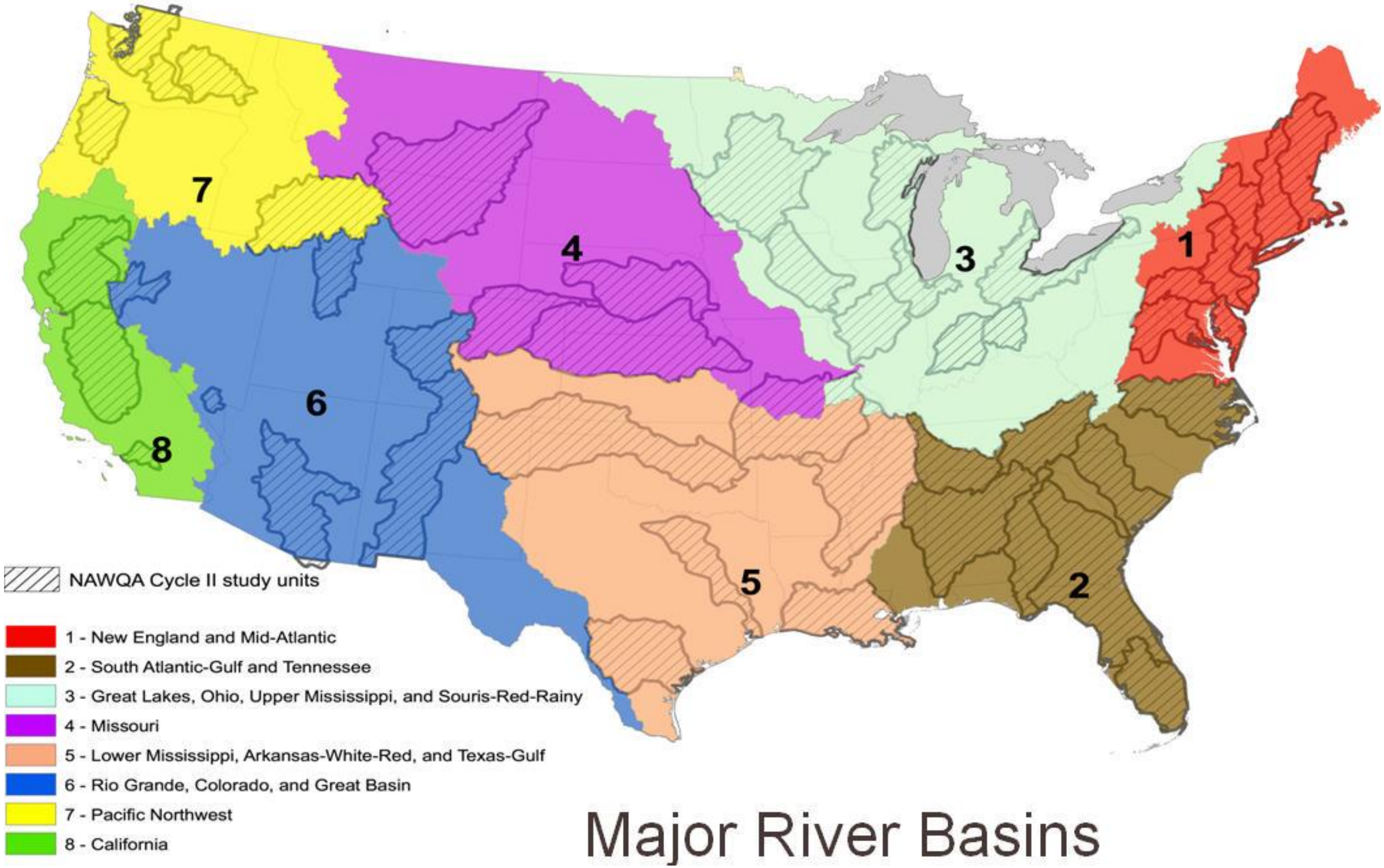
NATIONAL WATER QUALITY ASSESSMENT PROGRAM

Using spatially explicit models to estimate the impacts of changing agricultural practices

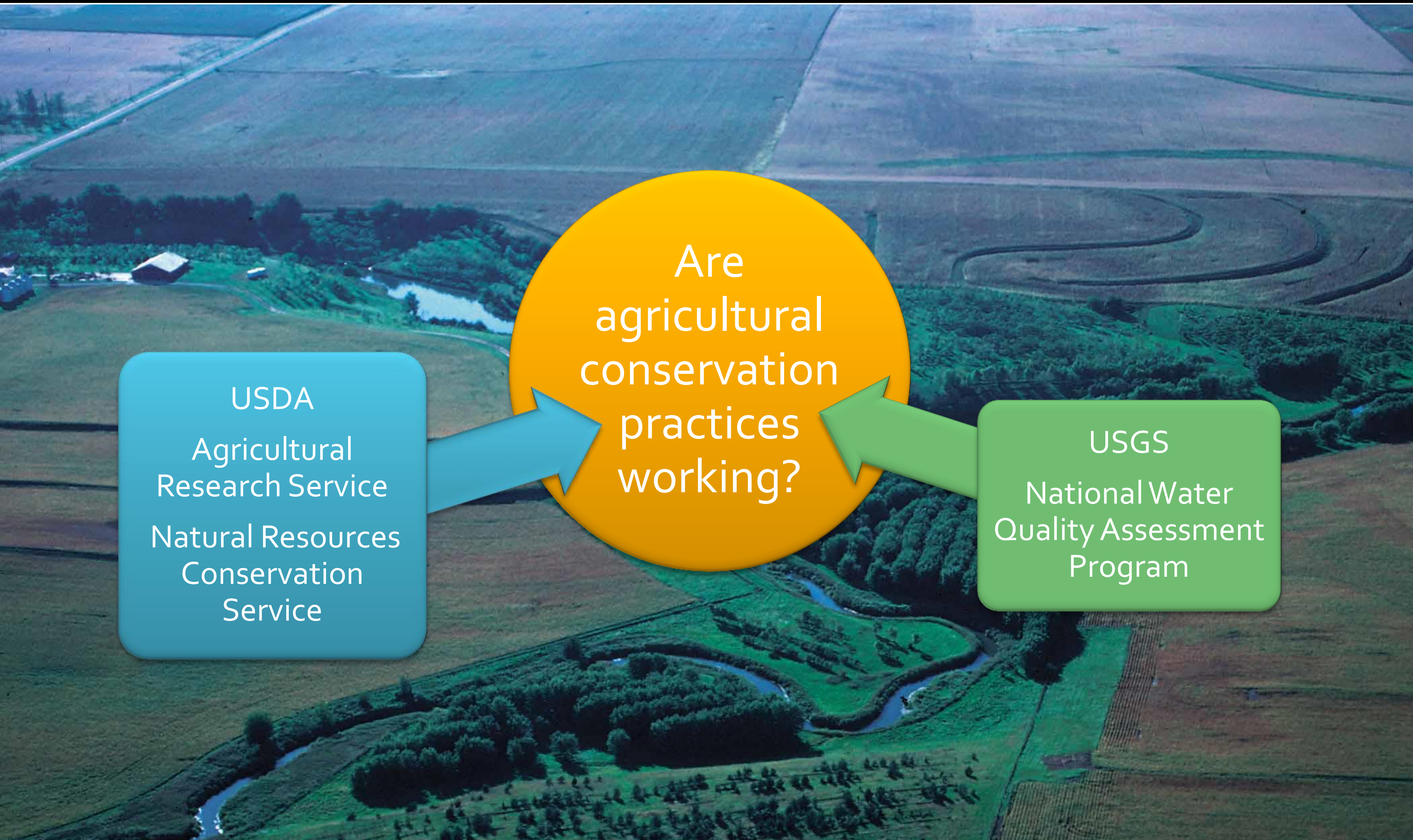
Ana Maria Garcia
North Carolina Water Science Center

National Water-Quality Assessment Program (NAWQA)



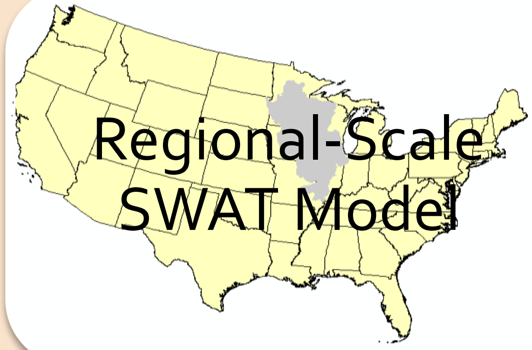
Major River Basins

Conservation Effects



National Assessment for Cropland

CEAP NRI Survey
APEX

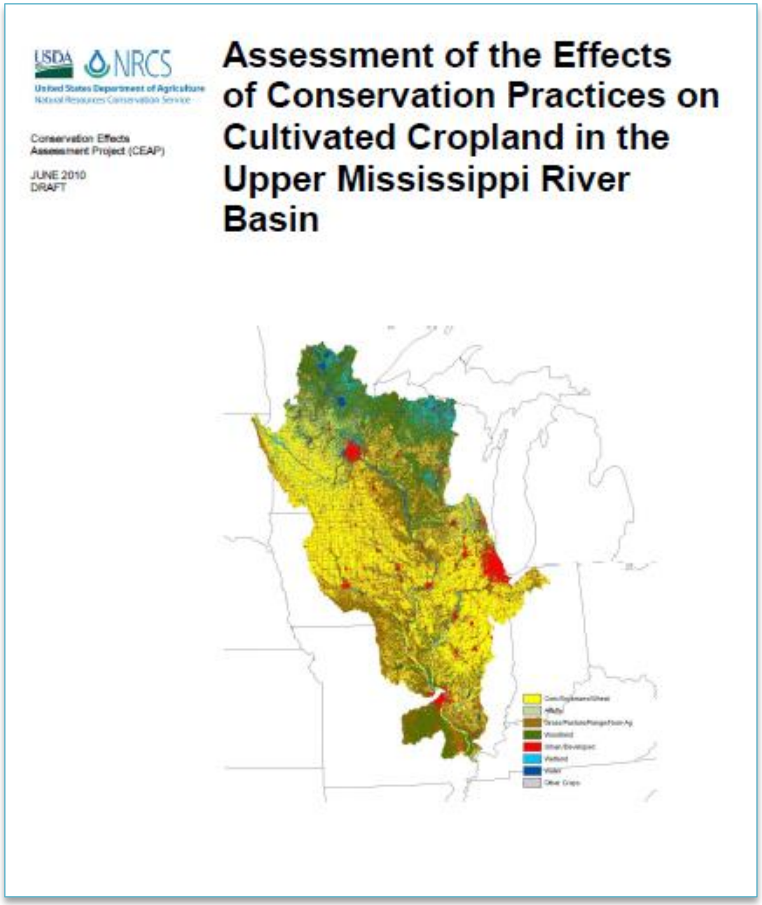


Regional-Scale
SWAT Model

Effects of conservation

National Assessment for Cropland

- CEAP Cropland Survey
  - Current information on farming practices including: crops grown, tillage practices, nutrient and pesticide application, conservation practices.


USDA NRCS
United States Department of Agriculture
Natural Resources Conservation Service

Conservation Effects Assessment Project (CEAP)

JUNE 2010
DRAFT

Assessment of the Effects of Conservation Practices on Cultivated Cropland in the Upper Mississippi River Basin

CEAP Methodology

BASELINE SCENARIO

APEX model results that account for conservation practices as reported in the CEAP Cropland Survey.

NO PRACTICE SCENARIO

APEX model results as if no conservation practices were in use.

The difference between these two scenarios is a measure of <u>conservation effect</u>.

Assume that field-scale effects are additive at the regional scale

Our approach …

Approach

- Convert APEX result into a spatially explicit annual variable that could be tested with SPARROW
- Use an existing SPARROW model to test empirically the explanatory power of the variable
- Use the predictive capabilities of SPARROW to calculate reductions associated with conservation effects and compare with reported values (CEAP Report, 2010)

SPARROW: a statistical model

- SPARROW employs a statistically estimated nonlinear regression model

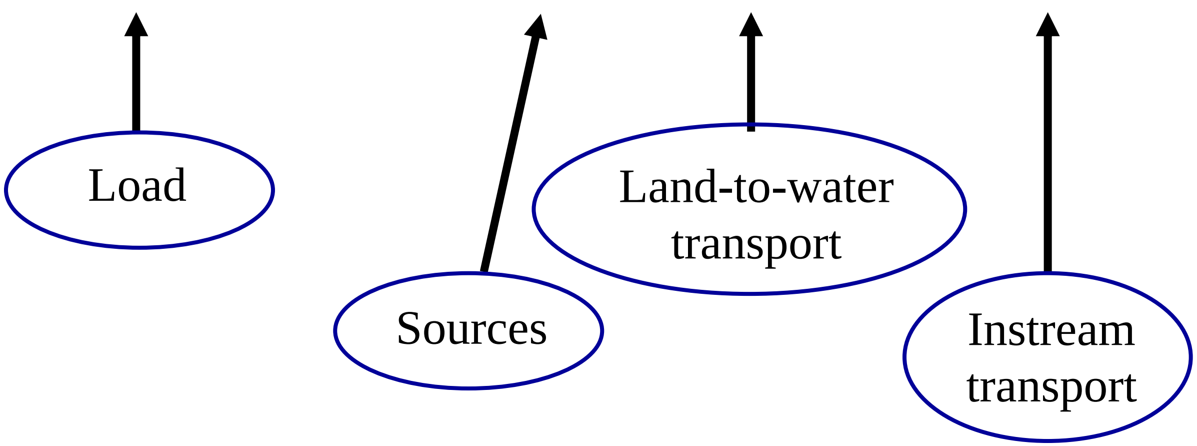
$$\text{Load}_i = \left\{ \sum_{j \in J(i)} \left[\sum_{n=1}^{N} S_{n,j} \underbrace{\beta_n \exp(-\alpha' Z_j)} \right] \underbrace{\exp(-\delta' T_{i,j})} \right\} \underbrace{\exp(\epsilon_i)}$$

  - Parameters of the regression equation are estimated by correlating stream water-quality records to spatially explicit data
    - **Inductive reasoning**, the model informs on how the system behaves
    - **Empirical** use of SPARROW

SPARROW: a semi-statistical model, with process-based elements

- Process based models are based on existing knowledge and general laws of physics
  - Process-based modeling is a form of **deductive reasoning** provide a summary of existing knowledge

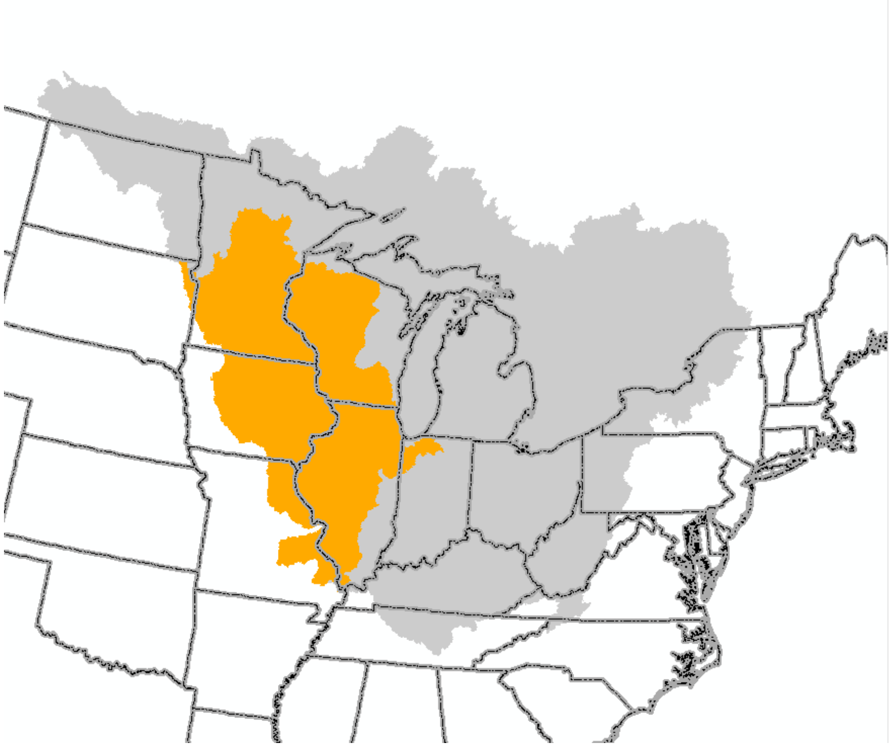
$$\text{Load}_i = \left\{ \sum_{j \in J(i)} \left[\sum_{n=1}^{N} S_{n,j} \beta_n \underbrace{\exp(-\alpha' Z_j)} \right] \underbrace{\exp(-\delta' T_{i,j})} \right\} \underbrace{\exp(\epsilon_i)}$$



•**Predictive** use of SPARROW

Great Lakes SPARROW MODEL

- Robertson and Saad, 2011
- The nitrogen model has five nitrogen sources: three that account for contributions from agricultural activities.
- The phosphorus model has six sources, three account for agricultural activities .



USGS Methodology

BASELINE SCENARIO

APEX model results that account for conservation practices as reported in the CEAP Cropland Survey.

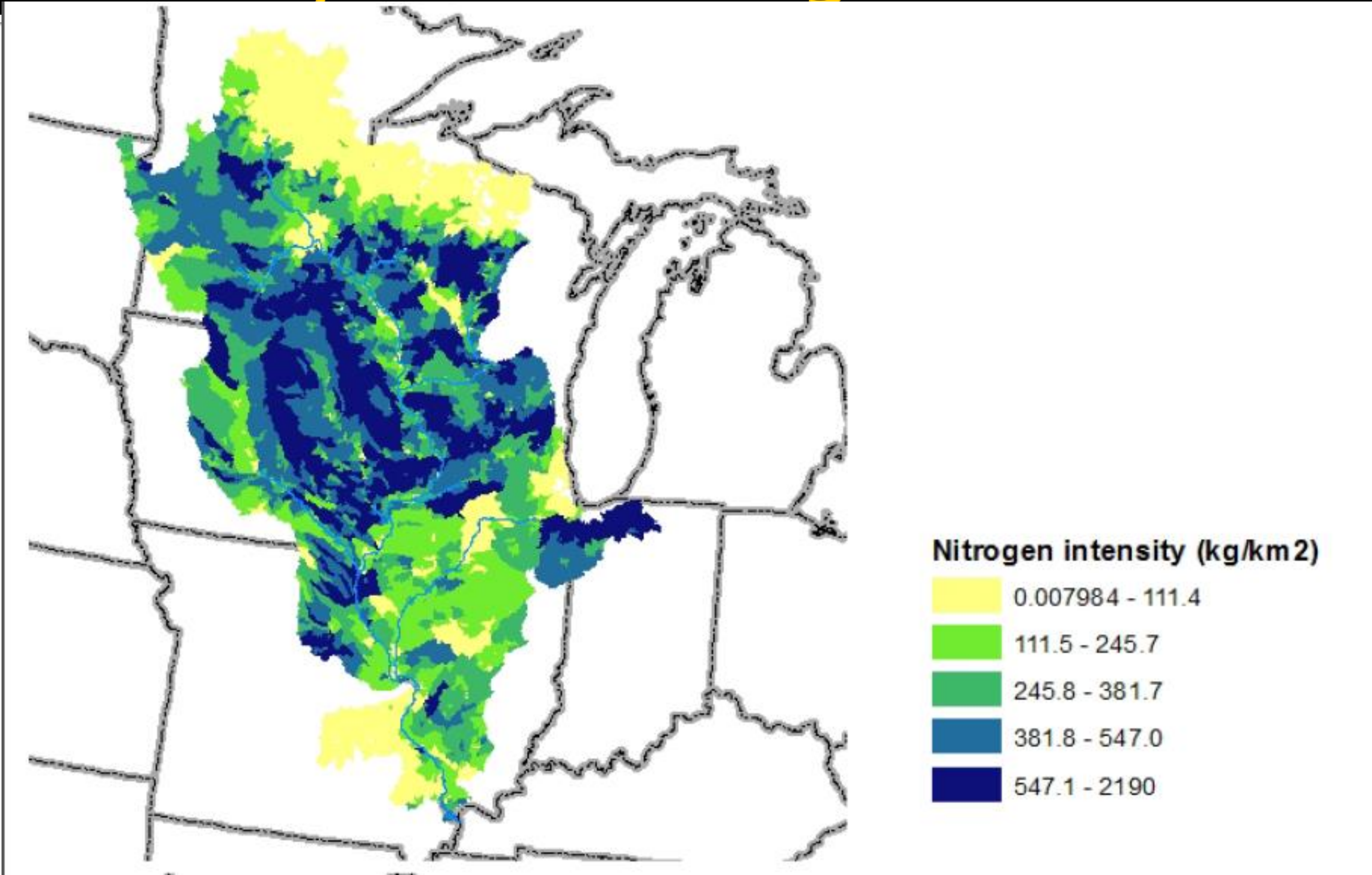
NO PRACTICE SCENARIO

APEX model results as if no conservation practices were in use.

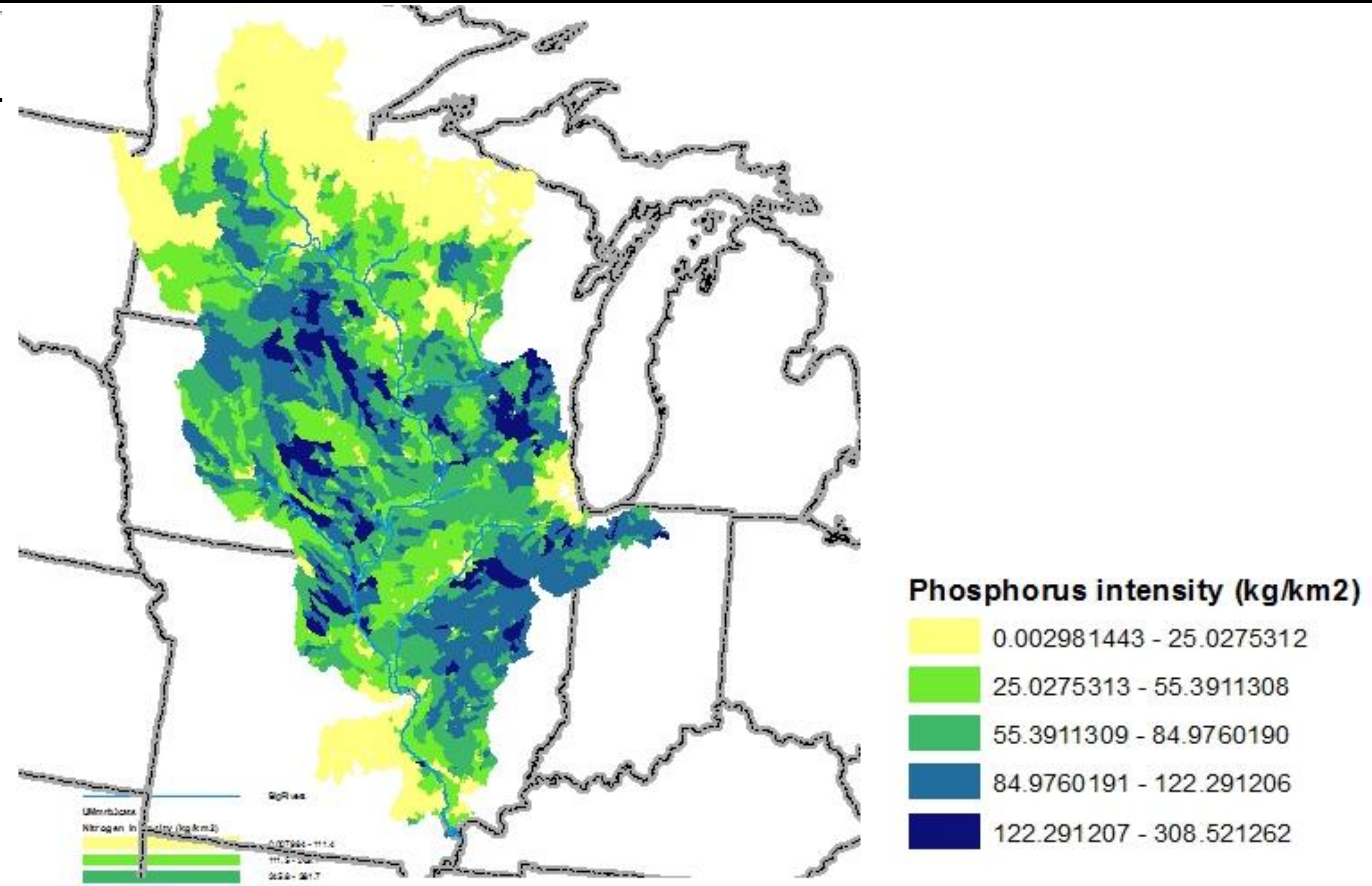
The difference between these two scenarios is a measure of conservation adoption intensity

Conduct test on whether or not field-scale effects scale up

Spatial distribution of conservation intensity – Total Nitrogen

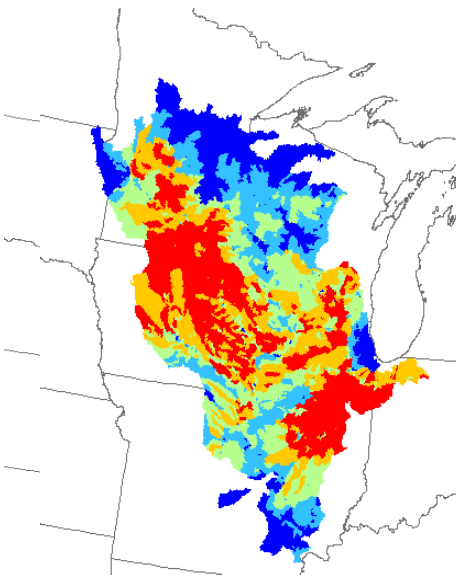


Spatial distribution of conservation intensity – Total Phosphorus



SPARROW modeling process

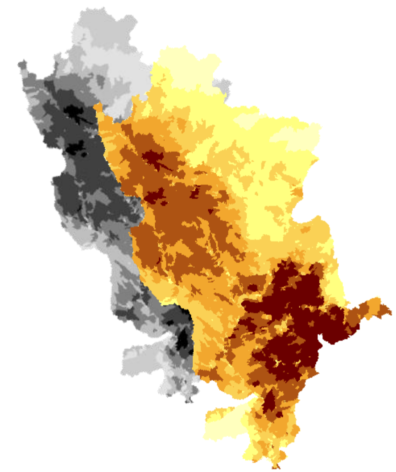
Monitoring Data
323 stations



Model Predictions
3627 catchments

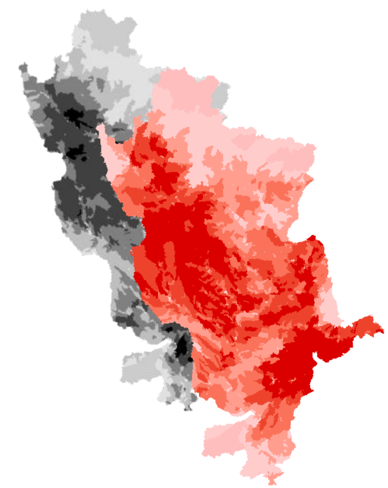
α

Source factors, such as manure applied to farmland

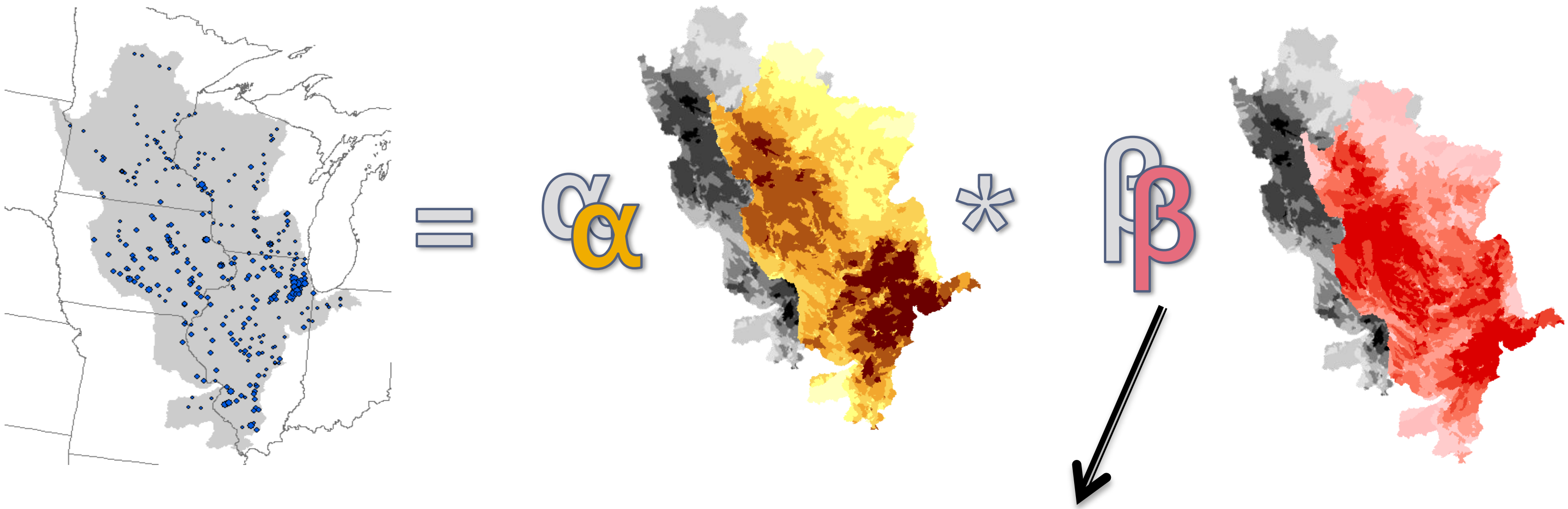


β

Transport factors such as tile-drainage



What we have found so far …



THE RESULT OF SPARROW ESTIMATION USING THE CONSERVATION EFFECTS VARIABLE LED TO A NEGATIVE AND SIGNFICANT COEFFICIENT FOR TOTAL NITROGEN AND A NEGATIVE, NOT SIGNIFICANT COEFFICIENT FOR TOTAL PHOSPHORUS

ESTIMATION OF NITROGEN MODEL USING CONSERVATION INTENSITY

Predictor variable	Data set used to represent model variable	Great Lakes, nested estimation of UMRB		Inclusion of conservation intensity variable	
		Estimate	P-level	Estimate	P-level
Point Sources	Permitted wastewater discharge (kg/yr)	0.80		0.80	0.00
Atmospheric deposition	Deposition of inorganic nitrogen (kg/yr)	0.55		0.54	0.00
Sources related to cropland agriculture	Applied manure, confined livestock (kg/yr)	0.25		0.25	0.00
	Applied manure, confined livestock, UMRB (kg/yr)	0.34		0.53	0.00
	Area of cropland (km2)	12.07		12.33	0.00
	Area of cropland, UMRB (km2)	19.30		22.11	0.00
Land-to-water delivery	Conservation variable (kg/km2)			-0.001	0.01
	Drainage density (km/km2)	0.11	0.03	0.11	0.02
	Precipitation (mm/yr)	0.002		0.002	0.00
	Air temperature (degrees Celcius)	-0.03	0.08	-0.04	0.04
	Fraction of catchment with with tiles	1.25		1.26	0.00
	Clay (average areal clay content as fraction)	0.02		0.02	0.00
In-stream attenuation	Stream loss (m3 / s < 1.133)	0.43		0.44	0.00
	Stream loss (1.134 < m3 / s < 1.982)	0.21	0.02	0.21	0.02
	Reservoir loss (m/yr)	5.32		5.42	

ESTIMATION OF PHOSPHORUS MODEL USING CONSERVATION INTENSITY

Model diagnostics		Great Lakes model with nested estimation of UMRB		Inclusion of conservation intensity	
Root mean square error (RMSE), log-transformed residuals		0.49		0.49	
Coefficient of determination (R^2) of yield estimate		0.73		0.73	
Predictor Variables	Data set used to represent model variable	Estimate	P-level	Estimate	P-level
Point Sources	Permitted municipal wastewater discharge (kg/yr)	1.06		1.06	
Non-point urban sources	Area in urban land (km2)	57.10		56.50	
Forest sources	Area in forest land (km2)	15.40		15.40	
Pasture sources	Manure from unconfined livestock production (kg/yr)	0.03		0.03	
Sources related to cropland agriculture	Manure from confined livestock production (kg/yr)	0.04		0.05	
	Manure from confined livestock production (kg/yr) - UMRB	0.12		0.12	
	Commercial fertilizer applied to cropland (kg/yr)	0.04		0.04	
	Commercial fertilizer applied to cropland (kg/yr) - UMRB	0.02		0.02	
Land-to-water delivery	Conservation intensity measure (kg/km2)			-0.001	0.279
	Soil permeability	-0.69		-0.68	
	Fraction of catchmentwith with tiles	-1.10		-1.10	
In-stream attenuation	Stream loss (m3 / s < 1.133)	0.26		0.26	
	Stream loss(1.134 < m3 / s < 1.982)	0.31		0.31	
	Reservoir loss (m/yr)	5.14		5.16	

Comparisons to reported reductions

USDA NRCS
United States Department of Agriculture
Natural Resources Conservation Service

Conservation Effects Assessment Project (CEAP)

JUNE 2010
DRAFT

Assessment of the Effects of Conservation Practices on Cultivated Cropland in the Upper Mississippi River Basin

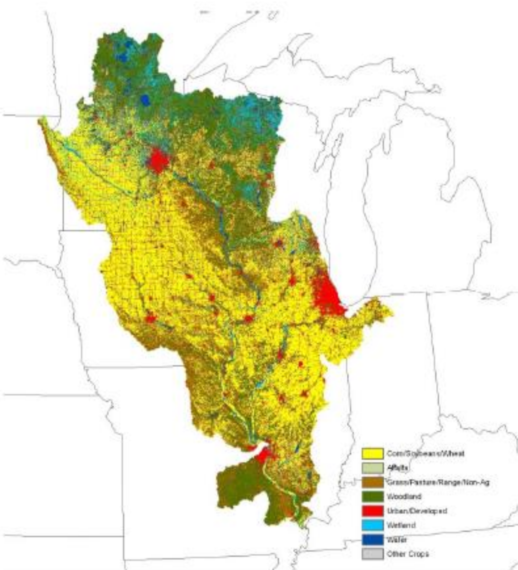
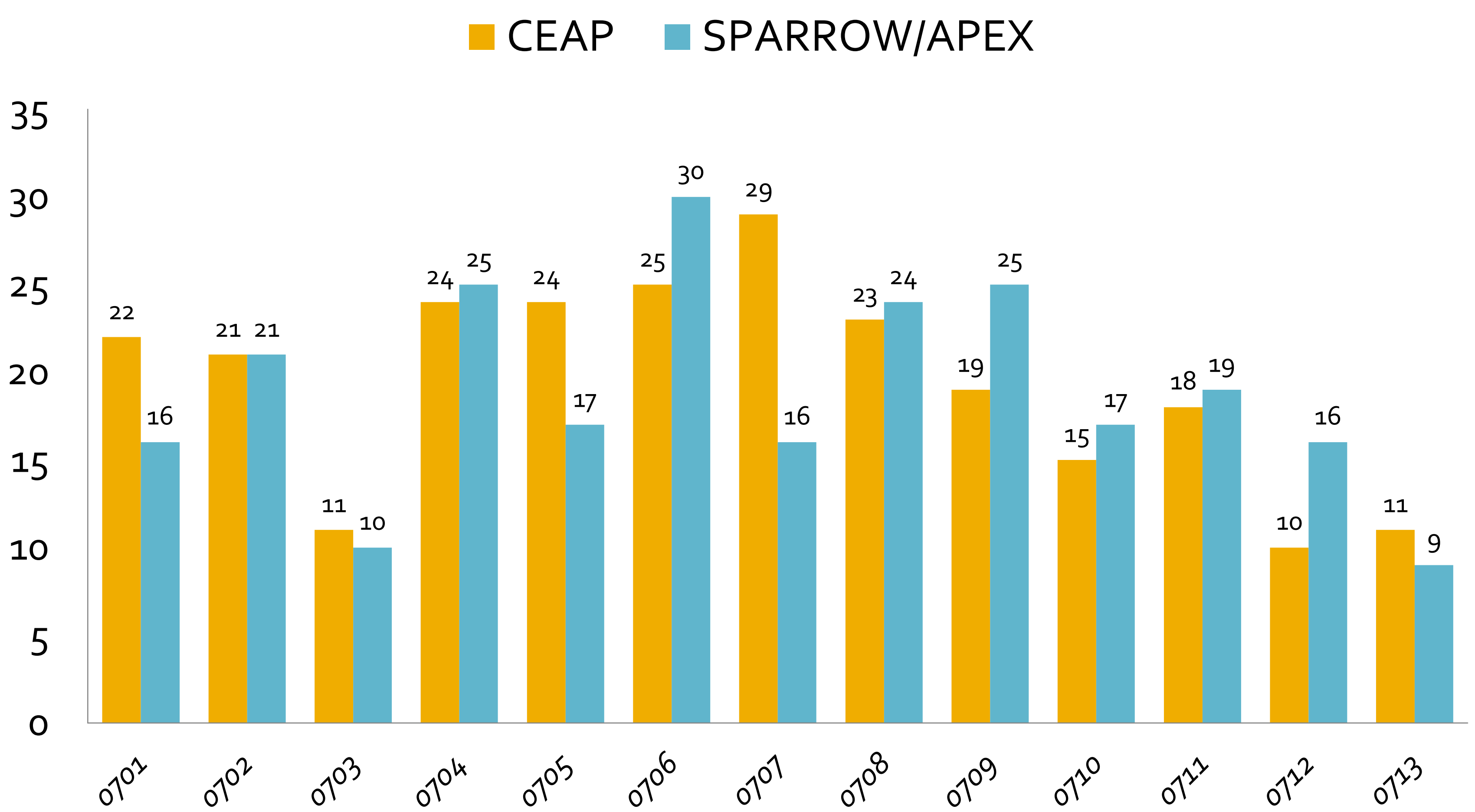


Table 25. Average annual *instream nitrogen loads* for the 14 subbasin outlets in the Upper Mississippi River Basin

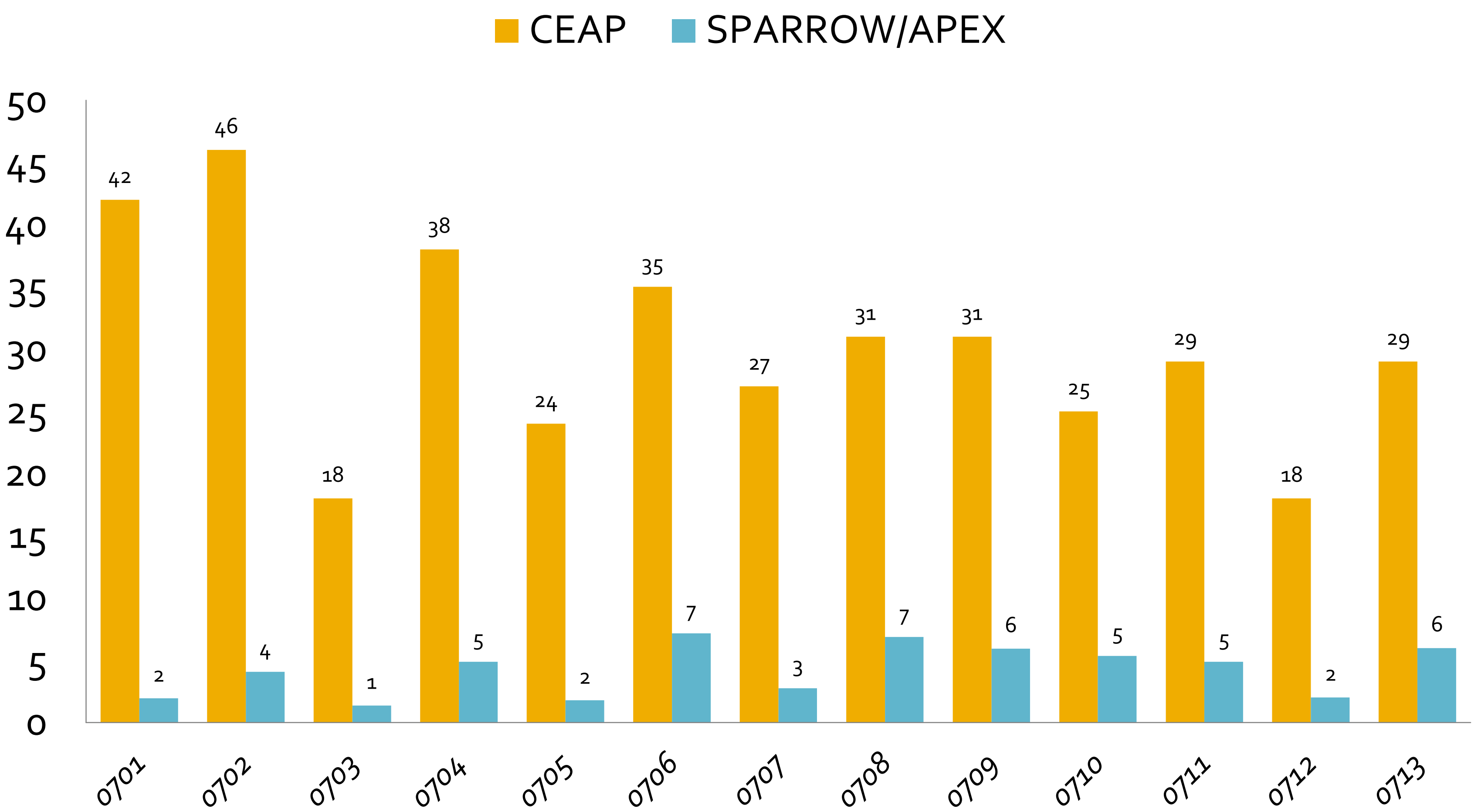
		Baseline conservation condition				Reductions in loads due to conservation practices	
Sub-basin code	Location of subbasin outlet	Load from all sources (1,000 pounds)	Background sources* (1,000 pounds)	Percent of load attributed to cultivated cropland sources	No-practice scenario (1,000 pounds)	Reduction (1,000 pounds)	Percent
	Tributary subbasins						
0702	Minnesota River	108,000	8,980	92	139,000	31,000	22
0703	St. Croix River	13,600	11,800	13	15,000	1,400	9
0705	Chippawa River	23,500	10,600	55	29,200	5,700	19
0707	Wisconsin River	43,400	16,600	62	59,300	15,900	27
0708a	Iowa River within 708	117,000	21,400	82	148,000	31,000	21
0709	Rock River	94,200	26,900	71	116,000	21,800	19
0710	Des Moines River	117,000	17,600	85	140,000	23,000	17
0713	Illinois River	424,000	198,000	53	454,000	30,000	6
0712	Upper Illinois River within 713	166,000	104,000	37	180,000	14,000	8
	Outlets along main stem						
0701	Mississippi Headwaters	185,000	37,500	80	241,000	56,000	24
0704	Upper Mississippi-Black-Root	304,000	79,000	74	401,000	97,000	24
0706	Upper Mississippi-Maquoketa-Plum	409,000	109,000	73	551,000	142,000	26
0708	Upper Mississippi-Iowa-Skunk-Wapsipinicon	764,000	181,000	76	995,000	231,000	23
0711	Mississippi at Grafton, Illinois	1,090,000	281,000	74	1,380,000	290,000	21

* Loadings from non-cultivated cropland were estimated by running an additional scenario that simulated a grass cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres, labeled "Background sources".
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

Nitrogen reductions attributable to conservation variable (percent)



Phosphorus reductions attributable to conservation variable (percent)



Summary

- Because of the static, long-term representation of water quality conditions provided by SPARROW, we are representing ‘well established’ practices in place since the 90’s
  - Reduced tillage and structural practices that reduce erosion and runoff.
  - Could differences between CEAP and USGS results be the result of timing differences?
- Predictions for phosphorus are limited by the lack of explanatory power in the estimation
  - Need to continue investigating up-scaling assumptions implicit in CEAP formulation

What's next

- Publish results and associated ancillary data in collaboration with USDA-NRCS and USDA-ARS.
- Perform similar exercise at another location, most likely Chesapeake Bay.
- Inclusion of conservation adoption intensity in data in 2012 SPARROW models
- Model integration research.