913
Amherstburg	45	0.67%	$749,410	$238,957
Bayham	21	0.31%	$393,904	$112,129
Blandford-Blenheim	89	1.33%	$1,533,009	$433,051
Brant	130	1.94%	$2,212,571	$734,707
Brooke-Alvinston	118	1.76%	$2,615,697	$772,624
Cambridge	<5	0.03%	$81,114	$26,827
Central Elgin	67	1.00%	$1,379,186	$465,011
Centre Wellington	65	0.97%	$2,081,358	$531,328
Chatham-Kent	1105	16.50%	$18,870,286	$5,461,440
Dawn-Euphemia	88	1.31%	$1,539,811	$429,949
Dutton/Dunwich	96	1.43%	$1,978,082	$555,114
East Garafraxa	34	0.51%	$806,126	$213,934
East Zorra-Tavistock	99	1.48%	$2,705,575	$806,768
Enniskillen	62	0.93%	$1,478,586	$378,693
Erin	35	0.52%	$964,188	$289,390

Township	Number of Projects	Percentage of Projects	Project Costs	Payment
Essex	157	2.34%	$3,393,638	$936,950
Fort Erie	<5	0.03%	$5,275	$2,211
Grand Valley	59	0.88%	$1,622,581	$404,055
Guelph/Eramosa	88	1.31%	$2,151,530	$680,644
Haldimand County	155	2.31%	$4,818,103	$1,304,481
Halton Hills	<5	0.03%	$13,907	$6,954
Hamilton	50	0.75%	$920,076	$302,879
Kingsville	206	3.08%	$6,333,366	$1,907,889
Lakeshore	132	1.97%	$2,306,149	$703,791
LaSalle	<5	0.01%	$20,374	$6,112
Leamington	177	2.64%	$8,417,893	$2,290,600
London	75	1.12%	$1,491,057	$477,466
Lucan Biddulph	65	0.97%	$1,779,082	$1,079,000
Malahide	121	1.81%	$3,650,052	$1,007,552
Mapleton	213	3.18%	$7,634,206	$2,156,730
Melanchthon	49	0.73%	$940,715	$285,456
Middlesex Centre	143	2.14%	$3,193,028	$920,746
Milton	<5	0.04%	$16,848	$8,424
Minto	<5	0.04%	$10,307	$5,736
Mono	<5	0.07%	$13,517	$6,026
Norfolk County	239	3.57%	$6,547,721	$1,861,340
North Dumfries	30	0.45%	$946,715	$274,852
North Perth	9	0.13%	$426,842	$154,219
Norwich	127	1.90%	$3,385,874	$986,038
Perth East	300	4.48%	$8,172,564	$2,502,143
Perth South	154	2.30%	$3,840,956	$1,148,031
Plympton-Wyoming	24	0.36%	$787,123	$199,611
Port Colborne	<5	0.06%	$96,013	$30,230
Puslinch	19	0.28%	$456,030	$143,740
Southgate	<5	0.07%	$297,503	$57,280
Southwest Middlesex	96	1.43%	$2,017,376	$576,325
Southwest Oxford	126	1.88%	$3,310,704	$1,071,094
Southwold	107	1.60%	$2,149,444	$685,600
St. Clair	169	2.52%	$3,316,760	$968,187
Strathroy-Caradoc	79	1.18%	$1,553,035	$489,638
Tecumseh	63	0.94%	$1,277,721	$389,372
Thames Centre	103	1.54%	$2,259,337	$659,101
Wainfleet	<5	0.03%	$26,586	$13,293
Warwick	119	1.78%	$2,796,960	$900,363
Wellesley	350	5.23%	$12,526,748	$4,103,072
Wellington North	108	1.61%	$2,827,162	$789,986
West Elgin	86	1.28%	$1,101,776	$328,046
West Perth	138	2.06%	$3,907,569	$1,129,001
Wilmot	55	0.82%	$1,879,485	$542,776
Woolwich	53	0.79%	$1,443,381	$446,116
Zorra	203	3.03%	$5,723,970	$1,692,022
Total	**6,696**	**100.00%**	**$164,454,267**	**$49,070,418**

Table 51: Number of Water Quality Improvement Projects by Conservation Authority (2005-2018)
SOURCE: OSCIA Program Records (2005-2018).

Conservation Authority	Number of Projects	Percentage of Projects	Project Costs	Payment
Grand River	1,649	25%	$47,906,561	$14,370,282
Upper Thames River	1,311	20%	$33,555,147	$10,566,817
Lower Thames Valley	1,162	17%	$21,267,856	$6,246,100
St. Clair Region	1,055	16%	$20,703,046	$6,045,764
Essex Region	774	12%	$22,160,450	$6,389,540
Long Point Region	461	7%	$12,547,829	$3,582,482
Catfish Creek	133	2%	$3,389,472	$1,007,021
Kettle Creek	124	2%	$2,405,711	$695,257
Niagara Peninsula	27	<1%	$518,194	$167,155
Total	**6,696**	**100%**	**$164,454,267**	**$49,070,418**

Table 52: Estimated Program Participation Rate by Township
SOURCE: OSCIA Program Records (2005-2018).

Township	Number of Projects	Number of Participating Farms	Estimated Eligible Census Farms	Estimated Program Participation
Adelaide-Metcalfe	100	45	156	29%
Amaranth	66	29	91	32%
Amherstburg	45	20	125	16%
Bayham	21	14	169	8%
Blandford-Blenheim	89	49	269	18%
Brant	130	77	610	13%
Brooke-Alvinston	118	55	212	26%
Cambridge	<5	<5	22	<5%
Central Elgin	67	31	171	18%
Centre Wellington	65	41	311	13%
Chatham-Kent	1105	451	1,956	23%
Dawn-Euphemia	88	49	267	18%
Dutton/Dunwich	96	38	149	25%
East Garafraxa	34	17	70	24%
East Zorra-Tavistock	99	51	248	21%
Enniskillen	62	33	267	12%
Erin	35	21	90	23%
Essex	157	86	188	46%
Fort Erie	<5	<5	14	7%
Grand Valley	59	27	71	38%
Guelph/Eramosa	88	39	214	18%
Haldimand County	155	80	532	15%
Halton Hills	<5	<5	<5	75%
Hamilton	50	26	122	21%
Huron East	<5	<5	<5	<5%
Kingsville	206	65	274	24%
Kitchener	<5	<5	21	<5%
Lakeshore	132	57	392	15%
LaSalle	<5	<5	33	<5%

Township	Number of Projects	Number of Participating Farms	Estimated Eligible Census Farms	Estimated Program Participation
Leamington	177	64	273	23%
London	75	33	111	30%
Lucan Biddulph	65	28	45	62%
Malahide	121	53	330	16%
Mapleton	213	121	568	21%
Melancthon	49	21	65	32%
Middlesex Centre	143	66	370	18%
Milton	<5	<5	23	<5%
Minto	<5	<5	<5	<5%
Mono	<5	<5	<5	<5%
Norfolk County	239	121	1,170	10%
North Dumfries	30	11	91	12%
North Perth	9	6	11	54%
Norwich	127	71	406	18%
Perth East	300	138	696	20%
Perth South	154	77	342	23%
Plympton-Wyoming	24	12	46	26%
Port Colborne	<5	<5	18	11%
Puslinch	19	12	85	14%
Sarnia	<5	<5	14	<5%
South Huron	<5	<5	17	<5%
Southgate	<5	<5	21	19%
Southwest Middlesex	96	44	243	18%
South-West Oxford	126	62	306	20%
Southwold	107	45	181	25%
St. Clair	169	79	398	20%
Strathroy-Caradoc	79	27	206	13%
Tecumseh	63	12	61	20%
Thames Centre	103	45	318	14%
Wainfleet	<5	<5	14	7%
Warwick	119	52	158	33%
Wellesley	350	147	465	32%
Wellington North	108	45	246	18%
West Elgin	86	34	184	18%
West Perth	138	76	339	22%
Wilmot	55	32	206	16%
Windsor	<5	<5	12	<5%
Woolwich	53	28	433	6%
Zorra	203	99	450	22%
Total	**6,696**	**3,079**	**15,970**	**20%**

Table 53: List of Water Quality Improvement Project Categories by Major BMP Group

BMP Group	Project Category	Number of Projects	Percent of Projects
Conservation Tillage	Equipment - Managing and planting cover crops	22	<1%
Conservation Tillage	Equipment - Modifications to reduce soil compaction	11	<1%
Conservation Tillage	Equipment - No-till planting units or components	827	12%
Conservation Tillage	Equipment - Planting in high-residue situations	75	1%
Conservation Tillage	Equipment - Strip-till units or components	60	1%
Conservation Tillage	Equipment - To enable banding, variable controlled application	1,022	15%
Conservation Tillage	Equipment - Vertical tillage planting units or components	8	<1%
Conservation Tillage	Combine collectors and spreaders to manage chaff	136	2%
Cover crops	Cover crops	491	7%
Erosion control	Erosion control structures	338	5%
Irrigation efficiency	Irrigation water efficiency improvements	262	4%
Manure management	Equipment - Modifications to improve manure application	230	3%
Manure management	Improved manure storage	756	11%
Organic amendments	Adding organic amendments	104	2%
Planning and assessments	Crop nutrient plan	97	1%
Planning and assessments	Nutrient management plan	730	11%
Planning and assessments	Other plans or assessments	68	1%
Protect and restore natural areas	Livestock exclusion fencing	155	2%
Protect and restore natural areas	Alternative watering system	41	1%
Protect and restore natural areas	Buffer strips	69	1%
Protect and restore natural areas	Fragile land retirement	3	<1%
Protect and restore natural areas	Grassland restoration	21	<1%
Protect and restore natural areas	Improved stream crossings	23	<1%
Protect and restore natural areas	Reforestation	32	<1%
Protect and restore natural areas	Wetland restoration	42	1%
Protect and restore natural areas	Windbreak and Shelterbelts	212	3%
Runoff prevention and recovery	Nutrient recovery from wastewater	343	5%
Runoff prevention and recovery	Livestock and facility runoff control	432	6%
Runoff prevention and recovery	Product and waste management	80	1%
Septic systems	Septic systems	5	<1%
Total		**6,696**	**100%**