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NUTRIENT INPUTS TO THE LAURENTIAN GREAT LAKES BY SOURCE AND WATERSHED ESTIMATED USING SPARROW WATERSHED MODELS[1]

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ABSTRACT: Nutrient input to the Laurentian Great Lakes continues to cause problems with eutrophication. To reduce the extent and severity of these problems, target nutrient loads were established and Total Maximum Daily Loads are being developed for many tributaries. Without detailed loading information it is difficult to determine if the targets are being met and how to prioritize rehabilitation efforts. To help address these issues, SPAtially Referenced Regressions On Watershed attributes (SPARROW) models were developed for estimating loads and sources of phosphorus (P) and nitrogen (N) from the United States (U.S.) portion of the Great Lakes, Upper Mississippi, Ohio, and Red River Basins. Results indicated that recent U.S. loadings to Lakes Michigan and Ontario are similar to those in the 1980s, whereas loadings to Lakes Superior, Huron, and Erie decreased. Highest loads were from tributaries with the largest watersheds, whereas highest yields were from areas with intense agriculture and large point sources of nutrients. Tributaries were ranked based on their relative loads and yields to each lake. Input from agricultural areas was a significant source of nutrients, contributing ~33-44% of the P and ~33-58% of the N, except for areas around Superior with little agriculture. Point sources were also significant, contributing ~14-44% of the P and 13-34% of the N. Watersheds around Lake Erie contributed nutrients at the highest rate (similar to intensively farmed areas in the Midwest) because they have the largest nutrient inputs and highest delivery ratio.

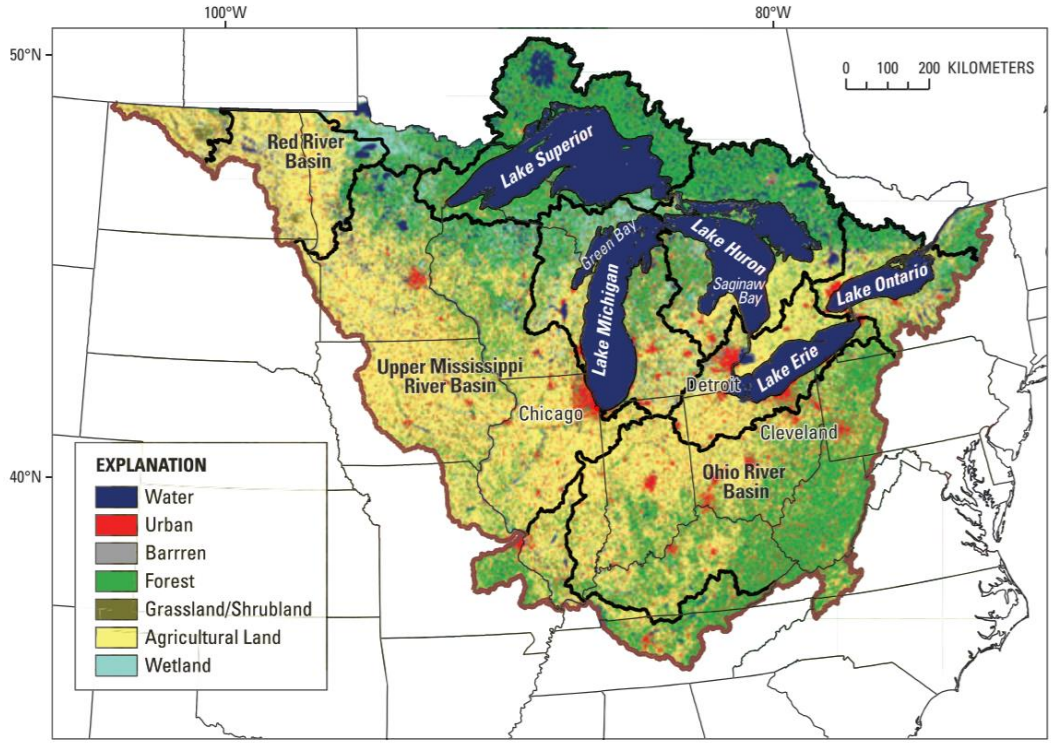


FIGURE 1. Land Use and Land Cover Across the Great Lakes Basin and Upper Midwest With Selected Metropolitan Centers Identified (U.S. drainage, USGS, 2000; Canadian Drainage, Geobase, 2009). Major River Basin #3 (MRB3) represents the U.S. portion of this area. All major basins are delineated.

TABLE 1. Morphometric Characteristics, Drainage-Basin Size, and Total Target Annual Phosphorus Load for Each Great Lake.

Great Lake	Lake Area (km^2)[1]	Lake Volume (km^3)[1]	Mean Depth (m)	Drainage Area (km^2)[1]	U.S. Drainage Area (km^2)	Drainage Area-to-Surface Area Ratio	Target Annual Phosphorus Load[2] (tonnes – to the entire lake)
Superior	82,100	12,100	147	124,115	43,594	1.5	3,400
Michigan	57,800	4,920	85	116,396	116,395	2.0	5,600
Huron	59,600	3,540	59	131,614	41,369	2.2	2,800
Erie	25,700	484	19	77,519	55,488	3.0	11,000
Ontario	18,960	1,640	86	63,750	35,661	3.4	7,000

[1]Great Lakes Information Network (2009).
[2]Target loads specified in Annex 2 of the Great Lakes Water Quality Agreement of 1972.

TABLE 4. Estimated Annual Loading and Yields of TP and TN Into Each Great Lake, Normalized to 2002.

		Total Phosphorus						Total Nitrogen		
Great Lake	U.S. Drainage Area (km^2)	2002 Total U.S. Load (tonnes)[1]	2002 Total U.S. Yield (kg/km^2)[1]	Delivery Ratio[2]	2002 Total U.S. Load From Direct Point Sources (tonnes)	2002 U.S. "Watershed" Loading (tonnes)	1983-1985 U.S. "Watershed" Loading (tonnes)[3]	2002 Total U.S. Load (tonnes)[1]	2002 Total U.S. Yield (kg/km^2)[1]	Delivered Load to Total Nondecayed Load Ratio
Superior	43,594	782	17.9	0.92	75	707	1,500	10,900	250	0.91
Michigan	116,395	3,430	29.5	0.86	374	3,060	3,230	70,000	601	0.84
Huron	41,369	927	22.4	0.91	126	801	1,550	25,900	625	0.89
Erie	55,488	4,610	83.1	0.96	1,150	3,470	5,670	136,000	2,450	0.96
Ontario	35,661	1,800	50.6	0.89	464	1,340	1,270	32,800	919	0.86

Notes: TP, total P; TN, total N.
[1]Loads and yields from the U.S. part of each lake's watershed, and do not include direct atmospheric deposition.
[2]The delivery ratio is computed as the total delivered load divided by the total nondecayed load.
[3]Loads from Rathke and McRae (1989).

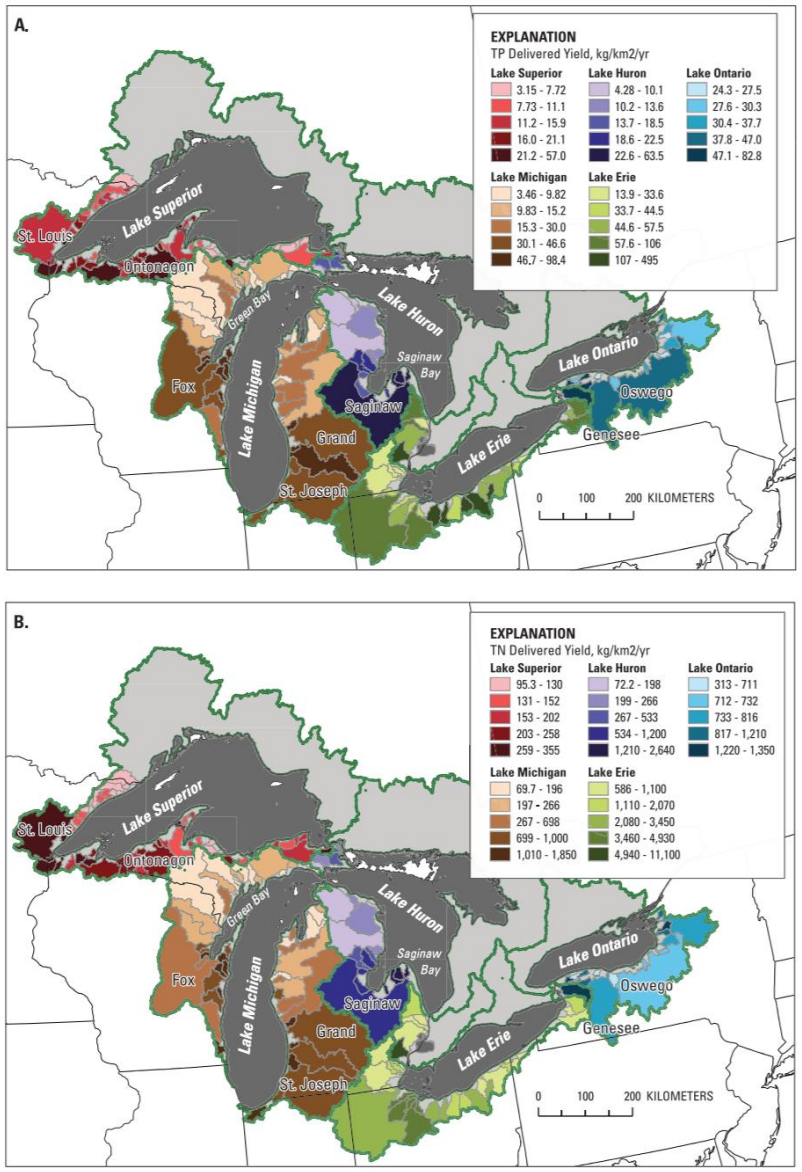
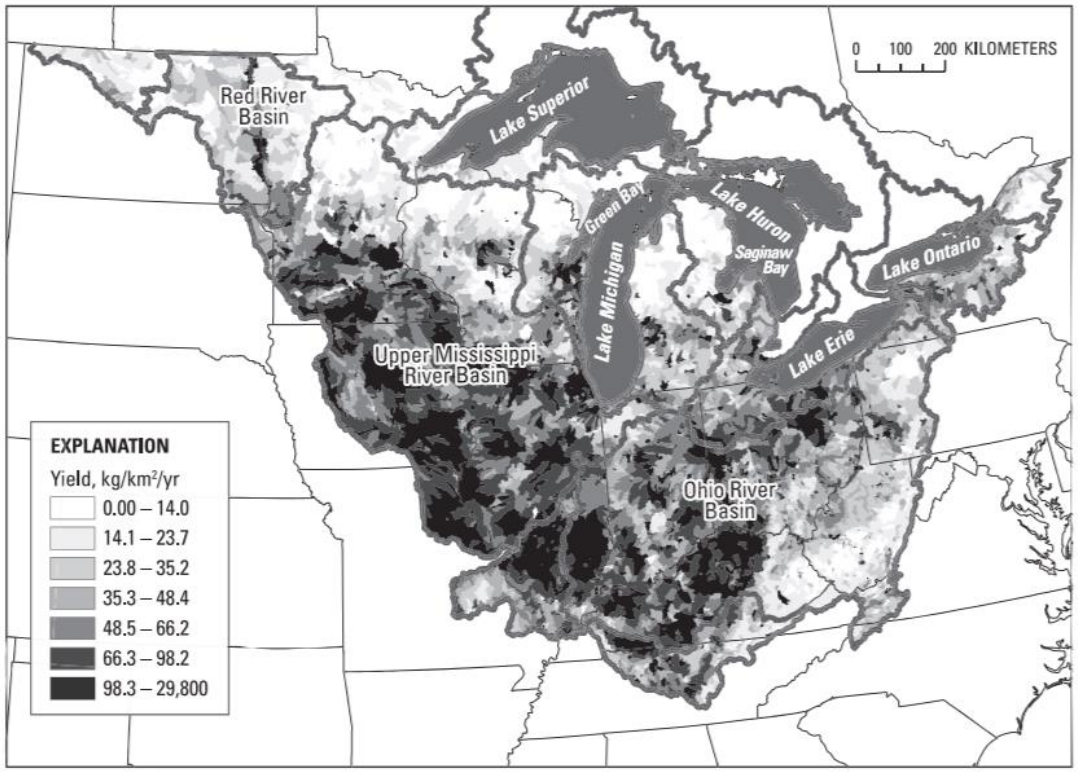
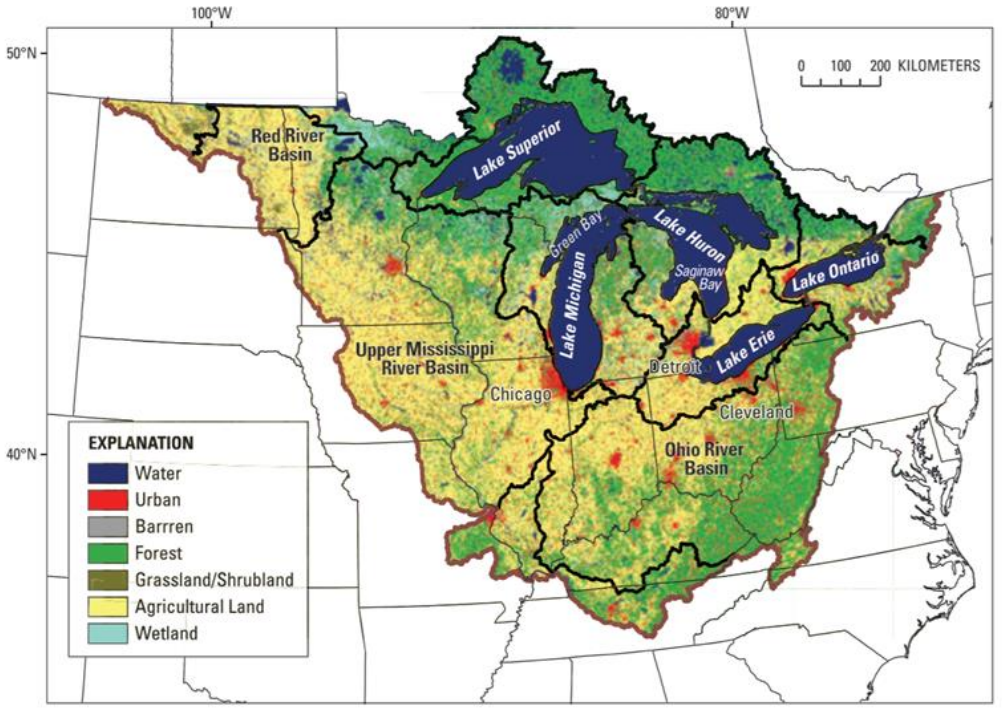


FIGURE 5. Distributions of Total Annual Delivered Yield From Each Tributary >150 km^2 to Each Great Lake for (A) Total P (TP) and (B) Total N (TN). Yields from tributaries to each Great Lake are scaled independently. The entire drainage of each lake is delineated; however, only the tributaries in the U.S. are included in the analyses.





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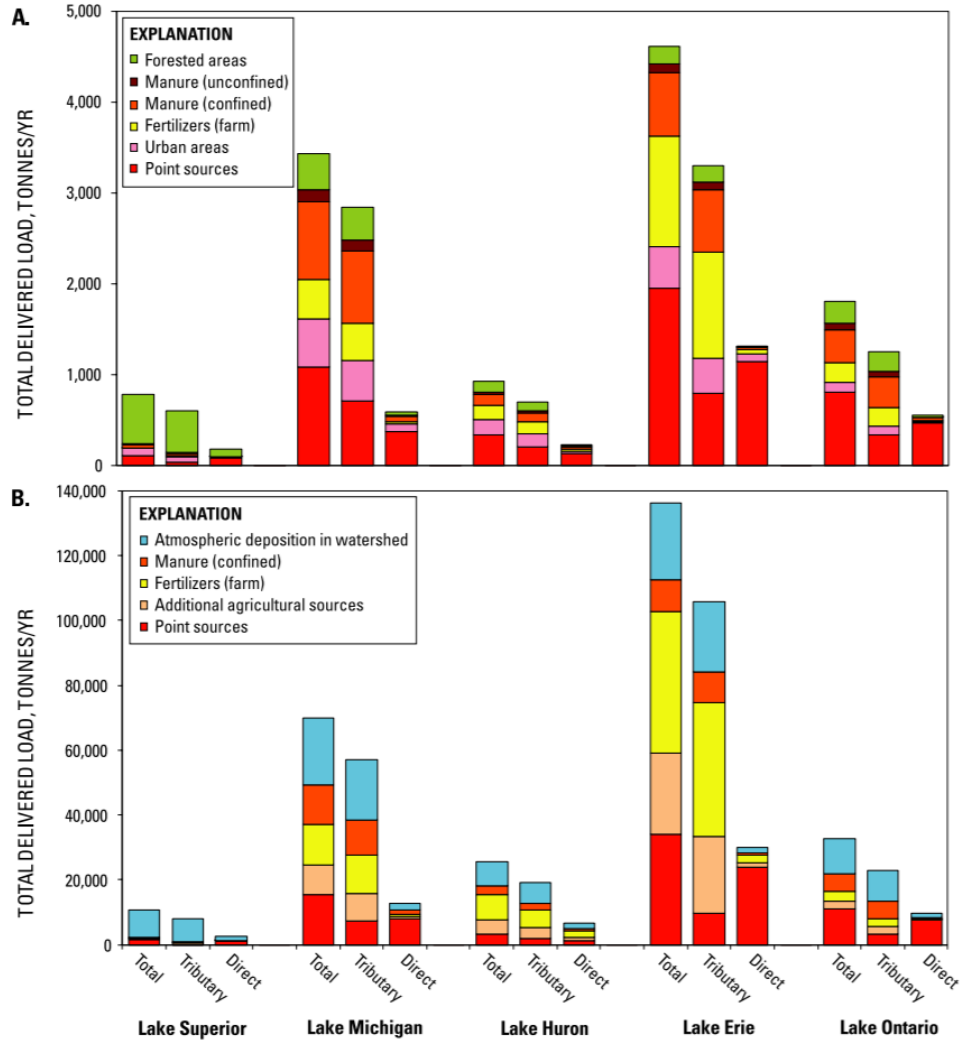

FIGURE 4. Total Annual Delivered Load (subdivided into tributary loading and direct loading from marginal areas around the lake) to Each Great Lake for (A) Total P (TP) and (B) Total N (TN). Loads are subdivided by source. (Note: input from direct atmospheric deposition is not included; all percentages by individual source are given in the Supporting Information.)