Investigating Watershed Models Sensitivity of Nutrients in the Chesapeake Bay Watershed

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Key questions

a) How model inputs are calculated?
b) How do our inputs match up to others?
c) What function does other models use?
d) How do other models coefficients compare with P532 sensitivities
e) Why other models coefficients might not be consistent with ours?

In order to answer question a) and b) I used information from the publication below

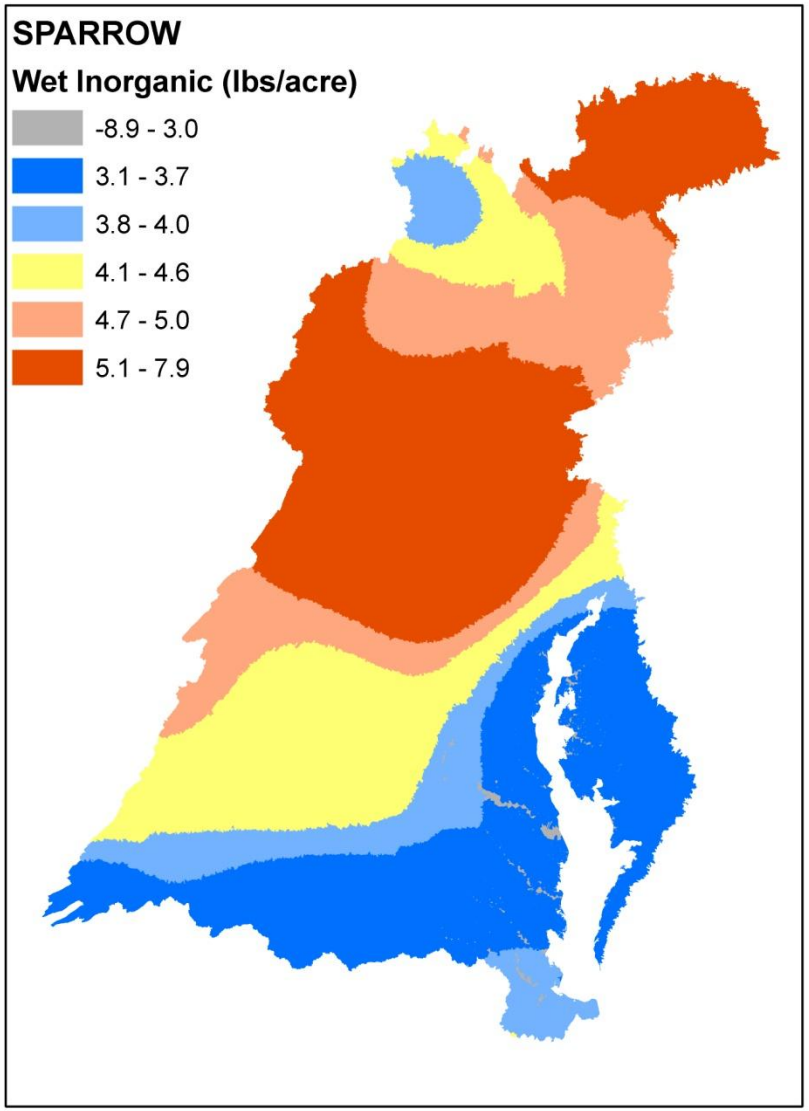
Scott W., J. Brakebill, and J. Blomquist. 2011. Sources, Fate, and Transport of Nitrogen and Phosphorus in the Chesapeake Bay Watershed: An Empirical Model. *USGS. http://pubs.usgs.gov/sir/2011/5167/*

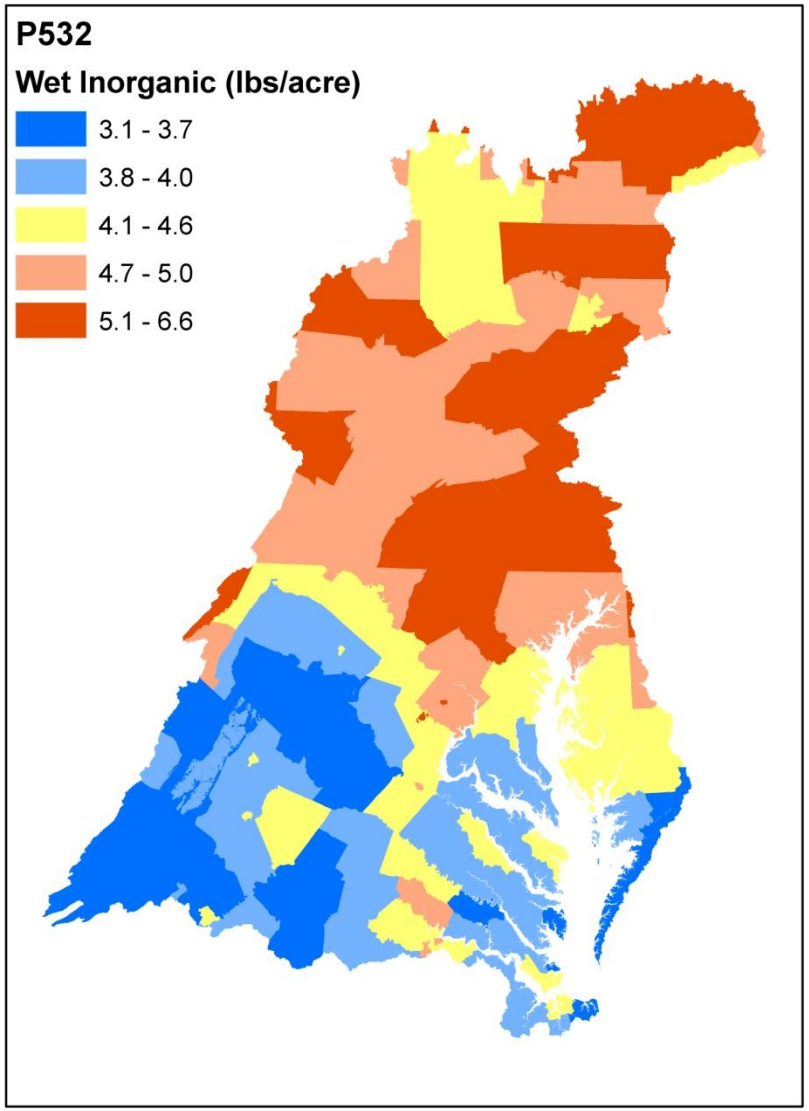
SPARROW Atmospheric Deposition Inputs

Wieczorek, M., and LaMotte, A. (2010) developed attributes for NHDPlus catchments for the conterminous United States: Average atmospheric (wet) deposition of inorganic nitrogen

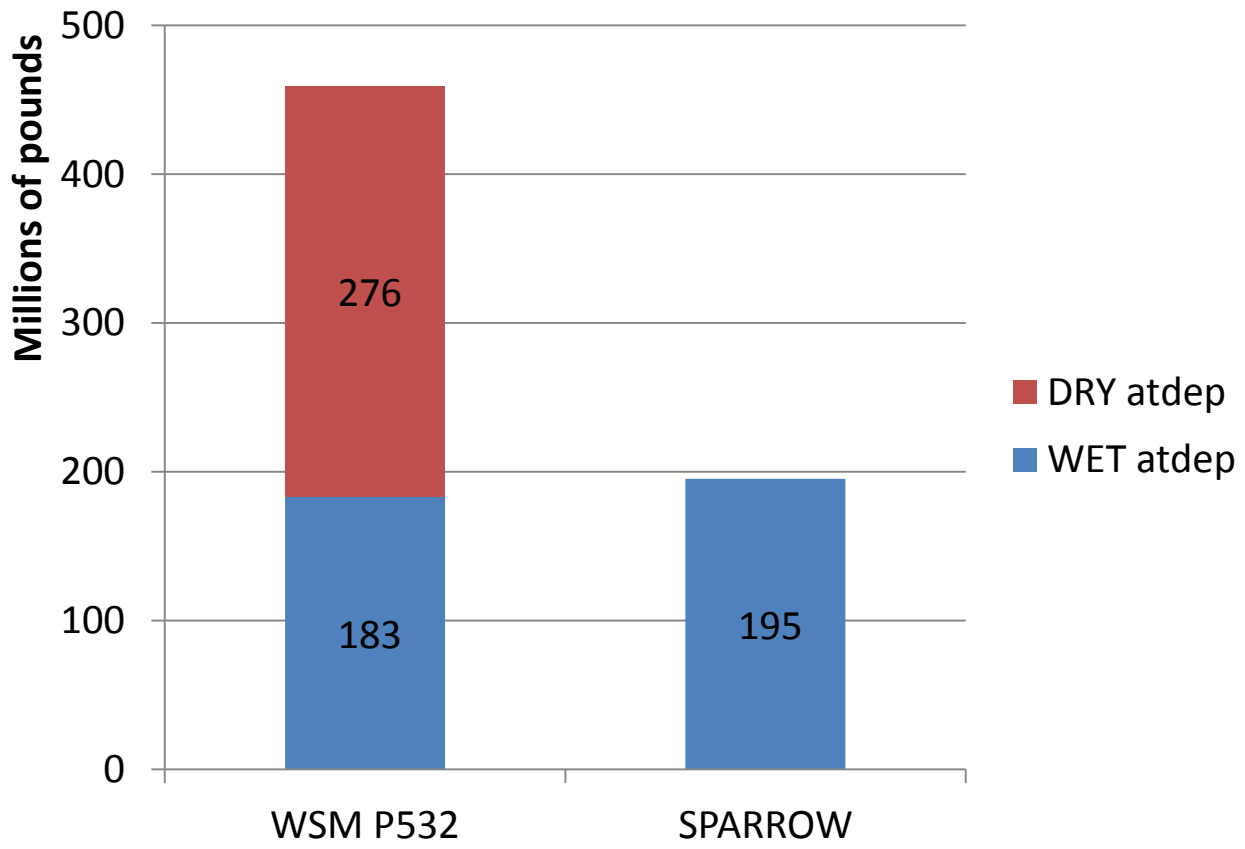
- Data from the National Atmospheric Deposition Program/ National Trends Network (NADP/NTN)
- IDW method to interpolate wet atmospheric inorganic nitrogen deposition.
- The atmosphere was assumed to be a negligible source phosphorus.

Atmospheric Deposition Inputs





Atmospheric Deposition Inputs



SPARROW Fertilizer and Manure Inputs

Wieczorek, M., and LaMotte, A. (2010) developed attributes for NHDPlus catchments for the conterminous Unites States: Nutrient inputs from fertilizer and manure, nitrogen and phosphorus.

•This data set represents the estimated amount of nitrogen and phosphorus in kilograms for the year 2002, compiled for every catchment of NHDPlus for the conterminous United States.

•The source data set is County-Level Estimates of Nutrient Inputs to the Land Surface of the Conterminous United States, 1982-2001 (Ruddy and others, 2006).

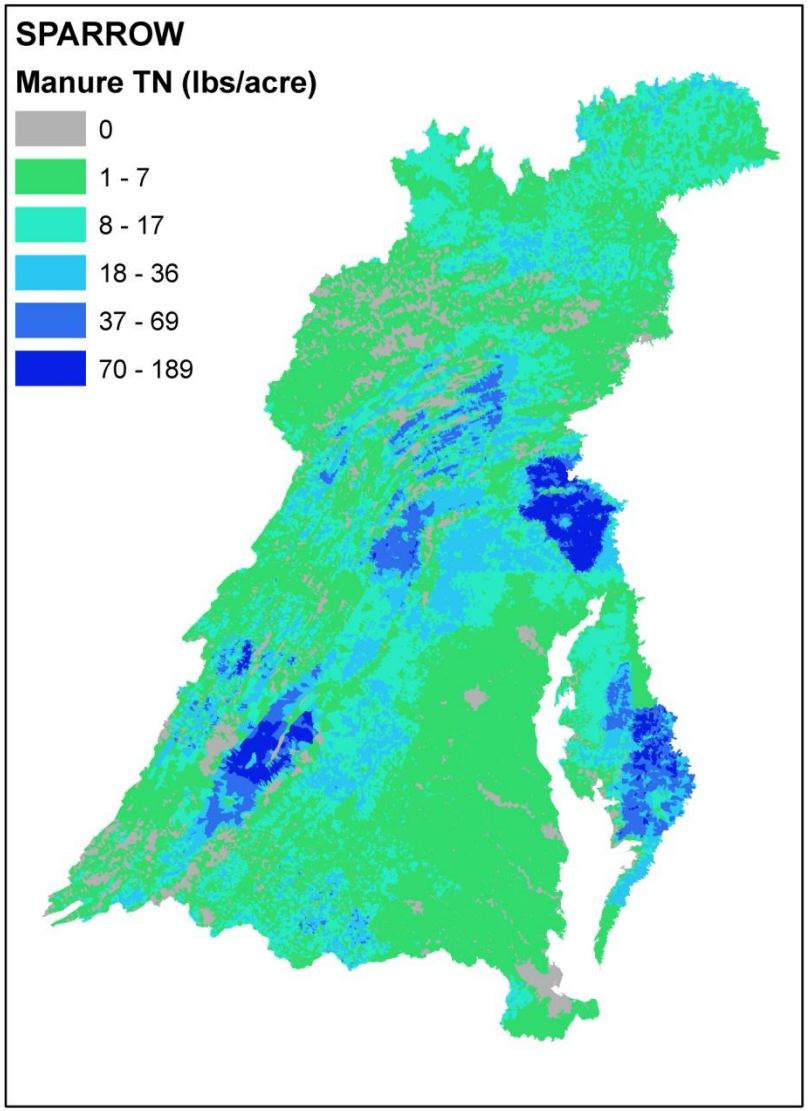
SPARROW Manure Inputs

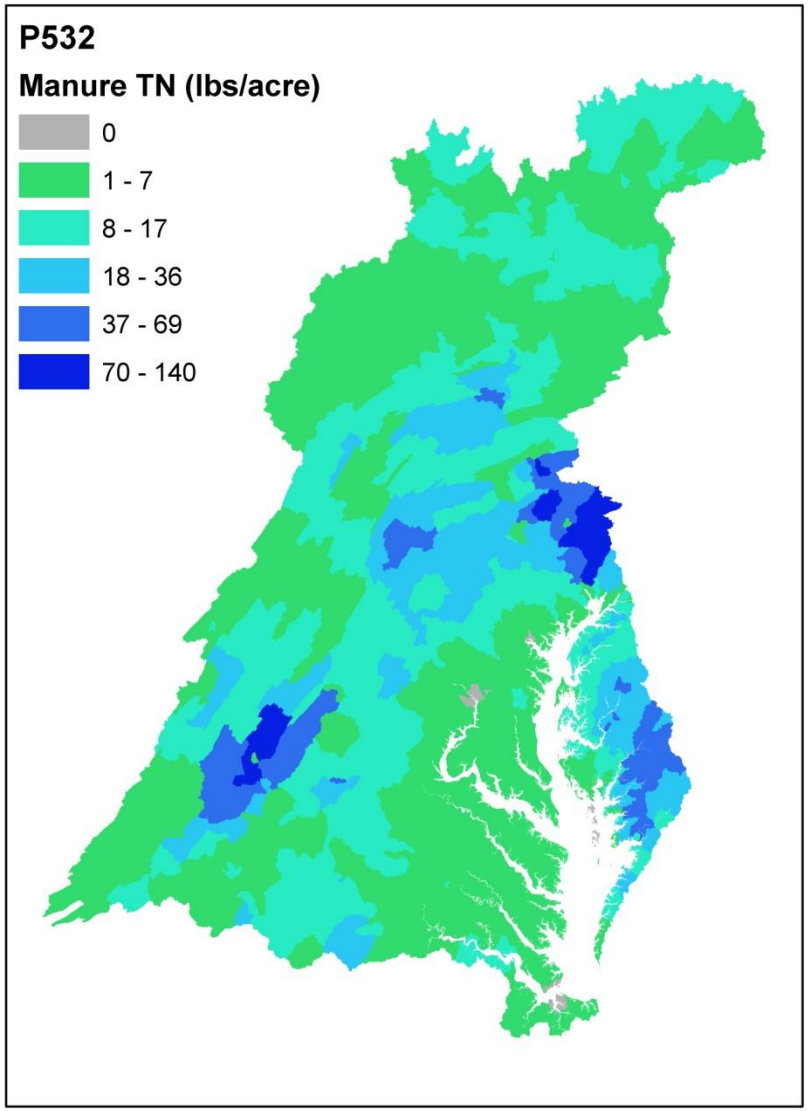
Mueller, D. and Gronberg, J. (2013) estimated county-level of nitrogen and phosphorus from animal manure for the conterminous United States.

- The nitrogen and phosphorus content of livestock wastes was estimated using Census of Agriculture farm-animal population counts and estimates of per-animal nutrient production rates.

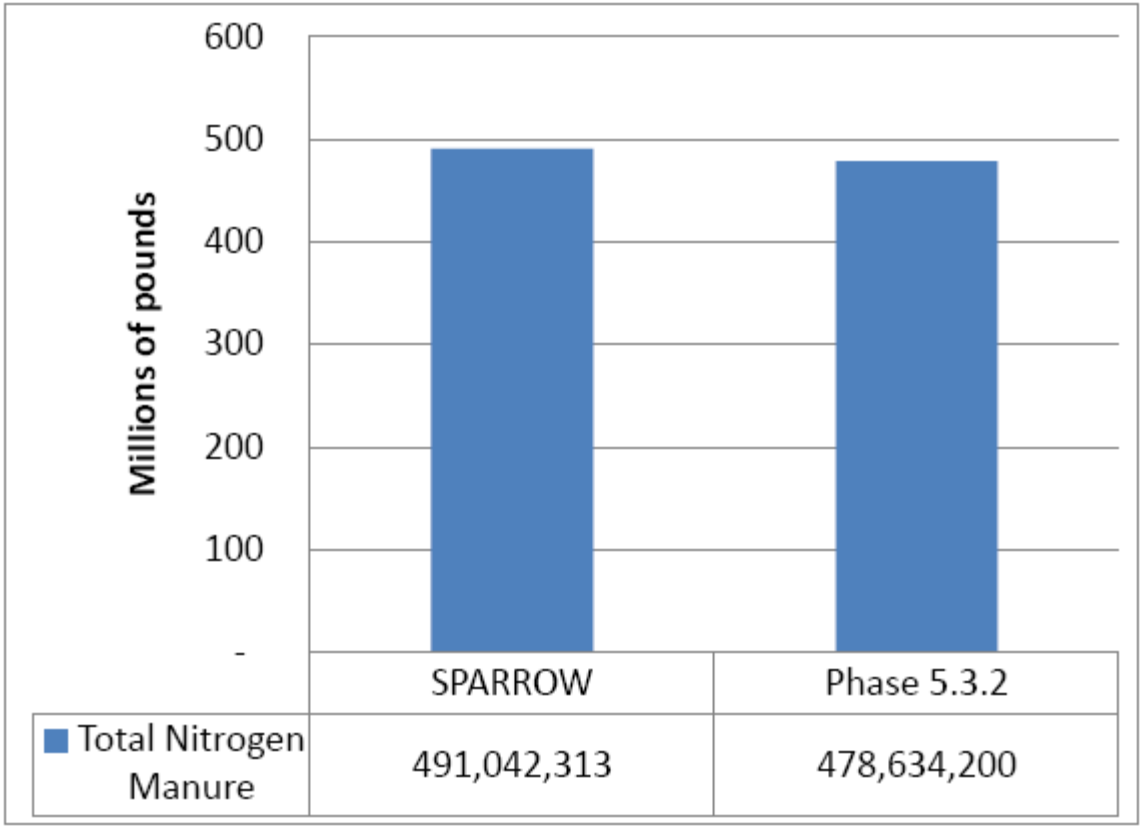
- The procedures used in this report for estimating nitrogen and phosphorus from animal manure are from Ruddy and others (2006) and include the following: (1) estimating animal populations, (2) calculating nitrogen and phosphorus content of the animal manure on the basis of animal populations and estimates of nitrogen and phosphorus content in manure, and (3) estimating the component of nitrogen and phosphorus from confined and unconfined livestock.

Manure Inputs for the year 2002



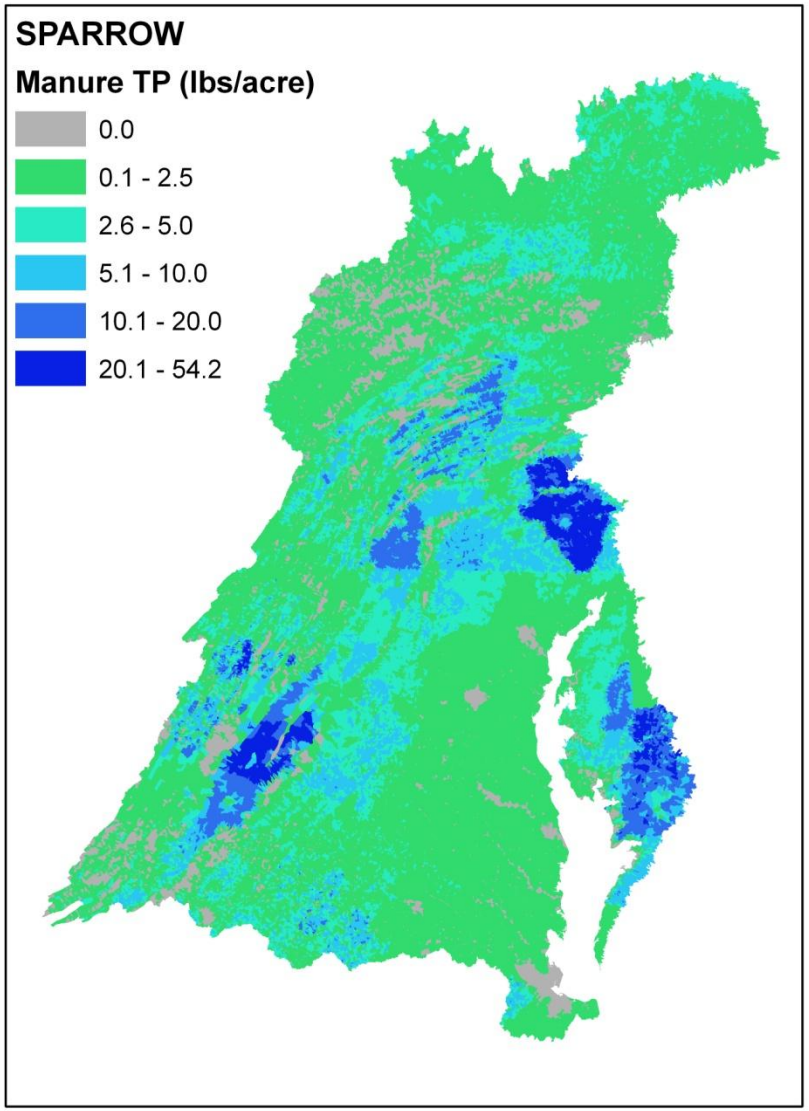


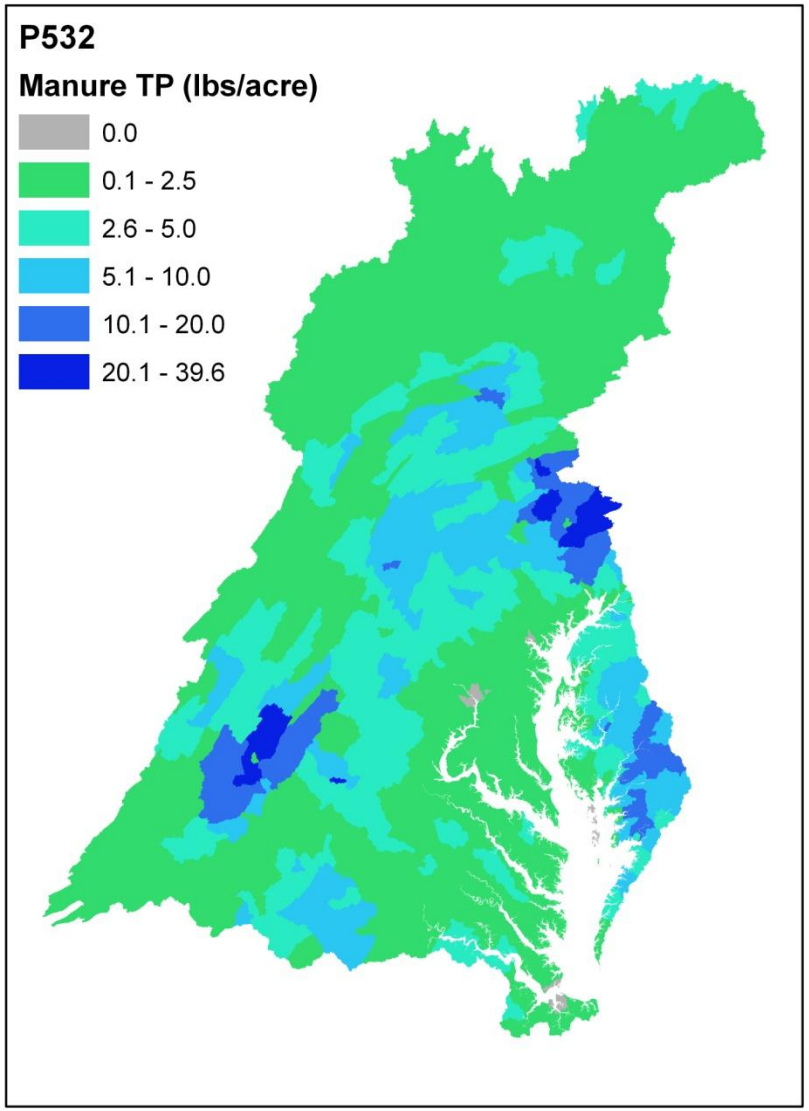
Manure Inputs for the year 2002



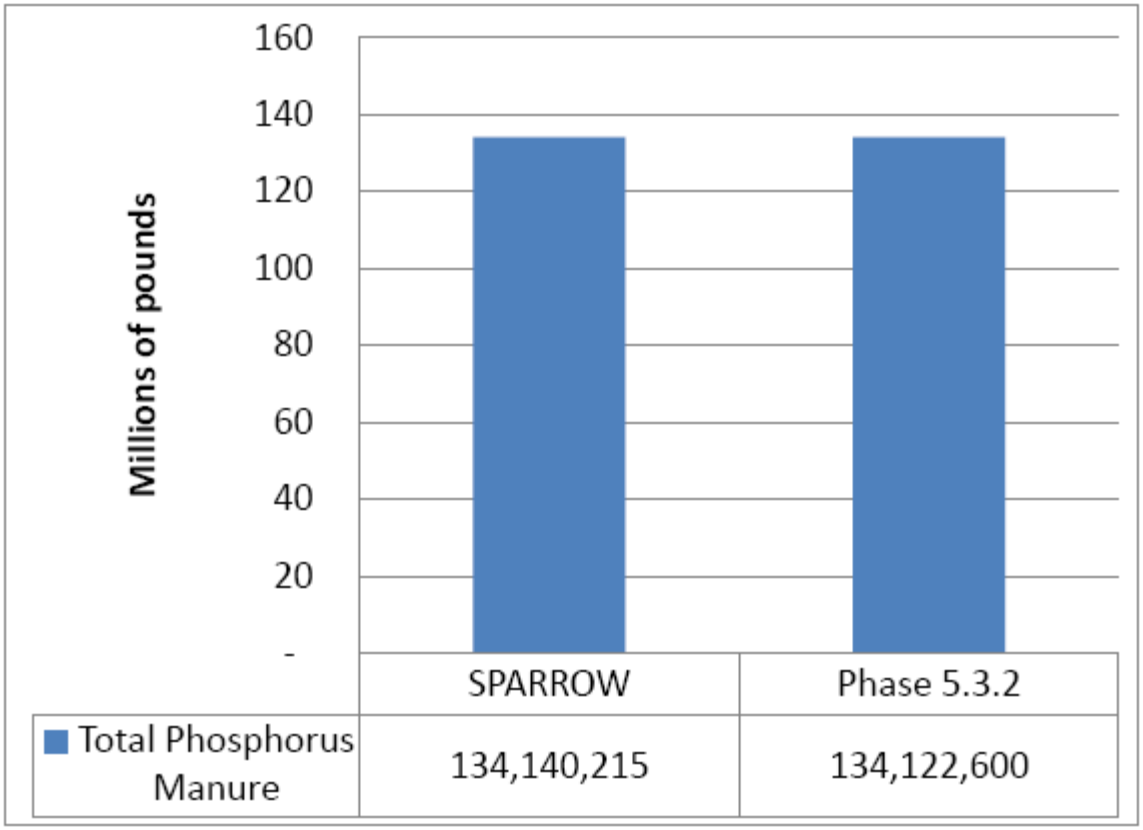
	SPARROW	Phase 5.3.2
Total Nitrogen Manure	491,042,313	478,634,200

Manure Inputs for the year 2002





Manure Inputs for the year 2002



SPARROW Fertilizer Inputs for the year 2002

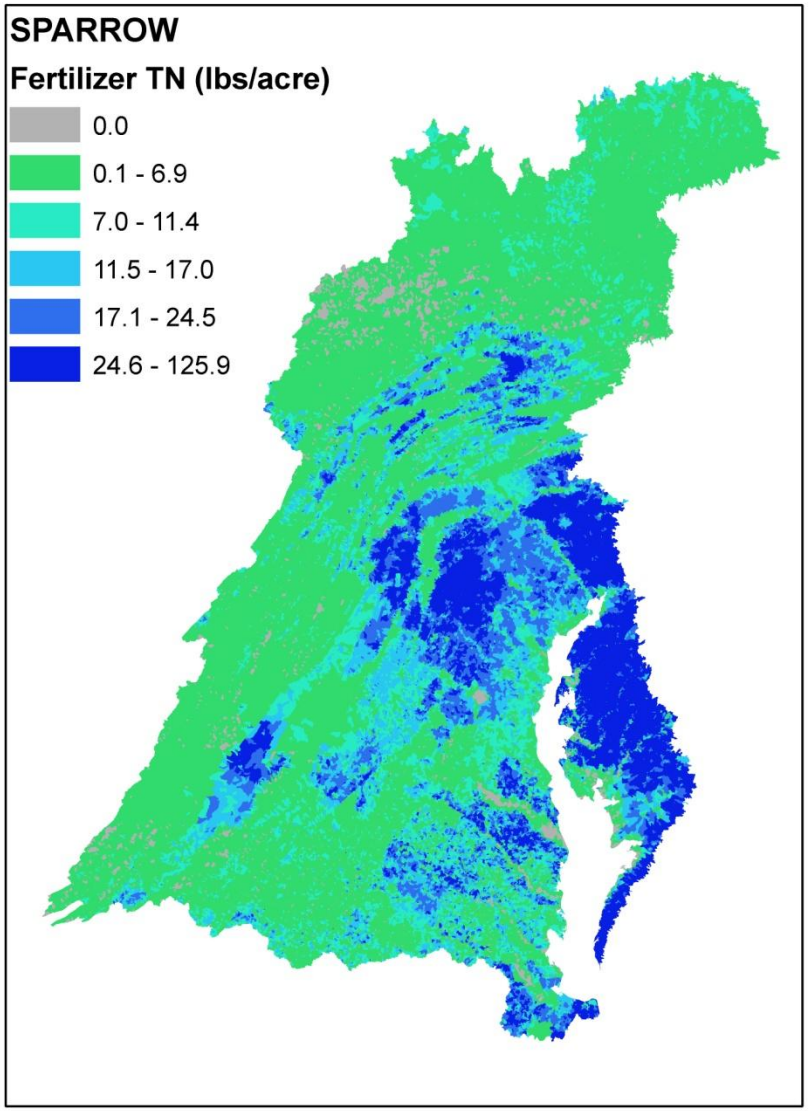
Gronberg, J., and Spahr, N. (2012) estimated county-level nitrogen and phosphorus from commercial fertilizer for the Conterminous United States

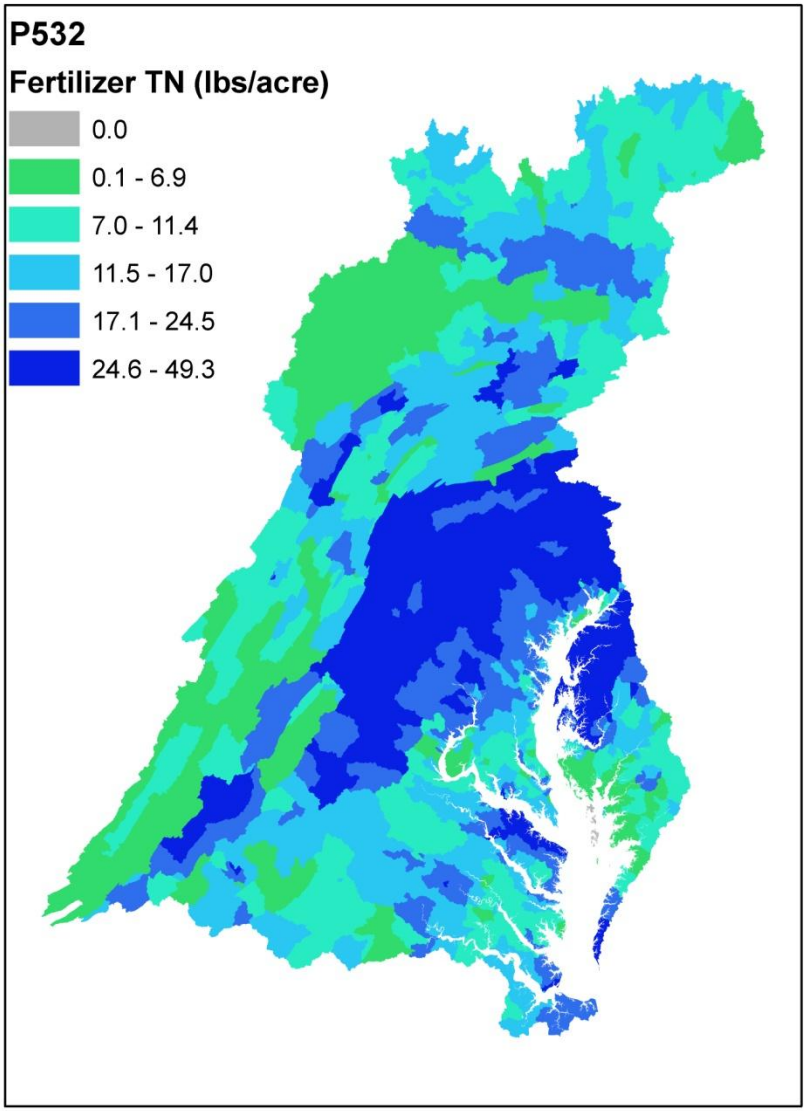
- Estimates were calculated from the Association of American Plant Food Control Officials fertilizer sales data, Census of Agriculture fertilizer expenditures, and U.S. Census Bureau county population.

- A national approach was used to estimate farm and nonfarm fertilizer inputs because not all states distinguish between farm and nonfarm use, and the quality of fertilizer reporting varies from year to year.

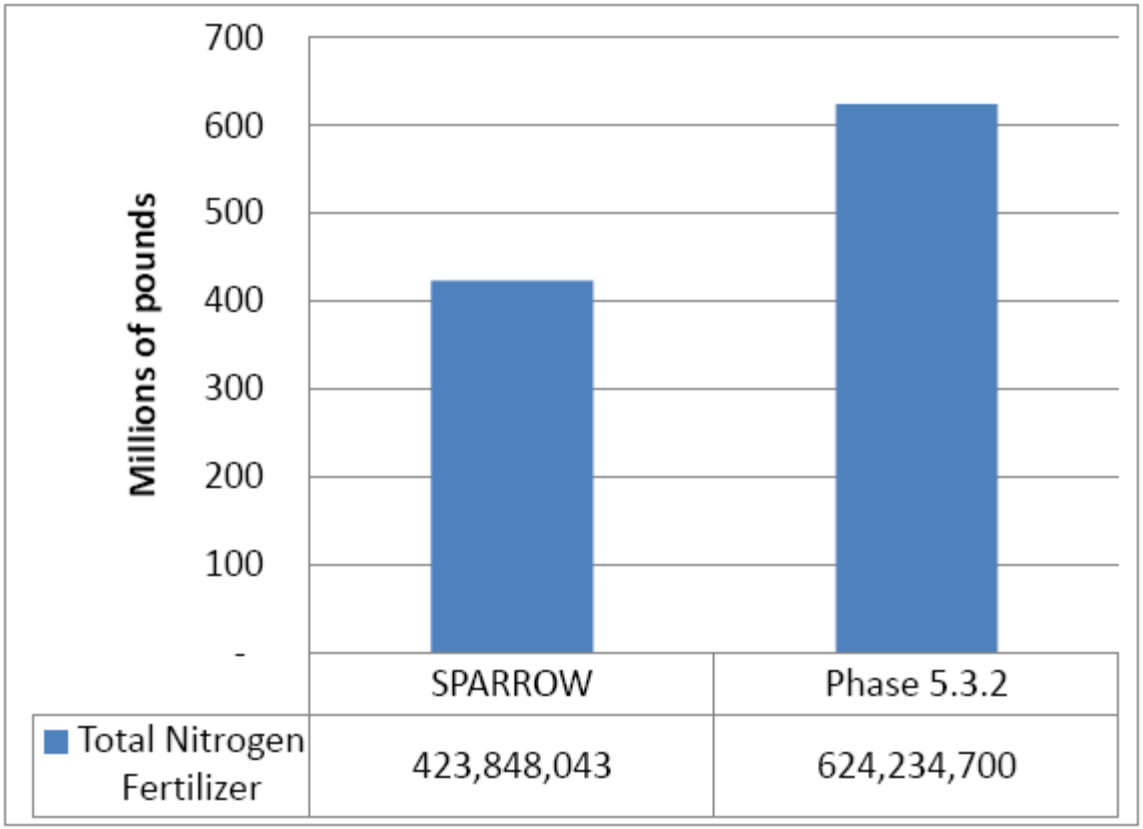
- For states that distinguish between farm and nonfarm use, the spatial distribution of the ratios of nonfarm-to-total fertilizer estimates for nitrogen and phosphorus calculated using the ***national-based farm and nonfarm proportions*** were similar to the spatial distribution of the ratios generated using ***state-based farm and nonfarm proportions***.

Fertilizer Inputs for the year 2002





Fertilizer Inputs for the year 2002



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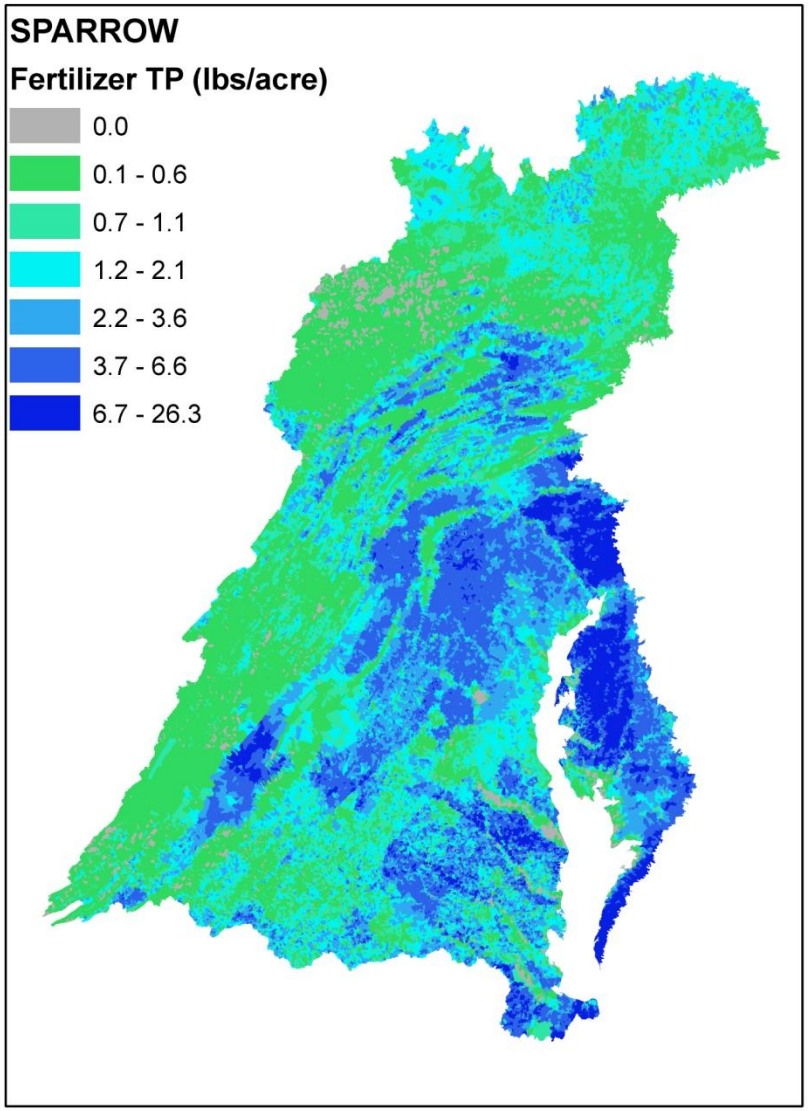

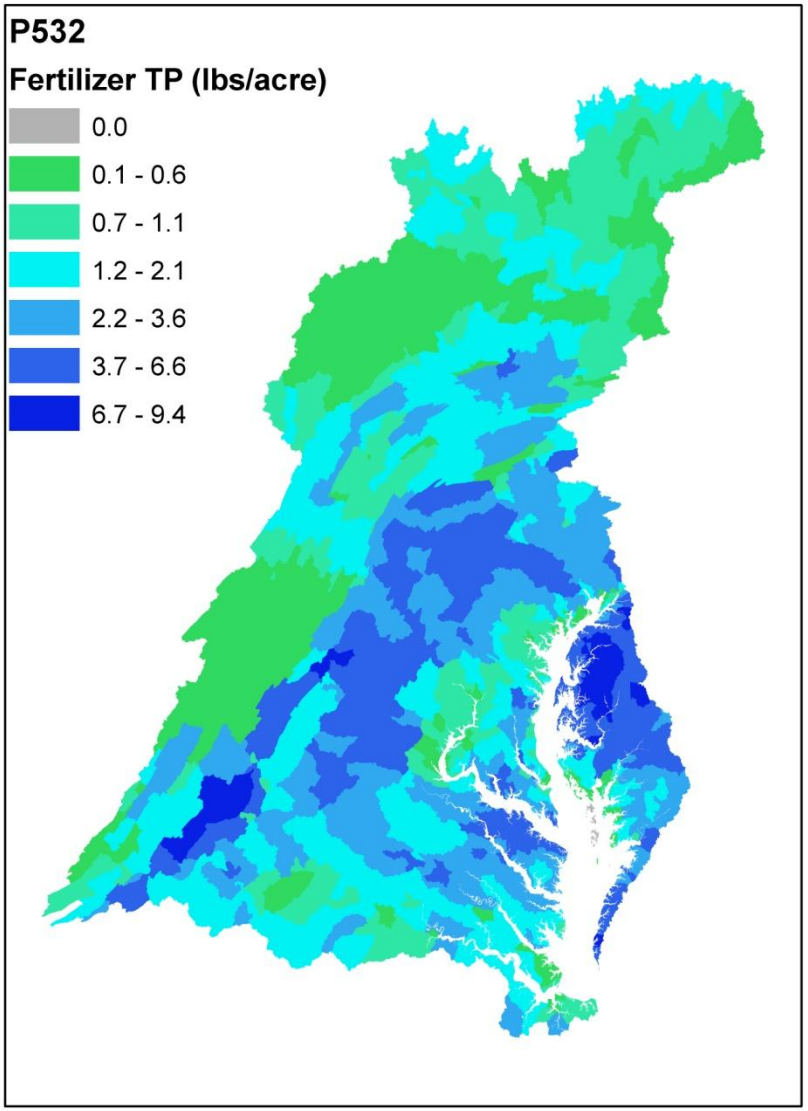

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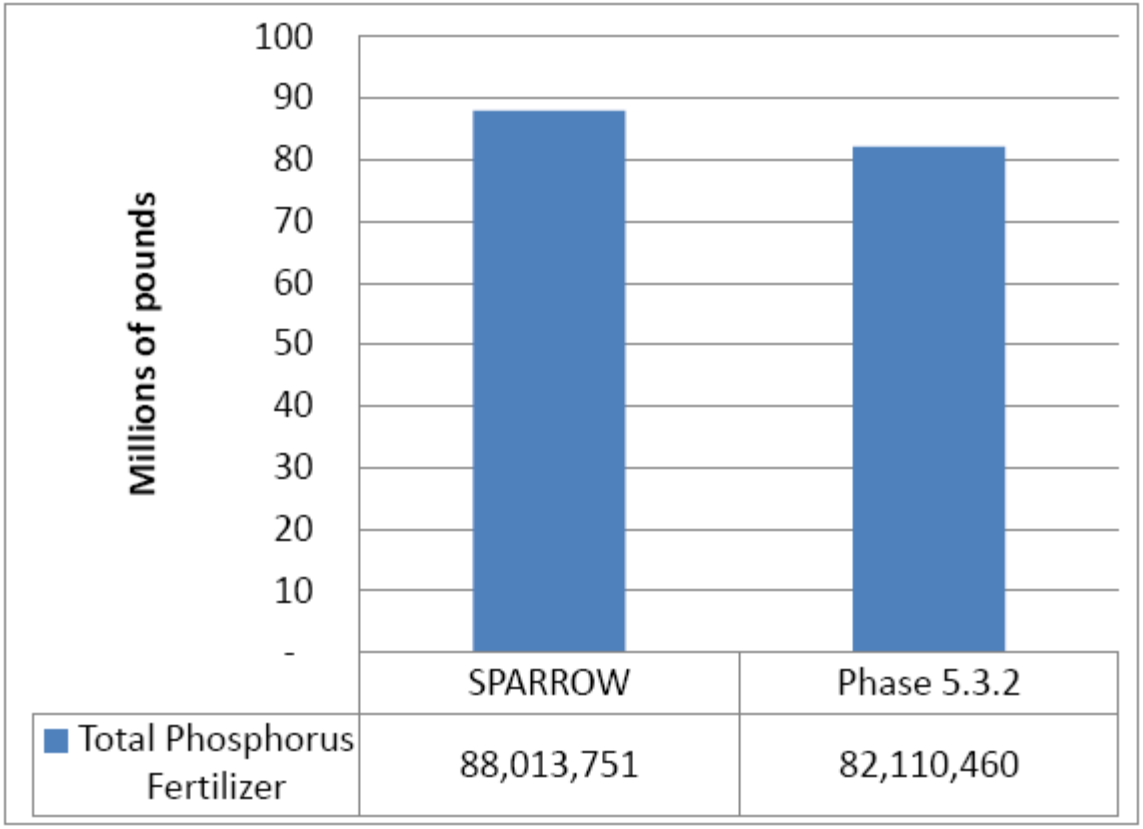
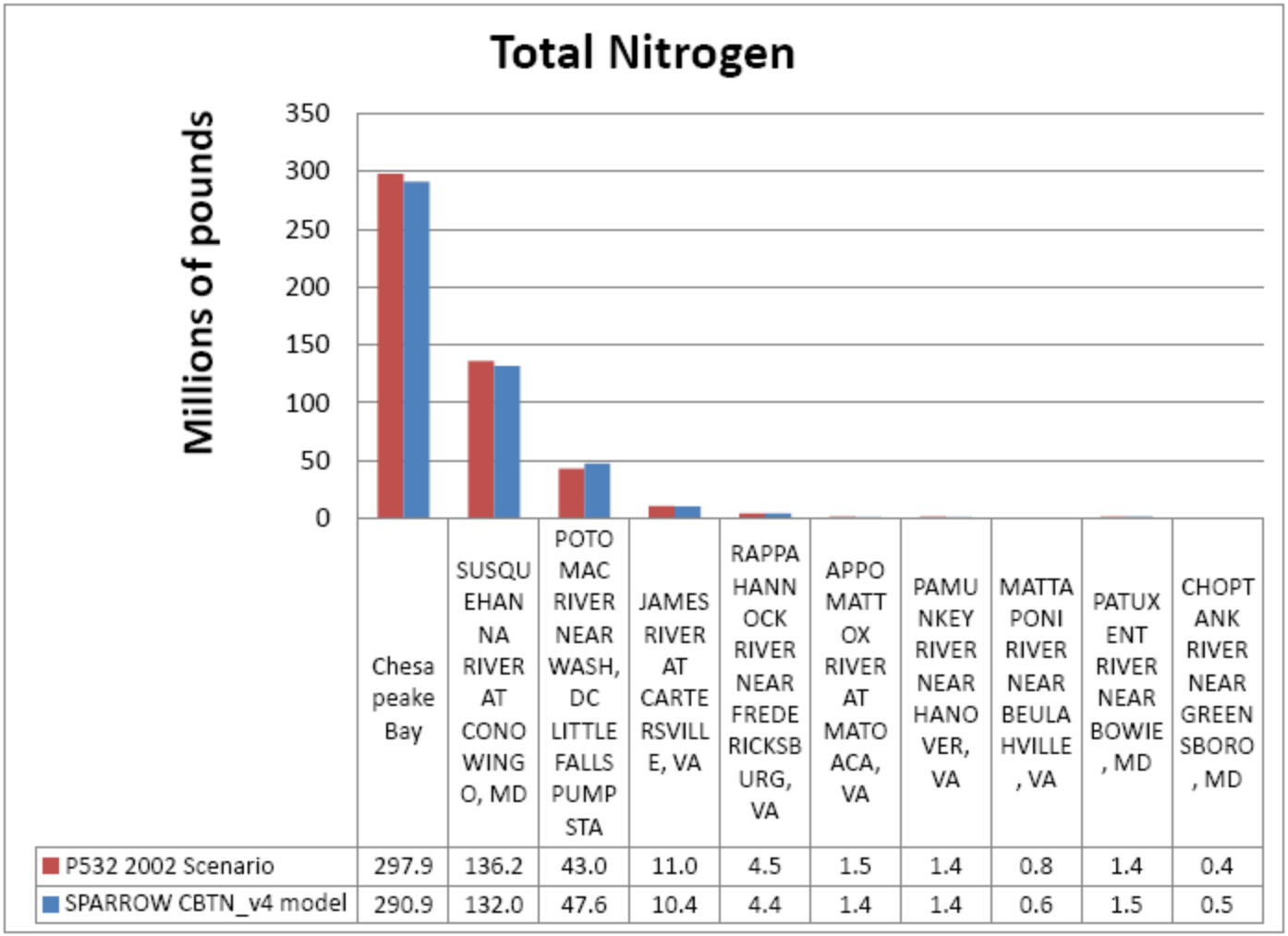
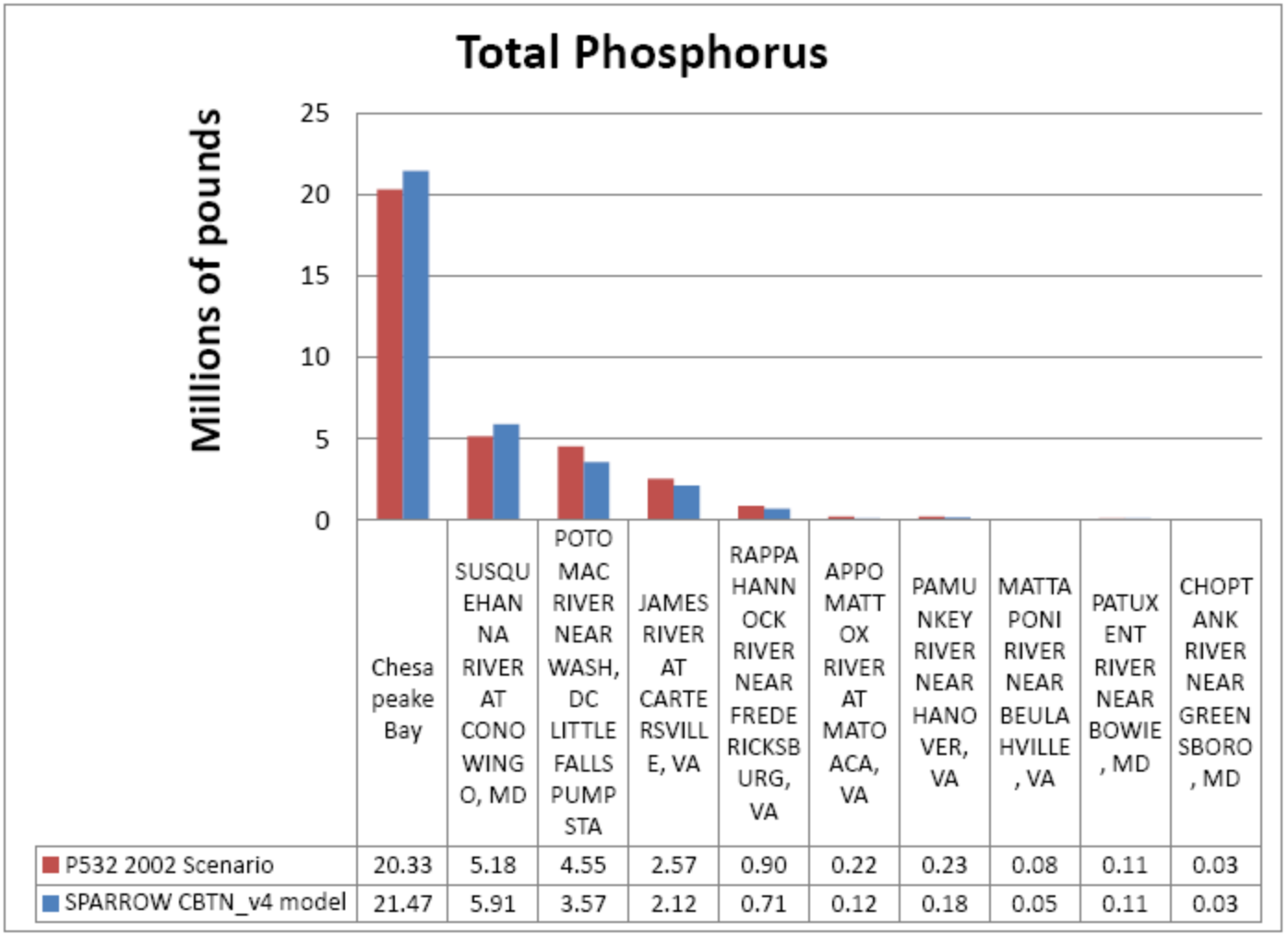


Models Outputs for the year 2002



	Chesapeake Bay	SUSQUEHANNA RIVER AT CONOWINGO, MD	POTOMAC RIVER NEAR WASH, DC LITTLE FALLS PUMP STA	JAMES RIVER AT CARTERSVILLE, VA	RAPPAHANNOCK RIVER NEAR FREDERICKSBURG, VA	APPOMATTOX RIVER AT MATOACA, VA	PAMUNKEY RIVER NEAR HANOVER, VA	MATTAPONI RIVER NEAR BEULAHVILLE, VA	PATUXENT RIVER NEAR BOWIE, MD	CHOPTANK RIVER NEAR GREENSBORO, MD
P532 2002 Scenario	297.9	136.2	43.0	11.0	4.5	1.5	1.4	0.8	1.4	0.4
SPARROW CBTN_v4 model	290.9	132.0	47.6	10.4	4.4	1.4	1.4	0.6	1.5	0.5

Models Outputs for the year 2002



	Chesapeake Bay	SUSQUEHANNA RIVER AT CONOWINGO, MD	POTOMAC RIVER NEAR WASH, DC LITTLE FALLS PUMP STA	JAMES RIVER AT CARTERSVILLE, VA	RAPPAHANNOCK RIVER NEAR FREDERICKSBURG, VA	APPOMATTOX RIVER AT MATOACA, VA	PAMUNKEY RIVER NEAR HANOVER, VA	MATTAPONI RIVER NEAR BEULAHVILLE, VA	PATUXENT RIVER NEAR BOWIE, MD	CHOPTANK RIVER NEAR GREENSBORO, MD
P532 2002 Scenario	20.33	5.18	4.55	2.57	0.90	0.22	0.23	0.08	0.11	0.03
SPARROW CBTN_v4 model	21.47	5.91	3.57	2.12	0.71	0.12	0.18	0.05	0.11	0.03

SPARROW Function

Smith, R. et al. (1997) described the methods for using SPARROW in regional water quality assessments.

The land-water delivery factor is parameterized as

$$D_n(Z_j) = \beta_n \exp(-\alpha' Z_j)$$

$$D_n(Z_j) = \beta_n$$

$$D_n(Z_j) = 1$$

for nonpoint sources, point sources, and upstream monitored loads, respectively, where β*n is a source-specific coefficient* and α is a vector of delivery coefficients associated with the land-surface characteristics *Zj.*

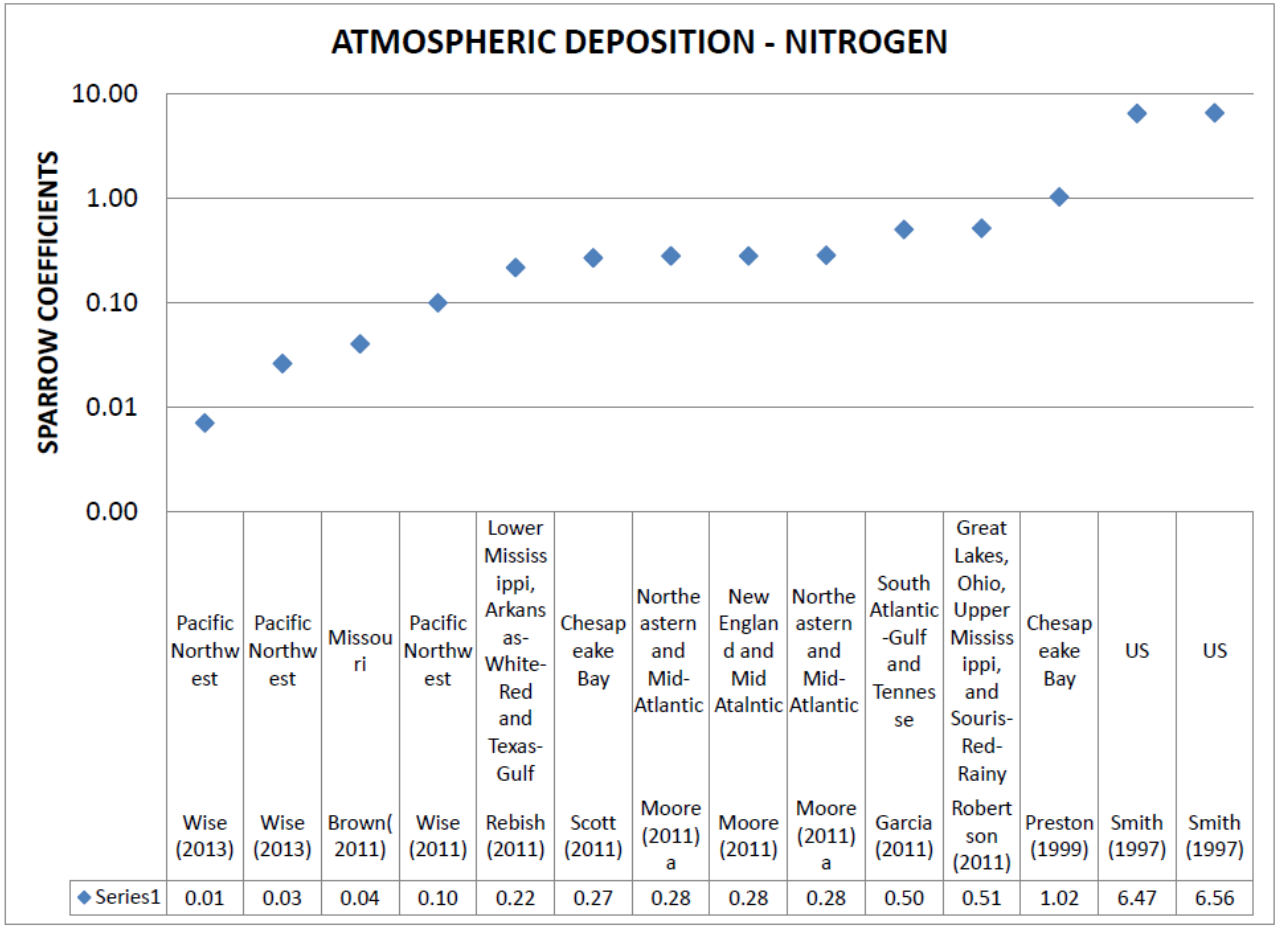
SPARROW Function

S is the contaminant load from *n* source delivered to a reach *i* from all reaches in a subbasin.

$$S_{n,i} = \sum_{j \in J(i)} s_{n,j} D_n(Z_j) K(T_{i,j})$$

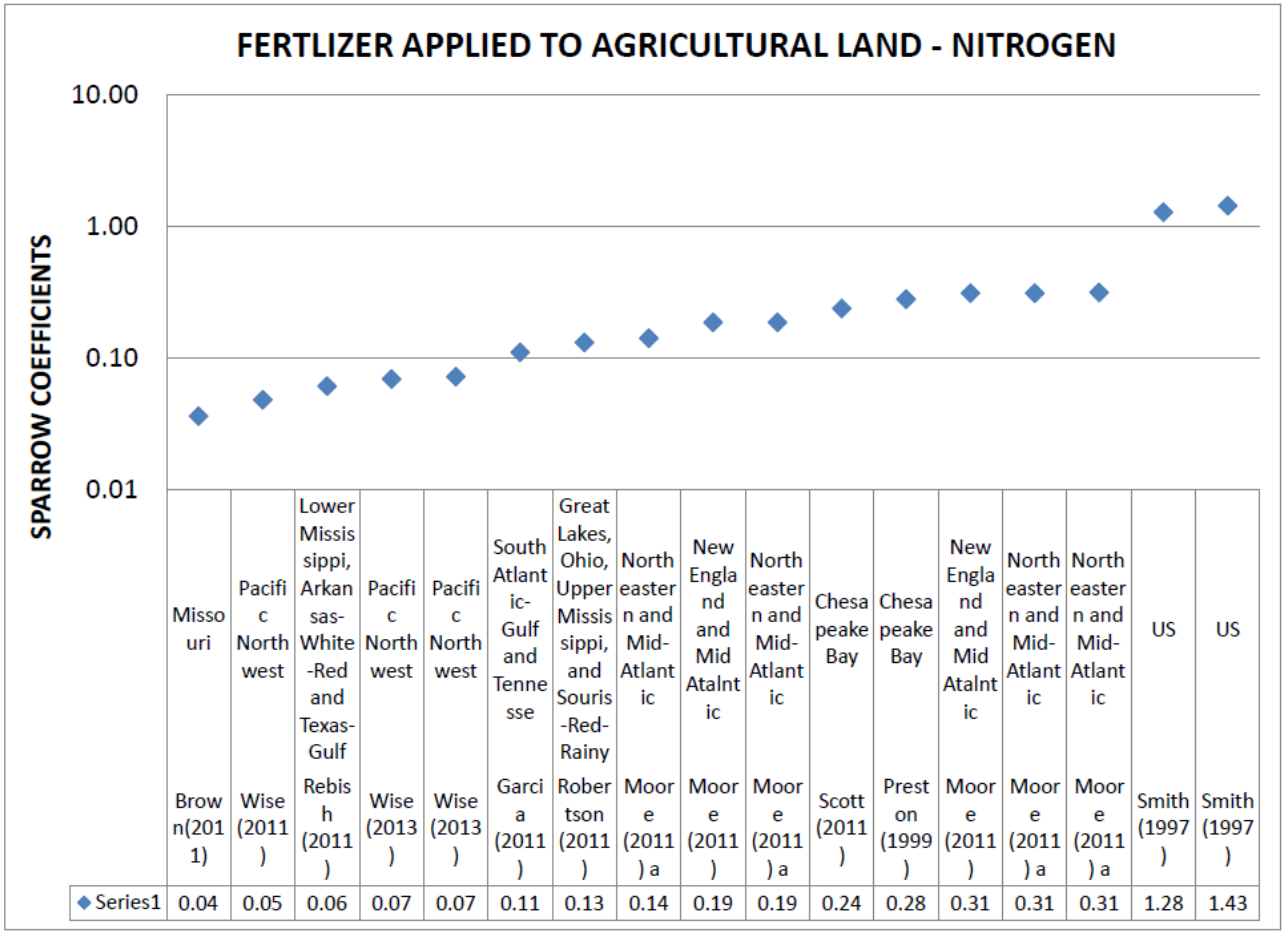
sn, j is a measure of the contaminant mass from a source *n* that is present in the drainage to reach *j, Dn(Zj)* is the proportion of *sn, j* that is delivered to reach j as a function of land-surface characteristics *Zj,* and *K(Ti, j)* is the proportion of contaminant mass present in reach *j* that is transported to reach *i* as a function of channel characteristics *Ti, j.*

SPARROW versus AGCHEM sensitivities



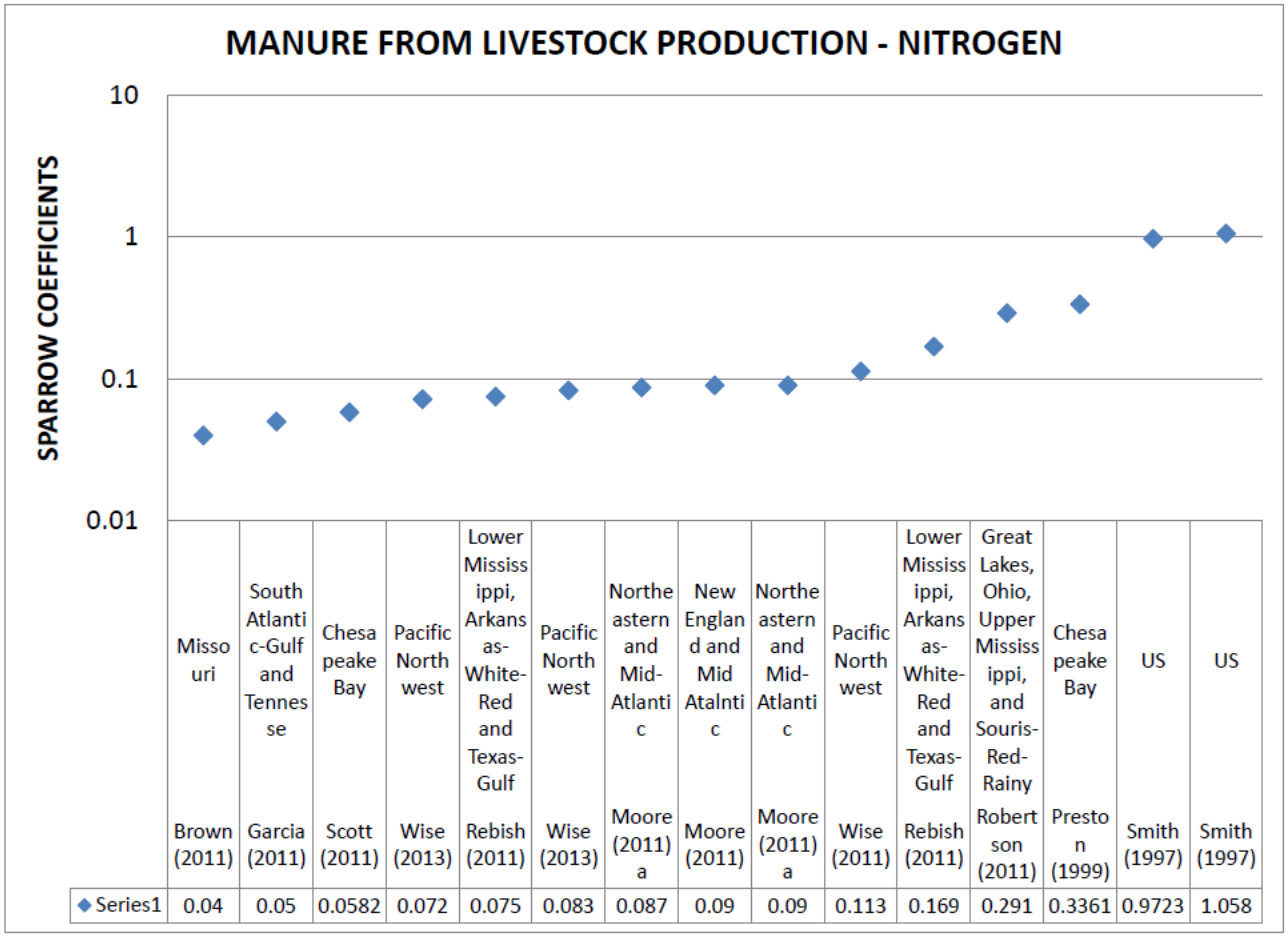
P532 TN slope between output and input	0.05 (Forest)
P532 slope of multivariate regression - Atdep	0.05 (Forest)
P532 ratio between input and output	0.29 (Forest)
P532 2002 scen EOS (pounds per acre)	3.76 (forest)

SPARROW versus AGCHEM sensitivities



P532 TN slope between output and input	0.24 (hwm), 0.53 (hom) , 0.20 (lwm)
P532 slope of multivariate regression - Fertilizer	0.26 (hwm), 0.25 (hom), 0.28 (lwm)
P532 ratio between input and output	0.28 (hwm), 0.23 (hom), 0.26 (lwm)
P532 2002 scen EOS (pounds per acre)	

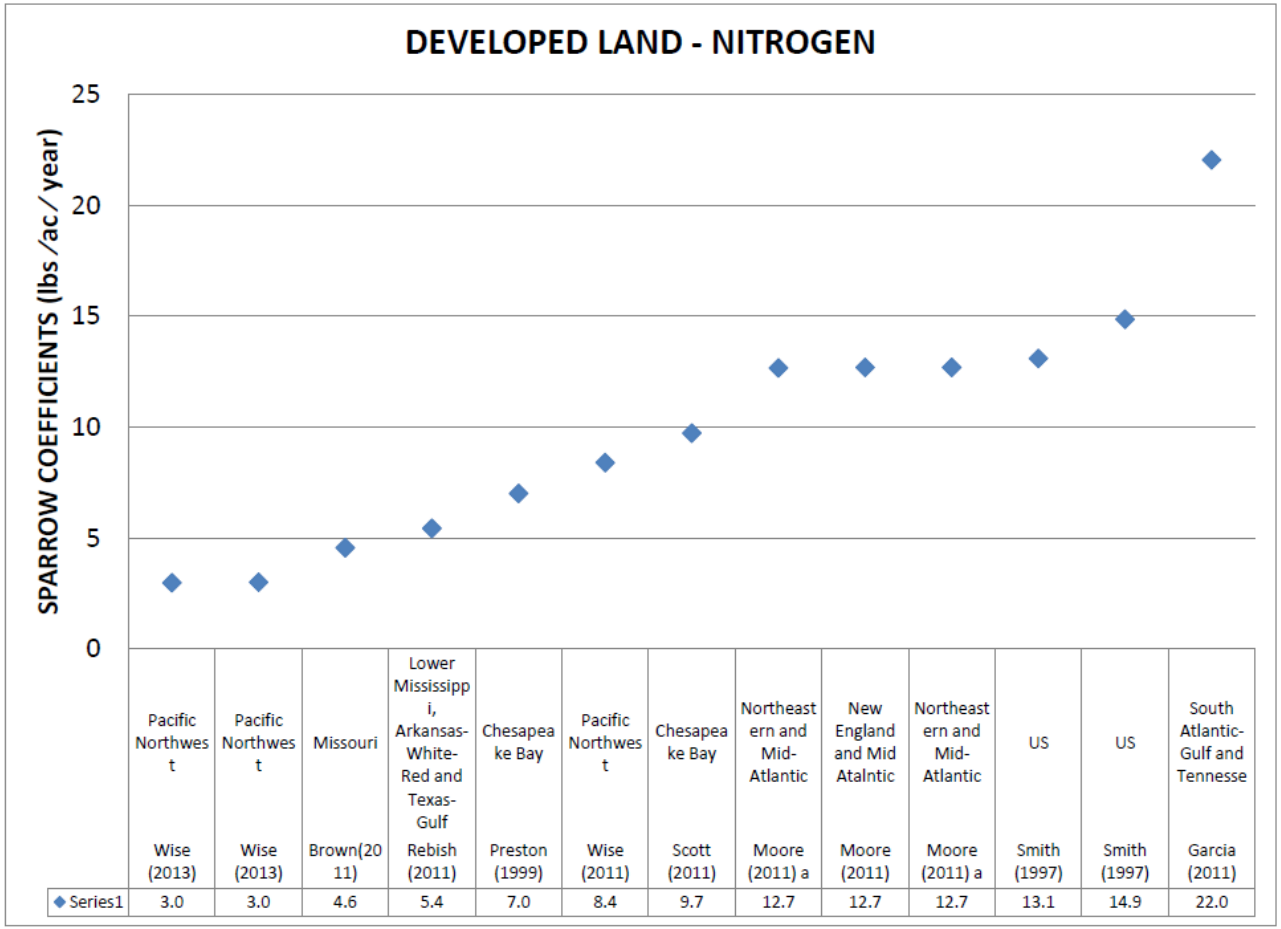
SPARROW versus AGCHEM sensitivities



	Missouri Brown (2011)	South Atlantic-Gulf and Tennesse Garcia (2011)	Chesapeake Bay Scott (2011)	Pacific Northwest Wise (2013)	Lower Mississippi, Arkansas-White-Red and Texas-Gulf Rebish (2011)	Pacific Northwest Wise (2013)	Northeastern and Mid-Atlantic Moore (2011)a	New England and Mid Atalntic Moore (2011)	Northeastern and Mid-Atlantic Moore (2011)a	Pacific Northwest Wise (2011)	Lower Mississippi, Arkansas-White-Red and Texas-Gulf Rebish (2011)	Great Lakes, Ohio, Upper Mississippi, and Souris-Red-Rainy Robertson (2011)	Chesapeake Bay Preston (1999)	US Smith (1997)	US Smith (1997)
Series1	0.04	0.05	0.0582	0.072	0.075	0.083	0.087	0.09	0.09	0.113	0.169	0.291	0.3361	0.9723	1.058

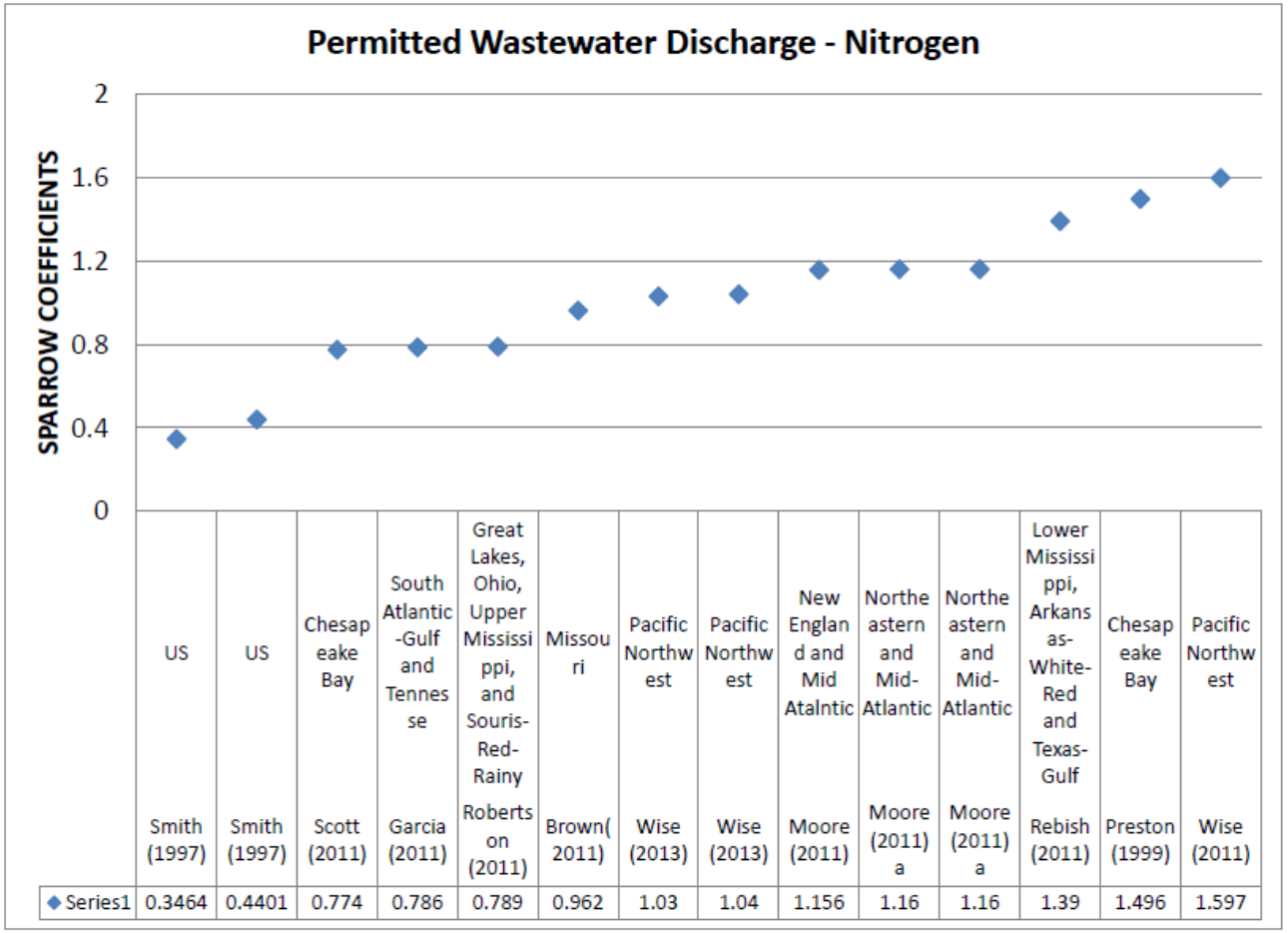
P532 TN slope between output and input	0.24 (hwm), 0.53 (hom) , 0.20 (lwm)
P532 slope of multivariate regression - Manure	0.21 (hwm), 0.21 (lwm)
P532 ratio between input and output	0.28 (hwm), 0.23 (hom), 0.26 (lwm)
P532 2002 scen EOS (pounds per acre)	

SPARROW versus AGCHEM sensitivities

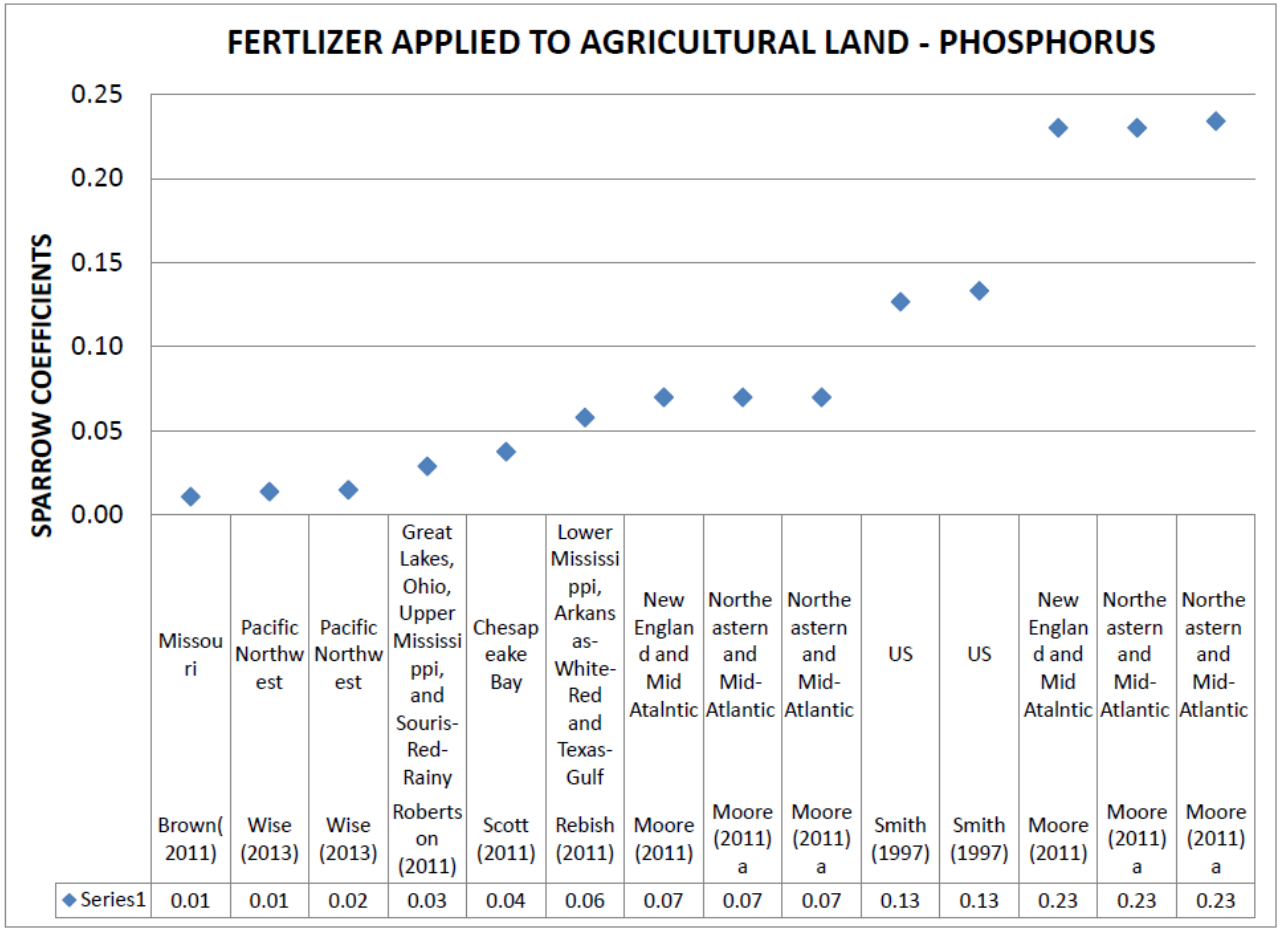


P532 TN slope between output and input	0.15 (npd)
P532 slope of multivariate regression - atdep/fert	0.15 / 0.07 (npd)
P532 ratio between input and output	0.22 (npd)
P532 2002 scen EOS (pounds per acre)	12.4 (rpd), 14.3 (npd), 19 (rid), 19.45 (nid)

SPARROW versus AGCHEM sensitivities

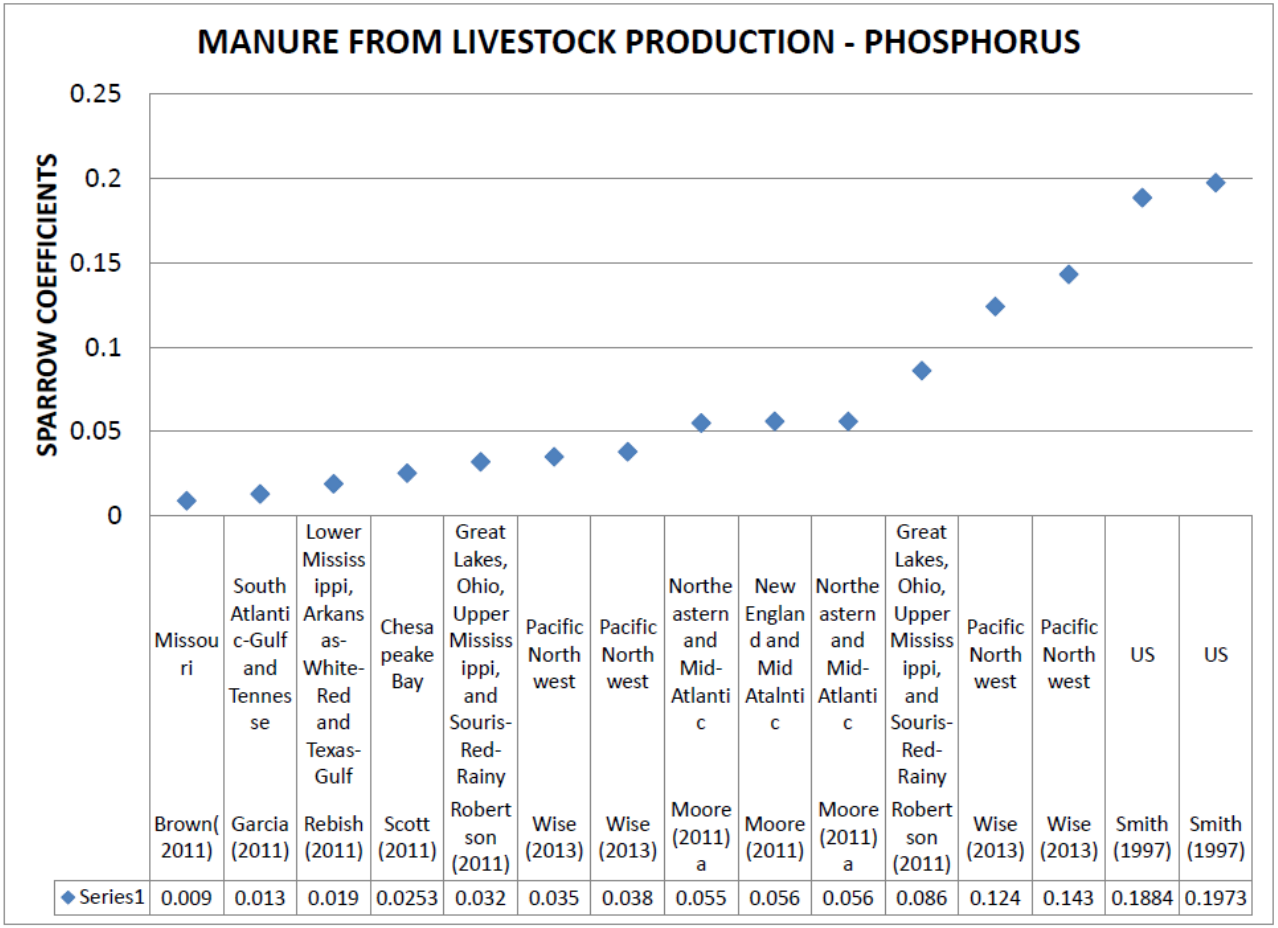


SPARROW versus AGCHEM sensitivities



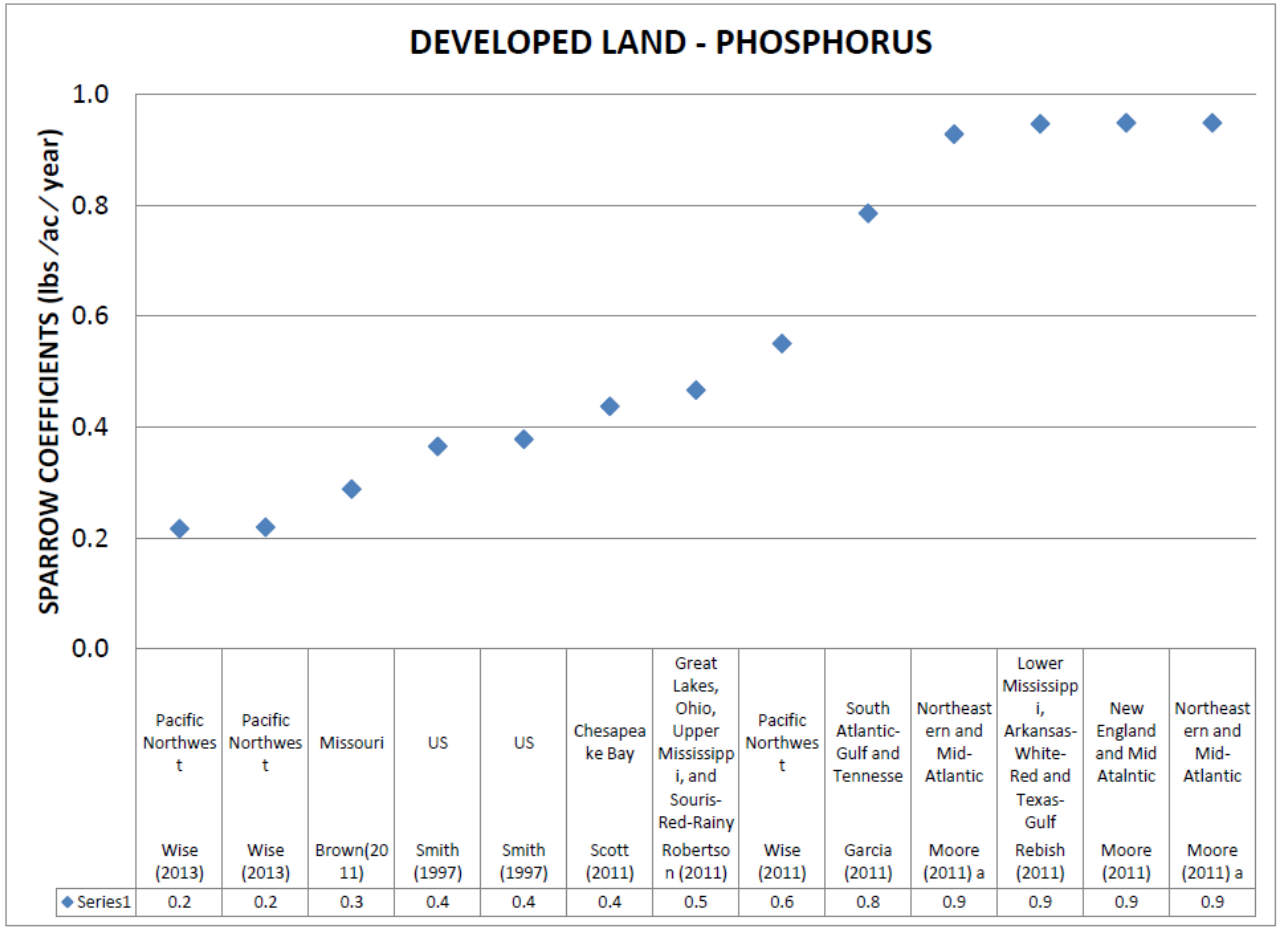
P532 TN slope between output and input	0.12 (hwm), 0.1 (hom), 0.1 (lwm), 0.1 (alf), 0.08 (hyw)
P532 slope of multivariate regression - Fertilizer	0.12 (hwm), 0.1 (hom), 0.11 (lwm), 0.09 (alf), 0.1 (hyw)
P532 ratio between input and output	0.1 (hwm), 0.1 (hom), 0.09 (lwm), 0.09 (alf), 0.08 (hyw)
P532 2002 scen EOS (pounds per acre)	

SPARROW versus AGCHEM sensitivities



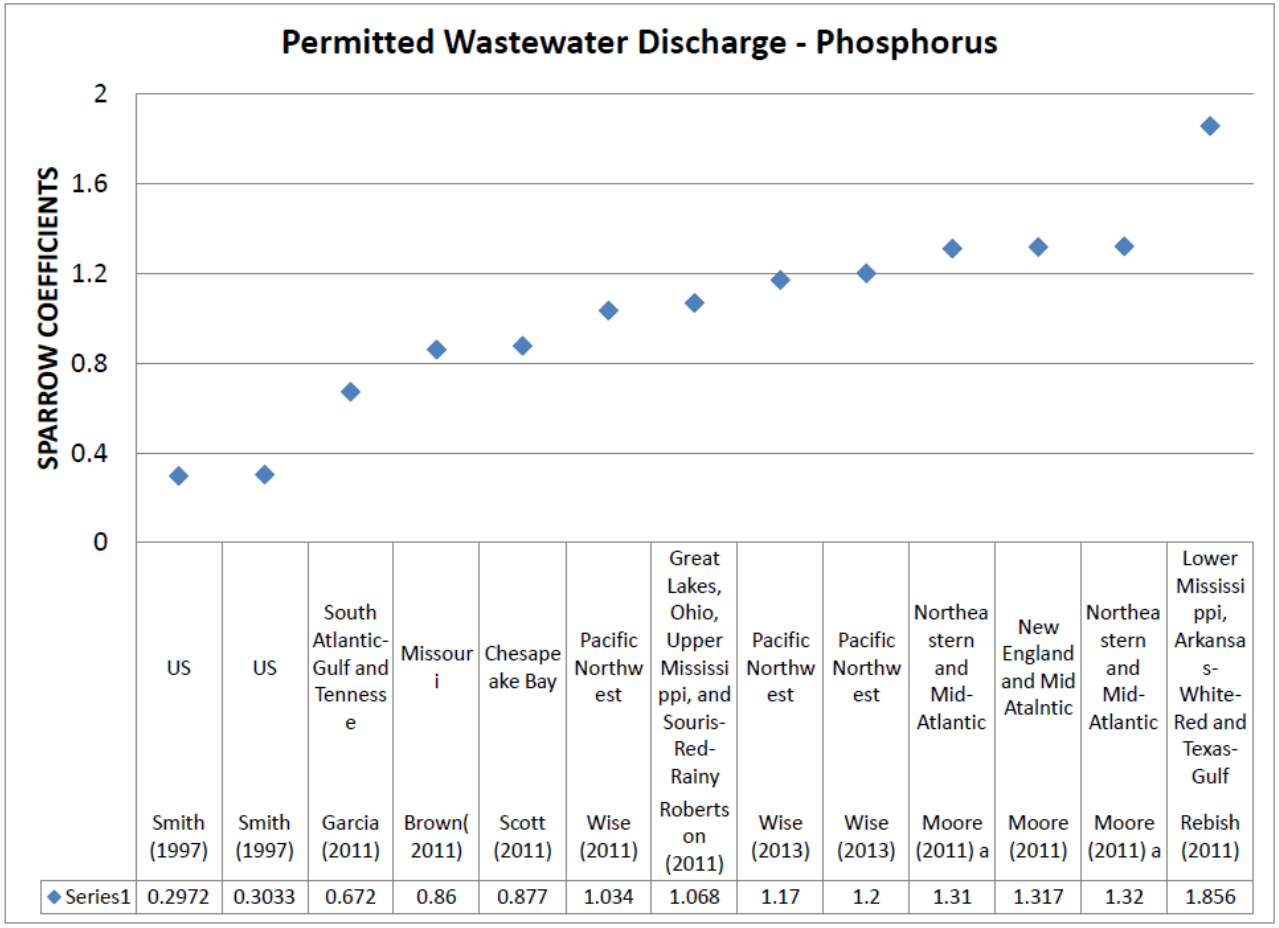
P532 TN slope between output and input	0.12 (hwm), 0.1 (hom), 0.1 (lwm), 0.1 (alf), 0.08 (hyw)
P532 slope of multivariate regression - Manure	0.14 (hwm), 0.13 (lwm), 0.15 (alf), 0.09 (hyw)
P532 ratio between input and output	0.1 (hwm), 0.1 (hom), 0.09 (lwm), 0.09 (alf), 0.08 (hyw)
P532 2002 scen EOS (pounds per acre)	

SPARROW versus AGCHEM sensitivities



P532 TN slope between output and input	
P532 slope of multivariate regression	
P532 ratio between input and output	
P532 2002 scen EOS (pounds per acre)	0.45 (rpd), 0.6 (npd), 1.73(rid), 2.11 (nid)

SPARROW versus AGCHEM sensitivities



Why SPARROW manure and fertilizer coefficients are so different?

- Sparrow estimates that 24% of TN from fertilizer and 6% of TN from manure was transported to the tributaries*

- Sparrow estimates that 3.8% of TP from fertilizer and 2.5% of TP from manure was transported to the tributaries*

	Sparrow **	P532 AGCHEM statistics		
	% transported to the tributaries	slope between output and input	slope of multivariate regression	ratio between input and output
Fertilizer TN	0.14 – 0.31	0.2- 0.53	0.25-0.28	0.23-0.28
Manure TN	0.06 – 0.33	0.2-0.53	0.21	0.23-0.28
Fertilizer TP	0.038 – 0.23	0.08-0.12	0.09-0.12	0.08-0.1
Manure TP	0.025 – 0.06	0.08-0.12	0.09-0.15	0.08-0.1

*Scott et al. (2011)

** All publications examined

Why SPARROW coefficients might not be consistent with ours?

- Inputs are not the same
- Different spatial distribution.
- Different modeling approach

Conclusions

- SPARROW uses only wet atmospheric deposition and did not show the same spatial distribution in some areas.
- Phase 5.3.2 and SPARROW used similar manure inputs and showed similar spatial distribution and rates.
- SPARROW total nitrogen fertilizer input was significantly lower and total phosphorus fertilizer was slightly higher than the P532. It did not showed similar spatial distribution.

Conclusions

- In spite of SPARROW's different input deck and approach to assess water quality , it showed the same output than P532 at 9 USGS stations.

- P532 multivariate regression slopes are similar than SPARROW's Nitrogen NLLS coefficients only for total nitrogen crop fertilizer.